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1012721

THE UNITED STATES OF AMERICA

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UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

August 01, 2019

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APPLICATION NUMBER: 62/748,083

FILING DATE: *October 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 *US62/748,083*



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	PPA17
		Application Number	
Title of Invention	Improved foundations 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
	David		Warner	
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	
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	PPA17
		Application Number	
Title of Invention	Improved foundations 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
	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 5

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 6

Legal Name				
Prefix	Given Name	Middle Name	Family Name	Suffix
	Daniel		Flanigan	

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PPA17
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Title of Invention	Improved foundations 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	201 8th Street			
Address 2				
City	Petaluma	State/Province	CA	
Postal Code	94952	Country ⁱ	US	

Inventor 7

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	Improved foundations for axial solar arrays and related systems and methods		
Attorney Docket Number	PPA17	Small Entity Status Claimed	☐
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	12	Suggested Figure for Publication (if any)	

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PPA17
		Application Number	
Title of Invention	Improved foundations 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.					

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	PPA17
		Application Number	
Title of Invention	Improved foundations 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.
--

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	PPA17
		Application Number	
Title of Invention	Improved foundations 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.

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	PPA17
		Application Number	
Title of Invention	Improved foundations 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.

- ☐ 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

Country¹

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	PPA17
		Application Number	
Title of Invention	Improved foundations 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.							

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	PPA17
		Application Number	
Title of Invention	Improved foundations 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

YPA17

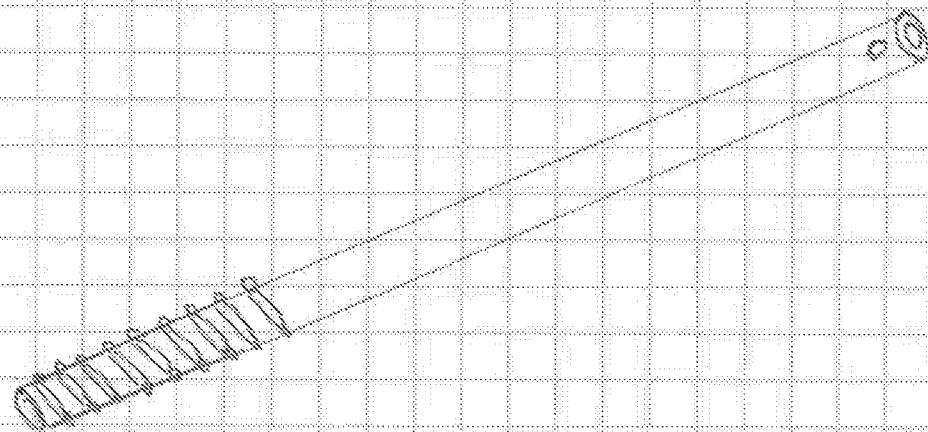


FIG. 2A

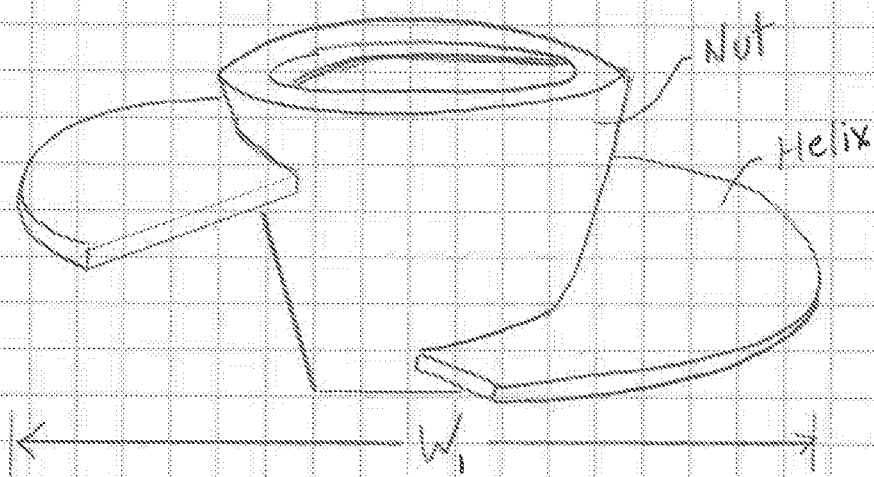


FIG. 26

Partial cut-away view

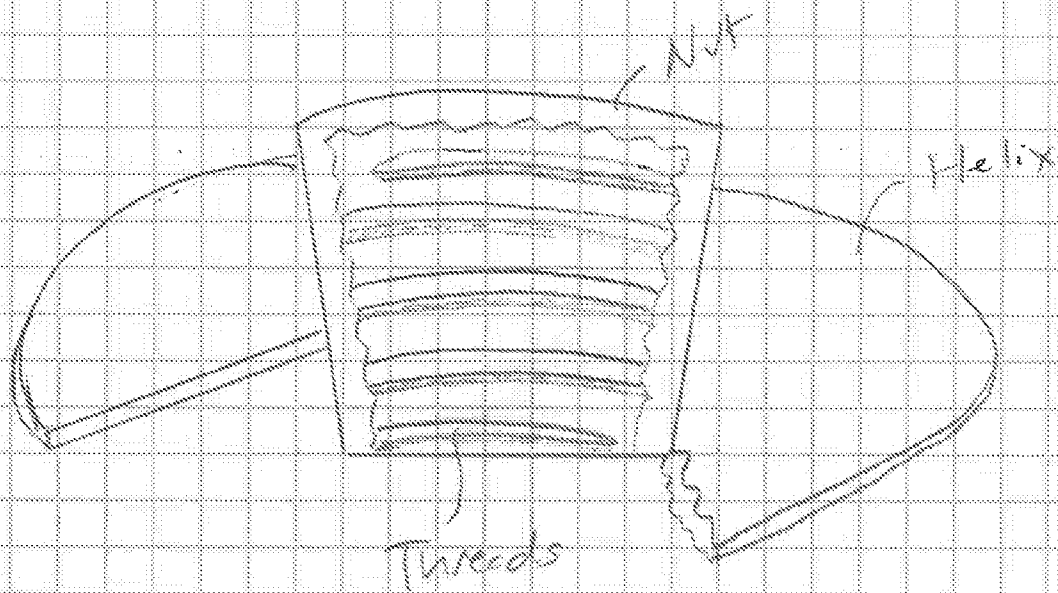


FIG. 3

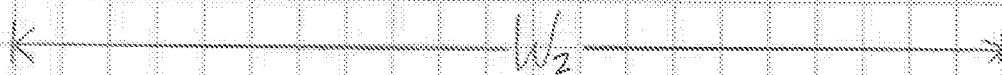
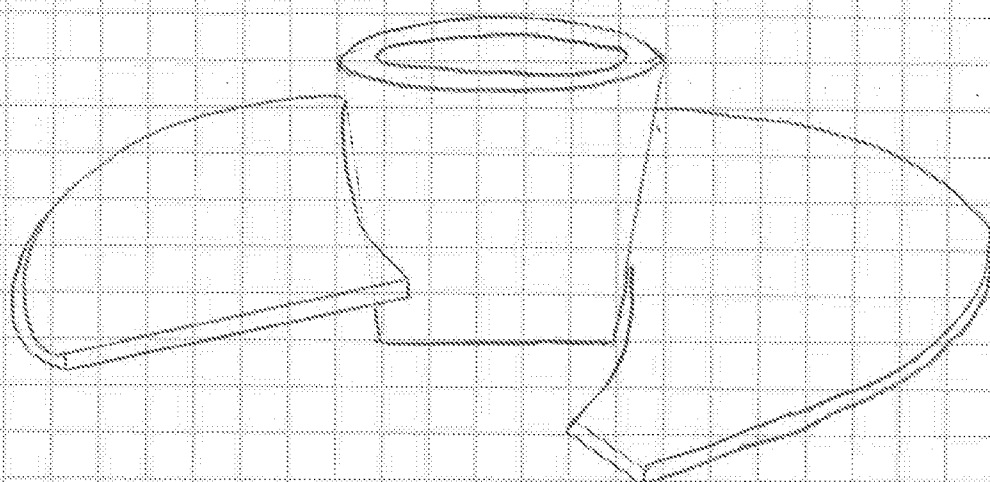


