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1021171

THE UNITED STATES OF AMERICA

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UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

September 15, 2019

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APPLICATION NUMBER: *62/777,690*

FILING DATE: *December 10, 2018*

RELATED PCT APPLICATION NUMBER: *PCT/US19/49275*

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS *US62/777,690*



Certified by

Anders Ivarsson

Under Secretary of Commerce
for Intellectual Property
and Director of the United States
Patent and Trademark Office

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PPA21
		Application Number	
Title of Invention	Force optimized A-frame-to-monopile adapter for single axis tracker		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2:

☐	Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)
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Inventor Information:

Inventor 1				
Legal Name				
Prefix	Given Name	Middle Name	Family Name	Suffix
	Charles		Almy	
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service				
City	Berkeley	State/Province	CA	Country of Residence ⁱ US
Mailing Address of Inventor:				
Address 1		1668 Lincoln St.		
Address 2				
City	Berkeley	State/Province	CA	
Postal Code	94703	Country ⁱ	US	
Inventor 2				
Legal Name				
Prefix	Given Name	Middle Name	Family Name	Suffix
	Jack		West	
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service				
City	San Rafael	State/Province	CA	Country of Residence ⁱ US
Mailing Address of Inventor:				
Address 1		612 Point Gallinas Road		
Address 2				
City	San Rafael	State/Province	CA	
Postal Code	94903	Country ⁱ	US	
Inventor 3				
Legal Name				
Prefix	Given Name	Middle Name	Family Name	Suffix
	Johann		Karkheck	

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PPA21
		Application Number	
Title of Invention	Force optimized A-frame-to-monopile adapter for single axis tracker		

Residence Information (Select One)		☒ US Residency	☐ Non US Residency	☐ Active US Military Service
City	Petaluma	State/Province	CA	Country of Residence ⁱ
US				

Mailing Address of Inventor:

Address 1	1421 Elizabeth Drive			
Address 2				
City	Petaluma	State/Province	CA	
Postal Code	94954	Country ⁱ	US	

Inventor 4

Legal Name				
Prefix	Given Name	Middle Name	Family Name	Suffix
	David		Mar	

Residence Information (Select One)		☒ US Residency	☐ Non US Residency	☐ Active US Military Service
City	Berkeley	State/Province	CA	Country of Residence ⁱ
US				

Mailing Address of Inventor:

Address 1	1932 Thousand Oaks Blvd.			
Address 2				
City	Berkeley	State/Province	CA	
Postal Code	94707	Country ⁱ	US	

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button.

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).			
☐ An Address is being provided for the correspondence information of this application.			
Customer Number	157339		
Email Address	pmancini@ojjo.com	Add Email	Remove Email

Application Information:

Title of the Invention	Force optimized A-frame-to-monopile adapter for single axis tracker		
Attorney Docket Number	PPA21	Small Entity Status Claimed	☒
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	11	Suggested Figure for Publication (if any)	

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PPA21
		Application Number	
Title of Invention	Force optimized A-frame-to-monopile adapter for single axis tracker		

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	☒ Customer Number	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)		
Customer Number	157339				
Prefix	Given Name	Middle Name	Family Name	Suffix	Remove
Registration Number					
Prefix	Given Name	Middle Name	Family Name	Suffix	Remove
Registration Number					
Additional Representative Information blocks may be generated within this form by selecting the Add button.					

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	PPA21
	Application Number	
Title of Invention	Force optimized A-frame-to-monopile adapter for single axis tracker	

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status			Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the Add button.			

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX) the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Application Number	Country ⁱ	Filing Date (YYYY-MM-DD)	Access Code ⁱ (if applicable)
Additional Foreign Priority Data may be generated within this form by selecting the Add button.			

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013. NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	PPA21
	Application Number	
Title of Invention	Force optimized A-frame-to-monopile adapter for single axis tracker	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PPA21
		Application Number	
Title of Invention	Force optimized A-frame-to-monopile adapter for single axis tracker		

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.								
Applicant 1								
If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.								
			Clear					
☐ Assignee	☐ Legal Representative under 35 U.S.C. 117	☐ Joint Inventor						
☒ Person to whom the inventor is obligated to assign.	☐ Person who shows sufficient proprietary interest							
If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:								
Name of the Deceased or Legally Incapacitated Inventor:								
If the Applicant is an Organization check here. ☒								
Organization Name	Ojjo, Inc.							
Mailing Address Information For Applicant:								
Address 1	47 Mark Drive							
Address 2								
City	San Rafael	State/Province	CA					
Country ¹	US	Postal Code	94903					
Phone Number	415-786-4685	Fax Number						
Email Address	pmancini@ojjo.com							
Additional Applicant Data may be generated within this form by selecting the Add button.								

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PPA21
		Application Number	
Title of Invention	Force optimized A-frame-to-monopile adapter for single axis tracker		

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Assignee 1				
Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.				
If the Assignee or Non-Applicant Assignee is an Organization check here. ☐				
Prefix	Given Name	Middle Name	Family Name	Suffix
Mailing Address Information For Assignee including Non-Applicant Assignee:				
Address 1				
Address 2				
City		State/Province		
Country i		Postal Code		
Phone Number		Fax Number		
Email Address				
Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.				

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PPA21
		Application Number	
Title of Invention	Force optimized A-frame-to-monopile adapter for single axis tracker		

Signature:

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Phillip D. Mancini/			Date (YYYY-MM-DD)	
First Name	Phillip	Last Name	Mancini	Registration Number	46743
Additional Signature may be generated within this form by selecting the Add button.					

