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(54) Title of the Invention: **A pile driver**
Abstract Title: **Pile driver with an extended lead mass arrangement and extended reach connector**

(57) A pile driver 10 comprises a base machine 20 with an adjustable extended lead mast arrangement. The base machine comprises a lower crawler unit 22 with an upper car body 40 rotateably mounted thereupon for rotation about an axis extending substantially perpendicular to the unit, the body 40 having a front section 44 with the mast arrangement and a rear section 48 with a counterweight 46. The mast arrangement comprises a lead mast 102 with upper 108, middle 110 and lower 112 sections and mast adjustment mechanism 150 on the section 44 and lead mast. The adjustment mechanism enables the lead mast to be moved away/towards the front section of body 40. The adjustment mechanism comprises a spotter arm 152, support arm 154, upper hydraulic cylinder 156 with a first end hingeably connected with the middle section, a lower hydraulic cylinder 160, and a lead mast linkage with three linkage coupling nodes. The nodes connect the linkage to the middle section, the second end of the upper cylinder, and a first end the support arm and lower cylinder. An extended reach connector comprises a bracket section 252 and bracket support member, with both arms hingeably connected to the bracket section.

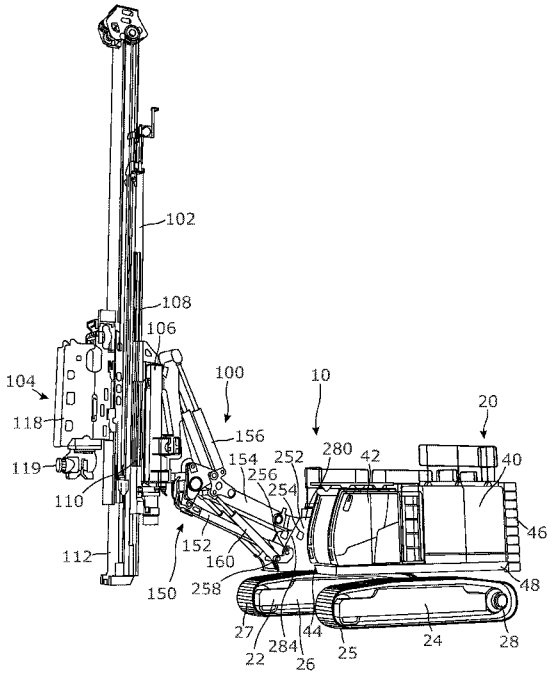

Figure 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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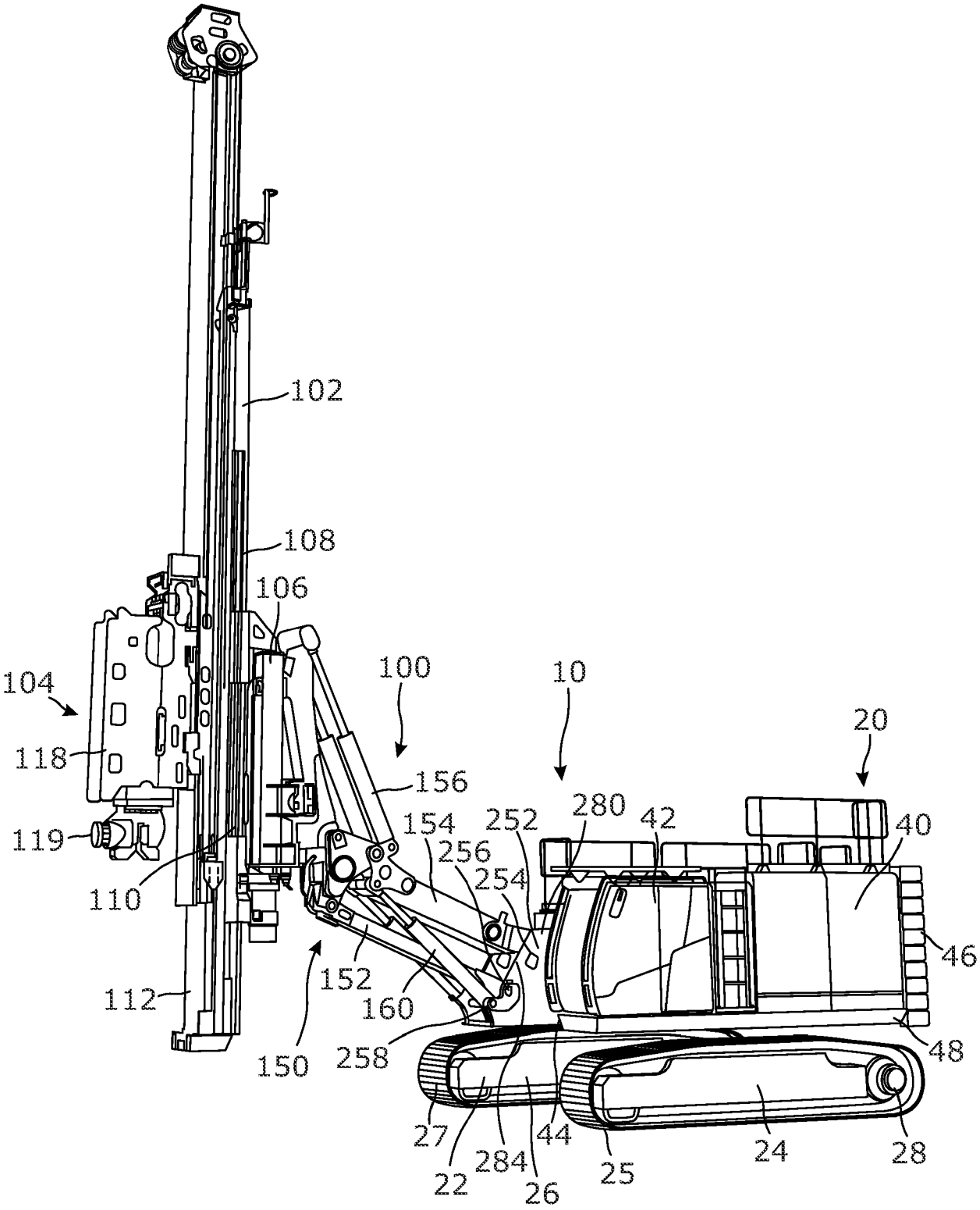