FIG. 4

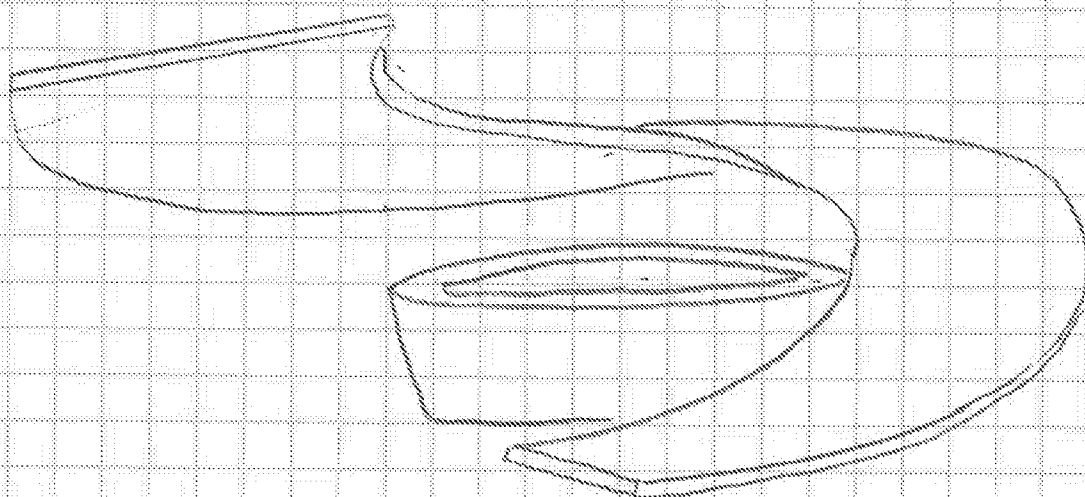


FIG. 5

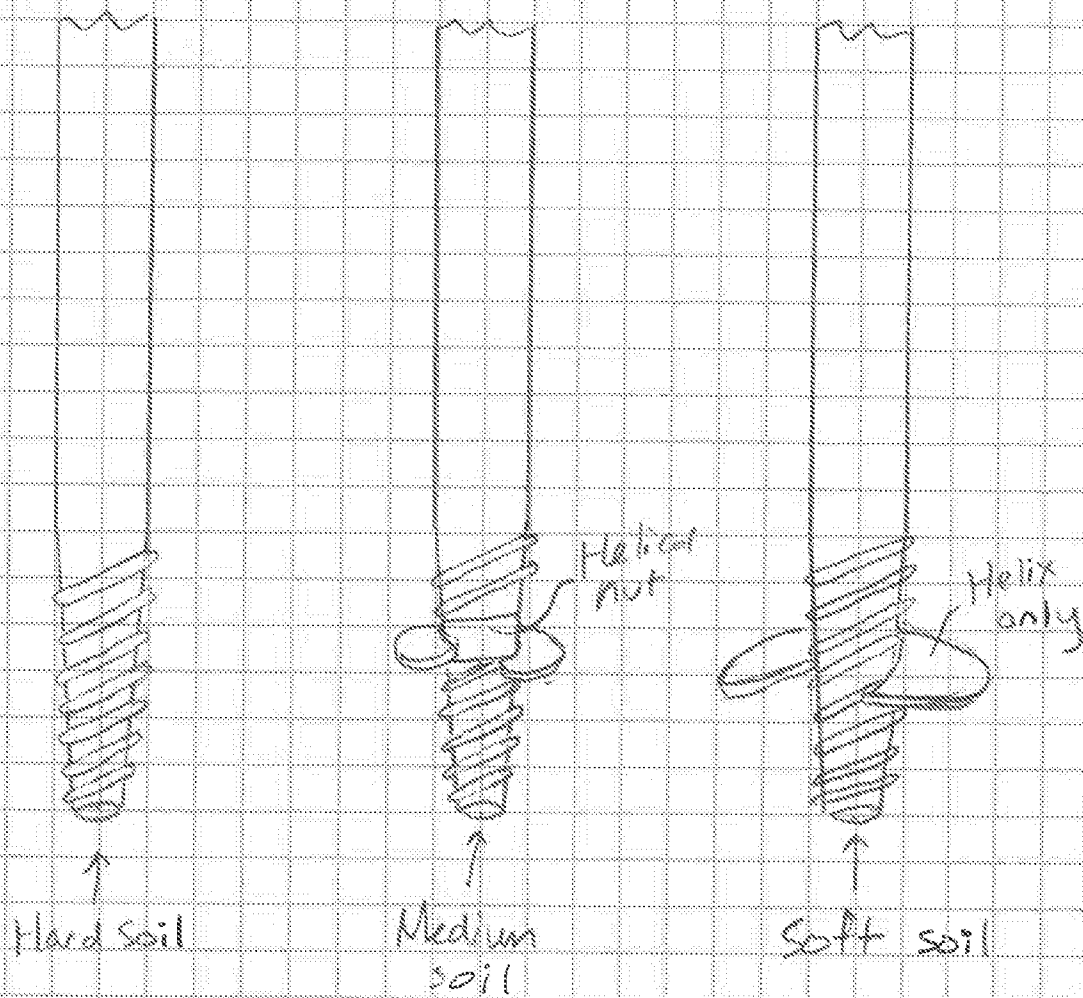


FIG. 6

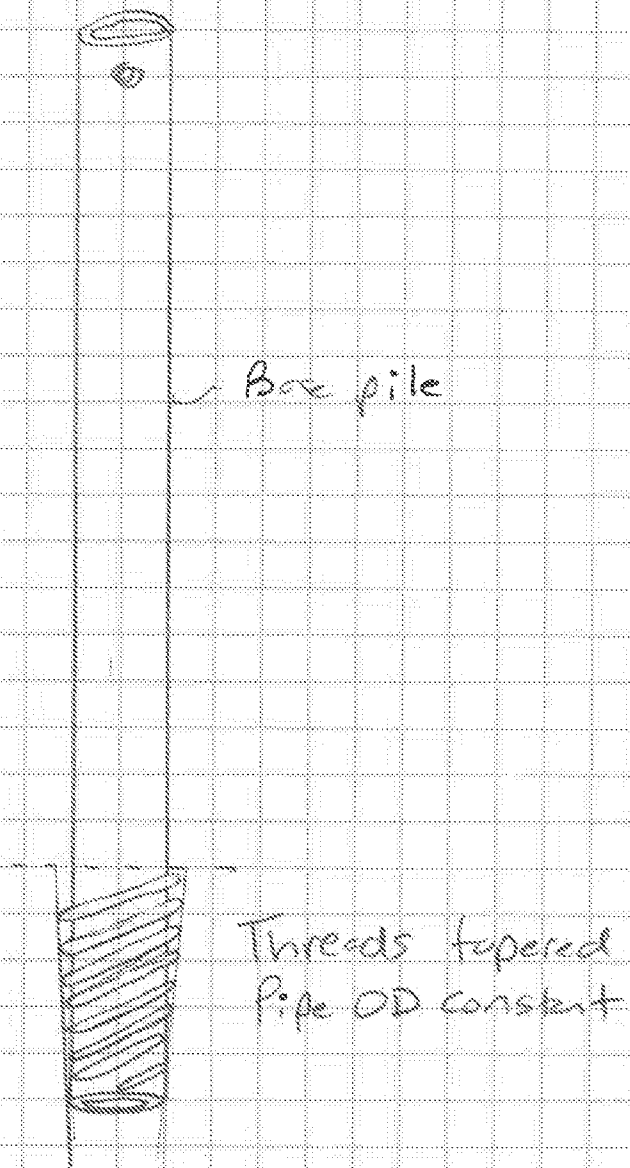


FIG. 7

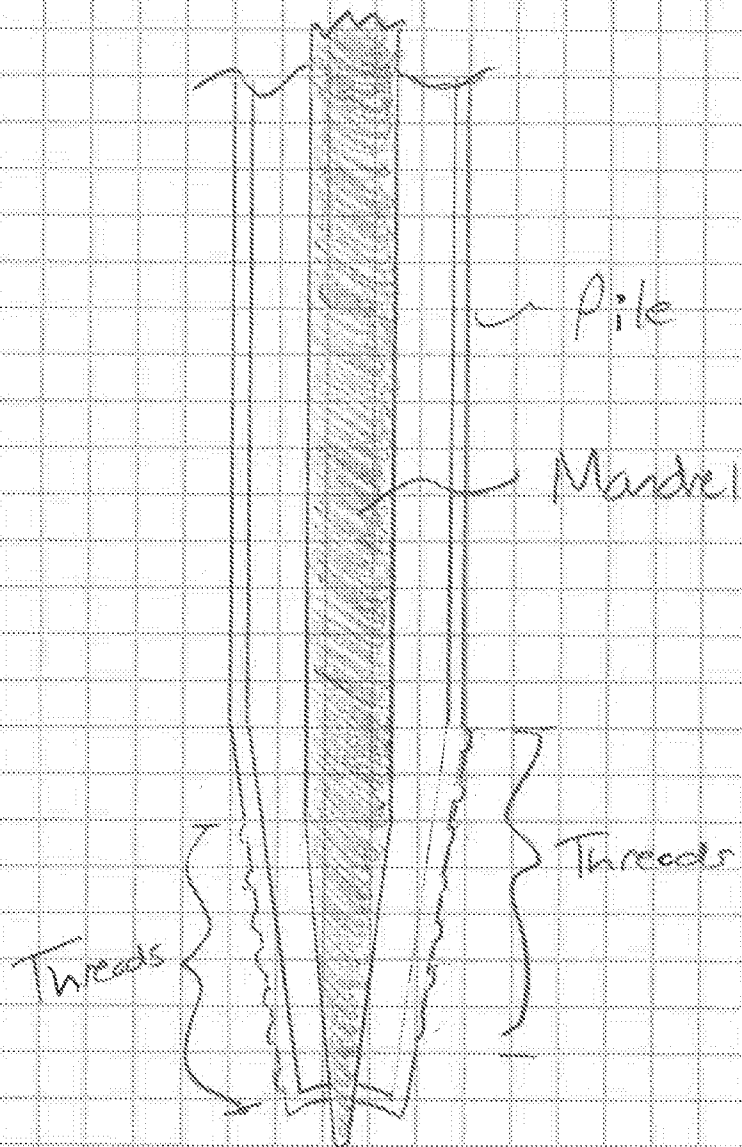


FIG. 8A

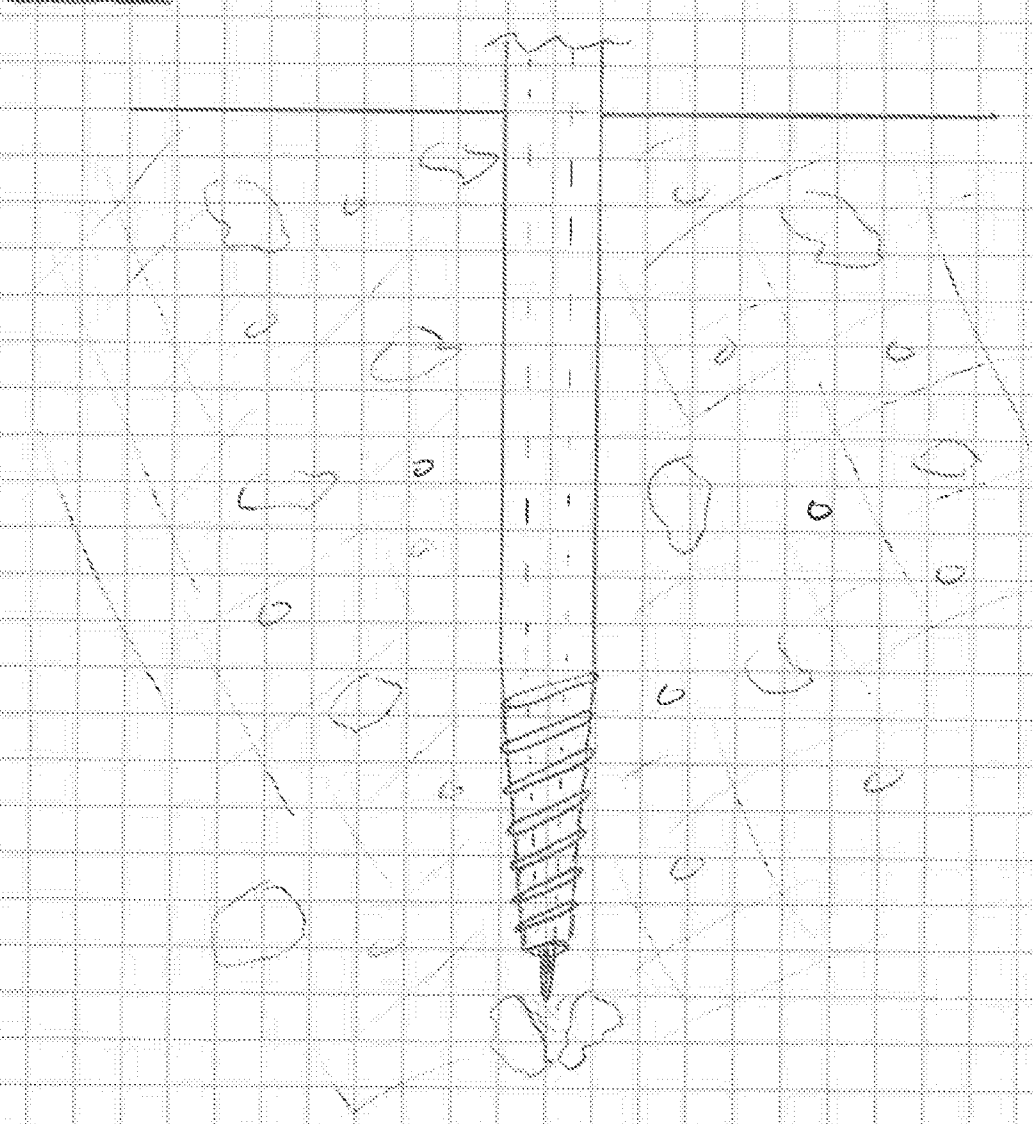


FIG. 8B

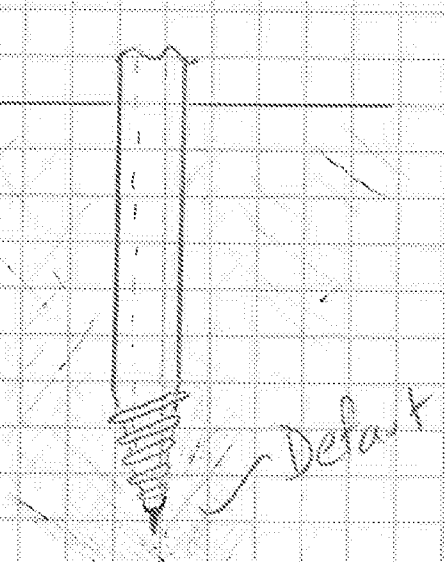


FIG. 8C

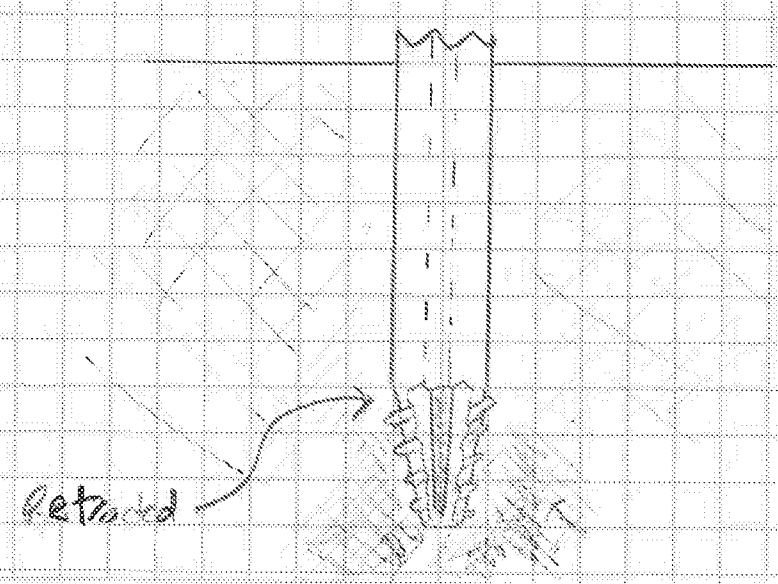


FIG. 9

Feedback Loop

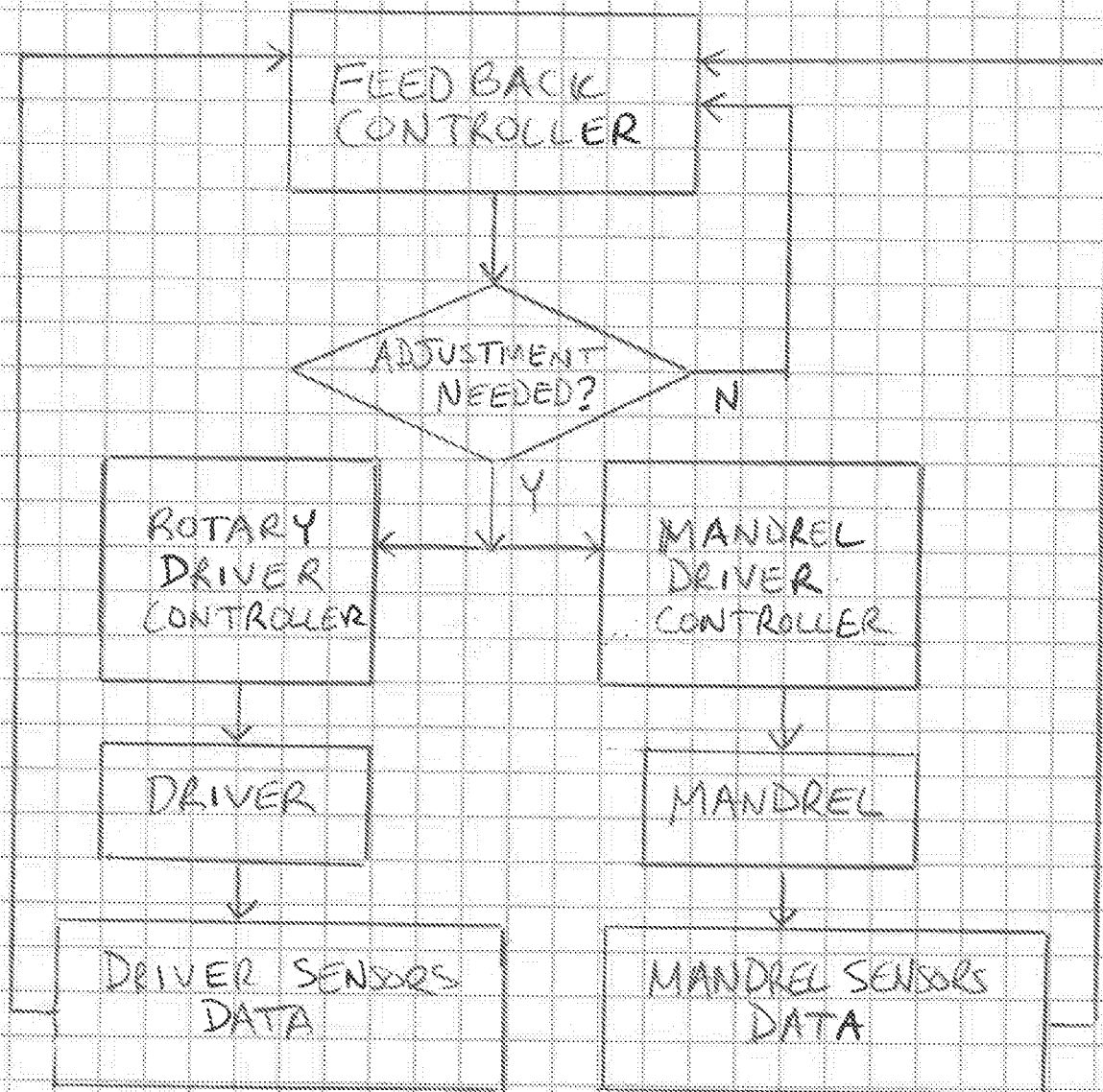


FIG. 10A

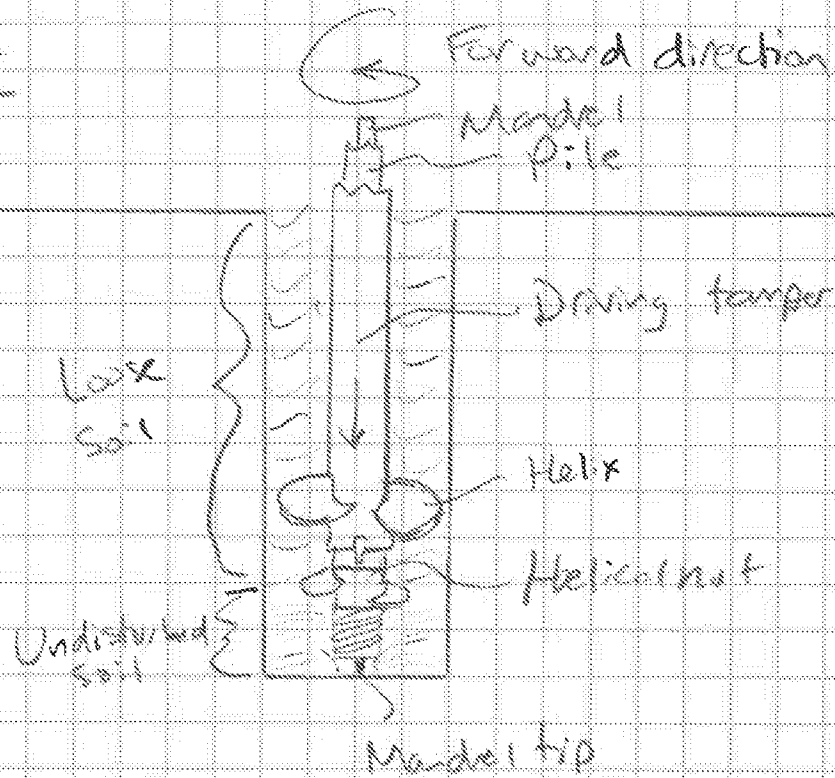


FIG. 10B

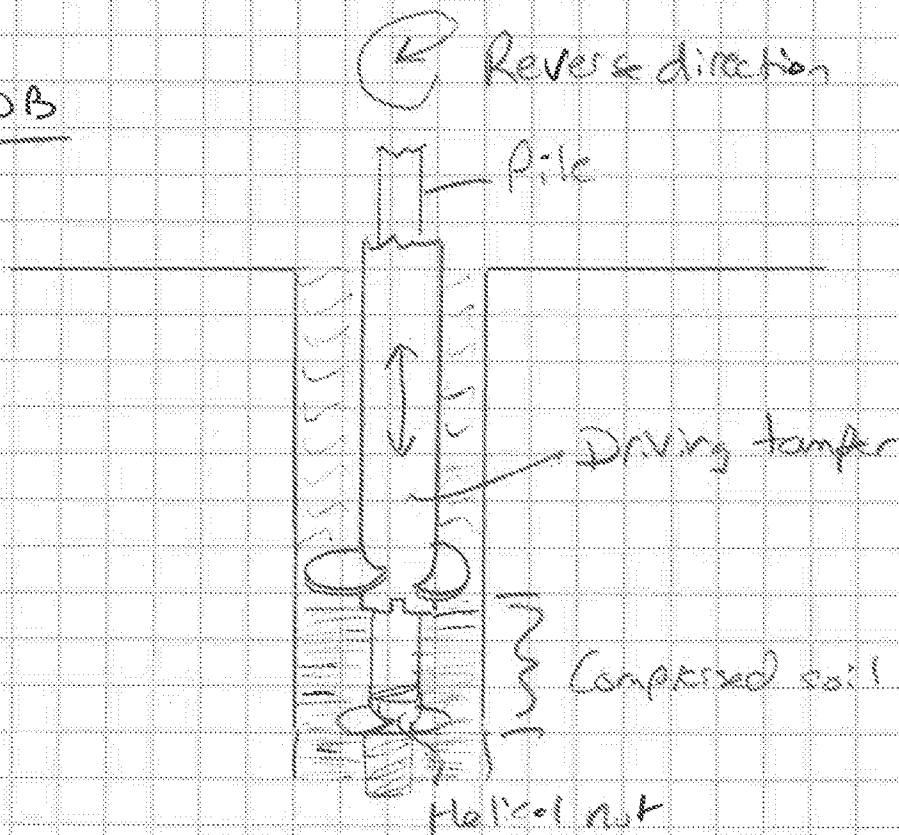


FIG. 11A

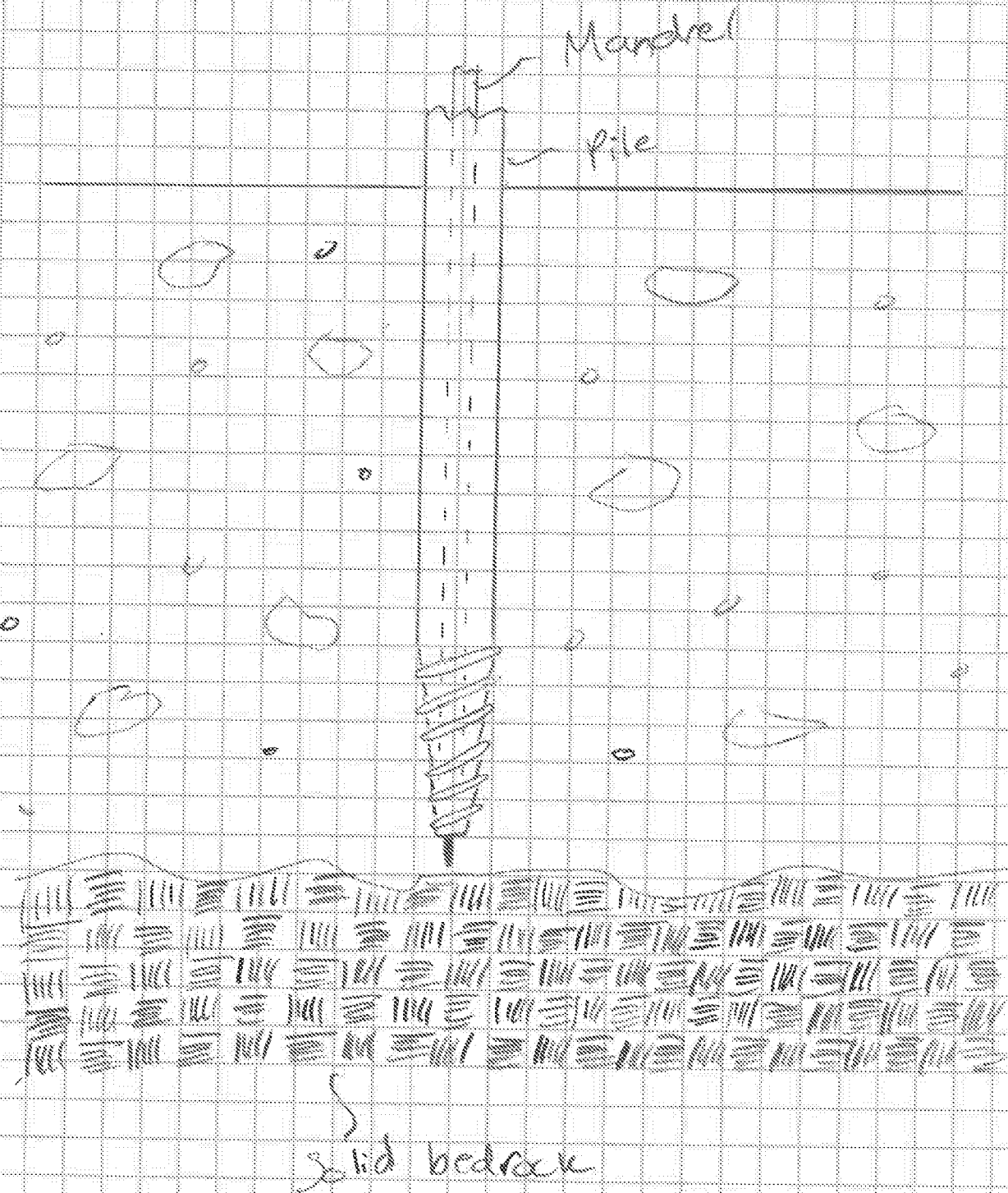


FIG. 11B

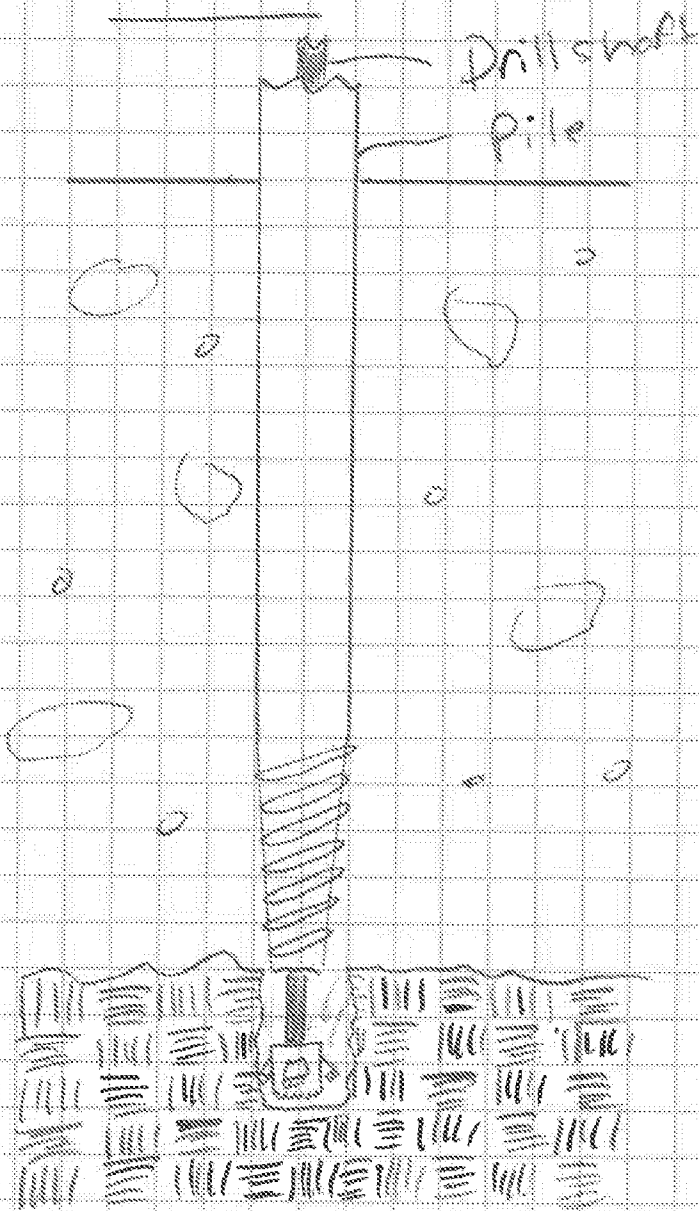


FIG. 11C

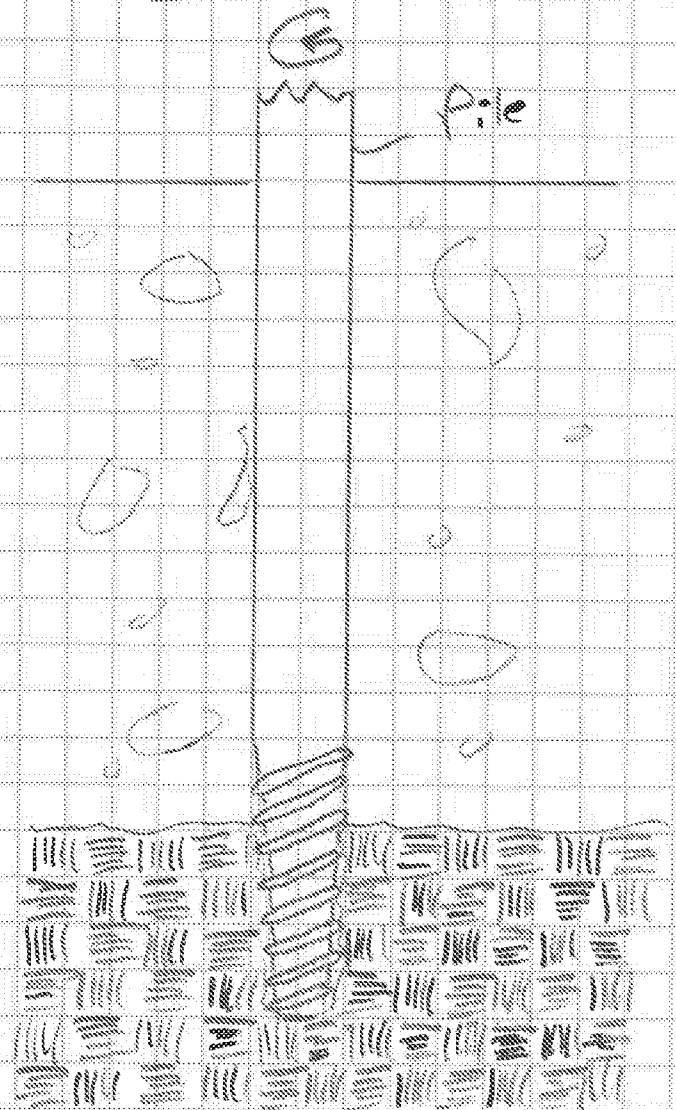


FIG. 12A

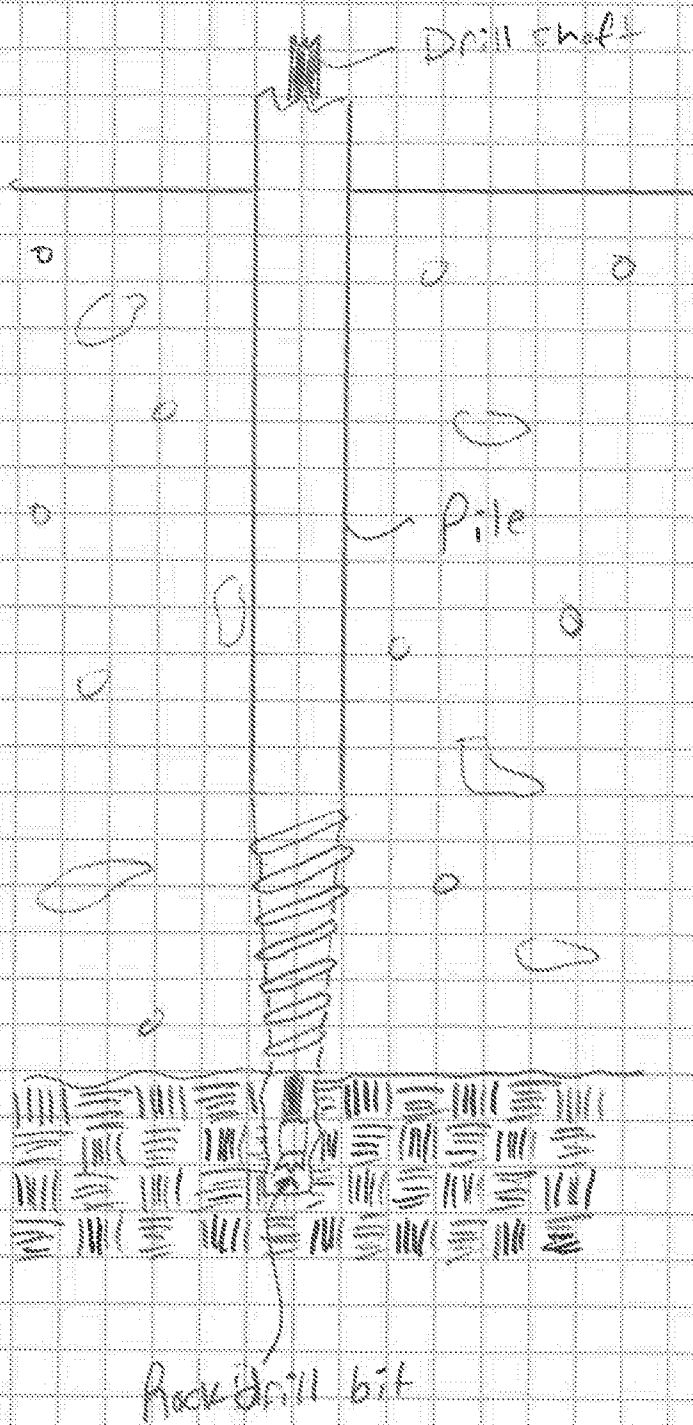
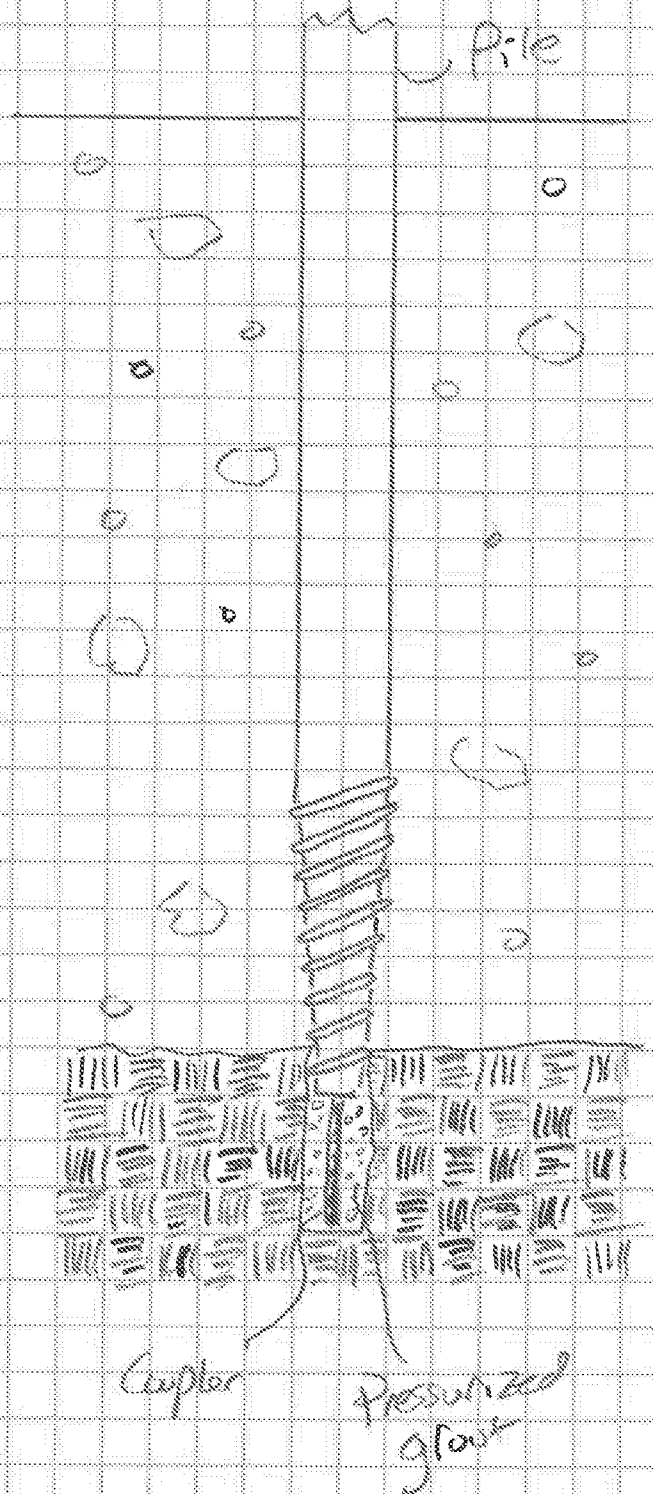


FIG. 12B



Electronic Acknowledgement Receipt

EFS ID:	34065516
Application Number:	62748083
International Application Number:	
Confirmation Number:	1059
Title of Invention:	Improved foundations 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:	PPA17