FIG. 1

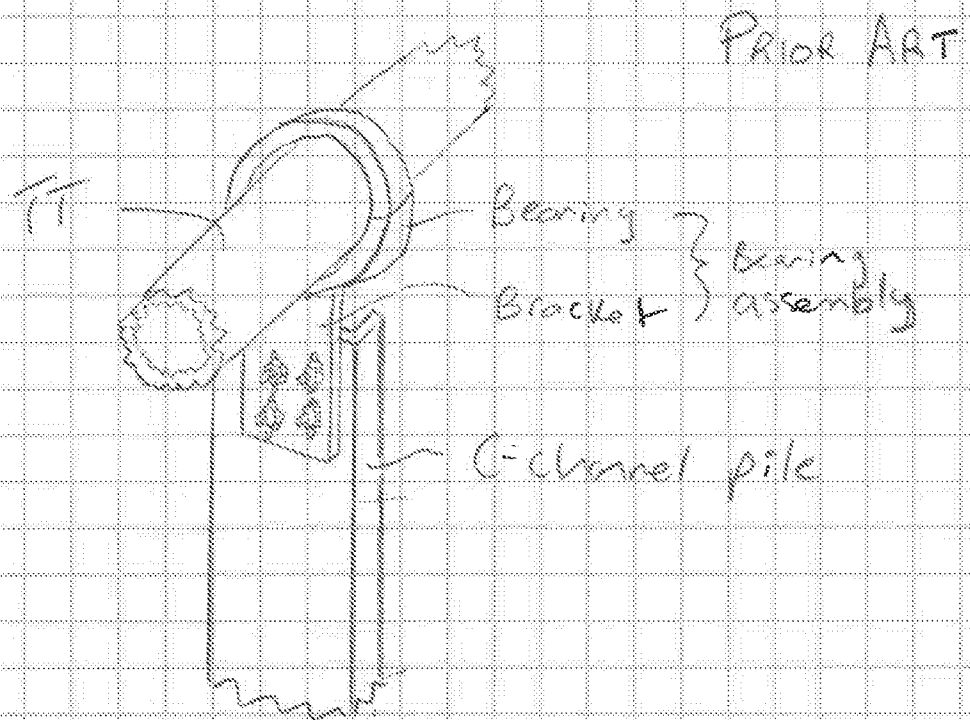


FIG. 2

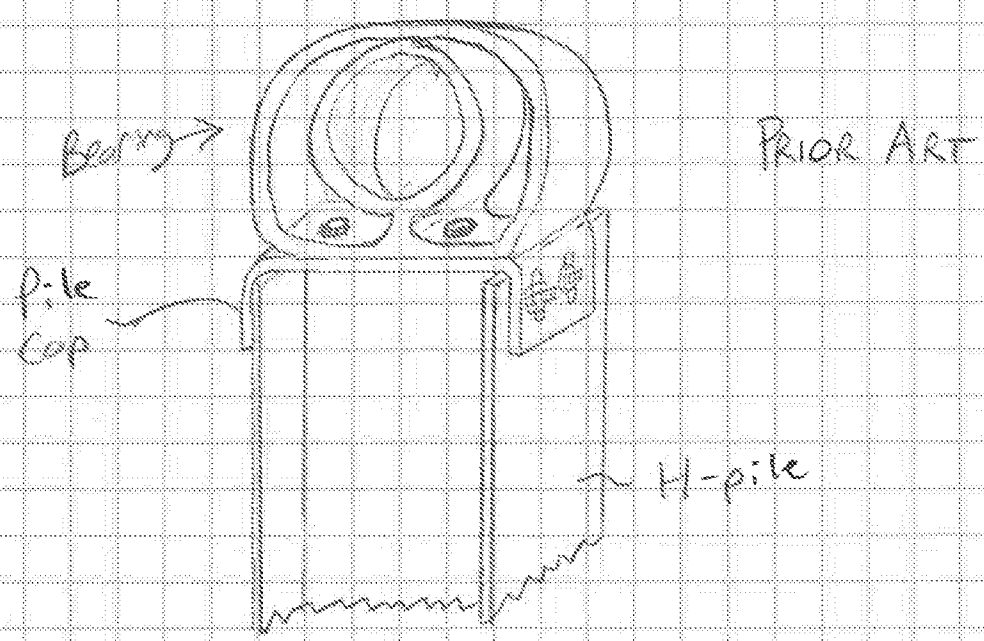


FIG. 3

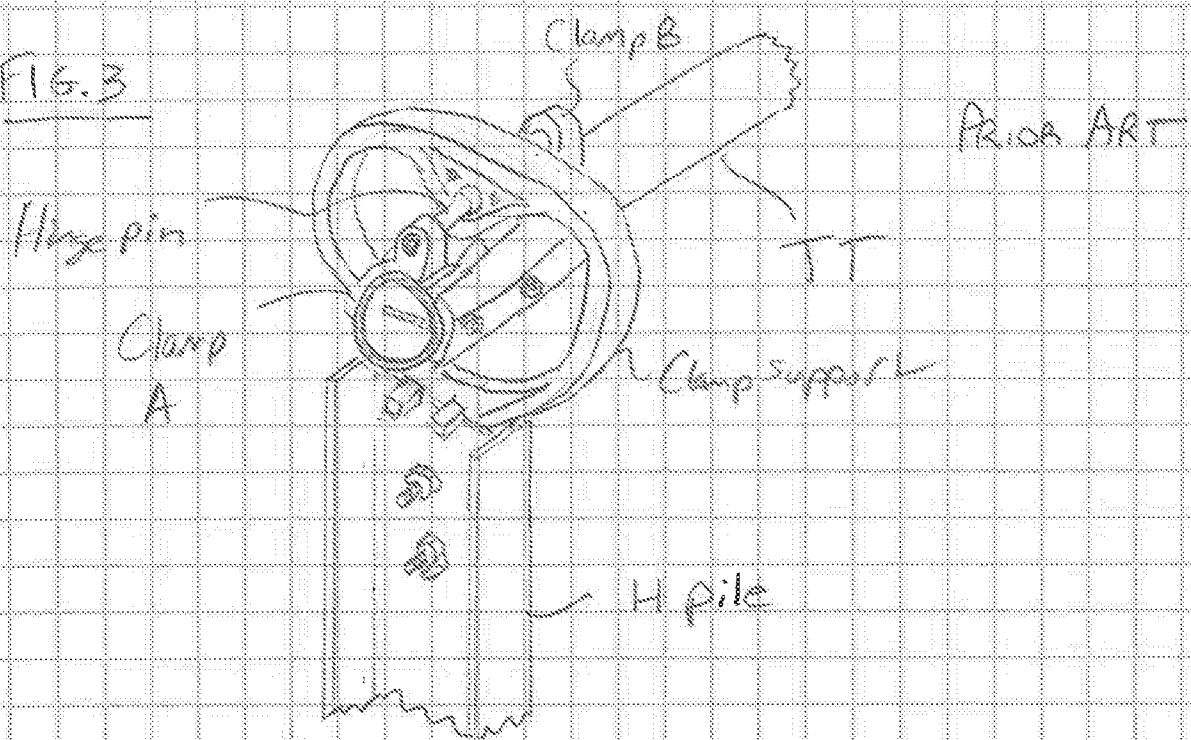


FIG. 4

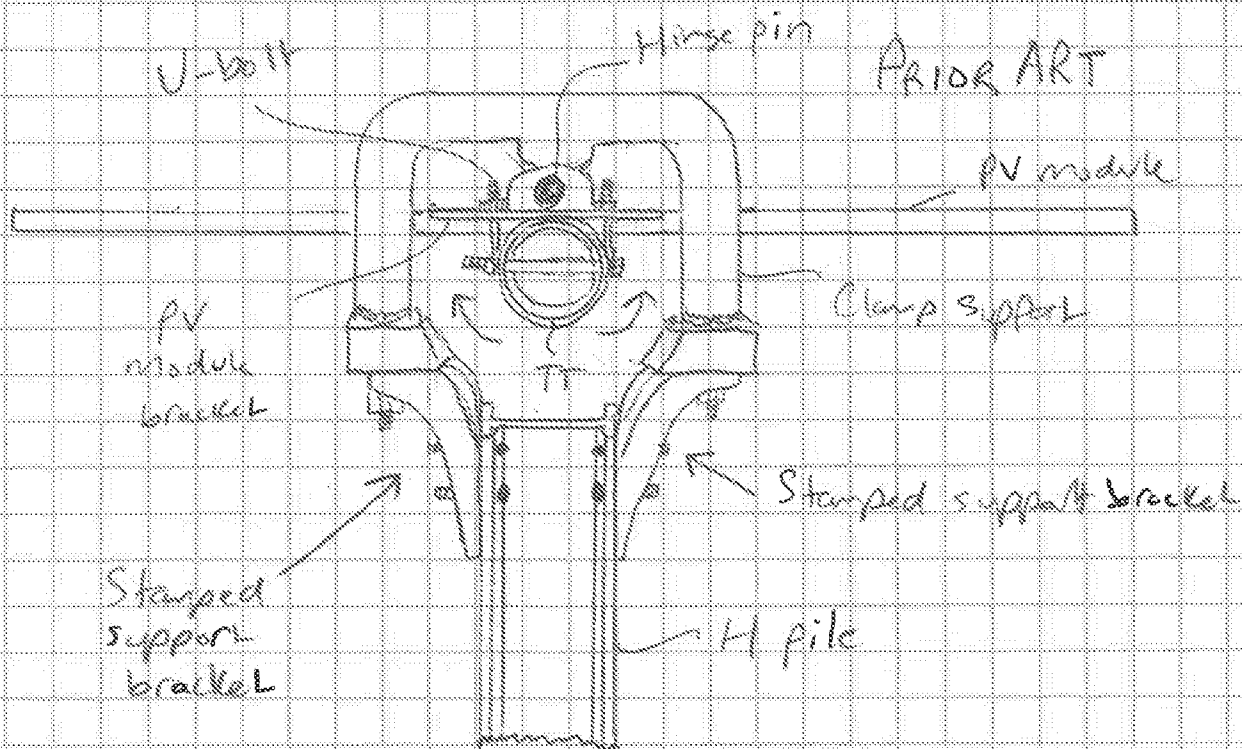


FIG. 5A

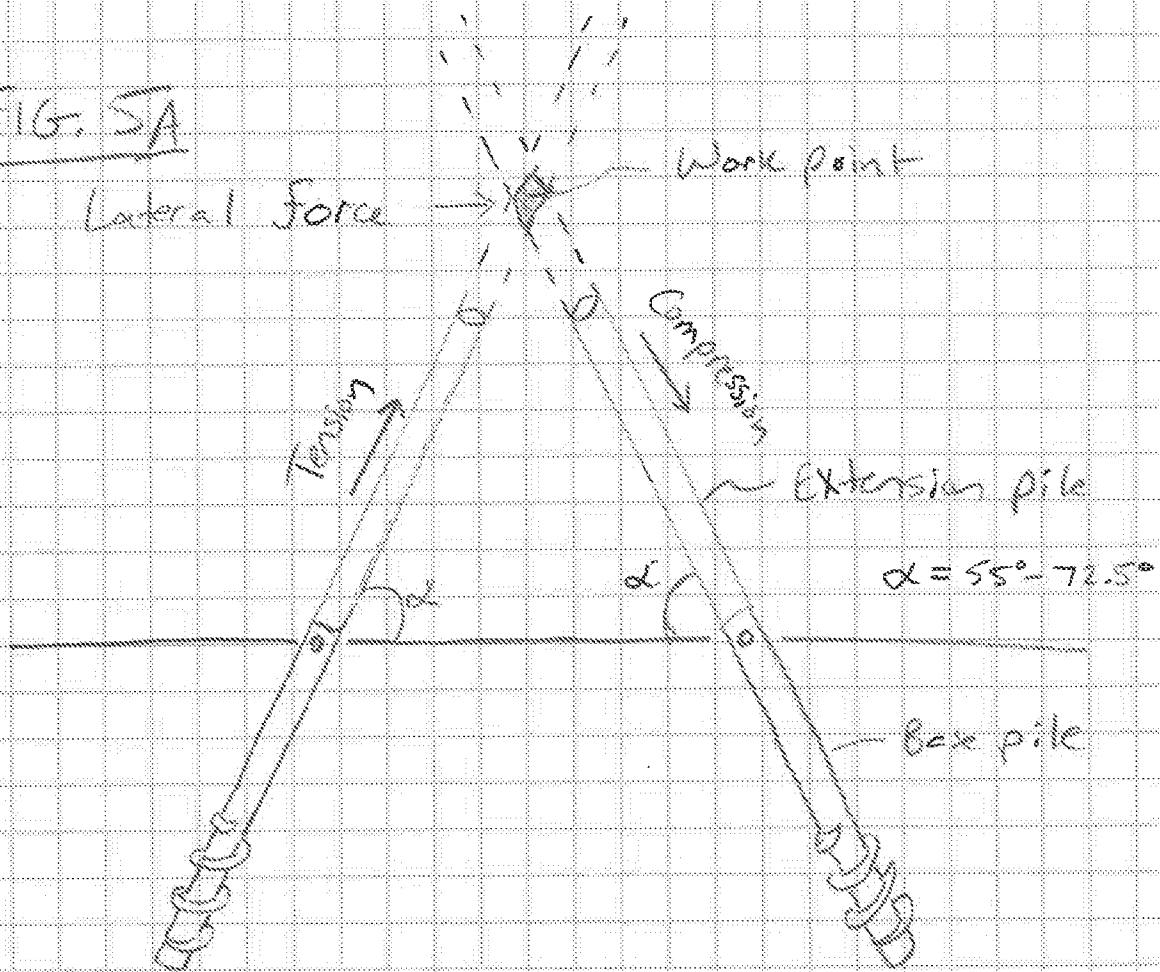


FIG. 5B

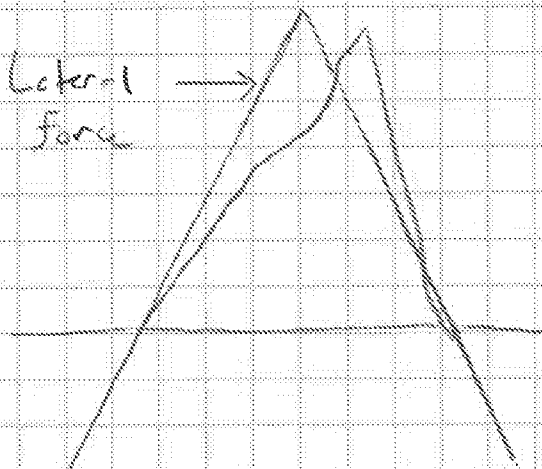


FIG. 5C

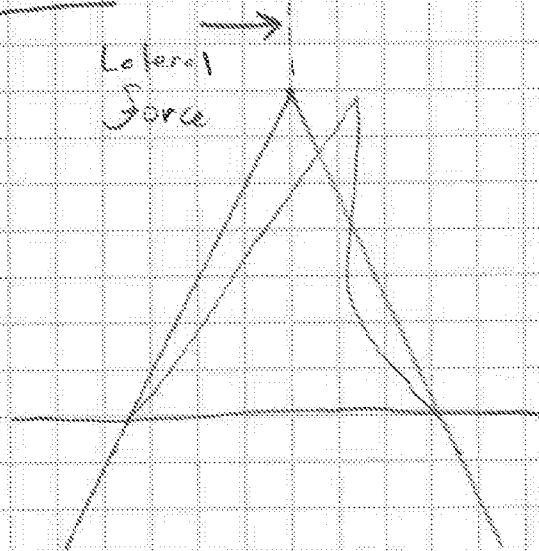


FIG. 6A

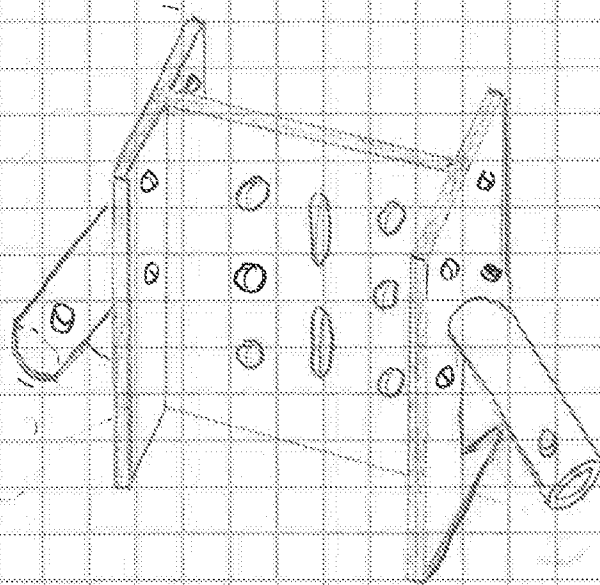


FIG. 6B

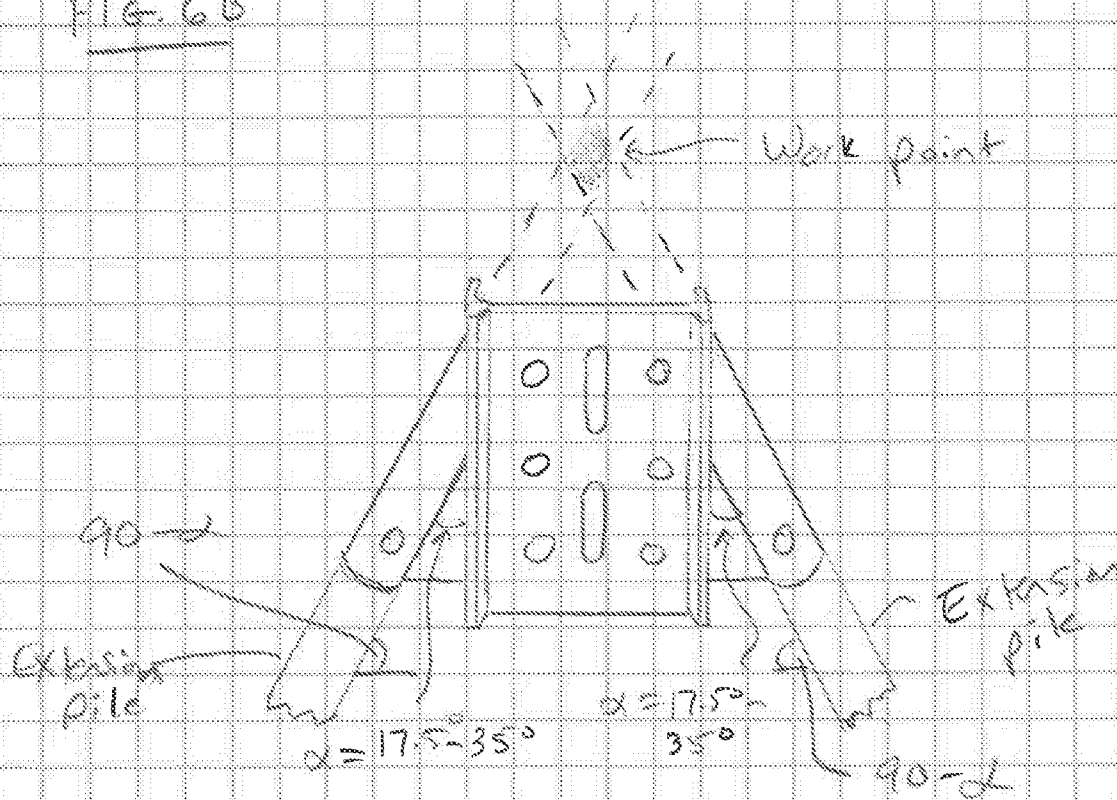


FIG. 7

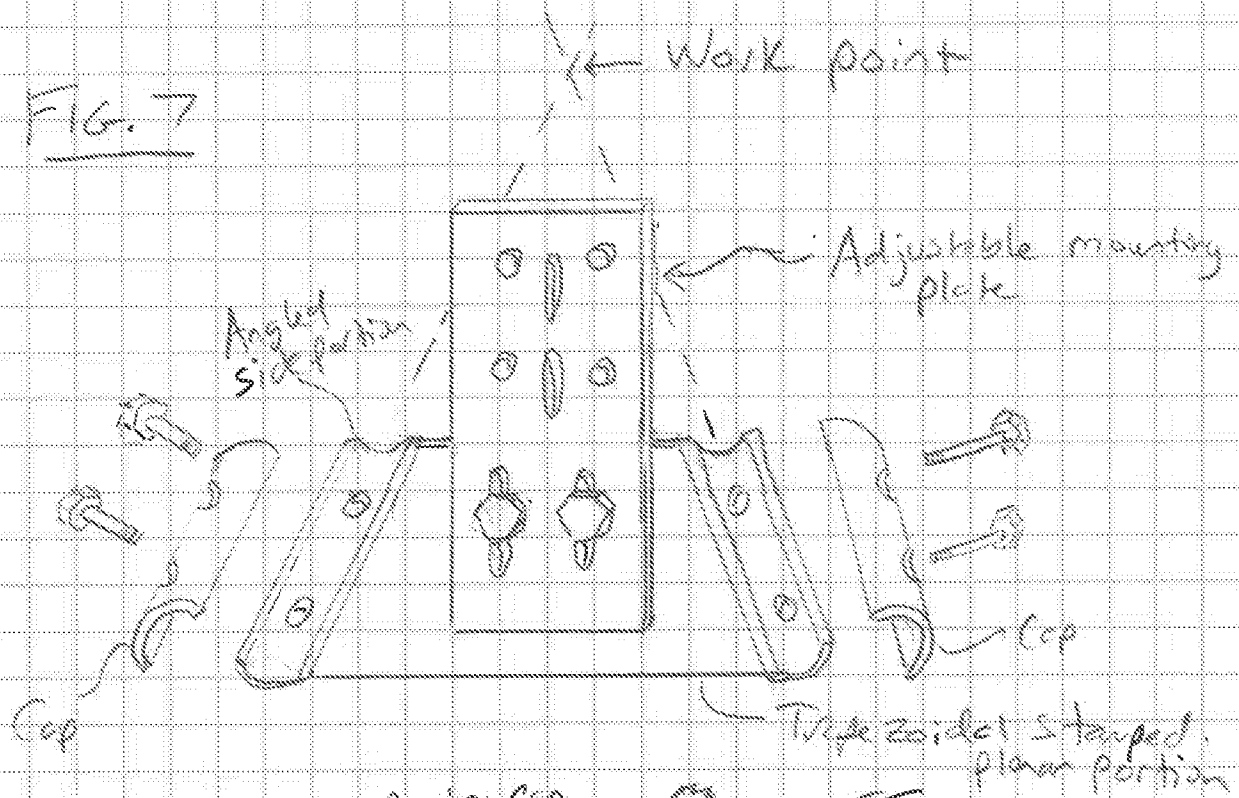


FIG. 8

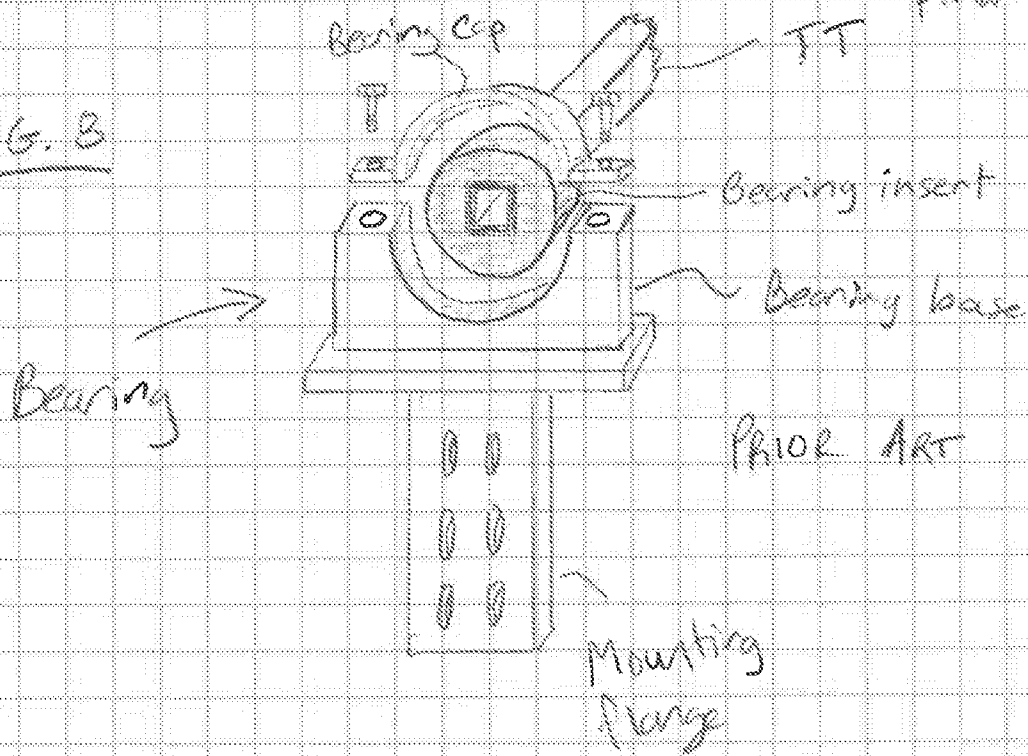


FIG. 9A

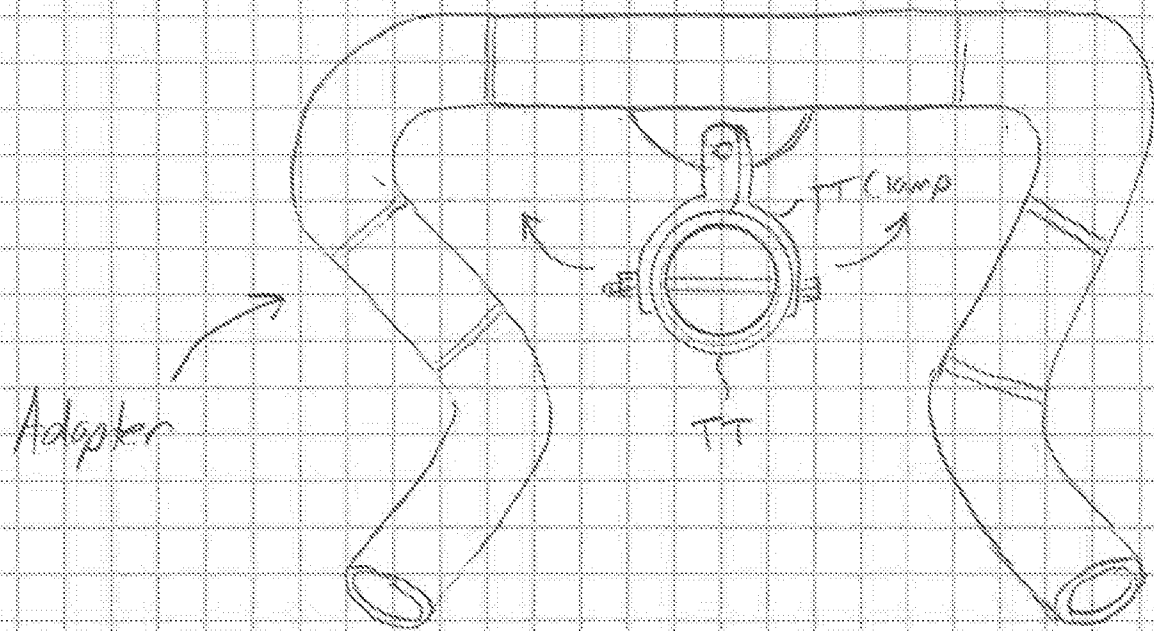


FIG. 9B

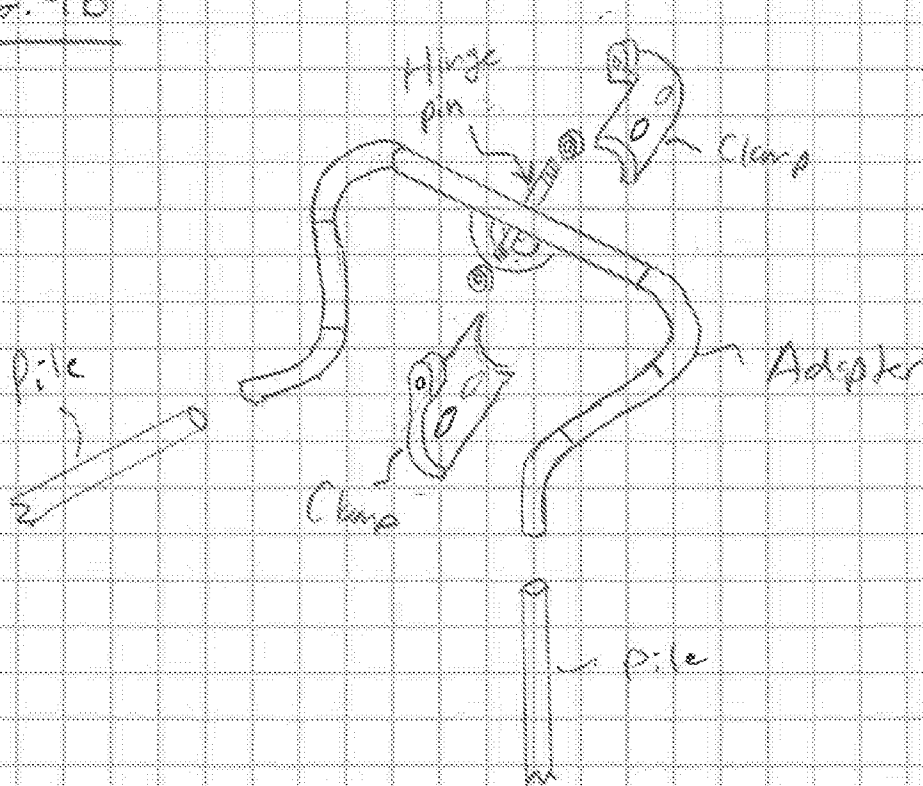


FIG. 9C

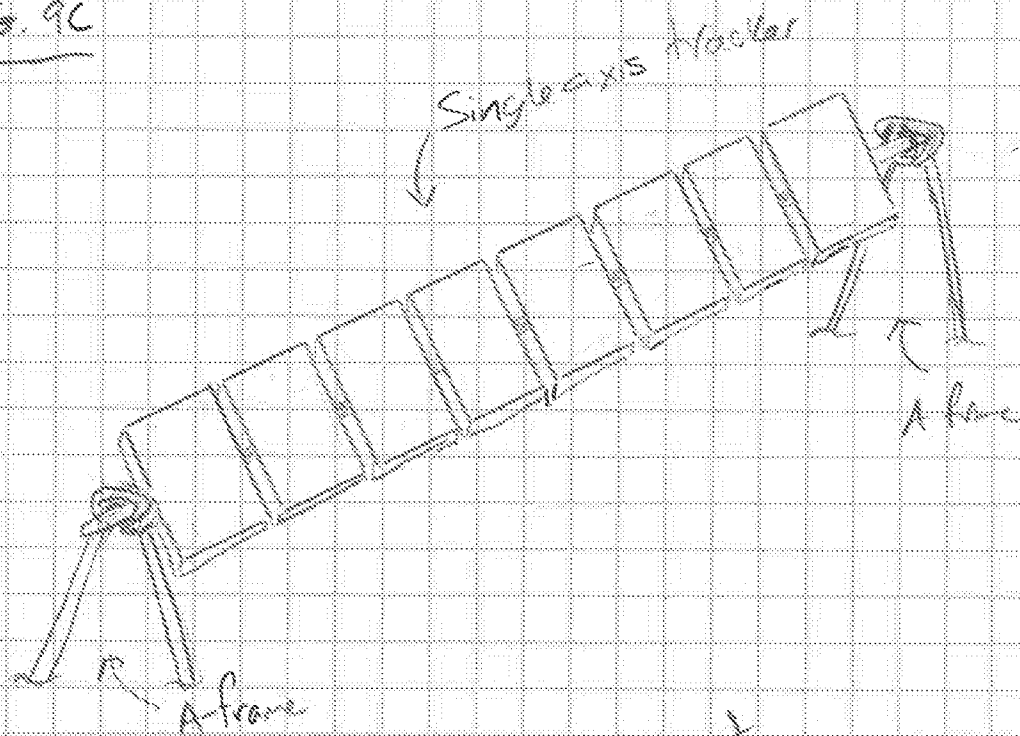


FIG. 9D

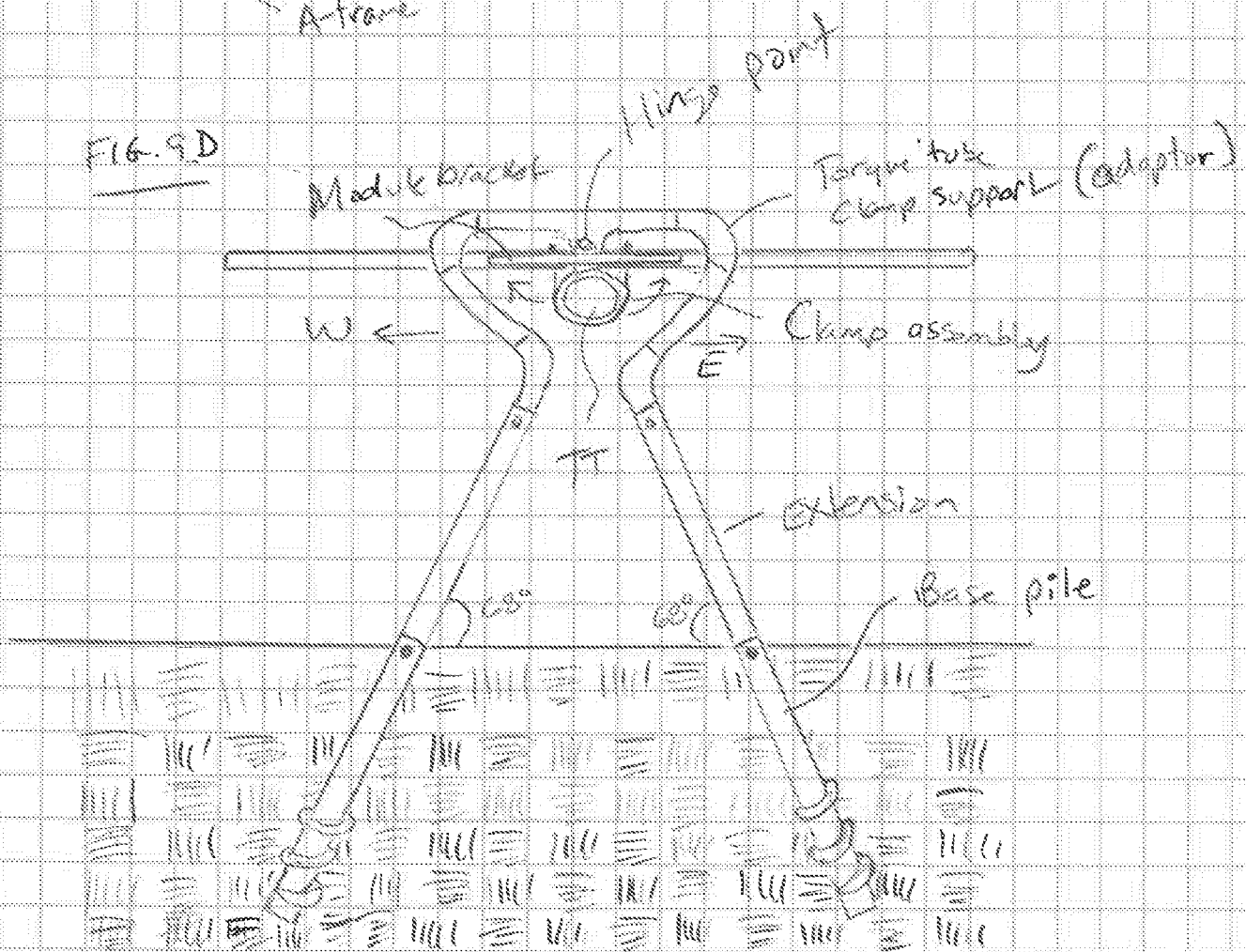


FIG. 10A

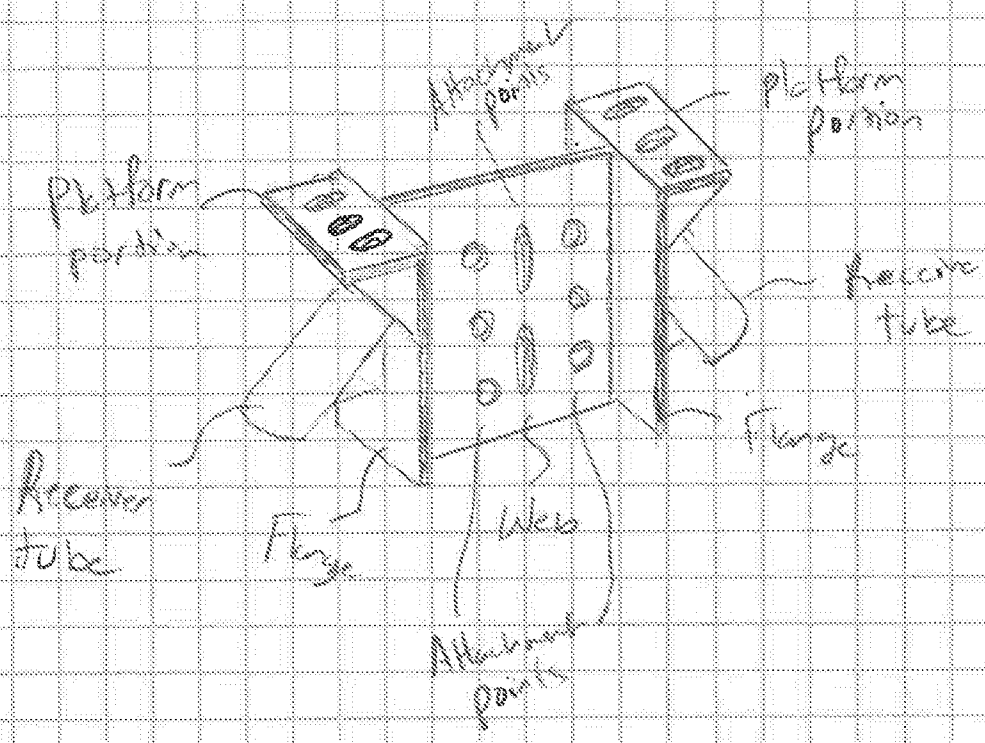


FIG. 11A

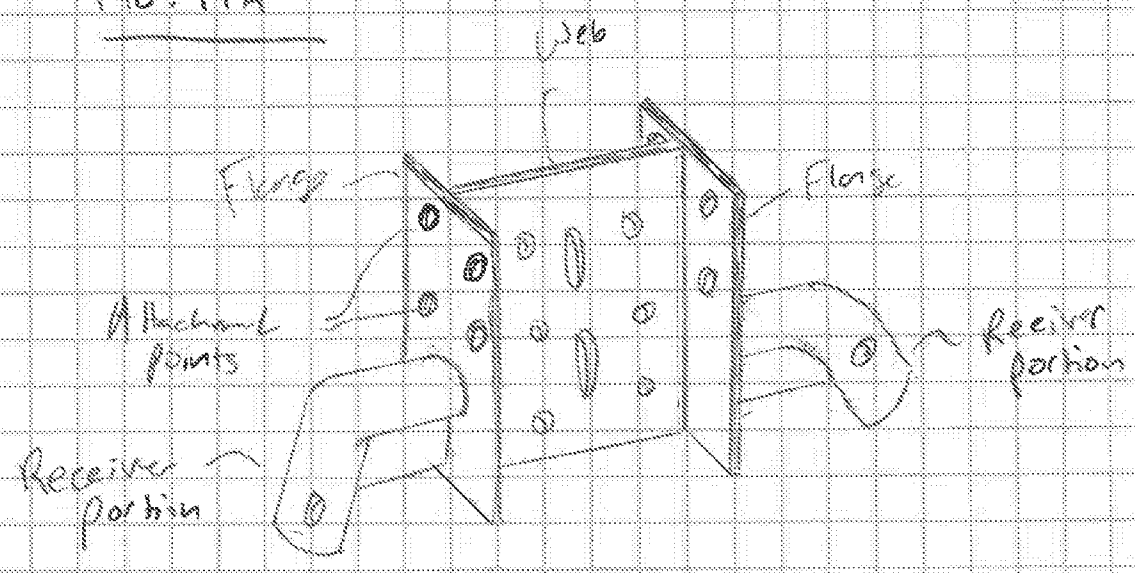


FIG. 10B

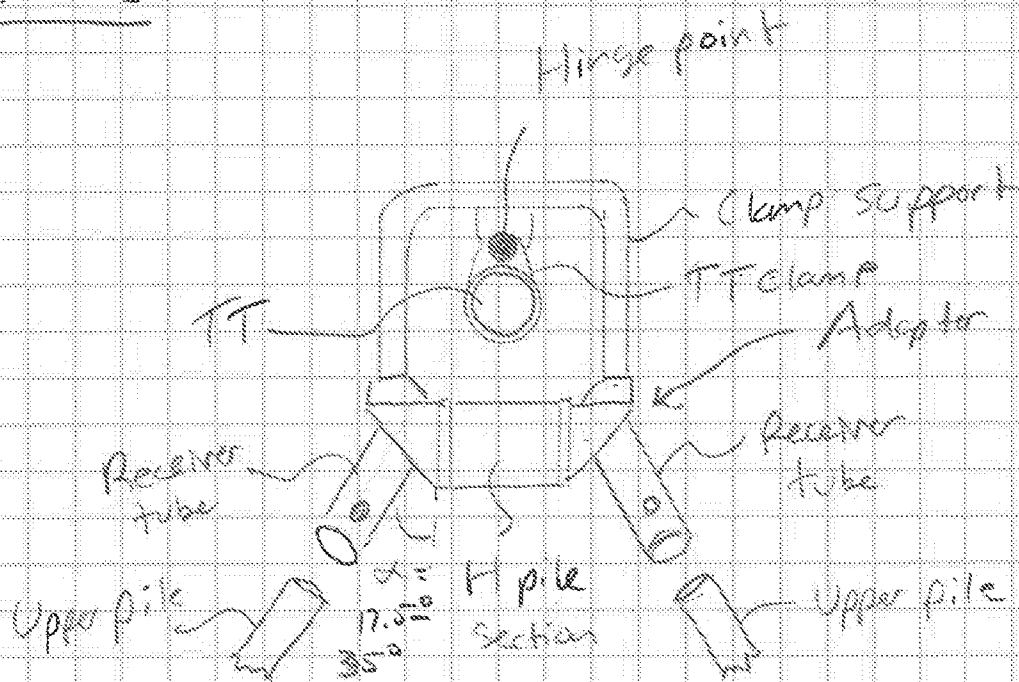


FIG. 11B

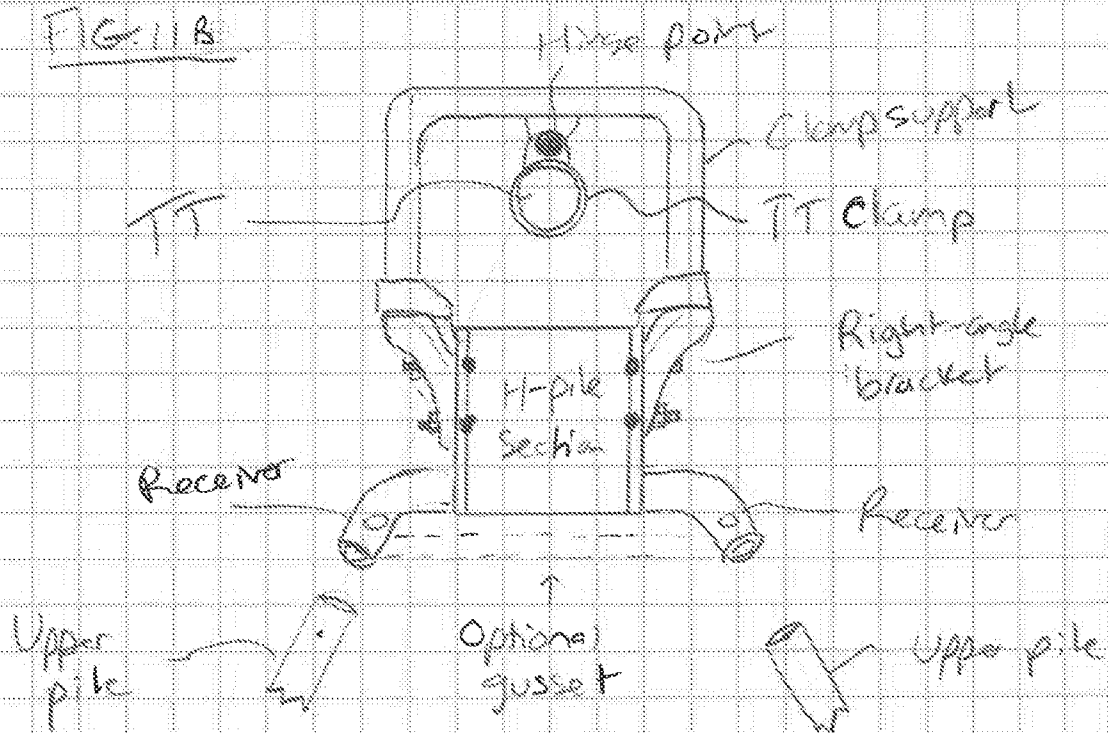


FIG. 12

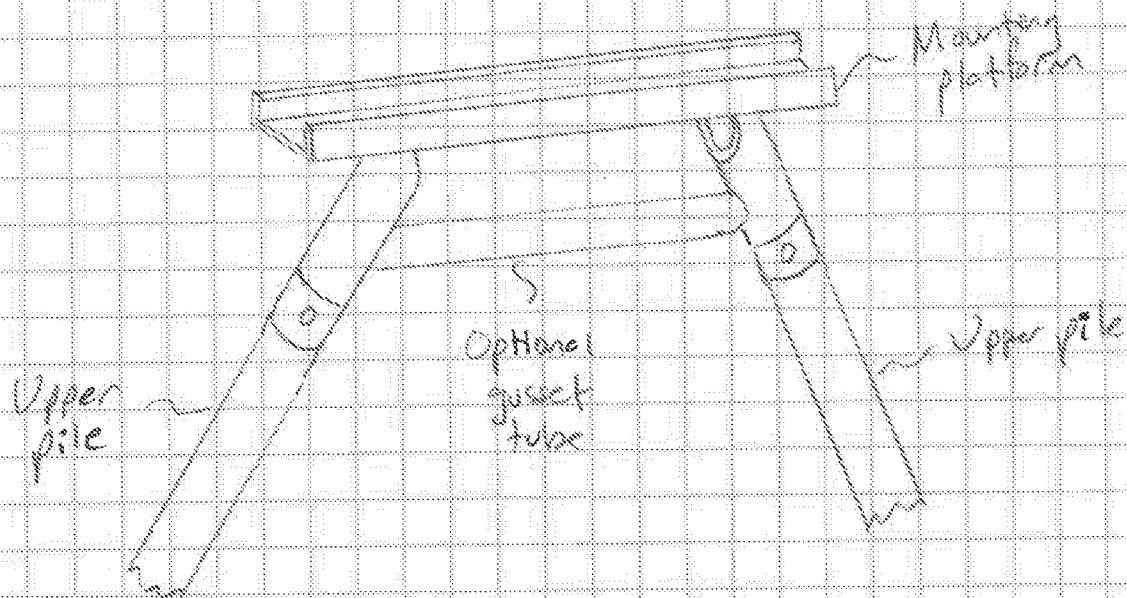


FIG. 13

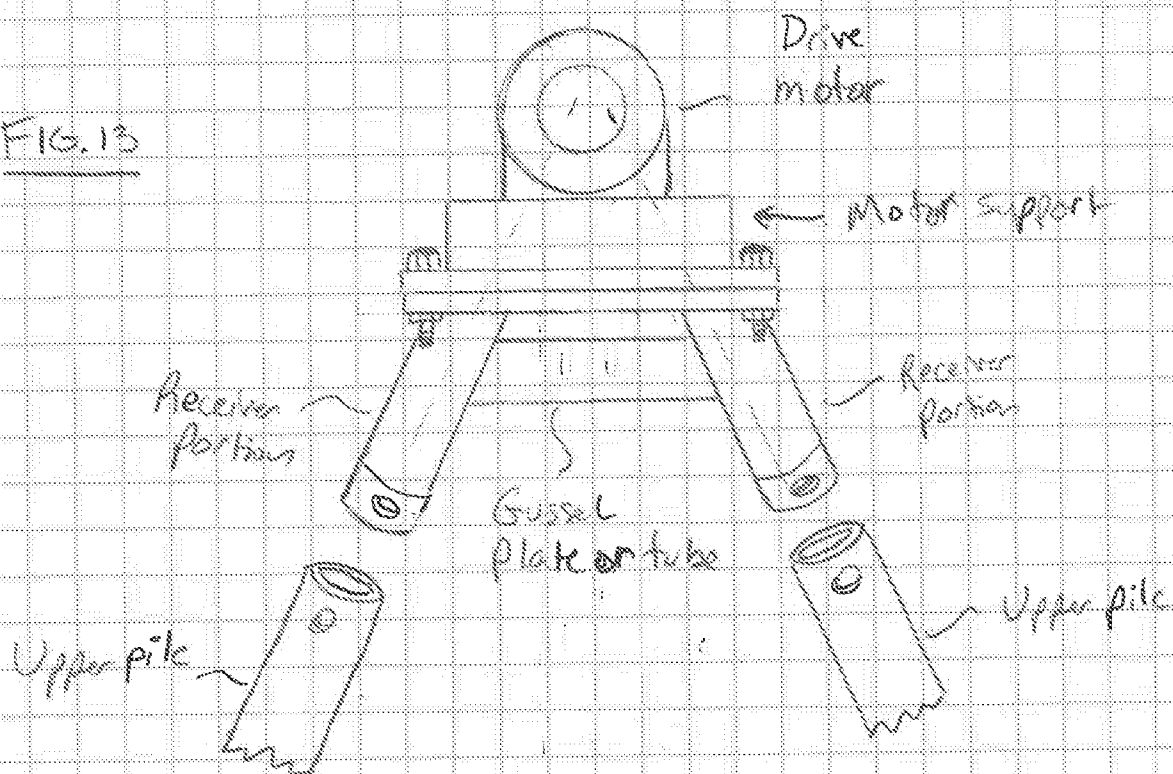


FIG. 14A

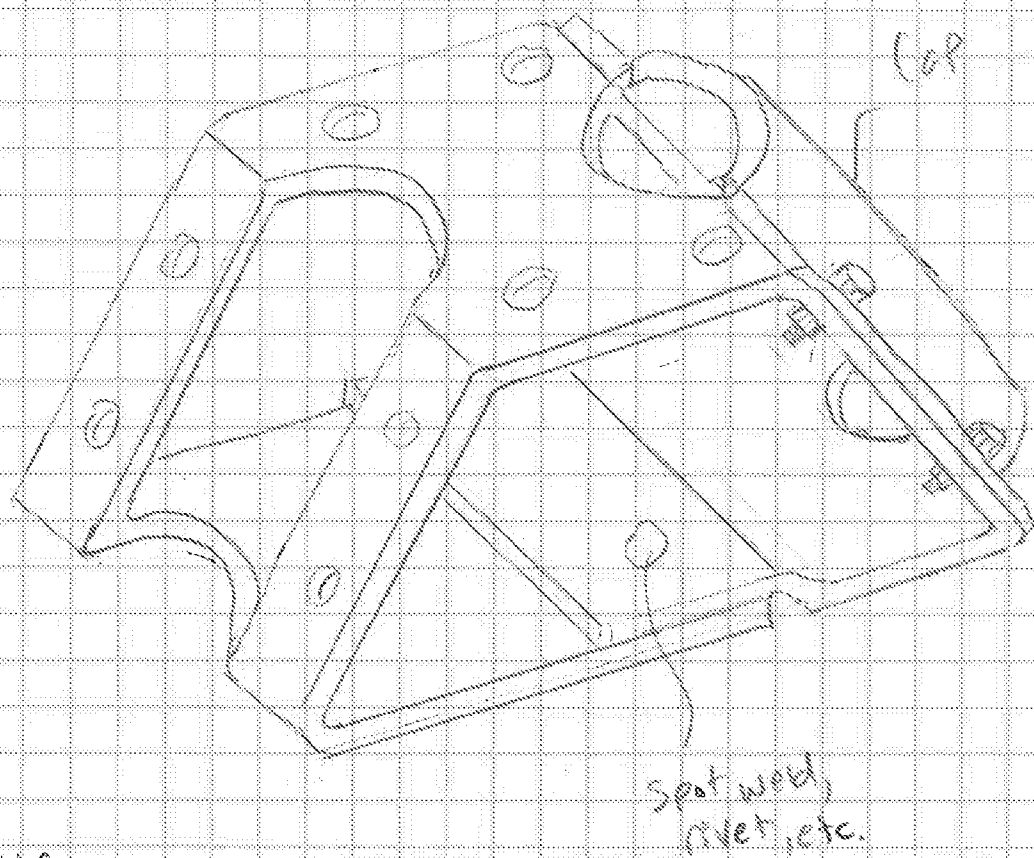
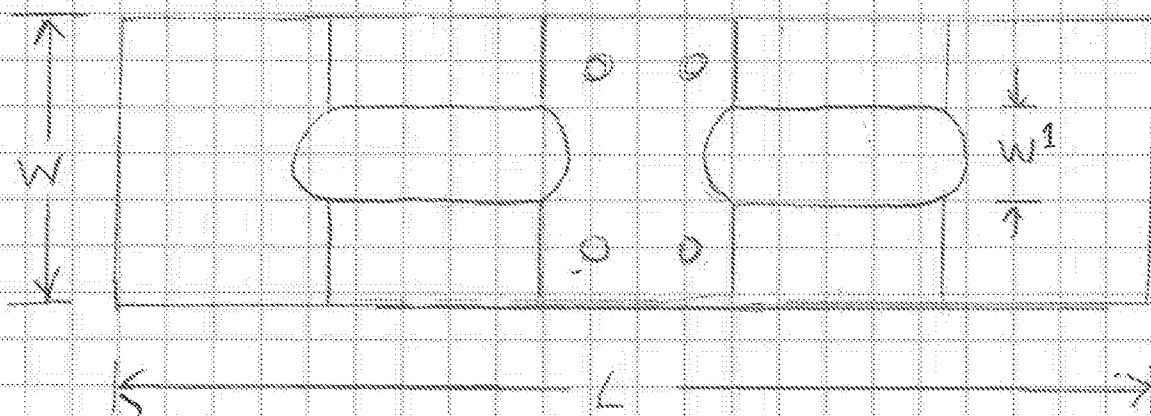


FIG. 14B



Electronic Acknowledgement Receipt

EFS ID:	34541758
Application Number:	62777690
International Application Number:	
Confirmation Number:	5088
Title of Invention:	Force optimized A-frame-to-monopile adapter for single axis tracker
First Named Inventor/Applicant Name:	Charles Almy
Customer Number:	157339
Filer:	Phillip Dominick Mancini
Filer Authorized By:	
Attorney Docket Number:	PPA21
Receipt Date:	10-DEC-2018
Filing Date:	
Time Stamp:	20:27:00
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	\$ 140
RAM confirmation Number	121118INTEFSW20280600
Deposit Account	
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	WebADS.pdf	145881	no	8
			b2ed0c8c213bd67d35fe0db350d6e2eea0b5a03fc		
Warnings:					
Information:					
2	Specification	PPA21.pdf	182426	no	30
			72c865cb4edca928f6e71268206b2715ca6fd0b7		
Warnings:					
Information:					
3	Drawings-only black and white line drawings	PPA21_DWGS.pdf	1781709	no	11
			98517db8edc212ed04b089f7d5358b31645df210		
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	29563	no	2
			968895ed62994091217792d2f82c7c16b9cd90b4		
Warnings:					
Information:					
Total Files Size (in bytes):			2139579		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

FORCE OPTIMIZED A-FRAME-TO-MONOPILE ADAPTER FOR SINGLE AXIS TRACKERS**BACKGROUND**

[0001] Solar energy is one of the world's largest sources of untapped energy. At sea level, the usable energy density of solar energy is approximately 250 watts per square meter. Using a two-dimensional model to approximate the earth's surface, 250 watts per square meter* π *6,371,000 meters² yields about 32,000 terra (trillion) watts of energy that continuously strikes the earth. Given that the sun will continue to radiate this energy for billions of more years, the survival of human life will ultimately depend on harnessing this essentially unlimited source of clean energy.