Figure 1

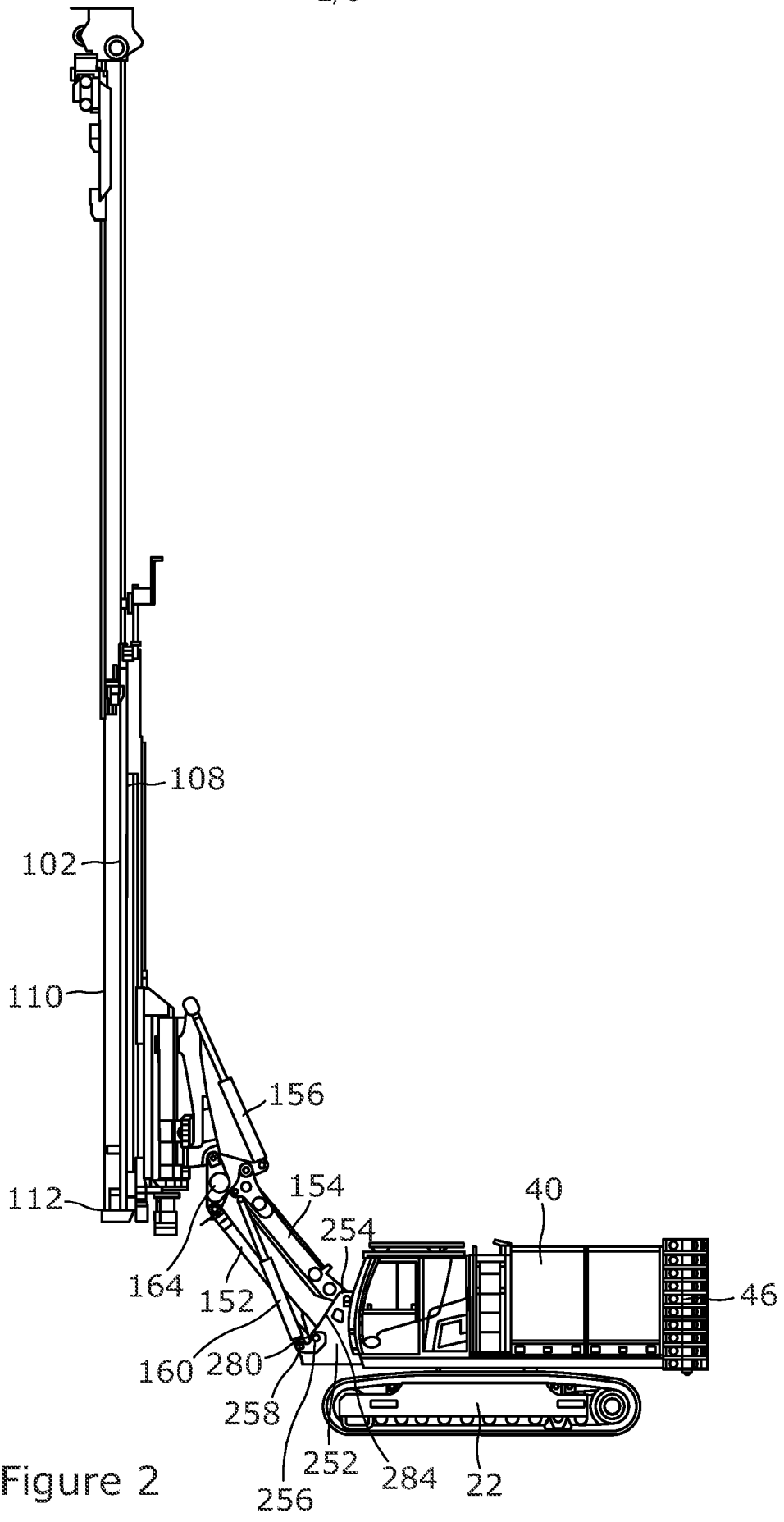

Figure 2

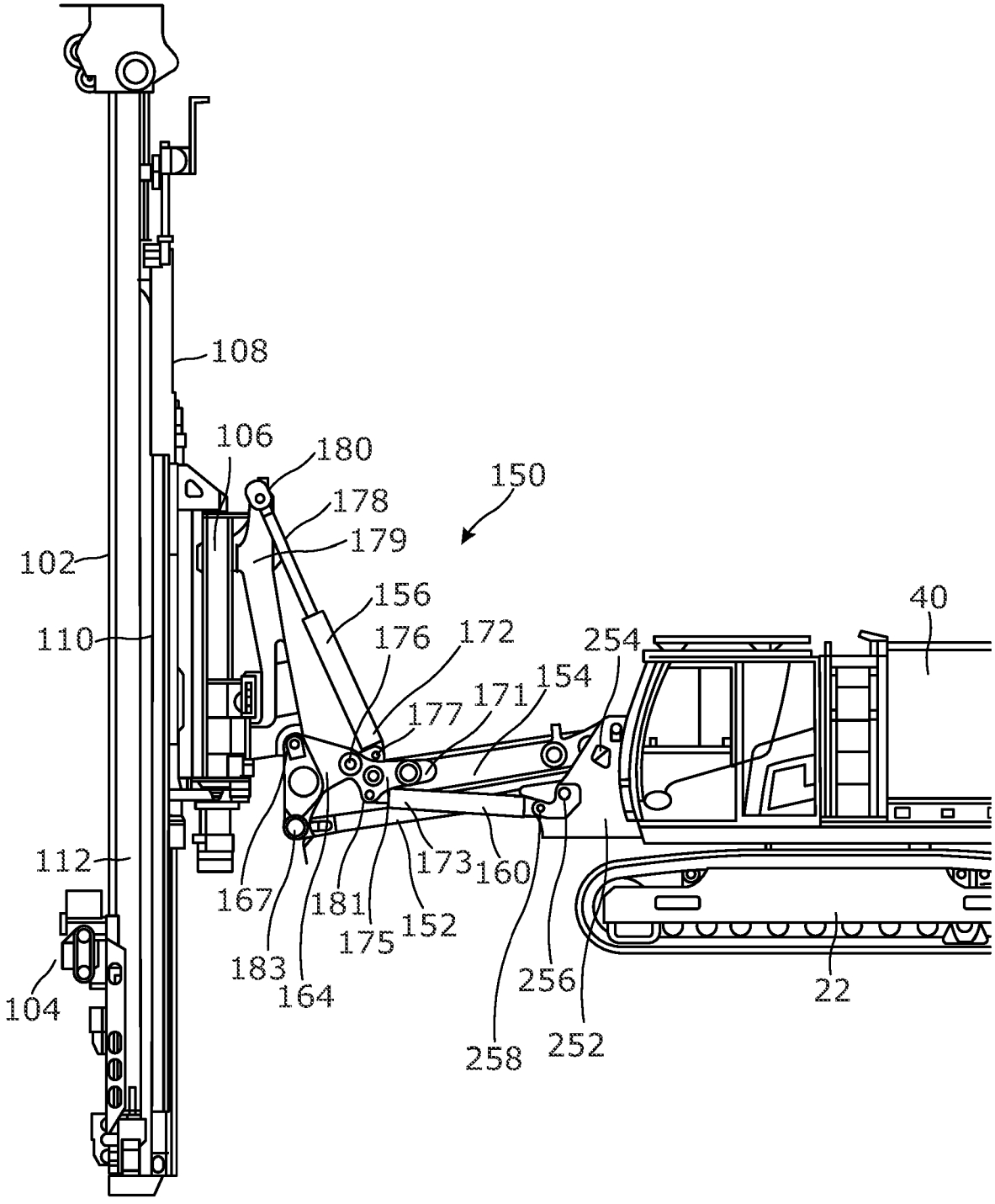

Figure 3

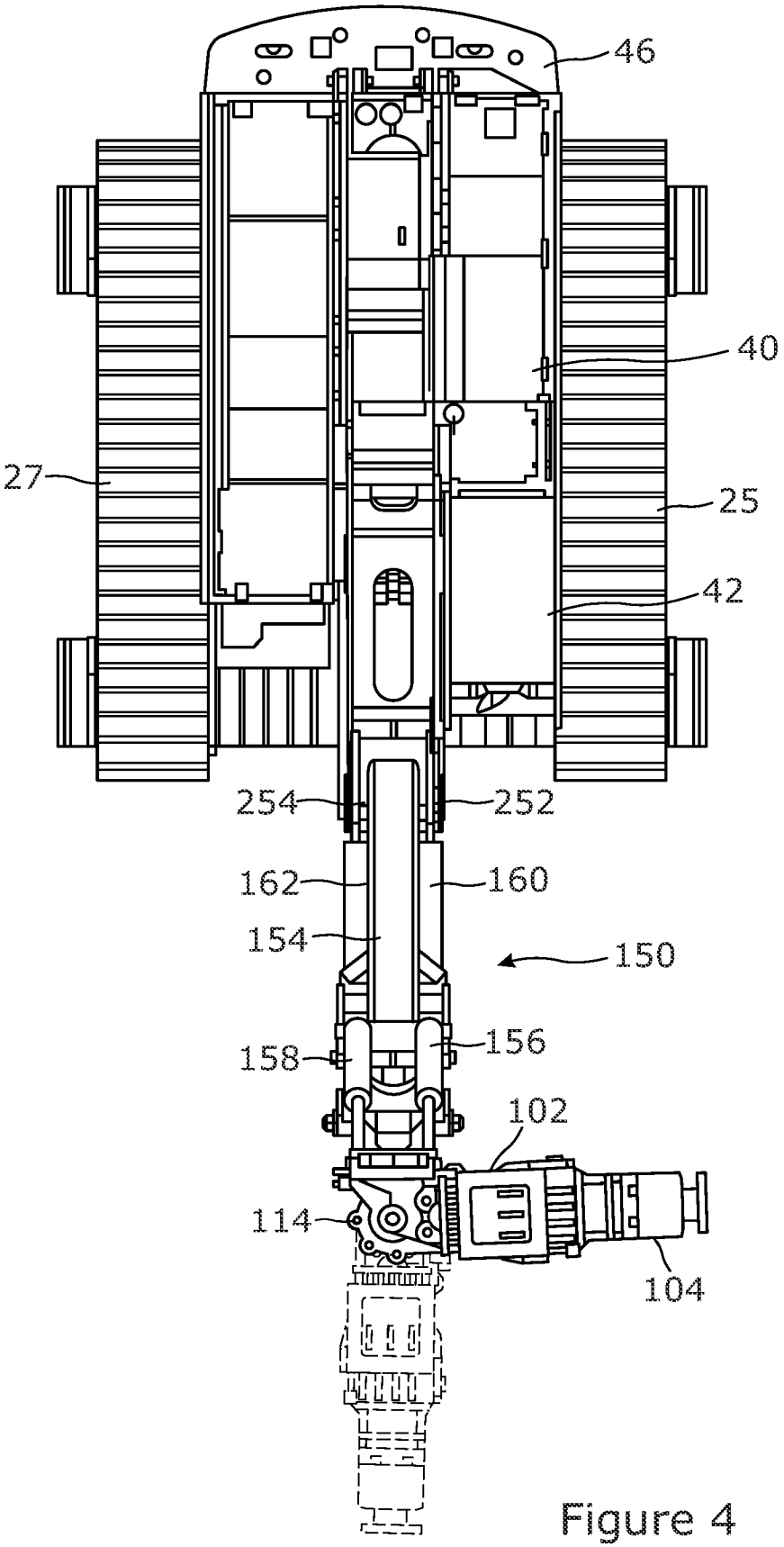

Figure 4

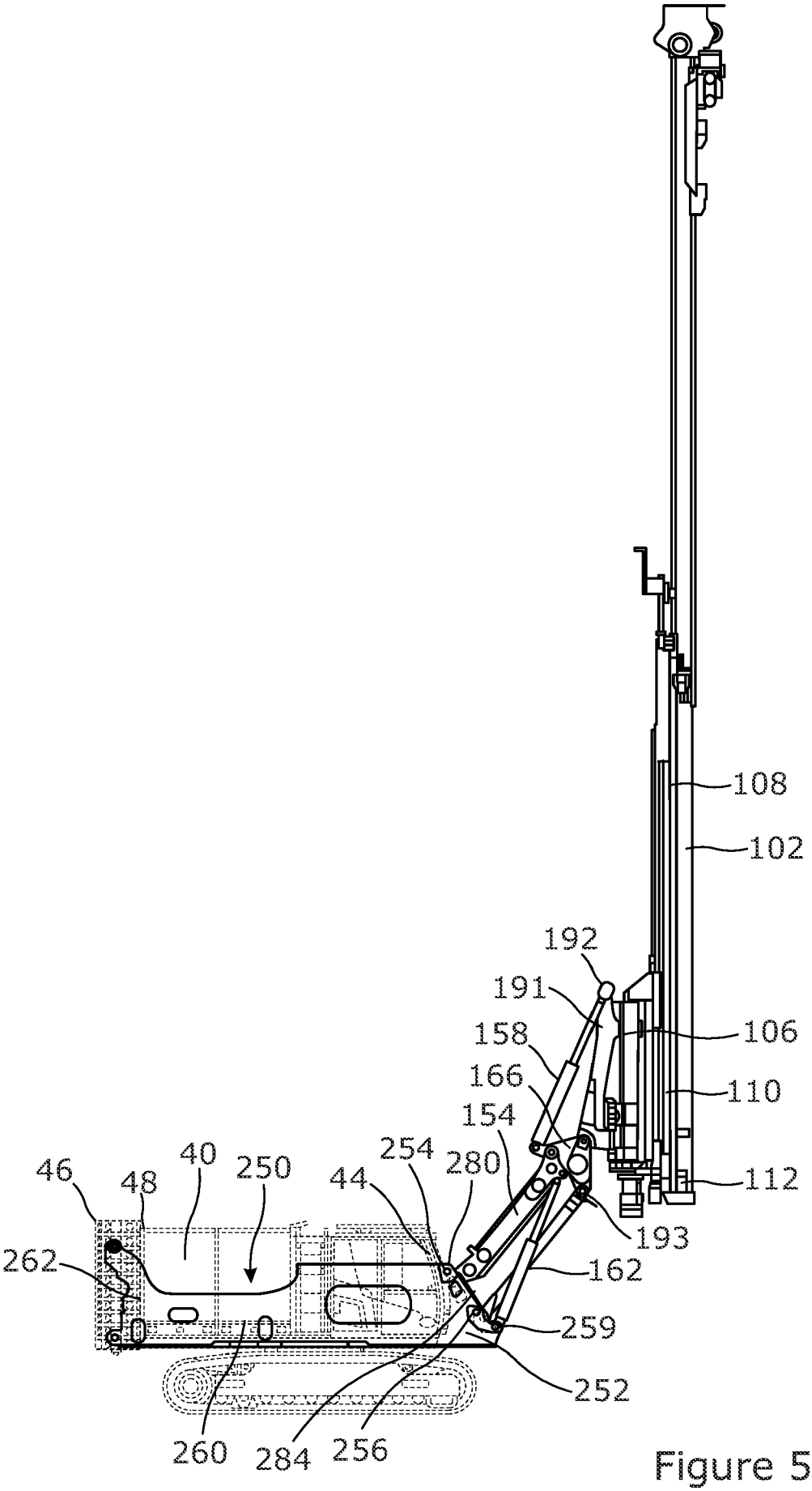

Figure 5

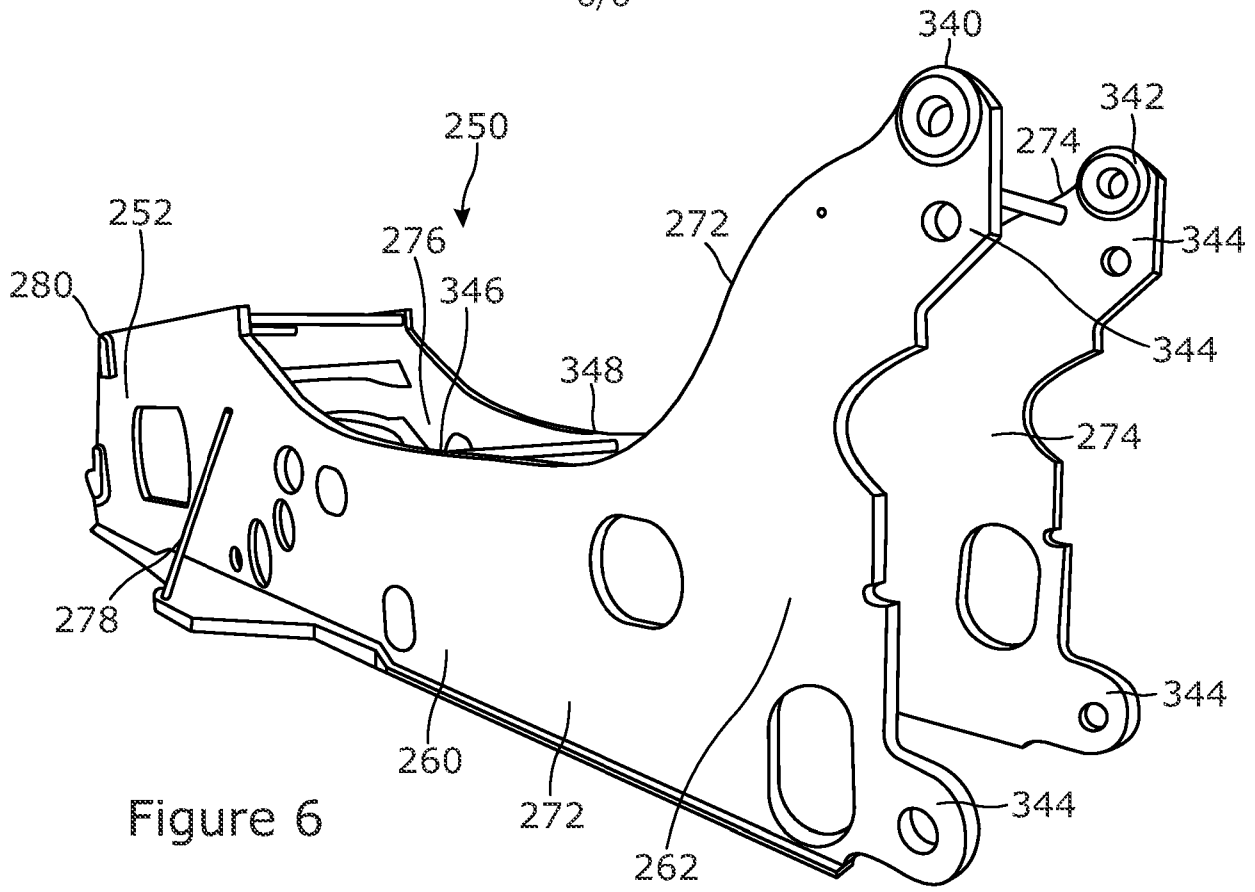

Figure 6

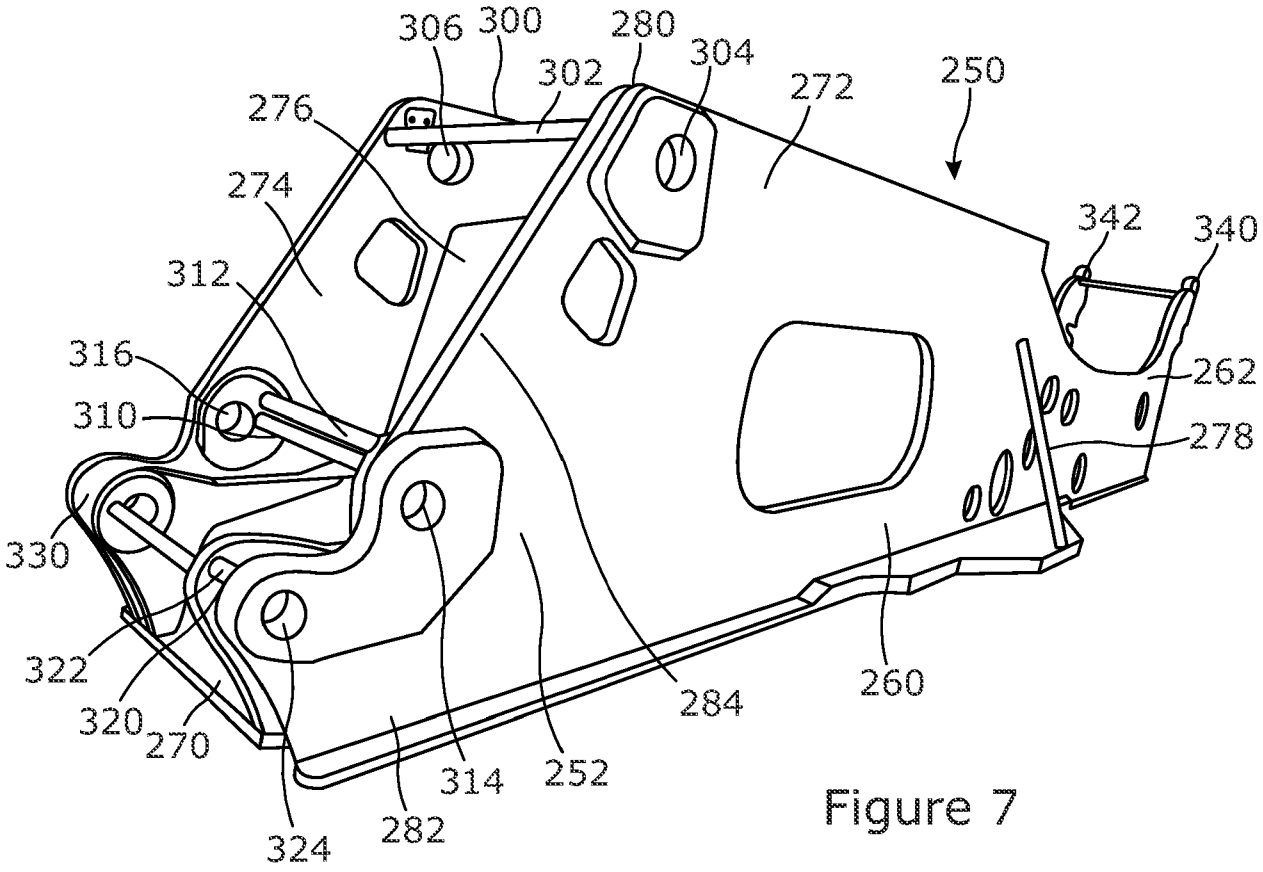

Figure 7

A PILE DRIVER

The present invention relates to pile driving. In particular, although not exclusively, the present invention provides apparatus for driving a piling, especially sheet piling, into and/or extracting a piling, especially sheet piling, from the ground, namely, a pile driver. Suitably, the pile driver is self-propellable. Suitably, the pile driver comprises an adjustable extended lead mast arrangement, preferably an adjustable extended lead mast arrangement comprising an extendible lead mast. The invention also provides a method of driving a piling into the ground and/or extracting a piling from the ground – preferably the piling comprises sheet piling. Further, the invention provides the use of the pile driver of the invention to drive a piling into the ground and/or extract a piling from the ground – preferably the piling comprises sheet piling.

In the construction industry, piling represents foundation(s) that are driven, bored or sunk into the ground to carry and transfer loads to soil considered to be weak in structure due to the soil conditions. Piling may be used when the bearing capacity of the soil is typically inadequate to support the structural load of heavy construction. Suitably, the piling transfers and distributes a load through material or stratum (e.g. soil) with inadequate bearing, sliding or up-lift capacity to more solid ground located further below ground with a higher bearing capacity and more capable of supporting the load without detrimental displacement. Accordingly, piling may be considered as a support which is used as a deep foundation.