Receipt Date:	19-OCT-2018
Filing Date:	
Time Stamp:	16:58:10
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	\$ 140
RAM confirmation Number	102218INTEFSW16591701
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	178053	no	9
			803e2c352758b08bccfb566c02aff387210d4c10		
Warnings:					
Information:					
2	Drawings-only black and white line drawings	PPA17DWGS.pdf	1826916	no	12
			d5a961400949e8e18e38c6ece479fc5ca37a0c3b		
Warnings:					
Information:					
3	Specification	PPA17.pdf	132951	no	19
			6f5f84af9b00967058167d94223a26bf83e012cd		
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	29678	no	2
			c4f3152cef45339de026eb02573be2b341b11459		
Warnings:					
Information:					
Total Files Size (in bytes):			2167598		

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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.

IMPROVED FOUNDATONS 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, $250\text{watts/square meter} \times \pi \times 6,371,000\text{ meters}^2$ yields about 32,000 terra (trillion) watts of energy that trikes 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] Ground screws are known in the art. These devices are used to securely attach signs, mobile homes, umbrellas and other devices to the ground. They typically consist of an elongated shaft with an open head at the top and a taper leading down to a point at the other end. A set of threads are wound around the shaft beginning at or near the point and running up the taper and in some cases up part of the shaft. A rotary driver or special-built ground screw driver is used to rotate them in the ground. In certain soil types, especially relatively dense soils, these devices are good at resisting axial forces of

compression and tension; in looser soils they are less effective. One reason that ground screws work well in denser soils is that the closed pointed end of the screw helps increase pressure around the tip of the screw. Also, when driving, the downward force is concentrated on the