[0002] As in any industry, achieving scale is critical to maximizing the competitiveness of solar energy relative to other energy sources. This economic reality militates in favor of large-scale (multi-megawatt to multi-gigawatt) solar power plants over residential solar, although there is room for both modalities in the market place. Large-scale or so-called utility-scale solar power plants are predominantly configured as either fixed-tilt or single-axis tracker arrays. Fixed-tilt arrays are arranged as East-West oriented rows of panels tilted to face South at an angle dictated by the latitude of the array site. By contrast, single-axis trackers consist of rows of solar panels arranged on a rotating North-South axis called a torque tube that sweeps through an East-facing orientation to a West-facing orientation through the course of each day, following the sun's daily progression through the sky. For purposes of this disclosure, both fixed-tilt and single axis trackers will be referred to herein collectively as axial solar arrays.

[0003] Utility-scale solar projects are financed against the projected annual revenue the system is expected to generate. The project developer signs a so-called power purchase agreement (PPA) with a party who agrees to buy the power offload at a predetermined kilowatt hour rate (e.g., 2.5-3.5 cents per kilowatt hour at today's prevailing rates) for a fixed number of years (e.g., 25-35 years). Knowing the lifetime of the system to be at least that long, and in many cases longer, and given the predictable stream of revenue the array will generate over its lifetime, banks and other investors may safely finance the construction of such projects.

[0004] Excluding land acquisitions costs or rents paid to the property owner, overall project costs typically include site preparation (road building, leveling, grid and water connections etc.), foundation piers, tracker hardware or fixed-tilt hardware, solar panels, inverters and electrical (conduit, wiring, trenching, etc.). Inherent in all of these are also labor costs. At today's prevailing rates, these costs total more than \$1 per watt of capacity. So, developing a 100-megawatt solar power plant today would cost more than \$100,000,000 dollars before any tax incentives. Depending on where it is located, such a system will generate power worth more than that over the useful lifetime of the system.

[0005] Many of the system component costs of axial solar arrays have dropped over the past few years including solar panels and solar mounting hardware, however, one area that has remained relatively constant is the cost associated with foundations. These structures physically couple solar trackers and fixed-tilt solar arrays to the earth. With a single-axis tracker, after the site has been prepped, a grid of H-piles, C-channel piles or other profile piles are driven into the ground at regular intervals with an impacting pile driver and the other array components are subsequently attached to the top of these piles. In a conventional, large-scale single-axis tracker array, foundations typically represent 5-7 percent of the total construction costs. Despite this relatively small share of the total array cost, any savings in steel and labor associated with the foundation piers will translate to a significant amount of money over a multi-gigawatt portfolio of solar power plant projects. This is particularly true with utility-scale projects because the financing and PPA deals are often locked-in years before any installation costs are incurred based on cost assumptions. Therefore, any savings in actual foundation costs will be recognized on top of profits already factored in the calculations that supported the project's development.

