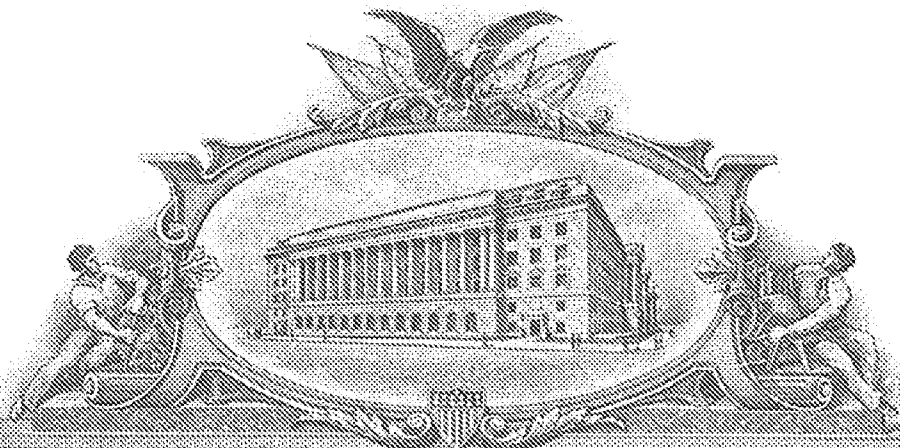


DOCUMENT MADE AVAILABLE UNDER THE PATENT COOPERATION TREATY (PCT)

International application number:	PCT/US2019/042763
International filing date:	22 July 2019 (22.07.2019)
Document type:	Certified copy of priority document
Document details:	Country/Office: US
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1012720



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APPLICATION NUMBER: 62/733,273

FILING DATE: *September 19, 2018*

RELATED PCT APPLICATION NUMBER: *PCT/US19/42763*

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS *US62/733,273*



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	PPA12
		Application Number	
Title of Invention	Foundation piers for axial solar arrays and related systems and methods		
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.)
--------------------------	---

Inventor Information:

Inventor 1					
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 2					
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Tyrus		Hudson		
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		523 Purrington Road			
Address 2					
City	Petaluma	State/Province	CA		
Postal Code	94952	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	PPA12
		Application Number	
Title of Invention	Foundation piers for axial solar arrays and related systems and methods		

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		Warner	

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

Mailing Address of Inventor:

Address 1	100 Iron Springs Road			
Address 2				
City	Fairfax	State/Province	CA	
Postal Code	94930	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	Foundation piers for axial solar arrays and related systems and methods		
Attorney Docket Number	PPA12	Small Entity Status Claimed	☒
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	5	Suggested Figure for Publication (if any)	

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PPA12
		Application Number	
Title of Invention	Foundation piers for axial solar arrays and related systems and methods		

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	PPA12
		Application Number	
Title of Invention	Foundation piers for axial solar arrays and related systems and methods		

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.
--

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	PPA12
	Application Number	
Title of Invention	Foundation piers for axial solar arrays and related systems and methods	

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.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	PPA12
	Application Number	
Title of Invention	Foundation piers for axial solar arrays and related systems and methods	

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.								

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PPA12
		Application Number	
Title of Invention	Foundation piers for axial solar arrays and related systems and methods		

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.							

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PPA12
		Application Number	
Title of Invention	Foundation piers for axial solar arrays and related systems and methods		

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

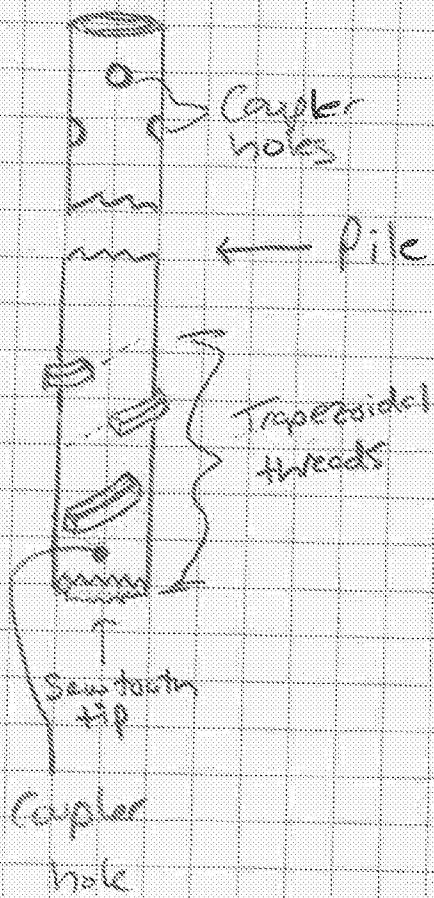
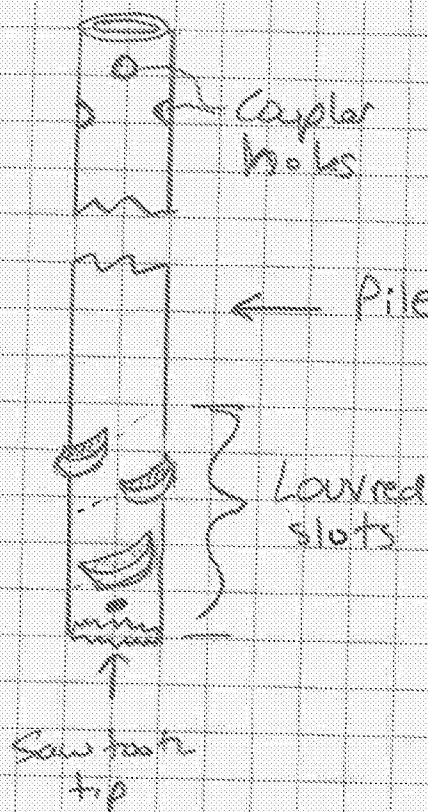