Suitably, piling may be used to support a large structure, for example, a building, bridge, tank, tower and/or wall. Further, piling may be used in applications such as embankments, retaining walls, bulkheads and anchorage structures, for example, to retain and/or mitigate displacement of heavy banks of earth and/or rocks.

Piling may be constructed from different types of materials. Suitable materials include steel, concrete including re-enforced concrete, timber and other metal/alloys thereof. Preferred materials for piling include steel and concrete.

Piling may have different structural forms and/or designs. Suitable structural forms and/or designs for piling include solid structures such as columns, tubes including fluted and tapered tubes, tubes with one or more sealed ends, and sheet material.

Piling may be classified according to its basic design, load bearing capacity and/or load distribution function (e.g. end-bearing, friction bearing or a combination thereof). Alternatively, or additionally, piling may be classified by how it is installed into the ground. Piling may be installed by driving a piling direct into the ground, for example by hammering a piling into the ground and simultaneously displacing the earth. Suitably, such piling is typically referred to as displacement piling. Alternatively, piling may be inserted into a pre-bored hole in the ground. Suitably, such piling is typically referred to as replacement piling. Suitably, the present invention provides a pile driver for driving piling into the ground (i.e. apparatus adapted for installing and/or removing displacement piling), preferably driving piling direct into un-excavated ground.