DESCRIPTION

[0006] The following description is intended to convey a thorough understanding of the embodiments described by providing several specific embodiments and details involving foundation piers for axial solar arrays, and in particular, for single-axis trackers. It should be appreciated, however, that the present invention is not limited to these specific embodiments and details, which are exemplary only. It is further understood that one

possessing ordinary skill in the art considering known systems and methods, would appreciate the use of the invention for its intended purposes and benefits in any number of alternative embodiments, depending upon specific design and other needs.

[0007] Turning now to FIG. 1, this figure shows a portion of a generic single-axis tracker. The portion shown in this example approximates the torque tube-to-bearing-to-pile connection of one of many available single-axis tracker systems available today. The exemplary system of FIG. 1 is supported by a plumb C-channel pile. A C-channel pile is simply a beam with a C-shaped cross section. In this example, the torque tube bearing assembly is attached directly to the web portion of the pile with four mounting bolts. Though only a single pile is shown here for ease of illustration, in a complete system several C-channel piles would be driven to the target depth along a North-South oriented row at the locations specified by the tracker system maker or in the site plan documents. The top end of each pile has a series of holes or slots pre-formed in it to enable the torque tube support element (e.g., bearing, clamp support, etc.) to be attached with conventional bolts, rivets or other suitable mechanical fasteners. In some cases, and as shown here, the torque tube support element is a bearing assembly – a generic structure consisting of a mounting bracket portion, a bearing, a bearing housing, and in some cases, a plastic or polymer bearing insert. In other cases, the torque tube support element may be an intermediate support structure such a pile cap, saddle or other device that supports the bearing, which in turn supports the torque tube. In systems that use bearings, the bearing surrounds and supports the torque tube while it rotates under power of a drive motor. In bearing-free systems, the torque tube hangs from above via a clamp hinged to a support bracket. Herein, the words “bearing” or “torque tube support element” are used generically to refer to some or all the single-axis tracker elements attached to top of the foundation pile that directly or indirectly support the torque tube.

[0008] FIG. 2 approximates a pile cap and bearing of another single-axis tracker, in this case, the DURATRACK HZ single-axis tracker from Array Technologies, Inc. of Albuquerque, NM. This pile cap and bearing assembly are dimensioned to fit over a standard wide-flange H-pile, such as a W6x9 or W6x12, both of which having a web depth of approximately six

inches. The bearing and pile cap may come preassembled as one piece so that installers need only bolt the pile cap to the preformed holes in the flanges of the pile to complete the installation. Alternatively, these elements may be joined on-site so that the position of the bearing can be adjusted in the East-West plane as well as vertically to align the bearing with the other bearings in the same row.