FIG. 2



PPA12

FIG. 3

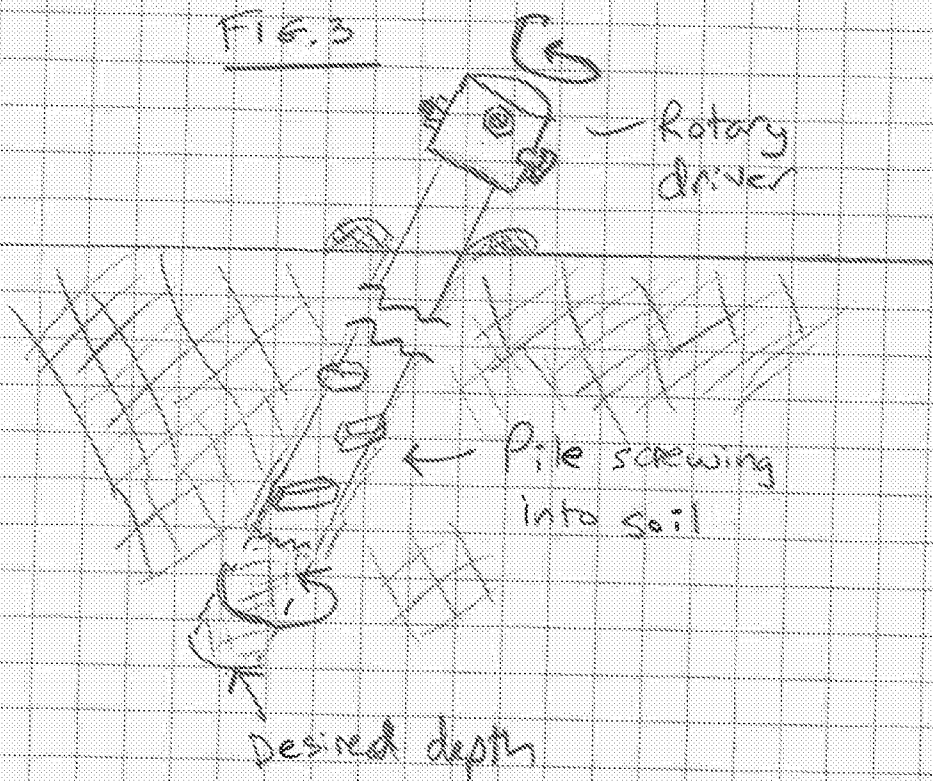


FIG. 4

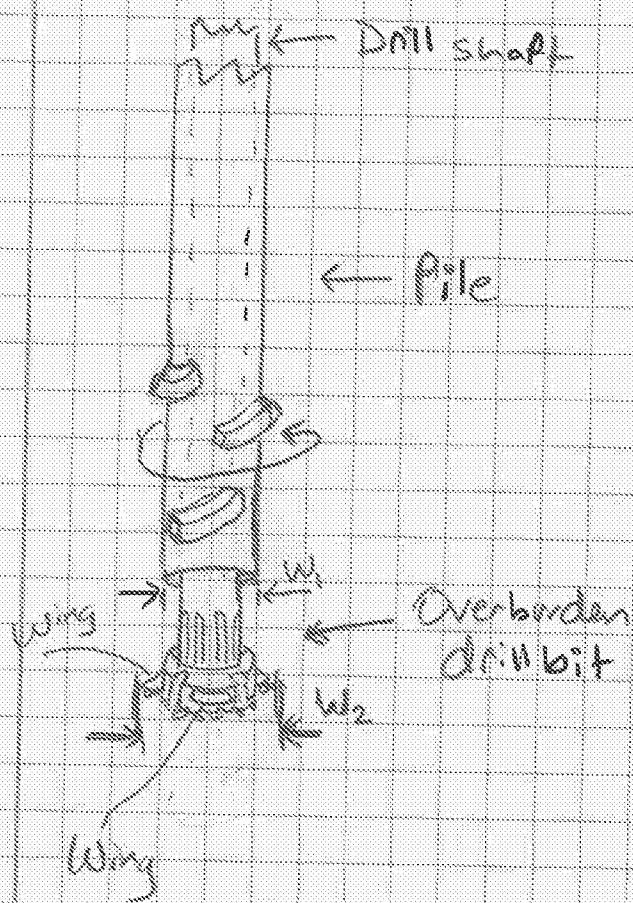


FIG. 5

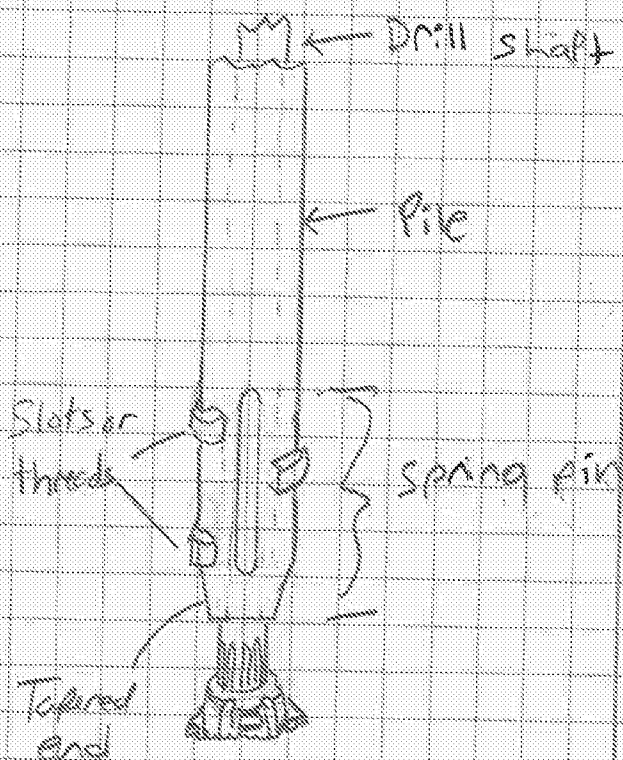