Suitably, a pile driver comprises a rig, for example a crawler crane unit, that includes pile driving attachments and/or components for driving piling into and/or removing piling from the ground. Typical pile driving attachments include: a lead mast to align a piling drive system and a piling whilst driving the piling into the ground; a piling drive system, such as a vibratory hammer, and gripper means to hold a piling; and/or a spotter for holding and positioning the lead mast at a predetermined distance and position away from the rig. Suitably, the type and/or specific configuration of pile driving attachments is variable and may depend, to a large extent, on the proposed use of the pile driver.

A pile driver may include different lead mast arrangements, for example: an extended lead mast arrangement (fixed or adjustable); a fixed underhung lead mast arrangement; or, swinging lead mast arrangement.

In a swinging lead mast arrangement, a first end of the lead mast is hung from a crane boom by a crane line; the second end of the lead mast is unrestrained. The swinging lead mast arrangement offers advantages in terms of simplicity of design and economics. Suitably, the lead mast may be positioned at variable distances from the crawler crane

unit by operating the crane boom. However, precise positioning of the second end of the lead mast is difficult and time-consuming, as the lead mast freely "swings" from the crane boom. Accordingly, human intervention is typically required when using a swinging lead mast arrangement to ensure a piling is correctly aligned and positioned when driven into the ground.

In an underhung lead mast arrangement a single end of the lead mast is hung from a crane boom by a crane line, and a spotter arm (e.g. an arm extending from the the crawler crane unit and coupled to the lead mast) is deployed to position and hold a lower part of the lead mast a distance away from the crawler crane unit. Suitably, the lead mast may be moved away from and back towards the crawler crane unit by operating the crane boom. Suitably, the spotter arm permits the lead mast to be positioned more precisely and with less human intervention. Suitably, the spotter supports and stabilises the lower part of the lead mast, thereby enabling the lead mast to be held more accurately in position when driving a piling. Accordingly, driving piling using an underhung lead mast arrangement is typically less time-consuming compared with using the swinging lead mast arrangement, as less human intervention is typically required. However, an underhung lead mast arrangement is typically more expensive than a swinging lead mast arrangement.

In an extended lead mast arrangement, the lead mast comprises at least 3 lead mast sections: (1) a middle lead mast section engaged (directly or indirectly) at an upper end to the boom point of the crane boom and engaged (directly or indirectly) at a lower end to a spotter arm; (2) an upper lead mast section extending upwardly from the middle lead mast section (1) and above the crane boom point connection; and, (3) a lower lead mast section extending downwardly from the middle lead mast section (1) and below the spotter arm connection. Suitably, the overall length of the lead mast extending downwardly below the crane boom point connection (i.e. lead mast sections (1) + (3)) is greater than the length of the upper lead mast section (2) extending upwardly above the crane boom point connection.

Suitably, an extended lead mast arrangement permits the use of a lead mast of increased length compared with an underhung lead mast arrangement. Advantageoulsy, a longer length lead mast permits a piling to be driven deeper into the ground and with greater force.

A pile driver including an extended lead mast arrangement may further include lead mast adjustment means to enable the lead mast to be positioned at different distances away from the crawler crane unit and without having to disassemble the lead mast arrangement (i.e. the adjustment means permits in-situ variation of the distance the lead mast is positioned away from the crawler crane unit). Suitably, such lead mast adjustment means typically comprise a mechanical kinematic adjustment mechanism, wherein the mechanical kinematic adjustment mechanism couples the lead mast to the crawler carne unit. An extended lead mast arrangement having such lead mast adjustment means may be referred to as an adjustable extended lead mast arrangement.

Suitably, in an adjustable extended lead mast arrangement the spotter arm is typically moveably, preferably hingeably, engaged (i.e. directly or indirectly engaged) with both the crawler crane unit and a lower part of the middle lead mast section; the crane boom is typically moveably, preferably hingeably, engaged (i.e. directly or indirectly) with both the crawler crane unit and an upper part of the middle lead mast section. Suitably, the adjustable extended lead mast arrangement may further include a slider unit associated with the lead mast and lead mast adjustment means to enable linear motion of the lead mast relative to the slider unit.

A major advantage of an adjustable extended lead mast arrangement is that the position and/or orientation of the lead mast relative to the crawler crane unit and ground may be adjusted in a controlled manner whilst the lead mast is coupled to the crawler crane unit. For example: (i) the lead mast may be positioned at variable distances extending away from the crawler crane unit (fore and aft movement of the lead mast with respect to the crawler crane unit); (ii) the lead mast may be raised and lowered relative to the crawler crane unit and ground (up and down movement with respect to the crawler crane unit and ground); (iii) the lead mast may be independently moved side to side (e.g. rotated

about an axis) relative to the crawler crane unit; and, (iv) the lead mast may be independently rotated in a substantially vertical theoretical plane realtive to the crawler crane unit and/or the ground (e.g. the pitch of the lead mast may be varied).

Accordingly, an adjustable extended lead mast arrangement enables controllable movement, positioning, support and orientation of the lead mast, whilst enabling a piling to be driven deeper into the ground and with greater force. Suitably, an adjustable extended lead mast arrangement allows piling to be driven into uneven ground. However, an adjustable extended lead mast arrangement, is typically significantly more expensive than a swinging lead mast arrangement and an underhung lead mast arrangement.

Putting economics aside, a major drawback of an adjustable extended lead mast arrangement is that the maximum attainable reach of the lead mast from the crawler crane unit is typically more restricted and/or limited compared with, for example, a swinging lead mast arrangement or underhung lead mast arrangement. It is believed such a restriction and/or limitation placed on the maximum attainable reach of the lead mast may reside in the configuration of an extended lead mast arrangement which requires an upper section of the lead mast to extend upwardly from and above the crane boom coupling point. Such a configuration typically decreases the stability of the crawler crane unit and promotes forward tipping of the crawler crane unit. Suitably, this instability is magnified as the lead mast is positioned further away from the crawler unit. Further, and to compensate for this inherent increased instability, the crane boom is typically coupled to the crawler crane unit at a region which corresponds to essentially the centre of gravity of the unit (i.e. the boom typically engages the middle of the crawler crane unit). Although, such a coupling arrangement typically improves the overall stability of the pile driver as forces are transferred through the centre of the crawler crane unit, the coupling arrangement has a further inevitable and consequential detrimental impact on the maximum attainable reach of the lead mast, as the crane boom and lead mast coupling point are positioned nearer to the crawler crane unit.

Accordingly, the restricted maximum attainable reach of a pile driver having an adjustable extended lead mast arrangement may prevent the use of such a pile driver in certain circumstances. For example, when it is necessary to drive piling into an area of ground and access to that ground is restricted and/or inaccessible to the crawler crane unit, such that the crawler crane unit can only be located at a distance exceeding the maximum attainable reach of the lead mast.

Accordingly, the present invention seeks to solve one or more of the above technical problems associated with a pile driver which includes an adjustable extended lead mast arrangement.

Accordingly, the present invention seeks to provide a pile driver including an adjustable extended lead mast arrangement whereby the lead mast has an increased attainable maximum reach, e.g. lead mast reach away from the crawler crane unit.

Accordingly, the present invention seeks to provide a pile driver including an adjustable extended lead mast arrangement whereby the lead mast has an increased attainable maximum reach and the pile driver exhibits improved stability (e.g. it is less prone to tipping forwards and/or backwards), especially in use when driving a piling.

Accordingly, the pile driver of the invention including an adjustable extended lead mast arrangement having a lead mast with an increased attainable maximum reach offers advantages over known pile drivers including an adjustable extended lead mast arrangement. For example, the pile driver of the invention may be deployed and used to drive piling into and/or remove piling from areas of ground whereby access to such an area is restricted and/or inaccessible to the crawler crane unit.

Thus, according to a first aspect, the present invention provides a pile driver for driving piling into and/or removing piling from the ground, the pile driver is self-propellable over ground and comprises a base machine having an adjustable extended lead mast arrangement, wherein:

the base machine comprises a lower crawler unit and an upper car body, the crawler unit having moveable ground engaging members to permit the crawler unit to move over the ground, the upper car body is rotateably mounted to the crawler unit to permit the car body to rotate about an axis that extends substantially perpendicular to the crawler unit, the upper car body having a front section which is associated with the adjustable extended lead mast arrangement and a rear section which is associated with a counterweight;

the adjustable extended lead mast arrangement comprises a lead mast having upper, middle and lower lead mast sections and a lead mast adjustment means which is associated with the front section of the upper car body and the lead mast, the lead mast adjustment means enables the lead mast to be moved away from and towards the front section of the upper car body in a substantial longitudinal direction relative to the upper car body, the lead mast adjustment means comprises a spotter arm, a support arm, an upper hydraulic cylinder having a first end hingeably associated with an upper part of the middle lead mast section, a lower hydraulic cylinder, and a lead mast linkage having at least 3 linkage coupling nodes, wherein the lead mast linkage is hingeably associated with a lower part of the middle lead mast section by coupling with first said linkage coupling node, the lead mast linkage is hingeably associated with each of the second said end of the upper hydraulic cylinder, a first end of the support arm and a first end of the lower hydraulic cylinder by coupling with said second linkage coupling node, and the lead mast linkage is hingeably associated with a first end of the spotter arm by coupling with said third linkage coupling node; and, wherein

the upper car body includes an extended reach connector comprising a bracket section and a bracket support member, the bracket section extends away from the front section of the upper car body in a substantially longitudinal direction relative to the upper car body, the bracket support member extends across the upper car body from the bracket section towards the rear section of the upper car body and counterweight, and wherein both the second said end of the spotter arm and second said end of the support arm of the lead mast adjustment means are each hingeably associated with the bracket section to enable each of said spotter arm and said support arm to rotate within a substantially vertical plane relative to the upper car body.

Preferably, the extended reach connector comprises the bracket section, the bracket support member and counterweight engagement means to enable the extended reach connector to engage with (e.g. be coupled to) the counterweight of the upper car body. Preferably, the bracket section is positioned at a first end of the extended reach connector and the counterweight engagement means is positioned at a second end of the extended reach connector. Preferably, the bracket section is positioned at a first end of the bracket support member and the counterweight engagement means is positioned at a second end of the bracket support member. Accordingly, the bracket support member of the extended reach connector is positioned between and couples the bracket section to the counterweight engagement means. Preferably, the bracket section, the bracket support member and optional, albeit preferred, counterweight engagement means represent an integrated (e.g. one-piece) structure.