[0009] Turning to FIG. 3, this figure shows a pile and bearing that was manufactured, sold and patented by NEXTracker of Fremont, CA under the trade name NX Series. Like the pile of FIG. 2, the pile shown here is also a conventional W6x9 or 6x12 H-pile. However, unlike the single-axis tracker of FIGS. 1 and 2, NEXTracker's single-axis tracker purports to be mechanically balanced. According to NEXTracker this means that there is no overturning moment to the system regardless of the orientation of the panels (e.g., East to West), lowering the amount of torque required to rotate the torque tube. In the case of the system shown in FIG. 3, this is accomplished by hanging the torque tube from above with a tube clamp that hingedly attaches to a hinge pin positioned above the tube. Rather than rotating the tube itself, the torque tube rotates about the hinge pin via the torque tube clamp. As a result, the torque tube and clamp swing like a pendulum as the tracker moves from East to West. This requires additional clearance in the East and West directions. Here the clearance is provided by the heart-shaped clamp support shown in FIG. 3. The clamp support in FIG. 3 is made from a single casting and attaches to the web of the H-pile with a vertical mounting portion analogous to the generic bearing shown in FIG. 1. The clamp support has a center hinge point near the top that accommodates the hinge pin. Either end of the hinge pin is received within respective recesses formed in the two-piece torque tube clamp, labeled "A" and "B" in the figure. The portions of the torque tube clamp that engage the torque tube are curved to match the curved outside diameter of the tube and are secured to the tube via bolts passing through pre-drilled holes in the clamp sections and in the tube. As the drive motor applies torque to the tube, the tube and clamp assembly swing about the hinge pin within the space defined by the heart-shaped clamp support. Where the torque tube engages the drive motor, it curves upward on either side so that the

axis of rotation at the motor is approximately aligned with the axis of rotation about the hinge pin.

[0010] Turning now to FIG. 4, this figure shows a later version of the NEXTracker NX series that uses a welded tubular torque tube clamp support that rests atop a pair of stamped right-angle brackets. The stamped right-angle brackets are bolted to the outer surface of the pile flanges at the head of the H-pile via pre-drilled holes in each flange. These brackets extend the width of the H-pile and provide a planar support surface for the feet of the torque tube clamp support to rest on. As shown, each foot has a bolt projecting out of it that passes through the horizontal surface of the right-angle bracket to secure the support to the pile. The tubular legs project upward away from the feet and curve 90 degrees towards one another, defining an upside-down U shape. A hinge point is formed at or welded onto the center of the clamp support. The hinge point receives the hinge pin that the respective halves of the torque tube clamp assembly rotate about. In the NEXTracker system, U-bolts are also fitted around the torque tube to clamp their PV module bracket to the tube. The edge of two adjacent PV modules are then attached to the module bracket.