FIG. 6

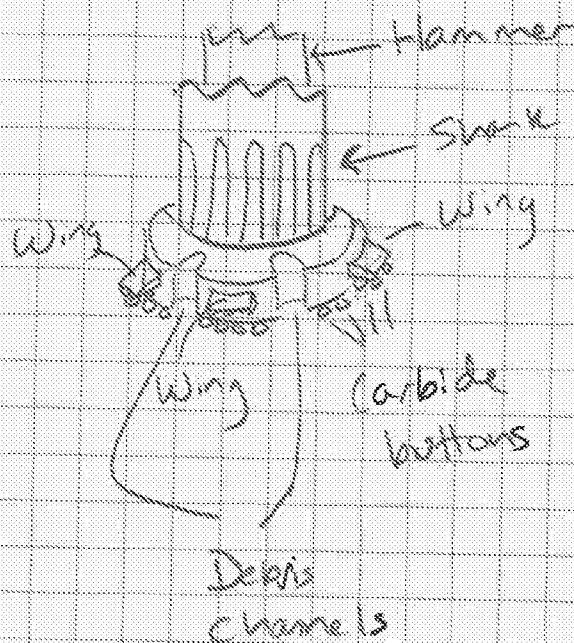


FIG. 7A

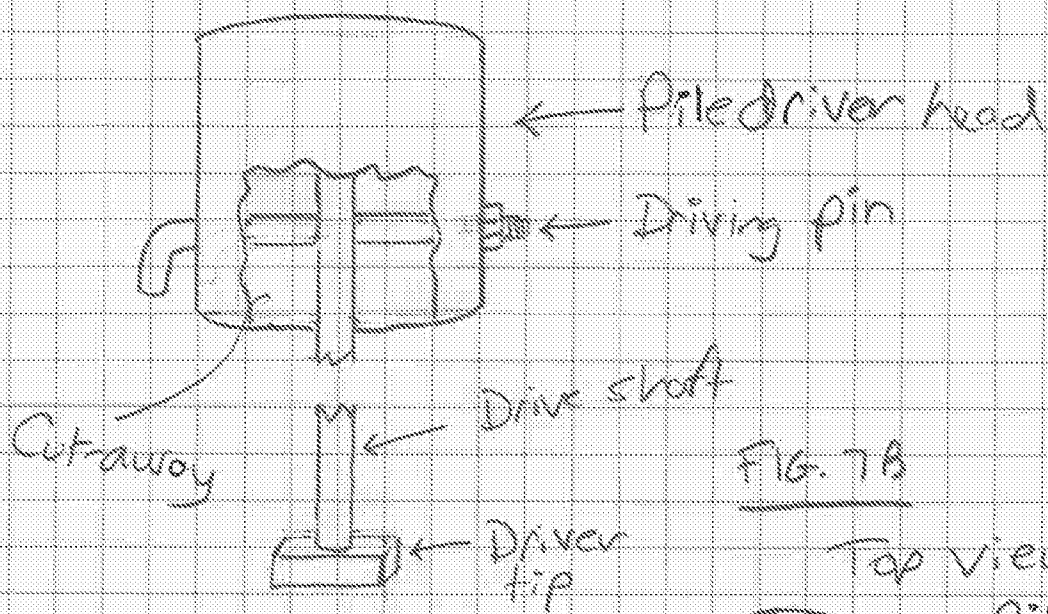


FIG. 7B

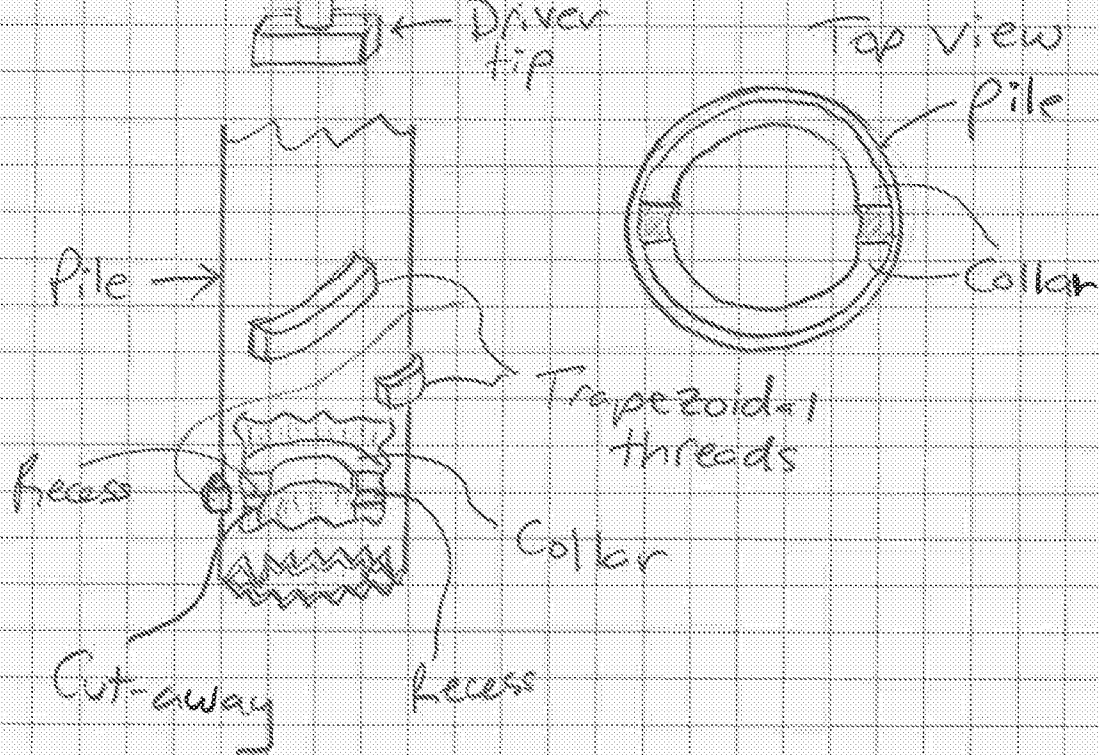


FIG. 8A