Preferably, the extended reach connector is permanently fixed to the upper car body. More preferably, the extended reach connector is permanently fixed to the upper car body by the bracket support member.

Preferably, the second said end of the support arm of the lead mast adjustment means is hingeably associated with a first bracket coupling point of the bracket section of the extended reach connector.

Preferably, the second said end of the spotter arm of the lead mast adjustment means is hingeably associated with a second bracket coupling point of the bracket section of the extended reach connector.

Preferably, the second said end of the lower hydraulic cylinder of the lead mast adjustment means is hingeably associated with the bracket section of the extended reach connector to enable the lower hydraulic cylinder to rotate in a substantially vertical theoretical plane relative to the upper car body. Preferably, the second said end of the lower hydraulic cylinder is hingeably associated with a third bracket coupling point of the bracket section.

Suitably, the support arm, spotter arm and lower hydraulic cylinder are each rotateable about an axis which extends in a lateral direction across the bracket support member.

Preferably, the first bracket coupling point of the bracket section is positioned above the second bracket coupling point of the backet section relative to the crawler crane unit. Preferably, the second bracket coupling point of the bracket section is positioned above the third bracket coupling point of the backet section relative to the crawler carne unit. Most preferably, the first bracket coupling point of the bracket section is positioned above the second bracket coupling point of the backet section and the second bracket coupling point is positioned above the third bracket coupling point relative to the crawler crane unit.

Preferably, the first bracket coupling point of the bracket section is positioned nearer to the upper car body than the second bracket coupling point of the backet section. Preferably, the second bracket coupling point of the bracket section is positioned nearer to the upper car body than the third bracket coupling point of the backet section. Most preferably, the first bracket coupling point of the bracket section is positioned nearer to the upper car body than the second bracket coupling point and the second bracket coupling point is positioned nearer to the upper car body than the third bracket coupling point.

Suitably, the bracket section which extends in a substantially longitudinal direction away from the front section of the upper car body (i.e. in a substantially forwardly facing direction relative to the upper car body) permits an end of both the spotter arm and support arm, and optionally second end of the lower hydraulic cylinder, of the lead mast adjustment means to be hingeably associated with (e.g. hingeably coupled to) the front section of the upper car body at a position which is outward from the front section, preferably outward from a forward facing front section, of the upper car body. Advantageously, such a coupling configuration enables the maximum attainable reach of the lead mast away from the upper car body to be increased by the lead mast adjustment means.

Suitably, the bracket section is dimensioned and configured to facilitate the transfer of tipping forces exerted at the front section of the upper car body (e.g. weight of extended lead mast, driving forces generated in use when driving or extracting a piling), in combination with the bracket support member, from the bracket section towards the rear section of the car body, thereby enhancing the stability of the base machine. Advantageously, such an arrangement enables the maximum attainable reach of the lead mast to be increased without significant adverse destabilisation of the base machine.

In a preferred embodiment, the bracket section has a substantially triangular cross-section when viewed side on with respect to the upper car body (i.e. side plan view of the extended reach connector), more preferably a substantially right angled triangular cross-section, which triangle cross-section extends away from the front section of the upper car body in a substantially longitudinal direction relative to the upper car body.

Suitably, when the bracket has a substantially triangular cross-section, especially right angled triangular cross-section, the bracket section defines a triangle apex positioned towards the front section of the upper car body, a triangle base positioned below the triangle apex and extending in a substantially longitudinal direction away from the front section of the car body, and a sloping triangle side extending downwardly from the triangle apex to the triangle base.

Suitably, when the bracket section has a substantially triangular cross section, the first bracket coupling point for engaging the support arm is positioned in the region of the triangle apex.

Suitably, when the bracket section has a substantially triangular cross section, the second bracket coupling point for engaging with the spotter arm is positioned in the region of the sloping triangle side wall and below the triangle apex, preferably in the region of the triangle base.

Suitably, when the bracket section has a substantially triangular cross section, the third bracket coupling point for engaging with the lower hydraulic cylinder is positioned in the region of the sloping triangle side wall, preferably in the region of the triangle base.

Suitably, the bracket section defines a channel for receiving the second end of the support arm and the second end of the spotter arm. Preferably, the second end of the support arm is positioned in the channel of the bracket section. Preferably, the second end of spotter arm is position in the channel of the bracket section. Most preferably, both second said ends of the support arm and spotter arm are positioned in the channel of the bracket section. Preferably, the second end of the lower hydraulic cylinder is not positioned in the channel of the bracket section. Preferably, the second end of the lower hydraulic cylinder is coupled to an outer side wall of the bracket section.

Suitably, the bracket support member extends across the upper car body in a substantially longitudinal direction relative to the upper car body from the front section of the upper car body to the rear section of the upper car body. Preferably, the bracket support member extends across essentially the entire length of the upper car body. Preferably, the bracket support member extends across the upper car body in a substantially horizontal theoretical plane that is perpendicular to the axis of rotation of the upper car body and crawler unit.

Suitably, the bracket support member comprises a beam structure. Preferably, the bracket section and the bracket support member together define a beam structure, more preferably a box beam type structure. Preferably, the beam structure comprises a base section and two opposing side walls disposed in a substantially parallel relationship and each side wall extending upwardly from the base section along the length of the base section, thereby defining a channel which extends longitudinally along the length of the beam structure. Preferably, each of the two opposing side walls of the bracket support member include a chamfered region. Suitably, the chamfered region(s) of the bracket support member are lower in height than the upper point (e.g. triangle apex) defined by the side wall(s) of the bracket section. Advantageously, such a configuration of the bracket section and bracket support member may further facilitate the transfer of tipping

forces from the bracket section along the bracket support member towards the rear section of the upper car unit, thereby promoting the stability of the upper car unit.

Preferably, the bracket support member engages with the counterweight at the rear section of the upper car body. Accordingly, the bracket support member includes counterweight engagement means to enable the bracket support member to engage with the counterweight at the rear section of the upper car body. Preferably, the counterweight may be releasably attached to the counterweight engagement means.

Preferably, the counterweight engagement means which forms part of the extended reach connector is dimensioned and configured to enable engagement of the counterweight with the extended reach connector so that at least part of the counterweight extends in a substantially vertical direction, preferably substantially upward vertical direction, relative to the bracket support means.

Preferably, the counterweight engagement means which forms part of the extended reach connector is dimensioned and configured to enable engagement of the counterweight with the extended reach connector so that at least part of the counterweight is positioned above the highest part (e.g. triangle apex) of the bracket section.

Preferably, the counterweight engagement means is defined by sloping opposing said side walls of the beam structure defining the bracket section and bracket support member, wherein the sloping opposing side walls extend upwardly and away from the end of the bracket support member. Suitably, said sloping side walls extend above the highest part of the bracket section.

Advantageously, the configuration of the counterweight engagement means *per se*, and in combination with the configuration of the bracket section and bracket support member, enables the counterweight to exert an increased downward and rearward force to the base machine, thereby further stabilising the base machine and mitigating forward tipping of the base machine promoted by the increased lead mast reach. Accordingly,

the bracket section, bracket support member and, when present, counterweight engagement means of the extended reach connector cooperate mechanically by virtue of the configuration of the extended reach connector.

Suitably, the lead mast linkage of the lead mast adjustment means is hingeably coupled to the lead mast, the upper hydraulic cylinder, the support arm, the lower hydraulic cylinder, and the spotter arm to enable the lead mast to be moved away from and towards the upper car body in a substantially linear direction within an x-y plane and/or to enable the lead mast to be rotated within said x-y plane.

Suitably, the upper hydraulic cylinder of the lead mast adjustment means comprises a hydraulic double-acting cylinder. Suitably, the lower hydraulic cylinder of the lead mast adjustment means comprises a hydraulic double-acting cylinder.

Suitably, the first said end of the upper hydraulic double acting cylinder is hingeably associated with (e.g. coupled to) an upper part of the middle lead mast section to enable the lead mast to rotate within a substantially vertical plane relative to the upper car body. Accordingly, the lead mast may rotate about an axis which extends laterally relative to the upper hydraulic cylinder. Suitably, such a rotateable association between the lead mast and upper hydraulic cylinder enables the lead mast to be moved in a substantially longitudinal direction away from, and towards, the front section of the upper car body and/or enables the pitch of the lead mast to be varied with respect to the upper car body. Suitably, the lead mast may be moved in a direction away from the front section of the upper car body and orientated so that the lead mast is substantially perpendicular to the ground or orientated at a different angle relative to the ground. Suitably, when the pile driver is not in use the lead mast may be orientated in a substantial horizontal position relative to the upper car body, thereby facilitating the transportation of the pile driver form one location to another location.

Preferably, the lead mast comprises an extendible lead mast. More preferably, the lead mast includes a telescopically extendable part which enable the length of the lead mast to be varied. Suitably, the lead mast has a minimum length (i.e. fully retracted lead

mast) of greater than or equal to 7, preferably greater than or equal to 8, more preferably greater than or equal to 9, most preferably greater than or equal to 9.5, metres. Suitably, the lead mast has a maximum length (i.e. fully extended lead mast) of less than or equal to 30, preferably less than or equal to 25, more preferably less than or equal to 24, most preferably greater than or equal to 23, metres.

In a preferred embodiment, the lead mast adjustment means includes a slider unit to enable the lead mast to be moved in a substantially linear direction relative to the slider unit. The slider unit may permit the lead mast to be raised and lowered relative to the ground.

Suitably, when the lead mast adjustment means includes a slider unit, the first end of the upper hydraulic cylinder is hingeably associated with a first upper section of the slider unit and the lead mast linkage is hingeably associated with a second lower section of the slider unit by the first linkage coupling node.

Suitably, the slider unit may further include a rotary unit to enable the lead mast to be rotated about an axis which extends substantially along the length of the slider unit (i.e. the lead mast may be rotated from side to side with respect to the upper car body; the yaw of the lead mast may be adjusted).