[0011] Turning now to FIG. 8, this figure shows another generic bearing assembly used in various single-axis tracker systems. The bearing assembly of FIG. 8 includes a vertical mounting flange with a plurality of attachment slots to enable it to be adjustably mounted to the web of an H or C-pile. A horizontal bearing base sits at the top of the flange. The bearing base includes a curved bearing surface for receiving a bearing insert that surrounds the torque tube. In this example, the torque tube is shown as having a square cross section. The bearing insert is required here to convert the portion of the torque tube within the bearing to a rounded cross section so that it can rotate within the bearing. The torque tube and bearing insert are seated in the half-circular recess in the bearing base and a bearing cap is bolted above it to trap the torque tube and bearing insert within the bearing. This configuration allows for easy maintenance and repair of the bearing and can work with a variety of different plumb piles.

[0012] Each of the prior art single axis trackers, bearing caps, bearings and other torque tube support elements corresponding to the single-axis tracker systems shown in FIGS. 1-4

and FIG. 8 are designed to attach to plumb (i.e., vertically oriented) monopile foundations, the current standard in the art. The inventors of the various embodiments of this invention have proposed a foundation system that relies on a A-frame consisting of a pair of foundation legs driven into the ground at reciprocal angles to one another (e.g., ± 60 degrees) rather than a single plumb monopile. A-frame foundation systems offers several advantages relative to monopiles. With a single-axis tracker, the weight of the system (e.g., axial load on the monopile) pales in comparison to the laterally forces that can be imparted by wind striking the solar panels attached to the torque tube when they are oriented at a steep East-facing or West-facing angle. Because monopiles don't perform as well against lateral loads as they do with axial ones, and lateral load potential far exceeds the axial load, plumb monopiles must be oversized to resist bending. With an A-frame foundation, if correctly designed, forces due to the system weight as well as lateral loads from wind striking the array will put the legs of the A-frame in tension and compression rather than in bending. This allows the legs to be smaller and lighter than a comparable monopile. This also allows the legs to be driven to shallower depths. Since both H-piles and A-frame legs are made of steel, their prices are at least partially correlated to their length and weight. Therefore, supporting the same size tracker with less steel reduces the overall system cost to the developer.

[0013] Although lateral loads increase with the length of a monopile, there are minimum heights specified by most tracker makers to allow the modules to rotate through the full range of angles without striking the ground or being susceptible to shading from weeds or other ground cover and to allow mowers to pass underneath. This minimum height is typically 4 feet or more. The above-ground portion of the piles may extend higher than that but the greater their height, the greater will be the lever effect of lateral forces wanting to bend the pile; these force increase linearly with the length of the pile. So, assuming a 2,500-pound lateral load rating, a monopile projecting four feet above ground will experience a 10,000-pound bending force (Force x Distance). By contrast, if the pile length is increased to five feet, the pile will experience a 25% larger bending force or 12,500-pounds.

[0014] In an A-frame, assuming axial movement is perfectly resisted, the primary failure mode is buckling rather than bending. The above-ground length of the legs, however, has little effect on their propensity to buckle at the short lengths (4-6 feet) and with the magnitude of axial forces seen in a single-axis tracker; much more important is the angle that they are oriented at and the location of the point of rotation with respect to the A-frame's work point. Regarding the former, moderately sloped A-frames (legs less than or equal to 72.5 degrees) experience much lower forces of tension and compression than steeper sloped ones for a given magnitude of lateral load force. For example, with each leg of the A-frame oriented at 60 degrees relative to grade, the tensile and compressive force that must be resisted by each leg is equivalent to 2,500-pounds. At 70 degrees, the tensile and compressive forces increase to 3,655-pounds each and at 80 degrees they jump to 7,198-pounds each. Therefore, there is an optimal range of angles for an A-frame foundation from about 50 degrees to about 72.5 degrees and within that range and even more ideal range that is limited to about 65 degrees at the upper end. This stems from the fact that the lateral load translates into tensile and compressive forces at the rate of $1/(\cos(\Theta))$ where Θ is the angle of the A-frame legs.

[0015] Regarding the second point, every A-frame has an ideal work point for resisting lateral loads that keeps it in pure tension and compression as opposed to a combination of that and bending. This is seen, for example, in FIGS. 5A-5C. 5A shows a partial A-frame foundation system for a single-axis tracker. The exemplary partial system of 5A consists of a pair of base foundation piles coupled to a pair of extension piles. The base piles include a thread form at their distal, below-ground end. They are rotated into the ground at reciprocal angles to one another (e.g., ± 60 degrees) with a rotary driver. The thread form helps keep the pile on trajectory during driving and adds greatly to the pile's ability to resist axial forces. The rotary driver may be an attachment to an excavator, tractor or other general-purpose machine, or with may be part of a special purpose pile driving machine such as those available from companies like Turchi and Pauselli.

[0016] In the system shown in this example, once the pair of adjacent base foundation piles have reached their target depth, an extension pile is added to the top end of each. In

other embodiments, the base foundation piles and extension piles may be consolidated into a single member. As shown, the extension piles continue the same axis (e.g., at the same angle) as their respective base piles, projecting upward along that axis in free space. They may be coupled to one another using a separate coupler, set screws, rivets, bolts, by nesting one within the other, by reciprocal male/female features formed into both, or by some combination of these techniques. As discussed in greater detail herein, after the base and extension piles are set, an adapter, saddle or other structure is attached to the two free ends to complete the A-frame and provide a platform for attaching the tracker system components that support the torque tube.

[0017] If an imaginary line is extended from the below-ground tip along the axis of each base pile and extension pile, the point of intersection of these lines will be the work point of the A-frame. The work point is the ideal point at which to apply forces to the A-frame to prevent any bending. The location of the work point relative to the ground will vary with the angle α of the A-frame's legs. In a single-axis tracker, forces are translated to the foundation via the axis of rotation of the of the system (i.e., the point that the rotating parts rotate about). In most single-axis tracker systems, the torque tube itself defines the axis of rotation. However, as discussed in the context of FIGS. 3 and 4, in the NEXTTracker system, the torque tube is offset from the axis of rotation. The tube is attached to a tube clamp which in turn rotates about a hinge point in a tube clamp support. Regardless of which brand or style of single-axis tracker that is supported, the axis about which rotation occurs will ideally overlap with the work point of the A-frame. Otherwise, if the rotation point is away from the work point, some bending will be introduced. If that happens, the A-frame legs must be stronger to resist the additional bending forces.

[0018] FIGS. 5B and 5C illustrate what may happen when the point of rotation is offset from the A-frame's work point. For example, in FIG. 5B the point of rotation and therefore the lateral load force is applied at a point lower than the A-frame's work point making the windward leg vulnerable to deforming inward in response. With this scenario, the windward leg must be beefier to resist this tendency. Similarly, in the example of 5C, the point of rotation and therefore the lateral force is applied at a distance above the work

point. In this case, the lateral load acts like a monopile extending above the work point and will tends to buckle the leeward leg. To prevent this tendency, the leeward leg requires additional buttressing. In recognition of this, and to avoid having to use additional material that eliminates some of the advantage of an A-frame foundation, various embodiments of the invention provide an adapter that joins the free ends of the base and foundation piles to complete the A-frame while controlling the location of the tracker rotation point so that it aligns or can be adjusted to align with the work point of the A-frame.

[0019] To that end, the discussion will now focus the various embodiments of the present invention. Beginning with FIGS. 6A and 6B, these figures are perspective and front views respectively of a universal adapter according to various exemplary embodiments of the invention. This type of adapter is referred to herein as an A-frame-to-H-pile adapter. The A-frame-to-H-pile adapter converts an A-frame foundation into the H-pile flange and web geometry that most single-axis trackers are designed for. Consequently, the adapter according to FIGS. 6A and B may be useable with any of the prior art tracker systems shown in FIGS. 1-4 or 8. The main body of the adapter is shown as a section of a conventional H or I-beam (e.g., W6x9) with a pair of receiver tubes projecting out of the flange on either side. In various embodiments, the receiver tubes project downward at reciprocal angles α to one another (e.g., +20 degrees and – 20 degrees) with respect to the surface of the flange. In various embodiments, the angles of the receiver tubes may be within a range of $\pm 17.5 - 35$ degrees with respect to the vertical flange surface to match the angle of the legs of the A-frame. For a given receiver tube angle, the legs of the A-frame will be angled at an angle equivalent to 90 degrees minus α so that the receiver and extension piles are on the same axis.

[0020] As shown, the exemplary adapter of FIGS. 6A and B has three sets of attachment features for attaching torque tube support elements to the A-frame foundation. The first set is formed as a pair of slots vertically bisecting the web. A second set of attachment features, shown as four distributed holes, are formed in each opposing flange. The third set of attachment features is also formed in the web, in this example, as six holes straddling the first set of attachment features. It should be appreciated that this configuration is

exemplary only and that in various embodiments, each set of features may consist of vertical slots, horizontal slits, fewer holes, more holes, or combinations of these features. The unifying concept of these potential variations is that the adapter completes the A-frame while approximating the top of a plumb H-pile or C-pile, the foundation geometry most tracker systems are designed to interface.

[0021] FIG. 6B illustrates the location of the work point of the A-frame above the adapter by following an imaginary line extending along the respective axes of the receiver tubes and their corresponding extension piles to the point where they would intersect in free space. The plurality of attachment features formed in the adapter enables the height of the torque tube bearing or other torque tube support device to be adjusted until the point of rotation of the torque tube is aligned with the A-frame work point. As discussed herein, this is important to keep the A-frame in tension and compression while minimizing and ideally eliminating any bending forces. The adapter shown in FIGS. 6A and 6B is made from a section of H-pile, and therefore requires a hot roll-forming process. Roll-forming processes require a great deal of energy to get the metal hot enough to enable it to be worked from a bar to a beam under the pressure of the rollers.

[0022] In some cases, it may be desirable to achieve the benefits of the adapter of FIGS. 6A and 6B with an adapter made with a less energy intensive manufacturing process. To that end, FIG. 7 shows an A-frame to monopile adapter that is manufactured from stamping or a combination of stamping and welding rather than hot roll-forming. The adapter of FIG. 7 is shown as a substantially planar trapezoidal member with a pair angled side portions. The side portions in this example consist of respective half tube sections angled at reciprocal angles to one another. In some embodiments, these side portions may be stamped in the same piece of sheet metal as the substantially planar trapezoidal member. In other embodiments, these side portions may be welded to the side edges of the planar trapezoidal member. In various embodiments, the half tube sections may be oriented at reciprocal angles in a range of ± 17.5 degrees to 35 degrees to match the chosen angle of the base and upper foundation piles.

[0023] As shown, the trapezoidal member includes a flange portion with attachment holes for attaching a torque tube bearing or, as in this case, an adjustable mounting plate. The mounting plate replicates the geometry of the web of an H-pile and allows the height of any tracker components attached to it be adjusted in the vertical direction to align the axis of rotation with the work point of the A-frame. In other embodiments, the bearing or torque tube support element may be attached directly to the trapezoidal member without the adjustable mounting plate. The free end of each leg of the A-frame (i.e., extension piles) will fit in the half tube sections and tubular caps are bolted through the legs and the angled side portions to securely capture the legs, completing the A-frame foundation. The caps in FIG. 7 are shown as having through-holes for passing fasteners through each leg of the A-frame, however, it should be appreciated that in other embodiments the tubular caps may include flat flanges on either side of the curved portion that engage with a flange and/or the trapezoidal member to receive mechanical fasteners holding them together. This may eliminate the need to punch holes in the above-ground ends of the extension piles.

[0024] Turning now to FIGS. 9A, B, C and D, these figures show various views of an A-frame adapter according to various embodiments of the invention that is designed to interface with a mechanically balanced tracker system such as that available from NEXTracker. As discussed in the context of FIGS. 3 and 4, instead of rotating about the torque tube, in NEXTracker's mechanically balanced tracker system, the torque tube clamp sections rotate about a hinge pin that is in turn supported by a torque tube clamp support. This causes the torque tube to sweep through an arc as it moves from an East-facing orientation to a West-facing orientation rather than simply rotating about its own axis.

[0025] Hanging the torque tube imposes a unique constraint relative to other single-axis tracker designs that support the tube from below. The torque tube clamp support must extend above the torque tube but the structure that does that must provide sufficient East-West clearance so that the hinged torque tube and clamp assembly can swing through their full arc of motion without interference. The tubular adapter of FIGS. 9A and B accomplishes this with a pair of opposing S-curved sections that mate with the free ends of the adjacent

extension piles in free space, curve outward to provide clearance for the arc of the torque tube and then curve back inwards where they meet in a straight section. The approximate midpoint of the straight section includes a hinge point (recess) that receives the hinge pin that supports the torque tube clamp. As with the torque tube clamp support included with the NX system (e.g., seen in FIGS. 3 and 4), the hinge pin passes through the hinge point of the adapter and the two halves of the hinge clamp are bolted onto opposing ends of the pin so that the clamp halves straddle the adapter. The two halves of the clamp are bolted to the torque tube to complete the connection.

[0026] In various embodiments, installation of the adapter shown in FIGS. 9A and B may be accomplished by attaching the entire adapter, clamp and hinge assembly onto the torque tube, via the bolts securing the clamp to the tube and then lifting the entire tube above the row of A-frame piles with a crane, forklift, loader or other device so that the free end of each adjacent pile pair may be inserted into respective openings of each adapter. Alternatively, the torque tube sections may be laid down on the ground between each adjacent A-frame pile pair before the adapter, hinge and clamp assembly are attached to the piles. The sections of torque tube may then be lifted into place and the clamps bolted to pre-drilled holes formed on a regular schedule along the torque tube sections. FIG. 9B shows the elements of the torque tube clamp and adapter in exploded form for ease of understanding but in various embodiments some or all these components may come pre-installed.