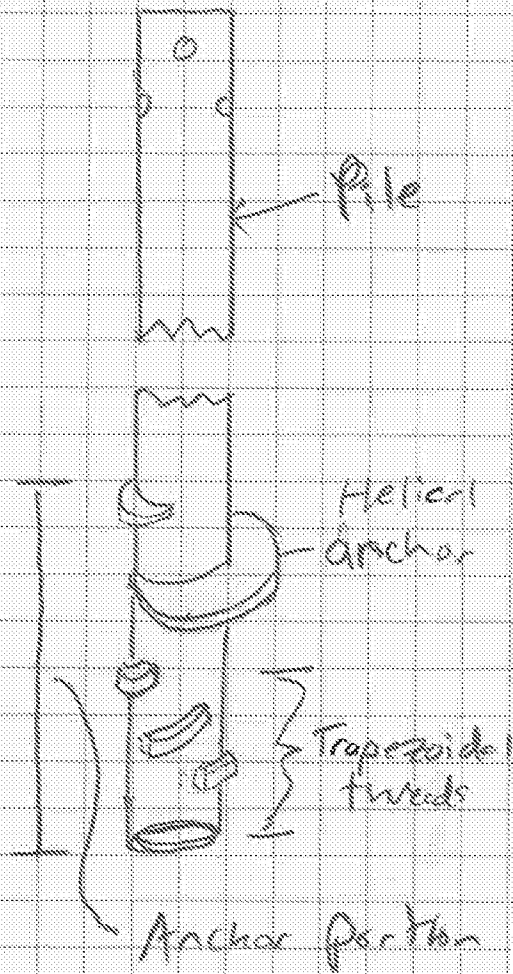


FIG. 8B

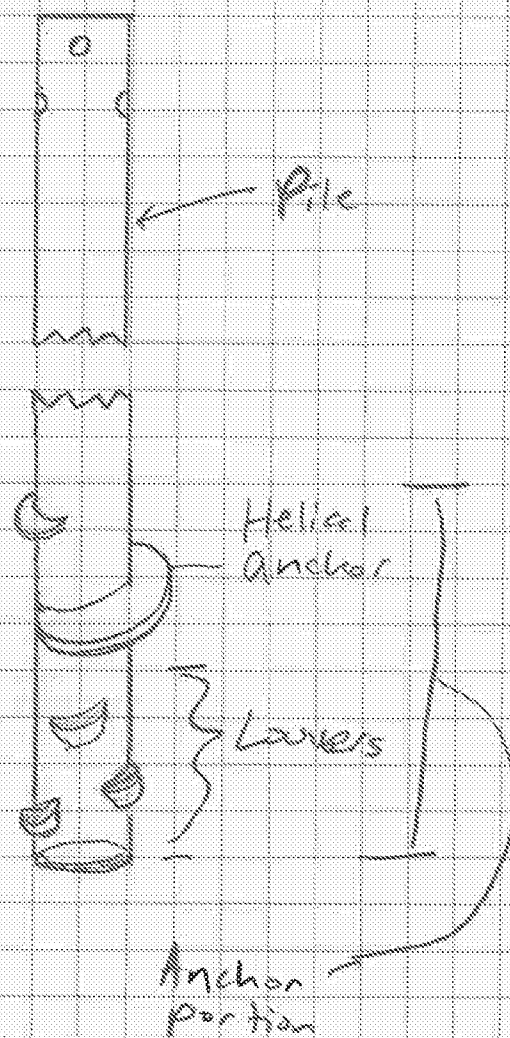


FIG. 9

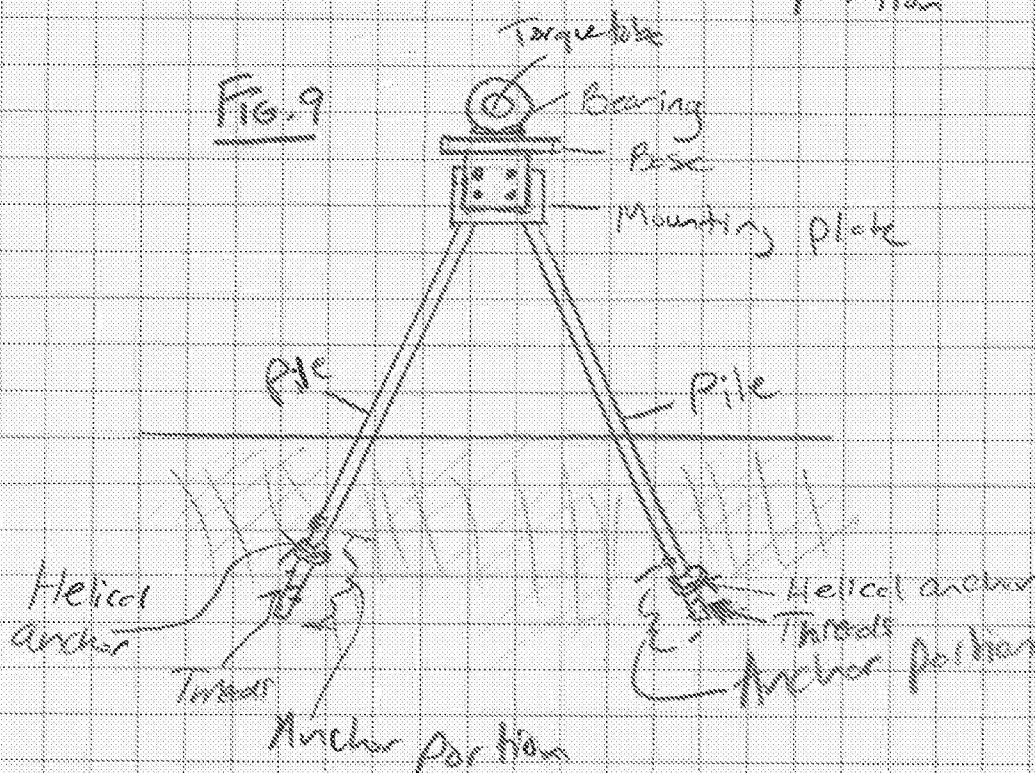
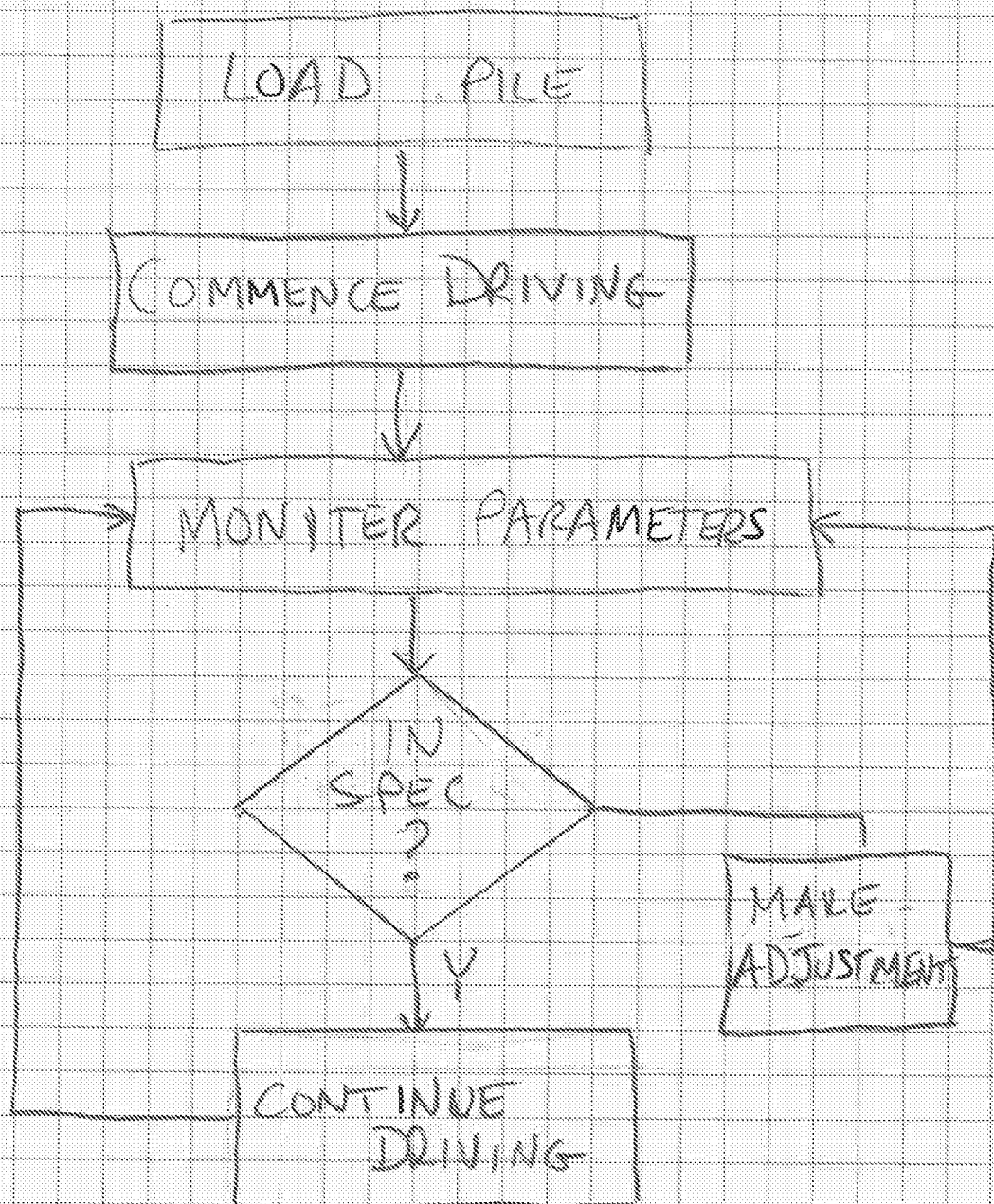