relatively small surface area of the tip, enabling it to break through small rocks and/or to displace them so that the screw can continue to travel down.

- [007] One shortcoming of ground screws is that they are expensive. The process of making the screw starts with forming a length of uniform pipe. Then, one end of the pipe is heated and inserted into a forming machine that imparts a taper. Then, after the pipe has cooled, another machine applies a strip of metal around the shaft in a thread pattern and finally that strip of metal is welded to the shaft. When the piece has cooled it is galvanized to protect it from oxidation. The additional hot process steps of heat treatment, tapering and welding significantly add to the cost relative to cold-formed piles. Also, ground screws cannot be reconfigured in the field so different variations must be contemplated at the time of manufacture.
- [008] One alternative to ground screws is the helical anchor. Helical anchors are shafts or pipes with one or more helical flights circumscribing their perimeter orthogonal to the shaft; usually the helical flight is located proximate to the underground end of the pile. Like ground screws, helical anchors are driven in with a rotary driver or other screw driving machine. Because of the much larger surface area of the helical flight, as compared to the threads on a ground screw, these devices perform very well in loose soils. They can also work in denser soils, but they become more difficult to drive, potentially bending or break the helical flight on the way down. Mitigating this requires using thicker metal and stronger welds which increase their cost. Also, they tend to break up the soil on the way down as the helix cuts through each layer, requiring them to be driven more deeply or the soil to be tamped or compressed above them. Finally, they are easily damaged by rocks in the soil during driving, and in fact, their relatively large orthogonal cross section makes the likelihood of encountering rocks far greater.