Suitably, the lead mast adjustment means, which may optionally include the slider unit, represents a kinematic mechanism. Suitably, the lead mast adjustment means enables the controlled adjustment and orientation of the lead mast. Accordingly, the lead mast may be placed at a plurality of positions in a substantially longitudinal direction away from the front section of the upper car body. The lead mast may be raised and or lowered relative to the ground. The pitch of the lead mast relative to the ground and upper car body may be changed. The lead mast may be rotated from side to side with respect to the upper car body.

Advantageously, the lead mast adjustment means and extended reach connector enable the lead mast to be positioned at a position further away from the upper car body without

significantly destabilising the pile driver. Suitably, the extended lead mast may be positioned a distance of greater than or equal to 6.5, preferably greater than or equal to 7.0, more preferably greater than or equal to 7.5, most preferably greater than or equal to 8.0, metres away from the front section of the upper car body. In comparison, the lead mast of a pile driver including an extended lead mast arrangement but not including the extended reach connector typically may only be positioned a maximum distance of less than 6 metres away from the front section of the upper car body.

Suitably, the extended lead mast is adapted to receive driving means for driving a piling into the ground. Suitably, the driving means is associated with the lead mast to permit linear movement, preferably linear reciprocal movement, of the driving means relative to the lead mast. Suitably, the driving means includes gripping means for holding a piling. A preferred driving means comprises a hammer for hammering a piling, preferably a displacement piling, into the ground. A suitable hammer includes an impact hammer, a drop hammer, double and single acting hammers, vibratory hammer. The hammer may be powered by an external combustion (e.g. diesel operated hammer), by steam or hydraulics. A preferred hammer comprises a vibratory hammer.

Preferably, the pile driver of the invention is adapted for driving displacement piling into or removing displacement piling from the ground.

Preferably, the pile driver of the invention is adapted for driving sheet piling into or removing sheet piling from the ground.

In accordance with a second aspect, the invention provides a method of driving a piling into the ground which comprises providing: a pile driver, as defined in accordance with the first aspect of the invention, which includes a driving means for driving a piling into the ground; providing a piling; and, operating the pile driver so that the driving means drives the piling into the ground.

In accordance with a third aspect, the invention provides a method of removing a piling from the ground which comprises providing: a pile driver, as defined in accordance

with the first aspect of the invention, which includes a driving means for removing a piling from the ground; and, operating the pile driver so that the driving means removes the piling from the ground.

In accordance with a fourth aspect, the invention provides the use of a pile driver, as defined in the first aspect, for driving a piling into and/or removing a piling from the ground.

Preferably, the piling, as defined in the second, third and/or fourth aspect, is a sheet piling.

Preferably, the piling, as defined in the second, third and/or fourth aspect, is a displacement piling.

Where claim 1 refers to a pile driver for driving piling into and/or removing piling from the ground, it refers to a pile driver 'suitable for' driving and/removing piling, the pile driver does not include the features of the optional, albeit preferred, driving means, or the features of the piling.

By the term *'hingeably associated'* with respect to the coupling of 2 components we mean that each component is hinged relative to the other component so that both components can move about a common transverse axis which allows each component to rotate in the same theoretical plane. Suitably, the 2 components may be directly associated, i.e. coupled direct to each other by a joint, or the 2 components may be indirectly associated, e.g. coupled to each other by a linkage.

By the term *'piling'* we mean a support which may be used as a deep foundation to transfer and distribute loads through ground material or stratum (e.g. soil) with inadequate bearing, sliding or uplift capacity to more solid ground material located at a depth with a higher bearing, sliding or uplift capacity and more capable of supporting a load. Suitably, a piling may be constructed from steel, concrete, timber and other metals. Preferably, a piling comprises steel, including reinforced steel, or concrete.

By the term *'displacement piling'* we mean a piling as defined herein which is driven into the ground and ground material is displaced essentially simultaneously.

By the term *'replacement piling'* we mean a piling as defined herein which is inserted (e.g. driven) into a hole in the ground and ground material is not displaced essentially simultaneously.

By the term *'sheet piling'* we mean a piling which is essentially in the form of sheet material. The sheet material may comprise different shapes, dimensions and configurations.

A preferred piling for use with the pile driver of the invention is a sheet piling, especially a displacement sheet piling.

By the term *'extended lead mast'* we mean a lead mast which comprises at least 3 sections: (i) a middle lead mast section which is associated with the front section of the upper car body by lead mast adjustment means; (2) a top lead mast section which extends upwardly from the middle lead mast section; and, (3) a bottom lead mast section which extends downwardly from the middle lead mast section. Accordingly, when the pile driver is in use, the bottom lead mast section is positioned closest to the ground and the top lead mast section is furthest away from the ground.

Other optional and preferred features of the invention are set out in the dependent claims, and the description, below. The features of one aspect of the invention can be combined in any complimentary manner, with one or more features of another aspect of the invention, the dependent claims, and/or with one or more features of the description, where such a combination of features would provide a working embodiment of the invention.

An embodiment of pile driver, in accordance with the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view from the front of a pile driver of an embodiment of the invention;

Figure 2 is a side view of a pile driver of an embodiment of the invention with the extended lead mast in a raised position;

Figure 3 is a side view of a pile driver of an embodiment of the invention with the extended lead mast in a lowered position;

Figure 4 is a top plan view from above of a pile driver of an embodiment of the invention;

Figure 5 is side view of a pile driver of an embodiment of the invention showing the extended reach connector;

Figure 6 is a perspective view of the extended reach connector from the counterweight engagement means end; and,

Figure 7 is a perspective view of the extended reach connector from the bracket end.

A self-propellable pile driver (10) having an adjustable extended lead mast arrangement (100) for driving a sheet piling into and/or removing a sheet piling from the ground using a vibratory hammer (104) is shown in Figures 1 to 5.

As shown in Figures 1 and 2, the pile driver (10) comprises a large weighted base machine (20), an adjustable extended lead mast arrangement (100) comprising an extended lead mast (102) which is hingedly coupled to a forward facing section of the base machine (20) by lead mast adjustment means (150), and a vibratory hammer (104) for vibrating a piling simultaneously with the creation of continuous downward movement. The large weighted base machine (20) is similar to a hydraulic excavator and comprises a lower crawler unit (22) and an upper car body (40).

The crawler unit (22) has separate left and right track drive systems (24, 26) each of which drive systems includes a continuous track (25, 27) which engages with the ground. The left (25) and right (27) continuous tracks are driven by one or more respective drive sprockets (28, 29), thereby enabling the unit to move forwards and backwards over the ground. The left track (25) is capable of independent movement

relative to the corresponding right track (27), thereby allowing the crawler unit (22) to turn from side to side. Each track drive system (24, 26) is capable of being extended in a lateral direction away from the base machine (22) to provide additional stability to the base machine (20), in use. A power pack in the upper car body (not shown) is used to drive and operate the crawler unit (22) and associated track drive systems (24,26), thereby providing a self-propellable pile driver (10).

The upper car body (40) is mounted to the crawler unit (22) and the upper car body is able to rotate with respect to the crawler unit (22) about a vertical axis which extends through the upper car body (40) and crawler unit (22), i.e. the upper car body (40) can swing from side to side relative to the crawler unit (22). Rotation of the upper car body (40) to the crawler unit (22) is achieved by a standard drive and gear system which is powered by a power pack in the upper car body (not shown). The upper car body (40) includes a cab (42) for an operator positioned at a front section (44) of the upper car body (40), a counterweight (46) at a rear section (48) of the upper car body (40) to stabilise the base machine (20), an extended reach connector (250), which includes a bracket section (252) that extends in a lateral direction and away from the front section (44) of the upper car body to couple with the lead mast adjustment means (150), and one or more power packs (e.g. combustion engine, pumps, electrical systems, gears, hydraulics etc) to power the base machine and associated components, (e.g. crawler unit, upper car body, lead mast adjustment means, slider, vibratory hammer etc.).

As is shown in Figures 1, 2, 3 and 5, the adjustable extended lead mast arrangement (100) comprises an extended lead mast (102), lead mast adjustment means (150) and a slider (106). The extended lead mast comprises an upper top lead mast section (108), a middle lead mast section (110) and a lower bottom lead mast section (112). The lead mast (102) includes a telescopic portion at the upper top lead mast section (108) to enable the length of the lead mast to be varied. The lead mast (102) is approximately 9.5 metres in length, when not telescopically extended; the lead mast (102) may be extended to approximately 22.5 metres in length, when in the fully telescopically extended position.

The extended lead mast (102) is coupled to the bracket section (252) of the extended reach connector (250) extending from the forward section (44) of the upper car body by lead mast adjustment means (150) and the slider (106).

The slider (106) is slideably coupled to the middle section (110) of the extended lead mast to enable the lead mast (102) to be moved in a substantially linear direction with respect to the slider (106). The use of the slider enables the lead mast (102) to be raised and lowered with respect to the ground, so that the lower section of the lead mast (112) may be positioned at different heights above and/or below ground level when in use. As is shown in Figure 4, the slider (106) includes a swivel motor (114) to enable the lead mast (102) to be rotated from side to side relative to the upper car body (40). The slider (106) may be considered to represent a part of the lead mast adjustment means (150).

As is shown in Figures 1 to 5, the lead mast adjustment means (150) comprises a lower spotter arm (152), an upper support arm (154), first left (156) and second right (158) upper hydraulic double-acting cylinders, first left (160) and second right (162) lower hydraulic double acting cylinders, and first left (164) and second right (166) lead mast linkages. Each of the components of the lead mast adjustment means (150) are associated with each other by a plurality of joints. The components of the lead mast adjustment means (150) cooperate with each other and provide a kinematic mechanism which, in use, enables controlled adjustment and movement of the lead mast (102) in a plurality of directions.

With reference to the specific parts of the lead mast adjustment means (150), the first left (156) and second right (158) upper hydraulic double-acting hydraulic cylinders are each essentially identical in dimension and configuration. The first left (160) and second right (162) lower hydraulic double-acting hydraulic cylinders are each essentially identical in dimension and configuration. The first left (164) and second right (166) lead mast linkages are each essentially identical in dimension and configuration. Accordingly, the respective left and right components in the lead mast

adjustment means (150) are configured so that the respective left and right components cooperate with each other in the kinematic lead mast adjustment mechanism.

The first left lead mast linkage (164) is hingeably coupled to a left side of a lower section of the slider (106) at a first lead mast linkage coupling node (167) using a boom ram foot pin (168). The second right lead mast linkage (166) is hingeably coupled to a corresponding position on the opposite right side of the lower section of the slider (106) at a first lead mast linkage coupling node (169) using boom ram foot pin (170). The first and second lead mast linkages (164,166) cooperate as a pair of linkages.