FIG. 10



Electronic Acknowledgement Receipt

EFS ID:	33767365
Application Number:	62733273
International Application Number:	
Confirmation Number:	5497
Title of Invention:	Foundation piers for axial solar arrays and related systems and methods
First Named Inventor/Applicant Name:	Jack West
Customer Number:	157339
Filer:	Phillip Dominick Mancini
Filer Authorized By:	
Attorney Docket Number:	PPA12
Receipt Date:	19-SEP-2018
Filing Date:	
Time Stamp:	14:47:11
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	\$ 140
RAM confirmation Number	092018INTEFSW14543700
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	145866	no	8
			b070ab9e6810208006c806dc71c654f14fa62915		
Warnings:					
Information:					
2	Specification	PPA12.pdf	119817	no	15
			afa79fab6bcdacee15610fec56f8edbe287e114d7		
Warnings:					
Information:					
3	Drawings-other than black and white line drawings	PPA12Drawings.pdf	825990	no	5
			51d8ceade61f028b23f52f630ecf44a554d0f4a1		
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	29578	no	2
			8ddd6a1a406475ea3f51846b740cbc05bd6aa5a7		
Warnings:					
Information:					
Total Files Size (in bytes):			1121251		

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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.

SCORE Placeholder Sheet for IFW Content

Application Number: 62733273

Document Date: 09/19/2018

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

Since this was an electronic submission, there is no physical artifact folder, no artifact folder is recorded in PALM, and no paper documents or physical media exist. The TIFF images in the IFW record were created from the original documents that are stored in SCORE.

- Drawing

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FOUNDATION PIERS FOR AXIAL SOLAR ARRAYS AND RELATED SYSTEMS AND METHODS**BACKGROUND**

- [001] Solar energy is one of the world's largest source of untapped energy. At sea level, the usable energy density is approximately 250 watts per square meter. Using a two-dimensional model to approximate the earth, $250 \text{ watts/square meter} * \pi * 6,371,000 \text{ meters}^2$ yields about 32,000 terra (trillion) watts of energy that strikes the earth at any moment. Given that the sun will continue to supply this energy for billions of more years, the survival of human life will ultimately depend on harnessing this essentially unlimited, clean energy source.
- [002] As in any industry, achieving scale is critical to maximizing the competitiveness of solar 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 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 South at an angle dictated by the latitude of the array site. By contrast, single axis trackers are rows of solar panels arranged on a rotating North-South axis called a torque tube that sweeps through an East to West rotation through the course of the day, following the sun's progression through the sky. For purposes of this disclosure, both fixed-tilt and single axis trackers will be referred to collectively as axial solar arrays.
- [003] Many large-scale solar projects are funded with so-called power purchase agreements (PPAs), whereby a customer agrees to purchase the power generated by the array at a predetermined megawatt hour rate (e.g., \$25-35 per megawatt hour at today's prevailing rates). Knowing the lifetime of the array (e.g., 35-40 years), a bank or other investor will be comfortable financing such a project given the predictable stream of revenue the array will generate over its lifetime.
- [004] Excluding land acquisitions costs, overall project costs typically include site preparation (road building, leveling, grid and water connections etc.), foundation piers, tracker hardware or fixed-tilt hardware, photovoltaics, inverters and electrical (conduit, wiring,

trenching, etc.). Inherent in all of these are also labor costs. At today's prevailing rates, this totals about \$1 per watt of energy. So, building a 100-megawatt solar power plant today would cost approximately \$100,000,000 dollars.

- [005] Many of these system component costs have dropped over the past few years, including solar panels and solar mounting hardware, however, one area that has been mostly overlooked is the cost associated with foundation piers. These structures physically couple solar trackers or fixed-tilt solar arrays to the earth. Typically, after the site has been prepped, a grid of H-piles or other structures are driven into the ground at regular intervals and other components are subsequently attached to those piles. In a conventional, large-scale single-axis tracker array, these piers will typically represent 5-7 percent of the cost of installing an array. Despite this relatively small share of the total array cost, any savings in steel and labor associated with foundation piers will amount to a significant amount of money over a multi-gigawatt portfolio of solar power plant projects. This is particularly true in the solar power plant business because many of these deals are locked in years before the installation costs are incurred. Therefore, the savings will be in addition to profits already factored in the calculations that supported the PPA. Reducing steel and associated labor costs used in foundation piers is the object of this application.

DESCRIPTION

- [006] Figures 1 and 2 of the drawings show foundation piles for an axial solar array according to various embodiments of the invention. The pile of FIG. 1 is an elongated tubular member having a circular cross-section and two open ends. The first or soil end in the example of figure 1 starts with a sawtooth tip. In various embodiments, this may assist with soil penetration during rotational driving over a flat edge. Heading up the pile, away from the soil end, is an anchor portion consisting of a series three-dimensional, trapezoidal threads. In various embodiments, these threads may only be sectional, that is following a thread-like pattern around the pile, but not continuously. Such trapezoidal threads may increase soil pressure on the pile and will also work like a helical anchor providing orthogonal surface area that will tend to resist axial forces of