- [009] Therefore, there is a need for a foundation pile that enjoys benefits of grounds screws and helical piles but that also ameliorates some, and ideally all their respective shortcomings. In other words, there is a need for a flexible yet effective solution that will work in different soil types, that does not require expensive hot forming processes or welding and that works with various rock mitigation techniques in line, without having to remove the pile.
- [010] Figure 1 shows a foundation pile according to various embodiments of the invention. The pile of FIG. 1 consists of an elongated, hollow pipe that is open at both ends. The top end is used to drive the pile into the ground with a rotary driver, ground screw driver or the like. This may be accomplished with one or more pairs of co-axial through-holes bisecting the center of the pile shaft that can receive a pin or other fastener to selectively couple the pile to its driver. The driver may fit outside or inside or both to engage the pile.
- [011] In the example of FIG. 1, the bottom end (i.e., below-ground end) has a taper where the pile's outside diameter reduces from its nominal width over the length of the pile to a smaller diameter. For example, when using two-inch ANSI Schedule 40 pipe or two-inch rigid metal conduit (RMC), both have an outside diameter of 2.375 inches. The taper may reduce the diameter at the distal end down to 2 inches or even smaller. In various embodiments, the threads may be formed through a cold-forming process whereby the end of the pipe is compressed by a die. Alternatively, the threads may be formed from a cold rolling process or a thread cutting process where threads are formed by removing material or deforming material. The threads will allow the pile to be screwed into the ground like a ground screw, however, as discussed in greater detail herein, the hollowed tip provides greater flexibility for mitigating circumstances frequently encountered when driving and allows the insertion of mandrel to be used during driving as discussed in greater detail below.
- [012] FIGS. 2A and 2B are perspective and partial cutaway views respectively of a helical nut usual with the foundation pile according to FIG. 1. In various embodiments, the helical nut consists of a central, cone-shaped nut portion and a helical flight circumscribing

nearly one complete circle around the nut. As shown in the cut-away view of FIG. 2B, inside of the nut may be threaded with conical threads that match the pitch of the threads formed on the tapered portion of the pile. In this way, the helical nut may be screwed onto the pile in the field, such as, for example, in soil where a pile alone will provide insufficient resistance to axial forces. The helical nut of 2A has an outside diameter W_1 . In various embodiments, an installer will have access to two or more different diameter helical nuts at the time of installation and will be able to select the appropriate one to use based on the soil conditions encountered at that site. For example, FIG. 3 shows a second helical nut with a helical flight having an outside diameter W_2 , which is larger than the outside diameter W_1 of the helical flight on the helical nut of FIG. 2A.

- [013] It should be appreciated that in various other embodiments, the threads on the pile may be tapered rather than the pile itself. In such embodiments, the threads of the helical nut may or may not be conical in shape. For example, FIG. 6 shows an elongated pile member according to various embodiments of the invention whereby the pile has a uniform inside and outside diameter along its entire length. Instead of imparting a taper to the pile itself, the taper is affected via the thread form. In various embodiments a tapered thread form may be attached to or formed on the pile with a die, thread former or thread cutter. Alternatively, a set of uniform threads may be formed on the pile and then the threaded end may be inserted into a grinder or other device that grinds them down at a slight angle to form a taper. This may be simpler to manufacture than tapering the pipe itself since it will not require a hot forming process.
- [014] Turning now to FIG. 4, this figure shows a helical nut configuration where the helix itself is dimensioned to fit directly over the threads of the pile without a central nut portion. The opening at the center of the helical flight and the pitch of the flight may preferably be set to approximate the width and pitch of the pile threads at a midpoint along their length so that the helix will reach a point where it can't be threaded any further. In some situations, it may be desirable to thread a nut on to the pile thread form after the helix is threaded on to bias the helix against the point on the threads where it can no

longer turn. This two-piece approach may be less expensive to manufacture than the helical nuts shown in FIGS. 2A/B and 3 because the optional nut portion is universal to different sized helixes.

- [015] Turning now to FIG. 5, this figure shows three essentially identical foundation piles configured for use in different soil types according to various embodiments of the invention. The first is just the base foundation pile by itself. In very compressed soils or soils that are mostly hard clay or full of cobble, the thread form on the base pile may be enough to allow it to be screwed by itself and still provide strong resistance to tension and compression. The second pile has a helical nut spun onto the tapered thread form at the base of the pile to convert the base foundation pile into a helical pile. This configuration may work well in medium dense and/or partially cobbled soils. Finally, the third pile has a large single helix spun directly onto the threads. As shown in FIG. 4, an optional nut may follow the helix to keep it pinned in place. This configuration may work best in the softest soils (e.g., sand, silt, loam, etc.).
- [016] Various embodiments of the invention rely on a mandrel to assist with driving. The opening at the end of the hollowed base pile makes this possible. For example, as seen in FIG. 6, during installation a mandrel may also be inserted into the top end of the pile, slid all the way down its length until it exits the below-ground end. This mandrel may be used to push soil out of the way as the pile threads its way down under the force of the rotary driver. In various embodiments, the mandrel may be connected to a separate driver. Reciprocating action within the pile by the mandrel driver may enhance this effect. Alternatively, or in combination, the mandrel may simply plug the hole at the tip of the pile while the pile is being rotated down to increase soil pressure around the tapered/threaded portion of the pile. If the pressure gets too great, the mandrel may retract, opening the tip to allow soil to plug that hole, thereby reducing the pressure around the tip. This may be accomplished with a spring or through automated control implemented by the mandrel driver in response to sensing a threshold level of soil resistance.

- [017] Reciprocating the mandrel may also allow it to displace and/or break up smaller rocks that are in the driving path. Without the mandrel's action, such rocks may cause a refusal and/or damage the end of the pile. In the field of solar pile driving, a refusal occurs when additional driving force fails to increase penetration of the pile. Usually, this indicates that the pile has struck a rock or in the extreme case solid bedrock. By reciprocating the mandrel, it functions as a chisel that can crumble small rocks, buried objects and pockets of dense soil. Various uses of the mandrel during driving are shown for example in FIGS. 7A, 7B and 7C.
- [018] Starting with 7A, in this figure as the base pile is being driven into the ground, via a rotary driver or screw driving equipment, the mandrel is reciprocating up and down within the shaft of the pile ahead of the pile tip. As it encounters small rocks or other obstacles the reciprocating action of the mandrel breaks them up into smaller pieces and pushes them out of the way so that the rotary driver can continue to spin in the pile to its target depth. It should be appreciated that in various embodiments, the mandrel may by default rest in the pile, projecting out of the tip to create a point for the pile like the point on a ground screw. The mandrel driver may apply steady downward pressure clocked to the rate of penetration of the pile will. In various embodiments, the mandrel may begin reciprocating only if or after a reduction in the penetration rate of the pile occurs, such as, for example when the pile encounters a rock. In other embodiments, the mandrel may always reciprocate to clear a path ahead of the pile.
- [019] FIGS. 7B and 7C show embodiments where the mandrel is used to control soil pressure around the tapered/threaded end of the pile during driving. In the default mode shown in this example, the mandrel projects out of the below-ground end of the pile as the pile spins down. In some embodiments, it may reside at the tip, traveling down with the pile to increase soil pressure around the pile threads. In other embodiments, it may also exert downward pressure independent of the pile. If the rotary driver encounters excessive driving resistance as indicated, for example, by a reduction or stoppage in downward travel or excessive resistance against the rotary driver or both, the mandrel may retract into the pile to allow dirt to plug in the end, thereby relieving the soil

pressure retarding driving. This reduction in pressure will reduce resistance to the rotary driver. It is important when screwing a pile or ground screw into the ground that the pile continues moving forward so that it doesn't auger or core the hole, which will reduce the pile's resistance to axial forces.

- [020] Various embodiments of the invention will benefit from automated real time feedback control to optimize driving time and prevent damage to equipment or the pile itself. To that end, turning now to FIG. 8, this figure shows an exemplary feedback control loop for the mandrel and rotary driver according to various embodiments of the invention. The feedback control loop may be implemented as a computer, a circuit board, an application specific integrated computer (ASIC), firmware or a combination of hardware and software. It may reside in a standalone enclosure communicatively coupled to the mandrel driver and the rotary driver, on the machine used to support these objects or even remote to them on a computer, tablet, mobile phone, etc., via one or more wireless communication links.
- [021] In various embodiments, the feedback controller will receive sensor data corresponding to operating parameters of the mandrel and/or the rotary driver. For example, the mandrel driver may communicate in real time the magnitude of the downward force it is exerting on the mandrel, the amount of soil resistance force it is experiencing, and/or the frequency and force of reciprocation. Similarly, the rotary driver may communicate its real time speed of rotation, direction of rotation, rotary pressure, and/or rate of penetration. This information may be used by the feedback controller to optimize each installation and to quickly manage exceptions (e.g., when driving slows or stops completely). The feedback controller may store one or more tables of optimal operating parameters or ranges of parameters and issue commands to the rotary driver and/or to the mandrel controller to maintain driving performance at or near the optimal parameters or within a range of acceptable operating parameters. The feedback controller may also store this information corresponding to the driving process for each pile in association with a location and/or other identifier for that pile. This information may be useful post-installation for the project developer, financier, geotechnical

engineer or other interested party for validation or other purposes. Also, by employing active feedback, adjustments to the mandrel and rotary driver may be made in real-time to prevent equipment breakage and alert the equipment operator to a refusal or other condition so that a separate mitigation protocol can be initiated. Unlike with pile driving where the operator is simply beating on the head of the pile (e.g., H-beam or I-beam) and there is little downside to trying to beat through the obstruction, with a rotary driver, driving a threaded pile or ground screw it is important not to attempt to drive through a refusal because the threads will start augering the hole as the pile spins in place. Also, because the pile is not solid, continued pressure by the rotary driver could damage it to a much greater extent than an H-pile. The feedback loop allows for these conditions to be quickly detected and mitigation techniques employed prior to augering the soil and/or damaging the pile. For example, if ground penetration slows or stops, the feedback controller may send a signal to the mandrel driver to activate or increase reciprocation while pausing the rotary driver to try to breakup whatever is impeding the pile's progress. After a certain amount of time elapses or after the mandrel has penetrated sufficiently far beyond the pile tip (i.e., to an acceptable depth), indicating that the obstruction has been mitigated, the feedback controller may issue a command to the rotary driver to resume driving. All of this may be done without the need for an operator to be closely monitoring performance parameters of the rotary driver or the mandrel.