Viewing the pile driver from the left side as shown in Figures 1 to 3, a first end (171) of the upper support arm (154), a lower end (172) of the left upper hydraulic double-acting cylinder (156), an upper end (173) of the left lower hydraulic double-acting cylinder (160) are each hingeably associated with each other and with the left lead mast linkage, to enable hinged movement of the components relative to each other. In particular, a left side (174) of the upper support arm (154) includes a left support linkage (175) at the first end of the support arm (154). The left support linkage (175) is hingeably coupled to the left lead mast linkage (164) using a boom pin (176). The lower end (172) of the left upper hydraulic double-acting cylinder (156) is hingeably coupled to the left support linkage (175) using a boom pin (177). The upper end (178) of the left upper hydraulic double-acting cylinder (156) is hingeably coupled to an upper side section (179) of the slider (106) with a hinged joint (180). The upper end (173) of the left lower hydraulic double-acting cylinder (160) is hingeably coupled to the left support linkage (175) using a boom pin (181).

A first end (182) of the lower spotter arm (152) is hingeably associated with the left lead mast linkage (164) by a first left spotter arm linkage (183) which is coupled to the left lead mast linkage (164) using a boom pin (183). The hinged joint which couples the lower spotter arm (152) to the left lead mast linkage (164) is separate from the hinged joint which couples the support arm (154) to the left lead mast linkage (164).

Viewing the pile driver from the right side as shown in Figure 5, it can be seen that the right side of the lead mast adjustment mechanism includes a complimentary set of components which are configured to cooperate with the components of the left side of the lead mast adjustment mechanism.

In particular, the first end (171) of the upper support arm (154), a lower end (184) of the right upper hydraulic double-acting cylinder (158), an upper end (185) of the right lower hydraulic double-acting cylinder (162) are each hingeably associated with each other and with the right lead mast linkage (166), to enable hinged movement of the components relative to each other. In particular, a right side (186) of the upper support arm (154) includes a right support linkage (187) at the first end of the support arm (154). The right support linkage (187) is hingeably coupled to the right lead mast linkage (166) using a boom pin (188). The lower end (184) of the right upper hydraulic double-acting cylinder (158) is hingeably coupled to the right support linkage (187) using a boom pin (189). The upper end (190) of the right upper hydraulic double-acting cylinder (158) is hingeably coupled to an upper right side section (191) of the slider (106) with a hinged joint (192). The upper end (185) of the right lower hydraulic double-acting cylinder (162) is hingeably coupled to the right support linkage (187) using a boom pin (193).

The first end (182) of the lower spotter arm (152) is hingeably associated with the right lead mast linkage (166) by a second right spotter arm linkage (194) which is coupled to the right lead mast linkage (166) using a boom pin (195). The hinged joint which couples the spotter arm (152) to the right lead mast linkage (166) is separate from the hinged joint which couples the support arm (154) to the right lead mast linkage (166).

Accordingly, and as shown in Figures 1 to 5, the lead mast adjustment means (150) represents a kinematic mechanism and enables controlled adjustment of the lead mast (102) through a plurality of degrees of freedom. The lead mast (102) may be placed at a plurality of positions in a substantially linear direction away from the front section (44) of the upper car body (40). The lead mast (102) may be raised and or lowered relative to the ground. The pitch of the lead mast (102) relative to the ground and upper

car body (40) may be changed. The lead mast (102) may be rotated side to side relative to the upper car body (40).

As shown in Figures 1 to 3 and 5, the lead mast adjustment means (150) is hingeably coupled to the bracket section (252) of the extended reach connector (250) to enable the lead mast adjustment means, and its associated component parts, to rotate in a theoretical plane that is perpendicular to the bracket section (252) and upper car body (40). In particular, the second end (196) of the support arm (154) is hingeably coupled to the bracket section (252) by a hinged joint (254), the second end (198) of lower spotter arm (152) is hingeably coupled to the bracket section (252) by a separate second bracket hinged joint (256), the second end (200) of the left lower hydraulic double-acting cylinder (160) is coupled to a left side of the bracket section (252) by a third bracket hinged joint (258), and the second end (202) of the right lower hydraulic double-acting cylinder (162) is coupled to a right side of the bracket section (252) by a fourth bracket hinged joint (259). Such a configuration enables hinged movement of each of the upper support arm (154), lower spotter arm (152), lower left hydraulic double-acting cylinder (160) and lower right hydraulic double acting cylinder (162) in a substantially vertical theoretical plane relative to the bracket section (252).

The extended reach connector (250) is shown in more detail in Figures 5, 6 and 7. The extended reach connector (250) comprises a bracket section (252), bracket support member (260) and counterweight engagement means (262). The bracket section (252), bracket support member (260) and counterweight engagement means (262) form an integrated part of the extended reach connector (250). The bracket section (252) is positioned at a first end (264) of the extended reach connector (250); the counterweight engagement means (262) is positioned at a second end (266) of the extended reach connector (250); and, the bracket support member (260) is positioned between and communicates with both the bracket section (252) and counterweight engagement means (260).

As shown in Figure 5, the bracket section (252) of the extended reach connector (250) extends away from the front section (44) of the upper car body (40) in a substantially

longitudinal direction relative to the upper car body (40). The bracket support member (260) extends across the length of the upper car body (40) in a lateral direction away from the front section (44) of the upper car body (40) to the rear section (48) of the upper car body (40). The bracket support member (260) is fixedly welded to the upper car body (40). The counterweight engagement means (262) of the extended reach connector (250) engages the counterweight (46) at the rear of the upper car body (40).

As shown in Figures 5, 6 and 7, the extended reach connector (250) is dimensioned and configured to enable the maximum attainable reach of the lead mast from the front section (44) of the upper car body (46) to be increased and enable an increased downward force at the rear section (48) of the upper car body (40) by the counterweight (46) to improve the stability of the pile driver (10) and compensate for the extended reach of the lead mast (102).

As shown in Figures 6 and 7, the extended reach connector (250) may generally be considered to define a beam structure. The beam (268) having a base section (270) having two opposing corresponding and substantially parallel side walls (272, 274) extending upwardly from the base section (270), with each side wall (272, 274) extending along the length of the base section (270). The two opposing side walls define a channel (276) which extends along the length of the extended reach connector (250). The two opposing side walls (272, 274) are supported with one or more braces (278) to further increase the rigidity of the extended reach connector (250).

The extended reach connector (250) may be considered to comprise a bracket section (252) for engaging the lead mast adjustment means (150) at a first end (264) of the connector (250), a counterweight engagement means (262) at the second end (266) of the connector (250), and a bracket support member (260) positioned between and connecting the bracket section (252) with the counterweight engagement means (262).

As shown in Figures 5, the bracket section (252) extends in a lateral direction away from the front section (44) of the upper car body (40). The bracket section (252) has a substantially right-angled triangular cross-section when viewed from the side of the

upper car body (40). The bracket section (252) defines an apex (280) located near the upper car body (40), a triangle base (282) extending in a lateral direction away from the upper car body (40) and a triangle side section (284) extending downwardly from the apex (280) to the triangle base (282). The substantially triangular profile of the bracket section (252) is also shown in Figure 7.

The bracket section (252) includes upper support arm (154) coupling means (300), lower spotter arm (152) coupling means (310), left lower hydraulic double acting cylinder (160) coupling means (320) and right lower hydraulic double acting cylinder (162) coupling means (330) to enable each of said support arm (154), spotter arm (152), left lower hydraulic double-acting cylinder (160) and right lower hydraulic double acting cylinder (162) of the lead mast adjustment means (150) to hingeably couple with the bracket section (252) and permit hinged movement of each of said components of the lead mast adjustment means (150) relative to the bracket section (252) (i.e. rotation in a substantially vertical theoretical plane relative to the bracket section).

The support arm coupling means (300) of the bracket section (252) comprises an axle (302) extending across the channel (276) from the first (272) to second (274) side wall of the bracket section (252) and a hole (304, 306) in each of said two opposing side walls (272, 274) to receive a retaining pin. The upper support arm (154) is received by the channel (276) and the support arm (154) is supported by and able to rotate about the axle (302).

The spotter arm coupling means (310) of the bracket section (252) is similar to the support arm coupling means (300) and comprises an axle (312) extending across the channel (276) from the first (272) to second (274) side wall of the bracket section (252) and a hole (314, 316) in each of said two opposing side walls (272, 274) to receive a retaining pin. The lower spotter arm (152) is received by the channel (276) and the spotter arm (152) is supported by and able to rotate about the axle (312).

The left lower hydraulic double acting cylinder coupling means (320) comprises an axle (322) extending outwardly from the first left side wall (272) of the bracket section (252)

and a hole (324) to receive a retaining pin. Accordingly, the left lower hydraulic double acting cylinder (160) is hingeably connected to the outer wall of the bracket section (252). The left lower hydraulic double acting cylinder (160) is supported by and able to rotate about axle (322).

The right lower hydraulic double acting cylinder coupling means (330) comprises an axle (332) extending outwardly from the second right side wall (274) of the bracket section (252) and a hole (334) to receive a retaining pin. Accordingly, the right lower hydraulic double acting cylinder (162) is hingeably connected to the outer wall of the bracket section (252). The right lower hydraulic double acting cylinder (162) is supported by and able to rotate about axle (332).

As shown in Figures 1 to 3 and 5, the support arm coupling means (300) is positioned in the region of the apex (280) of the triangular shaped bracket section (252). The spotter arm coupling means (310) is positioned on the triangular side wall (284) of the bracket section (252) below the support arm coupling means (300) and in the region of the triangle base section (282). Each of said lower hydraulic double-acting cylinder coupling means (320, 330) are positioned below the spotter arm coupling means (310). Advantageously, such a configuration enables an increased maximum attainable reach of the lead mast (102) and also enables the weight and forces of the lead mast (102) to be transferred towards the centre of gravity of the pile driver (10).

As shown in Figures 5 and 6, the counterweight engagement means (262) at the second said end (266) of the extended reach connector (250) is configured to engage a counterweight (46) so that part of the counterweight is positioned above the bracket section (252). This enables the counterweight (46) to exert an increased downward and rearward force to the base machine (20), thereby further mitigating any forward tipping of the base machine (20).