[0027] FIG. 9C is a perspective view of a section of a mechanically balanced single-axis tracker array installed on an A-frame foundation using the torque tube clamp support and torque tube clamp of FIGS. 9A and B, while FIG. 9D shows one complete A-frame foundation supporting the array section of 9C. Starting at the below ground end, the system consists of a pair of base foundation piles that have been rotated into the ground at reciprocal angles to one another, in this example ± 68 degrees. In various embodiments, each base foundation pile has a partial thread form at its distal end to help it resist axial forces. The partial thread form may be uniformly wide or may widen moving up the shaft of the pile. An extension pile is coupled to the above-ground end of each base pile along each base

pile's axis to form a partial A-frame using one of the various methods discussed herein. The open ends of the adapter are coupled to respective free ends of each extension pile to complete the A-frame. The hinge and clamp assembly are supported by adaptor via the hinge pin extending through the hinge point formed at the top of the adapter. The clamp assembly holds the torque tube in place so that it can rotate about the hinge point. In addition, in this system a pair of U-bolts straddle the torque tube to pin the module support bracket to the tube. PV modules are then attached along the torque tube to each module support bracket, with each bracket joining adjacent edges of two modules. In various embodiments, the adapter of FIGS. 9A-D is designed to work with foundation piles that have been installed at a specific angle so that the hinge pin at the top of the adapter will be precisely located at the hinge point of the A-frame.

[0028] Turning now to FIG. 10A, this figure shows another universal A-frame-to-monopile adapter according to various other embodiments of the invention. As with the universal adapter shown in FIGS. 6A and B, the adapter of FIG. 10A is configured as a section of H-beam with a pair of flanges interconnected by a web. A receiver tube projects downward out of the surface of each flange to receive one of the adjacent extension pile ends. These receiver tubes are oriented at an angle α with respect to the flange surface in a range of 17.5 degrees to 35 degrees to match the angle of the extension pile. The receiver tubes may include one or more holes to receive set screws, bolts or other mechanical fasteners used to secure them to the extension piles. Also, as shown, the web surface has two sets of attachment features for attaching a torque tube bearing or other torque tube support element configured to mate with the vertical attachment features formed in the web of a conventional H-pile or C-channel pile. In addition, the adapter of 10A has a pair of horizontal platform portions resting on the top of the opposing flanges. Triangles may be welded between these portions and the flange surface to provide additional rigidity to prevent them from deflecting under load. In various embodiments, these platform portions will allow the universal adapter to be used with tracker systems designed to mate with a horizontal support surface, or, alternatively to support a tracker drive motor which is typically mounted on a horizontal mounting surface.

[0029] FIG. 10B shows the universal adapter of 10A used with the current NEXTracker single-axis tracker. As shown, NEXTracker's torque tube clamp support bracket, the upside-down U-shaped tubular structure, rests on the horizontal platform portions of the universal adapter. In the figure, lines have been drawn along the axis of each of the upper pile sections and receiver tubes until they intersect to show that the dimensions of the universal adapter allow the torque tube clamp support's hinge axis to align with the A-frame work point. It should be appreciated that although FIG. 10B shows the universal adapter of 10A used with a NEXTracker single-axis tracker, this universal adapter may be used with single-axis trackers from various other tracker makers, including, but not limited to those shown in FIGS. 1, 2 and 8.

[0030] Turning to FIG. 11A, this figure shows another universal A-frame-to-H-pile adapter for a single-axis tracker according to various other embodiments of the invention. This adapter is like that of FIGS. 10A and B, with the exception that the receiver tubes are spaced further apart and have a bend in them. Also, the adapter of FIG. 11A does not include the horizontal platform portions above each flange. Depending on the dimensions of the tracker components, when supporting some trackers, there may not be enough room above the adapter to allow the axis of rotation to be aligned with the work point because the work point is too low. By spreading out the receiver tubes that mate with the extension piles, the work point is effectively elevated, providing more flexibility for alignment in the vertical direction.

[0031] Also, as noted herein, nearly all current single-axis tracker makers sell systems that are designed to connect to plumb monopiles. Therefore, to maximize compatibility with tracker companies it may be preferable to eliminate all redundancy in the adapter. For example, turning back to the adapter of 10A, when used with a current NEXTracker system such as that shown in 10B, the horizontal platform portions built into the adapter eliminate the need for NEXTracker's stamped right-angle brackets, shown in FIG. 11B. Therefore, if using such an adapter will be used to support its tracker, they are faced with the choice of selling fewer components or selling the customer a component that is not used, neither of which are ideal to the tracker maker. Therefore, in some cases it may be desirable to

provide a universal adapter that is compatible with OEM single-axis trackers without any functional redundancy. To that end, though universal and able to support tracker systems from many supplies, the adapter of FIG. 11A is optimized to support NEXTracker's NX series tracker without any functional redundancy by providing the attachment features that that the NX system is designed to attach to – namely four holes on each flange arranged in a rectangular pattern.

[0032] Turning to 11B, the stamped right-angle brackets bolt to the outside surface of each flange using the four holes formed in each flange. These brackets convert the vertical plane of the flange into a horizontal mounting platform; the feet of NEXTracker's torque tube clamp support sit on this horizontal mounting platform. The hinge assembly, torque tube clamp and tube are attached above in a manner consistent with that discussed herein. The application of the universal adapter of 11A in the system of 11B is exemplary only. It should be appreciated that this universal adapter may be used to support a variety of other tracker systems including but not limited to the prior art systems shown in FIGS. 1-2, and 8.

[0033] Turning to FIG. 12, this figure shows a universal A-frame adapter for a single-axis tracker according to further embodiments of the invention. The adapter shown here includes a mounting platform consisting of an elongated planar member and, in this example, a pair of vertical sides projecting upwards from either edge of the elongated planar member to form a trough-like planar mounting platform. This mounting platform may support a torque tube clamp support, such as in FIGS. 10B and 11B, or alternatively, a tracker driver motor or other torque tube support device configured to rest on a horizontal platform. The adapter of FIG. 12 has a pair of receiver tubes below the planar member, projecting away from the planar member at reciprocal angles to one another (e.g., in a range of ± 17.5 degrees to 35 degrees). In various embodiments, as discussed herein, the angle of the receiver tubes preferably allows them to receive the end of the extension pile so that it continues the axial line without changing angles. In some embodiments, it may be desirable to include a gusset or other support member connecting the two receivers to provide additional strength and rigidity to the adapter as shown in FIG. 12. Though not shown in the figure, the planar mounting platform may have various holes, bolts or other

features at predetermined positions to allow it to connect to various torque tube support elements of various manufacturers.

[0034] Turning to FIG. 13, this figure shows another universal adapter for supporting a torque tube drive motor or torque tube support element configured to rest on a horizontal support plane. Some tracker systems utilize a horizontal platform to support the drive motor because of the extra size and weight of the motor relative to bearings and other torque tube support elements. Also, in some cases, torque tube drive motors come mounted on a horizontal mounting plate requiring a pile cap or other horizontal support surface to be attached to the web or flanges of a monopile. The adapter shown here consists of a planar, horizontal mounting platform with a pair of receiver tubes projecting out of the bottom, away from the underside of the planar mounting platform at reciprocal angles to one another. In various embodiments, and as discussed in greater detail herein, these angles may preferably be in a range of ± 17.5 degrees to 35 degrees to allow the receiver tubes to mate with the ends of the extension piles along the same axis. Due to the increased forces and weight on a motor pile, it may be necessary or desirable to add a gusset plate or tube between the receiver tubes to increase overall strength and rigidity. In various embodiments, the adapter is dimensioned to keep the axis of rotation of the torque tube drive motor or other tracker component that defines the axis of rotation aligned with the work point of the A-frame. In various embodiments, spacers may be used between the horizontal mounting plate of the drive motor and the adapter to adjust the height of the axis of rotation to be aligned with the work point.

[0035] Turning to FIGS. 14A and 14B, these figures show an A-frame adapter for supporting a single-axis tracker according to various other embodiments of the invention. As discussed herein, cold formed steel shapes may be less expensive to manufacture than cast or hot formed shapes. The adapter of FIGS. 14A and 14B provides a cold formed alternative to the hot roll formed adapter of other embodiments that is formed from a single piece of flat stock. In various embodiments, the adapter is formed by punching, cutting or otherwise forming two elongated slots in a piece of flat, rectangular stock steel. In various embodiments, the width of the slots (labeled "W¹" in the figure) will be approximately

equal to the outside diameter of the extension pile (e.g., 2.375 inches). Once the piece of flat stock is folded, these slots will form the partial tubular recesses that receive the piles. The slots are preferably centered between the width “W” of the planar rectangular flat stock to distribute forces into the legs of the A-frame without introducing bending. In various embodiments, the slots may have edges that are serrated, have one or more tabs formed in them, or include another gripping or biting shape to enhance their ability to securely hold the A-frame legs. Because these slots are punched, this may be easily accomplished by controlling the geometry of the punch or die used to make the slots.

[0036] In various embodiments, the spacing between the slots and the length of the long dimension (labeled “L” in the figure) of the rectangular flat stock will be dictated by the dimensions of the A-frame. The length of the flat stock and locations of the folds will scale with the width between the free ends of the adjacent pile pairs. Folding the flat stock along the lines shown in FIG. 14B converts flat piece into a three-dimensional trapezoid. The slots turn into curved recesses dimensioned to receive the free end of two adjacent extension piles. The angle of each side fold preferably matches the desired angle of the A-frame legs (e.g., ± 55 -72.5 degrees) so that the angles of the adapter match the angles of the A-frame, allowing it to fit between the legs without changing their angle. Rivets, welds or other connectors may be used to join the free ends of the trapezoidal adapter at the bottom to provide strength and rigidity. Also, as shown in 14A, a tubular cap may be attached to each side of the adapter to capture the free end of each extension piles, thereby completing the A-frame. Four bolts and corresponding nuts may be used to join a tubular cap to either side of the adapter.

[0037] It should be appreciated that the embodiments described and claimed herein are exemplary only. Those of ordinary skill in the art will appreciate modifications and substitutions that retain the spirit and scope of the invention. For example, although the portion of the adapter that couples to the base and extension foundation piles is characterized herein as a receiver tube, they may insert into the free end of each pile and therefore the piles will “receive” these elements – in other words, they will fit within in the pile instead of the pile fitting within them. Also, the A-frame foundation system is

described herein as a two-piece foundation with a partially threaded base pile coupled to an above-ground extension pile. It should be appreciated that in various embodiments, there may be a below-ground extension pile attached to the base foundation pile. In other embodiments, the base foundation pile and extension pile may be combined into a single pile.

CLAIMS**Claim Set One:**

1. A system comprising:
 - a pair of base foundation piles, each base foundation pile comprising a straight elongated, hollow, tubular member having a substantially uniform inside diameter and a thread form at a first end;
 - a pair of upper foundation piles, each upper foundation pile coupled to a second end of one of the base foundation piles and comprising a straight elongated, hollow, tubular member; and
 - an adapter, the adapter comprising a continuous tubular member having a pair of opposing ends, a pair of opposing curved sections and middle section connecting the pair of opposing curved sections, the middle section having at least one hinge point, each opposing end coupled to a free end of one of the upper foundation piles to complete a continuous A-frame foundation having legs that are separated by an angle in a range of 35 degrees to 70 degrees.
2. The system according to claim 1 wherein the hinge point is located at the work point of the A-frame.
3. The system according to claim 1, wherein the adapter separates the legs of the A-frame by an angle in a range of 40 to 60 degrees.
4. The system according to claim 1, wherein the pair of opposing curved section curve towards each other and away from each other.
5. The system according to claim 1, further comprising a torque tube clamp connected to a torque tube, the torque tube clamp hinged to rotate about the hinge point when torque is applied to the torque tube.
6. An A-frame to monopile foundation adapter for a mechanically balanced single-axis tracker system comprising:
 - a tubular straight member having a first end and an opposing second end with a hinge point formed along the straight member between the first end and the second end;

a first pair of curved portions connected to the respective first and second ends of the straight member, the first pair of curved tubular members curving towards each other; and

a second pair of curved portions, the second pair of curved portions curving away from one another, wherein the second pair of curved tubular members are angled to couple with respective free ends of respective foundation piles to form an A-frame, wherein the second pair of curved portions curve away from one another at an angle in a range of 35 degrees to 70 degrees with respect to one another, and wherein the hinge point is located at a work point of the A-frame.

7. The system according to claim 6, wherein the second pair of curved portions curve away from one another by an angle in a range of 40 to 60 degrees.

Claim Set Two:

8. A universal A-frame to monopile adapter for an axial solar array comprising:

a main body portion, the main body portion comprising a pair of opposing flanges interconnected by a web portion;

a first plurality of attachment points formed in the web portion, the first plurality of attachment points oriented to mate with a torque tube support element of a first single-axis tracker system;

a second plurality of attachment points formed in each of the opposing flanges, orthogonal to the first plurality of attachment points and oriented to mate with a torque tube support element of a second single-axis tracker system; and

a pair of receiver portions, wherein in one of the pair of receiver portions projects out of a surface of each opposing flange, each receiver portion located between the second plurality of attachment points on its respective flange and oriented at an angle with respect to the surface of the flange in a range of 17.5 degrees to 35 degrees.

9. The adapter according to claim 8, further comprising a third plurality of attachment points in the web portion, on either side of the first plurality of attachment points, the third plurality of attachment points oriented to mate with a torque tube support element of a third single-axis tracker system.

10. A foundation system for a single-axis tracker comprising:

a pair of base foundation piles, each base foundation pile comprising a straight elongated, hollow, tubular member having a substantially uniform inside diameter, and a thread form at a first end;

a pair of upper foundation piles, each upper foundation pile coupled to a second end of one of the base foundation piles and comprising a straight elongated, hollow, tubular member; and

a universal A-frame to monopile adapter attached a free end of each upper foundation pile to form an A-frame, the universal adapter comprising:

a main body portion, the main body portion comprising a pair of opposing flanges interconnected by a web portion;

a first plurality of attachment points formed in the web portion, the first plurality of attachment points oriented to mate with a torque tube support element of a first single-axis tracker system;

a second plurality of attachment points formed in each of the opposing flanges, orthogonal to the first plurality of attachment points and oriented to mate with a torque tube support element of a second single-axis tracker system; and

a pair of receiver portions, wherein one of the pair of receiver portions projects out of a surface of each opposing flange, each receiver portion being located between the second plurality of attachment points on its respective flange and oriented at an angle with respect to the surface of the flange in a range of 17.5 degrees to 35 degrees to receive the free end of one of the upper foundation piles.