pull-out and compression. In various embodiments, these threads may be welded on post production. In other embodiments, they may be stamped through the surface of the pile. In the example of FIG. 1, the above-ground end of the pile has a series of coupler holes. In various embodiments, the rotary driver may have a sleeve that fits over the above-ground end and a pair of removable pins keeps the driver and strut together during driving. In other embodiments, if driving from the soil end is preferred, a post may span the diameter of the pile near the soil end allowing a driver to fit completely inside the strut and rotate it into the soil. For example, FIGS. 7A and 7B show a driver and pile that can be driven from the bottom. In this example, the driver has a head portion that is coupled to the top of the pile via pin or another fastener. A drive shaft extends down into the strut until the driver tip engages a collar formed inside the pile proximate to the bottom or soil end. In various embodiments, the driver tip may simply be a rectangular block of steel and the collar a thick ring that is bisected by a pair of recesses cut into the collar on either side that are dimensioned to receive the driver tip. This configuration is shown via the partial cut-away view of FIG. 7A and the top view of FIG. 7B. In this configuration the driver tip will extend down the hole with the pile until the target depth (TD) is reached. Upward pressure on the drive shaft will instantly release the driver tip from the collar without disturbing the pile. Teeth formed in the end of the pile may assist in driver. Also, as drawn, the pile has trapezoidal threads formed on the outside proximate to its end. It may be preferable to use louvers, threads or other patterns to enable the pile to be screwed into the earth.

- [007] In an A-frame type foundation, two such piles will be driven into the ground adjacent one another at reciprocal angles. These piles are then joined with a mounting plate or other structure that completes the A-frame and provides a bracket to attach other components to, such as torque tube bearing, motors and/or other single-axis tracker or fixed ground mount array components.
- [008] FIG. 2 shows a foundation pile for an axial solar array according to other embodiments of the invention. Like that of FIG. 1, the pile is an elongated tube member with a circular cross-section. This pile also includes an optional saw tooth tip at the soil end. It

should be appreciated that a separate toothed ring may be attached to the tip of the pile instead of forming teeth into the tube opening. The anchor portion of this pile includes a plurality of louvers that encircle the pile in a thread pattern. The louvers may all be the same length or, alternatively, may be of differing lengths. Also, in some embodiments the louvers may be open whereas in other embodiments they may be closed to prevent soil from entering the inside of the pile when subjected to axial pullout forces. Soil will typically plug up the first few inches to foot of the pile during driving so the decision of whether to form the louvers as openings into the pile or to form them as external features may depend on the properties of the soil they will be driven into.

- [009] FIG. 3 shows a rotary driver driving a foundation pile into the ground according to various embodiments of the invention. In this example, the pile has trapezoidal threads proximate to its soil end as well as a sawtooth pattern cut into to the opening. Sawtooth pattern will help break the soil and the threads will enable the pile to screw into the ground, like a screw going into wood, about its threads. The pile of FIG. 3 is being driven in from the top by a rotary driver until the desired depth is achieved. This configuration may be particularly advantageous in medium to high-density soils that are free of bedrock or cobble. Looser soils such as sand may not provide the desired resistance to axial pull-out with a helical anchor or other structure to expand the orthogonal cross-section of the pile.
- [010] While adequate for medium to hard soils, the system shown in FIGS. 1-3 may not work with rocky soil or soils over underlying bedrock. Such soils may require drilling to create a path for the pile. To that end, FIGS. 4-6 show a foundation pile for an axial solar array and related methods of installing such a pile according to various embodiments of the invention. Beginning with FIG. 4, this Figure shows a foundation pile like the one shown in FIG. 1 with partial trapezoidal threads, however, in this example, an overburden drill bit and shaft have been inserted into the pile. The bit shown in FIGS. 4-6 is a rock bit driven by an air hammer that pulverizes the rock with carbide buttons arranged on the

bit surface. This action may be used in combination with rotation to break up rock and spin the resulting rubble out of the way ahead of the pile.

- [011] It should be appreciated that in some circumstances it may be preferable to use a different type of bit (e.g., cross, roller/tri cone, hammer, fixed cutter). The bit of FIGS. 4-6 has the advantage that it is capable of fitting into a smaller casing than the maximum diameter of its bore. This is possible with a series of wings built into the outer face of the bit that can be compressed into a flush orientation when the bit is inserted into the pile and then spring outward to their full diameter when the bit emerges from the pile, increasing the bore of the drill potentially beyond the outside diameter of the pile (see, e.g., W_1 and W_2 in FIG. 4). After the drill bit reaches the target depth (TD), the bit and shaft are pulled up and out of the pile casing. When edge of the pile opening contacts the back of the wings, they are forced back into a flush orientation. During drilling (i.e., when the drill is pushing downward), they hold firm because the resistive pressure is on each wing's drilling surface, not on its back.
- [012] It should be appreciated that although partial trapezoidal threads are shown, other thread type or pre-distresses may be formed in the anchor portion of the pile. In addition, though not shown, a helical anchor may also be positioned above the threads such as that shown in FIGS. 8A and 8B. This may be preferable in soft soils or on piles that require additional pullout resistance (end piles, outer piles, motor piles, etc.).
- [013] FIG. 5 shows another foundation pile for use with a drill and case system according to various embodiments of the invention. The pile in FIG. 5 has a spring pin in the anchor portion consisting of a one or more axial slots and a tapered end. Drilling with remove hard material under the pile. As the pull continues to be driven, tapered end will help "steer" it into the recess created in the rock by the drill bit. The louvres, threads or other features built into the outer surface proximate to the end will help anchor the pile in the rock. In addition, the spring pin section will allow the pile to compress inwardly (i.e., to have a smaller outside diameter) pre-loading the pile end within the rock cavity. Because the rock is harder than the pile in most cases, this will allow the pile to partially collapse without destroying or randomly deforming it.

- [014] FIG. 6 is a detail drawing of one type of drill bit usable with the various embodiments of the invention. This bit has a drill face with debris channels and a plurality of impact buttons made from hardened steel or carbide. The bit also has a shank that controls and rotates the bit and a hammer that slides within the shank applying pneumatic pressure to the tip several times per second at varying air pressure. The bit also has a plurality of collapsible wings. Each wing has a series of buttons on its impact surface but is under spring tension so that it can collapse easily when pressure is applied to the rear of the wing (e.g., when the bit is withdrawn up the pile) but will not yield against the pressure of impact drilling. The debris channels provide a path for the broken-up rock material. Air pressure may assist in moving debris along the debris channels.
- [015] It should be appreciated that in all embodiments (shown and/or described and their equivalents) that utilize drilling and casing, it may be desirable to shoot pressurized grout or other material into at least the bottom of the casing, with or without a section of rebar. Because the drill bit expands once it exits the casing (e.g., the pile), it is possible to make a cavity with a larger diameter than the pile's outside diameter and to drive the bit further down the hole than the TD for the pile, it may be advantageous to fill that space with grout or other void-filling, strength-enhancing material. If a rebar or like structure is used, it could simply be pushed down the hole with a plastic centralizer or other like device until it bottoms out in the hole. Then, if pressurized grout is shot down the hole, the pile will be locked to the rock via the grout and section of rebar. Tensioning the rebar from above may further enhance the pile's resistance to axial pull-out forces.
- [016] Also, it should be further appreciated that in some embodiments, drilling and casing may not be performed simultaneous in all cases, but rather as a rock mitigation technique. For example, in some embodiments, the drill may simply reside somewhere inside the pile while the pile is driven, above the dirt plug. In such embodiments, if the pile can be driven to depth without the use of the drill, the drill may never be independently engaged but simply sit within in the pile until the driver is lifted, up and away from the pile. If, during driving of the pile, a refusal occurs, that is, further