The counterweight engagement means (262) is defined by upwardly sloping first (272) and second (274) side walls of the extended reach connector (250). The upper points (340, 342) of each of said first and second side walls of the extended reach connector

defining the counterweight engagement means (262) is above the upper point (280) (e.g. apex) of the corresponding side walls defining the bracket section (252). The counterweight engagement means (262) includes anchoring points (344) to permit a counterweight to be anchored thereto.

Each of the two opposing side walls (272, 274) of the bracket support member (260) include a chamfered region (346, 348) which is lower in height than the upper point (280) (e.g. apex) of the bracket section. Such a configuration further improves the stability of the base machine (10) as it promotes the transfer of forces form the bracket section (252) to the centre of gravity of the base machine (10) and enhances the downward force of the counterweight at the rear of the base machine (10).

The extended lead mast (102) includes a vibratory hammer (104) which is slideably engaged to the lead mast (102) to enable reciprocated linear motion of the hammer (104) relative to the length of the lead mast (102). The vibratory hammer (104), which is known to those skilled in the art, includes an anvil (118) and gripping means (119) for gripping a sheet piling. The vibratory hammer (104) is powered by a separate power pack incorporated in the upper car body (40) of the base machine (10).

The pile driver (10) may be used to drive displacement sheet piling into the ground. Suitably, a sheet piling is placed in position using a crane. The pile driver (10) is then moved into position and the lead mast (102) extended using the lead mast adjustment means (150). The lead mast is orientated and positioned with the lead mast adjustment means (150). The vibratory hammer (104) is connected to the sheet piling with the gripping means (112). The vibratory hammer (104) is then operated to drive the sheet piling into the ground.

Similarly, the pile driver (10) may be used to remove sheet piling from the ground. The pile driver (10) is moved into position and the lead mast (102) extended using the lead mast adjustment means (150). The lead mast is orientated and positioned with the lead mast adjustment means (150). The vibratory hammer (104) is connected to the sheet

piling with the gripping means (112). The vibratory hammer (104) is then operated, in a reverse motion, to remove the sheet piling into the ground.

Advantageously, the lead mast adjustment means further permits the lead mast (102) to be positioned in a substantially horizontal orientation with respect to the upper car body (40) when not in use (i.e. folded rearwards across the upper car body), thereby allowing the pile driver (10) to be transported more easily.

Claims

1. A pile driver for driving piling into and/or removing piling from the ground, the pile driver is self-propellable over ground and comprises a base machine having an adjustable extended lead mast arrangement, wherein:

the base machine comprises a lower crawler unit and an upper car body, the crawler unit having moveable ground engaging members to permit the crawler unit to move over the ground, the upper car body is rotateably mounted to the crawler unit to permit the car body to rotate about an axis that extends substantially perpendicular to the crawler unit, the upper car body having a front section which is associated with the adjustable extended lead mast arrangement and a rear section which is associated with a counterweight;

the adjustable extended lead mast arrangement comprises a lead mast having upper, middle and lower lead mast sections and a lead mast adjustment means which is associated with the front section of the upper car body and the lead mast, the lead mast adjustment means enables the lead mast to be moved away from and towards the front section of the upper car body in a substantial longitudinal direction relative to the upper car body, the lead mast adjustment means comprises a spotter arm, a support arm, an upper hydraulic cylinder having a first end hingeably associated with an upper part of the middle lead mast section, a lower hydraulic cylinder, and a lead mast linkage having at least 3 linkage coupling nodes, wherein the lead mast linkage is hingeably associated with a lower part of the middle lead mast section by coupling with first said linkage coupling node, the lead mast linkage is hingeably associated with each of the second said end of the upper hydraulic cylinder, a first end of the support arm and a first end of the lower hydraulic cylinder by coupling with said second linkage coupling node, and the lead mast linkage is hingeably associated with a first end of the spotter arm by coupling with said third linkage coupling node; and, wherein

the upper car body includes an extended reach connector comprising a bracket section and a bracket support member, the bracket section extends away from the front section of the upper car body in a substantially longitudinal direction relative to the upper car body, the bracket support member extends across the upper car body from the bracket section towards the rear section of the upper car body and counterweight,

and wherein both the second said end of the spotter arm and second said end of the support arm of the lead mast adjustment means are each hingeably associated with the bracket section to enable each of said spotter arm and said support arm to rotate within a substantially vertical plane relative to the upper car body.

2. A pile driver as claimed in claim 1, wherein the extended reach connector comprising the bracket section and bracket support member further includes counterweight engagement means to enable the extended reach connector to engage with the counterweight at the rear section of the upper car body.

3. A pile driver as claimed in claim 2, wherein the bracket section is located at a first end of the extended reach connector, the counterweight engagement means is located at the second end of the extended reach connector, and the bracket support member couples the bracket section with the counterweight engagement means.

4. A pile driver as claimed in any one of the preceding claims, wherein the second said end of the support arm of the lead mast adjustment means is hingeably associated with the bracket section of the extended reach connector by support arm coupling means.

5. A pile driver as claimed in any one of the preceding claims, wherein the second said end of the spotter arm of the lead mast adjustment means is hingeably associated with the bracket section of the extended reach connector by spotter arm coupling means.

6. A pile driver as claimed in any one of the preceding claims, wherein the second said end of the lower hydraulic cylinder of the lead mast adjustment means is hingeably associated with the bracket section of the extended reach connector by lower hydraulic cylinder coupling means.

7. A pile driver as claimed in any one of the claims 4 to 6, wherein said support arm coupling means of the bracket section is positioned above said spotter arm coupling means of the bracket section, and said lower hydraulic cylinder coupling means of the

bracket section, when present, is positioned below said spotter arm coupling means relative to the crawler crane unit.

8. A pile driver as claimed in any one of claims 4 to 7, wherein said support arm coupling means of the bracket section is positioned nearer to the upper car body than said spotter arm coupling means of the bracket section, and said lower hydraulic cylinder coupling means of the bracket section, when present, is positioned further away from the upper car body than said spotter arm coupling means.

9. A pile driver as claimed in any one of the preceding claims, wherein the bracket section has a substantially triangular cross-section, preferably a substantially right angled triangle cross-section, the bracket section defines a triangle apex positioned towards the front section of the upper car body, a triangle base positioned below the triangle apex and extending in a substantially longitudinal direction away from the front section of the car body, and a sloping triangle side wall extending downwardly from the triangle apex to the triangle base.

10. A pile driver as claimed in claim 9, wherein said support arm coupling means is positioned in the region of the triangle apex, the spotter arm coupling means is positioned in the region of the sloping triangle side wall and below the triangle apex in the region of the triangle base, and the lower hydraulic cylinder coupling means, when present, is positioned in the region of the sloping triangle side wall below said spotter arm coupling means.

11. A pile driver as claimed in any one of the preceding claims, wherein the bracket section defines a channel for receiving the second end of the support arm and the second end of the spotter arm.

12. A pile driver as claimed in any one of the preceding claims, wherein the bracket support member extends across the entire length of the upper car body and the bracket support member engages the counterweight at the rear section of the upper car body.

13. A pile driver as claimed in any one of the preceding claims, wherein the bracket section and bracket support member together define a beam structure comprising a base section and two opposing side walls disposed in substantially parallel relationship and each side wall extending upwardly from the base section, the two opposing side walls extending along the length of the base section.

14. A pile driver as claimed in claim 13, wherein each of said two opposing side walls of the bracket support member include a chamfered region, and each of said chamfered regions are lower in height than the highest part of the bracket section.

15. A pile driver as claimed in claim 13 or 14, wherein the counterweight engagement means of the extended reach connector is defined by sloping opposing said side walls of the beam structure, and the sloping opposing side walls extend upwardly and away from the bracket support member.

16. A pile driver as claimed in any one of the preceding claims, wherein the counterweight engagement means is configured to enable engagement of the counterweight so that at least a part of the counterweight is positioned above the highest part of the bracket section.

17. A pile driver as claimed in any one of the preceding claims, wherein the lead mast adjustment means further includes a slider unit.

18. A pile driver as claimed in any one of the preceding claims, wherein the lead mast has a maximum attainable reach in a direction away from the upper car body of greater than 6.5 metres.

19. A pile driver as claimed in any one of the preceding claims, wherein the lead mast adjustment means enables the lead mast to be rotated in a theoretical plane that is substantially perpendicular to the upper car body and the bracket section.

20. A pile driver as claimed in any one of the preceding claims, wherein the lead mast includes a driving means, preferably a vibratory hammer, for driving a piling into and/or removing a piling from the ground.

21. A method of driving a piling into the ground which comprises providing: a pile driver, as claimed in any one of the preceding claims, which includes a driving means for driving a piling into the ground; providing a piling; and, operating the pile driver and driving means to drive the piling into the ground.

22. A method of removing a piling from the ground which comprises providing: a pile driver, as claimed in any one of claims 1 to 20, which includes a driving means for removing a piling from the ground; and, operating the pile driver and driving means to remove the piling from the ground.

23. The use of a pile driver as claimed in any one of claims 1 to 20 for driving a piling into and/or removing a piling from the ground.

24. The method of claim 21 or 22 or the use of claim 23, wherein the piling is a sheet piling, preferably a displacement sheet piling.

Intellectual Property Office

Application No:	GB2118235.7	**Examiner:**	Owain Llewellyn
Claims searched:	1-24	**Date of search:**	20 May 2022

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-24	ABI, September 2020, Telescopic Leader Mast, Sheet Piling UK, [online], Available from: https://www.sheetpilinguk.com/wp-content/uploads/2020/09/ABI_TM20LR_SR35F_deen_0920.pdf [Accessed 20 May 2022] See especially the figures on pages 2 and 5.
X	1-24	Sheet Piling UK, 19 February 2021, "Sheet Piling (UK) Ltd TM20 Long Reach Leader Rig", Youtube.com, [online], Available from: https://www.youtube.com/watch?v=nHqH0PcFUq4 [Accessed 20 May 2022]. See the whole video.
A	-	US 2010/0319222 A1 (LANZL et al.) see especially figure 1 and paragraphs [0038]-[0041].
A	-	CN 202969381 U (TAI AN JIAHE HEAVY INDUSTRY MACHINERY CO) see especially figure 1 and the WPI abstract [Accession number: 2013-R35642].

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

E02D

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC, Patent Fulltext

Intellectual Property Office

International Classification:

Subclass	Subgroup	Valid From
E02D	0007/16	01/01/2006