11. The system according to claim 10, wherein the torque tube support element comprises a torque tube clamp support.

12. The system according to claim 10, wherein the torque tube support element comprises a torque tube bearing.

13. The system according to claim 10, further comprising a torque tube supported by the universal adapter via a torque tube support element attached to one of the first or second attachment points.

14. The adapter according to claim 11, further comprising a third plurality of attachment points located on either side of the first plurality of attachment points in the web portion, the third plurality of attachment points oriented to mate with a torque tube support element of a third single-axis tracker system.

Claim Set Three:

15. A universal A-frame to monopile adapter for a tracker drive motor support comprising:
a motor pedestal, the motor pedestal comprising a substantially planar surface with a plurality of drive motor attachment features formed therein; and

a pair of receiver tubes attached to a base of the motor pedestal so as not interfere with any of the plurality of attachment features and projecting away from the pedestal at angle with respect to one another, the angle in a range of 35 degrees to 70 degrees, the receiver tubes dimensioned to receive respective legs of a foundation support system to form an A-frame foundation support for the tracker drive motor.

16. The universal support according to claim 16, wherein the receiver tubes project away from one another at an angle in a range of 40 to 60 degrees.

17. A foundation system for a tracker drive motor comprising:

a pair of base foundation piles, each base foundation pile comprising a straight elongated, hollow, tubular member having a substantially uniform inside diameter, and a thread form at a first end;

a pair of upper foundation piles, each upper foundation pile coupled to a second end of one of the base foundation piles comprising a straight elongated, hollow, tubular member; and

a universal tracker drive motor A-frame to monopile adapter attached to the pair of upper foundation piles to form an A-frame, the adapter comprising:

a motor pedestal, the motor pedestal comprising a substantially planar surface with a plurality of drive motor attachment features formed therein; and

a pair of receiver tubes attached to a base of the motor pedestal so as not interfere with any of the plurality of attachment features and projecting away from the pedestal at angle with respect to one another, the angle in a range of 35 degrees to 70 degrees,

the receiver tubes dimensioned to receive respective free ends of the upper foundation piles to form an A-frame foundation support for the tracker drive motor.

18. The foundation system according to claim 17, wherein the receiver tubes project away from one another at an angle in a range of 40 to 60 degrees.

Claim Set Four:

19. A universal A-frame to monopile adapter for a single-axis tracker comprising:

a main body portion, the main body portion comprising a pair of opposing flanges interconnected by a web portion, and a pair of platform portions, each one of the pair of platform portions positioned in a common plane above a respective one of the opposing flanges and oriented orthogonal to both the opposing flanges and the web portion;

a first plurality of attachment points, the first plurality of attachment points formed in the pair of platform portions and positioned to mate with a torque tube support element of a first single-axis tracker system; and

a pair of tubular receiver portions, one of the pair or receiver portions projecting out of a surface of each opposing flange, each tubular receiver portion located below one of the pair of platform portions and oriented at an angle in a range of 17.5 degrees to 35 degrees with respect to the flange in a common plane with one another.

20. The adapter according to claim 19, further comprising a second plurality of attachment points located in the web portion, the second plurality of attachment points positioned to mate with a torque tube support element of a second single-axis tracker system.

21. The adapter according to claim 20, wherein one of the first or second attachment point is positioned to mate with a tracker drive motor support element.

22. A foundation system for a single-axis tracker comprising:

a pair of base foundation piles, each base foundation pile comprising a straight elongated, hollow, tubular member having a substantially uniform inside diameter, and a thread form at a first end;

a pair of upper foundation piles, each upper foundation pile coupled to a second end of one of the base foundation piles and comprising a straight elongated, hollow, tubular member; and

a universal A-frame to monopile adapter attached to the pair of upper foundation piles to form an A-frame, the universal adapter comprising:

a main body portion, the main body portion comprising a pair of opposing flanges interconnected by a web portion, and a pair of platform portions, each one of the pair of platform portions positioned in a common plane above a respective one of the opposing flanges and oriented orthogonal to both the opposing flanges and the web portion;

a first plurality of attachment points formed in the platform portions, the first plurality of attachment points positioned to mate with a torque tube support element of a first single-axis tracker system; and

a pair of tubular receiver portions, one of the pair of receiver portions projecting out of a surface of each opposing flange, each tubular receiver portion located below one of the pair of platform portions and oriented at an angle in a range of 17.5 degrees to 35 degrees with respect to the flange in a common plane with one another.

23. The system of claim 22, further comprising a torque tube clamp support having a pair of feet, each of the feet resting on a respective one of the pair of platform portions and mechanically fastened to the platform portions via the first plurality of attachment points.

24. The system of claim 23, further comprising a torque tube clamp hingedly attached to the torque tube clamp support via a hinge point in the torque tube clamp support, the hinge point located at a work point of the A-frame and the torque tube clamp attached to a portion of a torque tube.

CLAIM SET FIVE:

25. A universal A-frame to monopile adapter for a single axis tracker comprising:

a trapezoidal shaped planar portion having a first long edge, a second short edge and a pair of angled side edges connecting the first long edge to the second short edge;

a first plurality of attachment points formed in the planar portion;

a pair of receiver portions, each one of the receiver portions attached to a respective one of the angled side edges; and

a pair of tubular cap portions, each tubular cap portions dimensioned to mate with a respective one of the receiver portions to capture a free end of a foundation pile thereby forming an A-frame support structure, the angled side edges oriented at reciprocal angles to one another, the reciprocal angles defining a pair of intersecting vectors that intersect at a work point above the trapezoidal planar portion and are separated by an angle in a range of 35 to 70 degrees.

26. The adapter according to claim 25, further an adjustable mounting plate, the adjustable mounting plate attached to the trapezoidal shaped planar portion via the plurality of attachment points, the adjustable mounting plate comprising a first plurality of attachment points for attachment to the trapezoidal shaped planar portion and a second plurality of attachment points for attaching to a torque tube support element.

27. A foundation system for a single-axis tracker comprising:

a pair of base foundation piles, each base foundation pile comprising a straight elongated, hollow, tubular member having a substantially uniform inside diameter, and a thread form at a first end;

a pair of upper foundation piles, each upper foundation pile comprising a straight elongated, hollow, tubular member; and

a universal A-frame to monopile adapter attached to the pair of upper foundation piles to form an A-frame, the universal adapter comprising:

a trapezoidal shaped planar portion having a first long edge, a second short edge and a pair of angled side edges connecting the first long edge to the second short edge;

a first plurality of attachment points formed in the trapezoidal shaped planar portion;

a pair of receiver portions, each one of the receiver portions attached to a respective one of the angled side edges; and

a pair of tubular cap portions, each tubular cap portion dimensioned to mate with a respective one of the receiver portions to capture a free end of each upper foundation pile to form an A-frame, the angled side edges oriented at reciprocal angles to one another, the reciprocal angles defining a pair of intersecting vectors that intersect at a

work point above the trapezoidal planar portion and are separated by an angle in a range of 35 to 70 degrees.

CLAIM SET SIX:

28. A universal A-frame to monopile adapter for an axial solar array comprising:

a main body portion, the main body portion comprising a pair of opposing flanges interconnected by a web portion;

a first plurality of attachment points formed in each of the opposing flanges oriented to mate with a torque tube support element of a first single-axis tracker system; and

a pair of receiver portions, wherein each one of the pair of receiver portions projects out of a surface of each opposing flange at a first angle and curves to a second angle, the second angle in a range of 17.5 degrees to 35 degrees with respect to the flange to couple to a free end of respective foundation piles to form an A-frame, wherein the receiver portions are spaced apart so that the an axis of rotation of the torque tube support element is aligned with a work point of the A-frame.

29. The adapter according to claim 28, further comprising a second plurality of attachment points formed in the web portion, the second plurality of attachments points oriented to mate with a torque tube support element of a second single-axis tracker system.

30. An A-frame foundation system for a single-axis tracker comprising:

a pair of base foundation piles, each base foundation pile comprising a straight elongated, hollow, tubular member having a substantially uniform inside diameter, and a thread form at a first end;

a pair of upper foundation piles, each upper foundation pile coupled to a second end of one of the base foundation piles and comprising a straight elongated, hollow, tubular member; and

a universal A-frame to monopile adapter attached to the pair of upper foundation piles to form an A-frame, the universal adapter comprising:

a main body portion, the main body portion comprising a pair of opposing flanges interconnected by a web portion;

a first plurality of attachment points formed in each of the opposing flanges oriented to mate with a torque tube support element of a second single-axis tracker system; and

a pair of receiver portions, wherein each one of the pair of receiver portions projects out of a surface of each opposing flange at a first angle and curves to a second angle, the second angle in a range of 17.5 degrees to 35 degrees with respect to the flange to couple to a free end of respective foundation piles to form an A-frame, wherein the receiver portions are spaced apart so that the an axis of rotation of the torque tube support element is aligned with a work point of the A-frame.

31. The system according to claim 30, further comprising a pair of right-angle brackets, each right-angle bracket attached to a respective one of the opposing flanges via the first plurality of attachment points, the pair of right-angle brackets defining a planar mounting surface for the single-axis tracker.

32. The system according to claim 31, further comprising a U-shaped torque tube clamp support resting on and attached to a planar mounting surface provided by the pair of right-angle brackets.

33. The system according to claim 32, further comprising a torque tube clamp assembly hingedly attached to torque tube clamp support about a hinge pin passing through a hinge point in the torque tube clamp support, the hinge pin aligned with a work-point of the A-frame.

CLAIM SET SEVEN:

34. A universal A-frame to monopile adapter for a mechanically balanced axial solar array comprising:

a mounting platform, comprising at least one elongated planar surface with respective orthogonal edges running along either side of the elongated planar surface;

a pair of spaced apart receiver portions projecting away from a bottom side of the mounting platform, the pair of receiver portions projecting away from the bottom side at reciprocal angles with respect to the bottom side of the mounting platform, the reciprocal angles in a range of 50 degrees to 72.5 degrees with respect to the bottom side.

35. The adapter according to claim 34, further comprising a gusset member perpendicular to the at least one elongated planar surface and interconnecting the pair of spaced apart receiver portions.

36. An A-frame foundation system for a single-axis tracker comprising:

- a pair of base foundation piles, each base foundation pile comprising a straight elongated, hollow, tubular member having a substantially uniform inside diameter, and a thread form at a first end;

- a pair of upper foundation piles, each upper foundation pile coupled to a second end of one of the base foundation piles and comprising a straight elongated, hollow, tubular member; and

- a universal A-frame to monopile adapter attached to the pair of upper foundation piles to form an A-frame, the universal adapter comprising:

- a mounting platform, comprising at least one elongated planar surface and a plurality of attachment points formed in the planar surface;

- a pair of spaced apart receiver portions projecting away from a bottom side of the mounting platform, the pair of receiver portions projecting away from the bottom side at reciprocal angles with respect to the bottom side of the mounting platform, the reciprocal angles in a range of 50 degrees to 72.5 degrees with respect to the bottom side.

37. The system of claim 36, further comprising a torque tube clamp support having a pair of feet, each one of the feet resting on the mounting platform and mechanically fastened to the platform via the plurality of attachment points.

38. The system of claim 37, further comprising a torque tube clamp hingedly attached to the torque tube clamp support via a hinge pin passing through a hinge point, the hinge point located at a work point of the A-frame and the torque tube clamp attached to a portion of a torque tube.

Claim Set Eight:

39. A single-axis tracker comprising:

a plurality of adjacent support pile pairs driven into the ground along a row, each adjacent support pile pair driven into the ground at reciprocal angles to one another and projecting above ground along respective axes;

a plurality of adapters, one for each adjacent support pile pair, each adapter joining respective above-ground ends of each pile pair to form an A-frame and providing at least one mounting surface;

a torque tube support element connected to each adapter via the at least one mounting surface;

a torque tube coupled to the torque tube support element and operable to rotate about an axis of rotation via the torque tube support element; and

a plurality of photovoltaic modules attached to the torque tube, wherein the axis of rotation is positioned at a point of intersection of the respective axes.

40. An A-frame to monopile adapter for a mechanically balanced single-axis solar tracker comprising:

a pair of opposing coupling portions, the coupling portions arranged at reciprocal angles to one another and adapted to couple to respective free ends of a pair of adjacent, angled foundation piles to form an A-frame foundation structure; and

an H-pile-shaped body portion attached to the pair of opposing coupling portions, the H-pile shaped body portion having at least one set of attachment features formed in a surface thereof to enable attachment of a torque tube support element of a single-axis tracker system and locate an axis of rotation of the torque tube at a work point of the A-frame.

41. A mechanically balanced single axis tracker system comprising:

a plural a plurality of adjacent support pile pairs driven into the ground along a row, each adjacent support pile pair driven into the ground at reciprocal angles to one another and projecting above ground along respective axes;

a plurality of A-frame to monopile adapters, one for each adjacent support pile pair, the A-frame to monopile adapter joining respective above-ground ends of each adjacent support pile pair to form an A-frame and providing at least one vertical mounting surface;

a torque tube support element connected to each adapter via the at least one mounting surface; and

a torque tube coupled to the torque tube support element and operable to rotate about an axis of rotation, wherein the axis of rotation is aligned with a work point of the A-frame.

42. A single axis tracker system comprising:

a torque tube;

a plurality of torque tube support elements connected to the torque tube at spaced apart intervals, the torque tube support elements defining an axis of rotation of the torque tube;

a plurality of adapters, one supporting each torque tube support element; and

a plurality of adjacent foundation pile pairs, one pair for each adapter, each foundation pile pair comprising a pair of piles driven into supporting ground at respective angles to one another and projecting above ground along respective axes and attached to one of the plurality of adapters, wherein each adapter supports a torque tube support element so that the axis of rotation is aligned with an imaginary area of intersection of the respective axes.