downward pressure and rotation by the rotary driver does not result in the pile penetrating deeper into the soil, the drill may be selectively engaged. In such cases, while the pile driver continues to rotate or while it stays still, the drill is activated and pushed all the way down the pile shaft until it engaged whatever is preventing the pile from being driven. The drill will hammer away at the rock, moving debris out of the way until the drill has reached or exceeded the TD, after which point it is withdrawn from the hole or at least drawn up into the pile so that it no longer projects out of the pile. Then driving of the pile can continue until the TD has been reached. Because the diameter of the drill bore is very close to the outside diameter of the pile, including any trapezoidal threads, louvres or other features, this stage of driving will involve metal on rock and may result in some deformation of the pile tip and/or other threads and features as the pile is forced into the rock cavity. If a helical anchor is present on the pile, the pile will only be able to be further driven the span between the pile end and the location of the helical pile (e.g., 18 inches). This may require an upper portion of the pile to be cut off to make it even with the height of the adjacent pile or other piles in that row. In embodiments where the drill is used only as a mitigation technique, the drill will only be used where it is necessary, and not prematurely worn out by drilling through dirt, clay or sand, before it is needed.

- [017] Also, various embodiments of the invention may rely on one or more feedback loops to optimize drilling and driving and to maintain consistency and speed. For example, in embodiments where driving is attempted first while the drill remains idle within the pile, a controller may monitor the speed of rotation and the rate of penetration. If the rate of penetration falls out of spec for pile as dictated by soil conditions and the size and pitch of the anchor or other thread-like features, the controller may alter the speed of the driver. In extreme cases, where penetration stops, the controller may automatically stop the driver and engage the drill, causing it to drill through the dirt plug and continue boring out a hole for the pile. Even during drilling, feedback to the controller regarding performance metrics of the drill (e.g., rate of rotation, rate of penetration, level of vibration, air pressure of the hammer, etc.) and performance

metrics of the driver (speed, downward pressure, rate of penetration) may cause the controller to issue control signals to the drill, the driver or both to optimize performance. This could, for example, mean increasing or decreasing drill speed, increasing or decreasing drill air pressure, increasing or decreasing downward pressure on the drill, increasing or decreasing the rotational speed of the pile driver, and/or increasing or decreasing downward pressure on the pile driver. This will keep the process running at its most efficient operating point without overstressing the equipment.

- [018] To that end, FIG. 10 is a flow chart illustrating steps of an exemplary process for driving a foundation pile for an axial solar array according to various embodiments of the invention. The processing begins with loading the pile. In some embodiments, the above-ground end of the pile may be attached to the rotary driver, such as with a locking pin or other fastener. In other embodiments, a portion of the driver may be slid into the pile before locking the two structures together with a locking pin or other device. In still further embodiments, a drill tip may be inserted into the pile as it is attached to the driver.
- [019] The next step is to commence driving. As discussed herein, this may involve a variety of different operations. In some embodiments, the rotary driver will be engaged to begin driving the pile into the earth. In other embodiments, a drill may be activated to begin drilling at or below the in-ground end of the pile to create a bore for the pile. In still further embodiments, the rotary driver may engage while the drill remains inactive but ready within the pile. Once driving has commenced, various parameters or performance metrics associated with the driving operation are monitored. As discussed herein, this may include monitoring the speed of penetration of the driver, the rotational speed of the driver, downward pressure on the driver, penetration depth, the rotational speed of the drill, the penetration depth or rate of penetration of the drill, and/or vibration of the drill head. These parameters may be compared against expected or predetermined parameters for the current conditions (e.g., soil type, presence of water, size of pile, size of anchor if used, etc.). If the parameters are within

specification, driving may continue in the same manner while the parameters are periodically checked (e.g., multiple times per second, multiple times per minute, etc.). If, however, any of the parameters are found to be out of spec, the controller may force an adjustment of one or more controllable parameters of either the rotary driver, the drill or both.

- [020] As one example, if the controller determines that the penetration rate of the pile is too slow it may speed up the rotation rate and/or increase downward pressure. If this doesn't bring measured parameters back into spec, it may issue a command to discontinue driving and to engage the drill. Similarly, if the drill is moving slower than expected, the controller may adjust air pressure, the drill's rotational speed, and/or downward pressure on the drill and then monitor to see these adjustments bring the drill's measured parameters back within spec. This may continue iteratively until the TD is reached.
- [021] FIG. 9 shows a foundation for an axial solar array composed of a pair adjacent foundation piles according to various embodiments of the invention. The pair of piles has been driven into the ground at reciprocal angles to one another using one or more the techniques discussed herein. In this example, each pier has a helical anchor and several resistance enhancing features (e.g., louvres, threads, etc.) formed in the anchor portion. The above-ground ends of the adjacent piles are joined together with a mounting plate. The mounting plate completes the A-frame, making a unitary structure, and providing a vertical foundation to attach additional components of a single-axis tracker system or fixed-tilt array, as is often done with H-piles in conventional foundations. Typically, the plate will have a series of holes or grooves to allow some adjustment in the vertical and/or horizontal direction to compensate for differences from foundation to foundation in the same row. In this example, a base having a vertical portion and a horizontal portion are attached to the vertical mounting plate. If separate, a bearing that receives and surrounds a portion of the torque tube is mounted to the base. Some tracker system manufacturers may combine the bearing and the base into a single part. The various embodiments of the invention are agnostic as to the

specific structure used to attach the torque tube. The goal of the various embodiments of the invention is to provide a universal foundation that provides the same interoperability as conventional H-pile foundations while meeting or exceeding their performance with less cost.

CLAIM SET 1:

1. A foundation for an axial solar array comprising:
 - an elongated pile member having a first end and an opposing second end; and
 - a plurality of projections proximate to the first end circumscribing the pile member to form a thread pattern.
2. The foundation of claim 1, further comprising a plurality of cutting teeth formed along an edge of the first end.
3. The foundation according to claim 1, wherein the plurality of projections comprises a plurality of trapezoidal threads.
4. The foundation according to claim 1, wherein the plurality of projections comprises a plurality of louvers.
5. The foundation according to claim 1, the strut further comprising a plurality of coupler holes for coupling a rotary driver proximate to the second end.
6. The foundation according to claim 1, further comprising a spring pin portion formed in the pile member proximate to the first end, wherein the projections are formed on the spring pin portion.
7. The foundation according to claim 1, further comprising a helical anchor formed on the elongated pile member proximate to the first end, above the plurality of projections.
8. The foundation according to claim 1, further comprising a tensioner centralized within the pile and extending through the first end, and a volume of grout cementing the tensioner to the pile.
9. The foundation according to claim 8, wherein the tensioner extends out of the second end of the pile so that it may be tensioned above ground after the volume of grout has dried.
10. A method of forming a foundation for an axial solar array comprising:
 - attaching a rotary driver to a first end of an elongated pile member, the elongated pile member having a plurality of projections circumscribing a portion of it proximate to a second end;

inserting a bit of the drill inside a shaft of the elongated pile member at the first end until it emerges from the second end;

driving the drill bit into supporting soil below the pile member with the drill to form a bore;

simultaneously driving the pile member behind the drill bit to case the bore;

withdrawing the drill bit from the pile member when a target depth is reached; and

continuing to drive the pile member within the bore to the target depth.

11. The method according to claim 10, wherein the steps of driving the drill bit and driving the pile member are performed with independent drivers.
12. The method according to claim 10, wherein inserting a bit of the drill inside the shaft of the elongated pile member comprises adjusting a bore of the drill bit end to a first dimension, the first dimension having a diameter smaller than an inside diameter of the pile member.
13. The method according to claim 12, wherein driving the drill bit into the supporting soil comprises adjusting a bore of the drill bit to a second dimension, the second dimension larger than the first dimension.
14. The method according to claim 13, further comprising activating a feedback loop, the feedback loop receiving data representative of a real-time performance of at least one of the drill and the rotary driver and sending a control signal to at least one of the one of the drill and the rotary driver to effect a change in a performance metric.
15. The method according to claim 13, wherein the performance metric is a metric selected from the group consisting of a rate of rotation of the rotary driver, a downward pressure of the rotary driver, a rate of rotation of the drill, a downward pressure of the drill, and a drill bore diameter.
16. The method according to claim 10, further comprising inserting a centralized tensioner within the bore so that it projects out of the second end and injecting a volume of grout into the bore to cover at least a portion of the tensioner.
17. The method according to claim 16, further comprising tensioning the tensioner from above ground after the volume of grout has dried.

18. A method of forming a foundation for an axial solar array comprising:
 - attaching a rotary driver to a first end of an elongated pile member;
 - inserting a bit of the drill inside a shaft of the elongated pile member so that is concealed within the pile;
 - driving the pile into the ground with the rotary driver until a refusal occurs, thereupon, activating the drill to drive the drill bit down the pile until it emerges from a second opposing end;
 - operating the drill to create a bore until the bit at least reaches a target depth; and
 - resuming driving of the pile until it reaches the target depth.
19. The method according to claim 18, wherein the steps of driving the pile member and operating the drill are performed with independent drivers.
20. The method according to claim 18, wherein inserting a bit of the drill inside the shaft of the elongated pile member comprises adjusting a bore of the drill bit to a first dimension, the first dimension having a diameter smaller than an inside diameter of the pile member.
21. The method according to claim 20, wherein activating the drill to drive the drill bit down the pile until it emerges from the second opposing end comprises adjusting a bore of the drill bit to a second dimension, the second dimension larger than the first dimension.
22. The method according to claim 18, further comprising activating a feedback loop, the feedback loop receiving data representative of a real-time performance of at least one of the drill and the rotary driver and sending a control signal to at least one of the one of the drill and the rotary driver to effect a change in a performance metric.
23. The method according to claim 22, wherein the performance metric is a metric selected from the group consisting of a rate of rotation of the rotary driver, a downward pressure of the rotary driver, a rate of rotation of the drill, a downward pressure of the drill, an amount of air pressure supplied to the drill, and a drill bore diameter.
24. The method according to claim 13, further comprising inserting a centralized tensioner within the bore after the pile reaches the target depth so that it projects out of the

second end and injecting a volume of grout into the bore to cover at least a portion of the tensioner.

25. The method according to claim 16, further comprising tensioning the tensioner from above ground after the volume of grout has dried.

26. A system comprising:

- a rotary driver;

- a drill having a drill bit attached thereto via a drill shaft;

- a first foundation pile, the first foundation pile comprising an elongated member having a first end and an opposing second end; and

- an anchor portion formed on the first foundation pile proximate to the first end,

- wherein the rotary driver is operable to rotate the first end of the foundation pile into supporting ground while the drill bit and drill shaft are contained within the foundation pile.

27. The system according to claim 26, wherein the drill is operable to drive the drill bit through the first end and into the soil to create a bore for the first foundation pile if the rotary driver encounters a refusal.

28. The system according to claim 26, wherein the drill is operable to drive the drill bit ahead of the first foundation pile to create a bore that is simultaneously cased by the first foundation pile.

29. The system according to claim 26, wherein the anchor portion comprises a helical anchor formed on the first foundation pile proximate to the first end.

30. The system according to claim 26, wherein the anchor portion comprises a series of trapezoidal threads formed on and circumscribing a portion of the first pile.

31. The system according to claim 26, wherein the anchor portion comprises a series of louvers formed on and circumscribing a portion of the first foundation pile in a thread pattern.

32. The system according to claim 26, wherein the anchor portion comprises a spring pin portion comprising at least one axial slot.

33. The system according to claim 26, further comprising a controller operable to receive performance information from at least one of the drill and the rotary driver during use and to adjust an operation of at least one of these devices based on the received performance information.
34. The system according to claim 33, wherein adjusting an operation comprises making at least one adjustment selected from the group consisting of a rate of rotation of the rotary driver, a downward pressure of the rotary driver, a rate of rotation of the drill, a downward pressure of the drill, an air pressure supplied to the drill, and a drill bore diameter.
35. The system according to claim 26, further comprising a second foundation pile, driven into the ground adjacent to the first foundation pile, wherein the first foundation pile and second foundation pile are joined together above ground to form an A-frame structure with a support member for supporting a torque tube bearing of a single-axis tracker.
36. The system according to claim 26, further comprising a centralized tensioner inserted into the pile after it reaches the target depth so that it projects out of the second end and a volume of grout injected into the bore to cover at least a portion of the tensioner within the pile.
37. The method according to claim 16, further comprising tensioning the tensioner from above ground after the volume of grout has dried.