- [022] Continuing with this example, if the mandrel is unable to penetrate the obstruction, as detected by the inability to make the mandrel penetrate any deeper after a predetermined amount of time, the feedback controller may send a signal to a user interface, indicator light or other device to alert the operator that a refusal has occurred. In some embodiments, as will be discussed in greater detail this may cause the operator to withdraw the mandrel altogether and to insert a rock drill in its place to create a cavity below the pile.
- [023] FIGS. 10A and 10B show a process for installing a foundation pile that relies on below-ground tamping that is usable with foundation piles according to various embodiments

of the invention. In this process, the base foundation pile has a helical nut attached to the threaded end as described herein. The pile is then sleeved into and attached to a driving tamper that is in turn attached to the rotary driver. In various embodiments, the driving tamper also has a helix formed at its base. The helix of the driving tamper may be set to the same pitch as the helical nut on the base pile even if it has a larger outside diameter. In various embodiments it may be desirable to align the end of the helical nut on the base pile with the start of the helical flight on the driving tamper. This may be accomplished by mating an alignment feature on the helical nut with one or more complimentary alignment features on the driving tamper that orient them.

- [024] Once attached, the driving tamper and base pile assembly is driven into the ground with the rotary driver. In some embodiments, a mandrel may also be inserted into the shaft of the base pile to assist in driving as discussed in greater detail herein, for example by providing steady downward pressure or reciprocating. Once the base pile and driving tamper assembly have reached the target depth, the driving tamper may be lifted slightly to decouple it from the alignment features so that it can be rotated in reverse without disturbing the base pile. As the driving tamper reverses its way out, it may intermittently move up and down in a tamping motion to tamp the soil between the helix formed on the driving tamper and the helix and threads at the base of the pile. On the way out, the helix functions as the tamper, compressing the column of soil above the pile. As indicated in the drawings by the tight horizontal lines, the tamping action compacts the soil that was loosened by the cutting actions of the respective helices on the pile and the driving tamper on the way down. In various embodiments, reverse rotation and tamping may continue as the driving tamper is rotated out of the soil until it is completely withdrawn, and a continuous column of compressed soil has been formed above and around the base pile. This column of compressed soil will greatly increase the pile's resistance to pull-out in the axial direction. Also, though shown as being driven into the ground orthogonal to the ground's surface, in various embodiments, it may be desirable to drive the assembly into the ground at an angle, that is, diagonally.

- [025] It should be appreciated that the mandrel may be utilized in the embodiments shown in FIGS. 10A and 10B in the same manner as in other embodiments. That is, it may be used to clear objects ahead of the pile and tamper assembly and even to break up rocks in the driving path. It may also be used to control soil pressure around the threaded end of the pile. In addition, a feedback loop may be employed in the same manner to optimize the driving process and to quickly identify issues requiring mitigation.
- [026] Turning now to remaining figures, 11A-C, 12A and 12B, these figures show various stages of refusal mitigation when using a foundation pile and related methods according to various embodiments of the invention. In 11A, the pile is being rotated into the ground with a rotary driver and the mandrel is reciprocating in and out of the below-ground end of the pile. The reciprocating action may be a default motion employed during driving or may have been activated in response to a reduction or stoppage of penetration, as detected by a human operator or automatically by the feedback control loop as discussed herein. In this example, the reciprocating action of the mandrel is insufficient to break up the solid bedrock. As discussed herein, this condition may be detected by the operator or by an automated feedback loop from the failure of the mandrel to penetrate any further despite reciprocation. In various embodiments, the operator will then remove the mandrel from the pile and replace it with a rock drill. In some embodiments, the rock drill may be a different attachment to the same machine driving the mandrel. In other embodiments, the rock drill may be a different machine, requiring the mandrel driver to be pivoted or otherwise moved out of the way to make room for the rock drill. The rock drill is then slid all the way down the shaft of the pile until it encounters the bedrock and then is activated to begin pummeling the rock below. As is known in the art, rock drills typically use pressurized air to generate the hammering action and to blow the crushed rock spoils out of the way. The specific action of the rock drill (e.g., hammering, rotating) will in part be dictated by the type of drill bit used. For example, a button bit typically employs hammering action alone where as other types of bits may rely on a combination of hammering and rotary cutting.

- [027] In various embodiments the rock drill will continue its action until a cavity has been formed in the rock having the desired depth. This depth may be the minimum depth required to secure the pile or the original target depth of the pile. In either case, once the cavity is created, the rock drill is removed, or least partially withdrawn from the pile so as not to project out of the pile and the rotary driver is again engaged to drive the pile tip into the cavity. In some embodiments, the pile may be able to be driven all the way to the bottom of the cavity as shown in FIG. 11C. This will depend on the size of the bore relative to the outside diameter of the pile, how clean and free of spoils the cavity is and the geometry and dimensions of the thread form.
- [028] In some embodiments, the pile may not be able to be fully driven into the cavity formed by the rock drill. This may be simply be a consequence of the blind underground conditions (e.g., cleanliness of the borehole, density of soil above the borehole) or by using a non-expanding rock drill (e.g., one that does not have a diameter larger than the inside diameter of the pile). In either case, it may only be possible to drive the tip or a small portion of the pile into the cavity. This may be true whether a tapered pile or tapered threads are used at the below-ground end of the pile. In such cases, the pile may be rotated until it cannot penetrate any deeper. Then, the drill may be withdrawn from the pile and a coupler dropped in its place. In various embodiments, the coupler may simply be a piece of rebar or other ridged material that is small enough to fit within the pile and the cavity but long enough to extend from the bottom of the cavity into the pile. One or more centralizers or other like devices may be used to maintain the coupler's orientation within the pile and the cavity. After the coupler has been placed, an operator may inject a volume of pressurized grout, epoxy or other suitable material into the pile causing it to fill the cavity completely, surrounding the coupler as well as filling the portion of the pile containing the coupler. Once this pressurized grout, epoxy or other suitable material sets, the pile will be firmly coupled to the bedrock.
- [029] It should be appreciated that in other embodiments a mechanical coupler may be used to couple the pile to the bedrock instead of injecting an adhesive fluid. For example, a one-way device that can be inserted into the pile from above may be pushed all the way

down until it bottoms out in the drill cavity. This device may have barbs, tangs or other projections that engage the walls of the cavity as well as the pile. Alternatively, or in addition a ledge or other stop formed near the tip of the pile may facilitate the use of such as device so that it only needs to lock into the walls of the cavity.

[030] The embodiments of the present invention are not to be limited in scope by the specific embodiments described herein. For example, although many of the embodiments disclosed herein have been described with reference to systems and methods for installing foundation for axial solar arrays, the principles herein are equally applicable to foundations for other structures. Indeed, various modifications of the embodiments of the present invention, in addition to those described herein, will be apparent to those of ordinary skill in the art from the foregoing description and accompanying drawings. Thus, such modifications are intended to fall within the scope of the following appended claims. Accordingly, the claims set forth below should be construed in view of the full breath and spirit of the embodiments of the present inventions as disclosed herein.

CLAIMS

Claim Set One

1. A system comprising:
 - a hollow elongated pile member having a first end and an opposing second end, the second end including a tapered portion and a first set of threads, the first set of threads circumscribing the tapered portion; and
 - a helical nut, the helical nut having a helical flight circumscribing a nut portion, wherein the nut portion is threaded on an inside surface thereof to mate with the first set of threads formed on the elongated pile member.
2. The system according to claim 1, further comprising a mandrel located inside and projecting out of the second end of the elongated pile member, wherein the mandrel forges a path ahead of the second end of the elongated pile member when the pile member is rotated into supporting soil.
3. The system according to claim 1, wherein forging a path comprises exerting pressure on the soil ahead of the second end of the elongated pile member.
4. The system according to claim 1, wherein forging a path comprises hammering the soil with a reciprocating action ahead of the second end of the elongated pile member.
5. The system according to claim 1, further comprising a rock drill located inside the elongated pile member, the rock drill projecting through the second end to form a cavity in submerged rock ahead of the second end to receive the tapered portion if the pile encounters a refusal during driving.
6. The system according to claim 1, further comprising a helix threaded onto the first set of threads formed on the elongated pile member.

Claim Set Two

7. A foundation system for an axial solar array comprising:
 - an elongated pile member having a taper at one end;
 - a thread form circumscribing the taper; and
 - a helical nut, the helical nut comprising a center portion having a set of internal threads and a helical flight circumscribing the center portion, wherein the internal threads of the

helical nut are dimensioned to mate with the thread form on the elongated pile member to selectively couple the helical nut to the pile member.

8. The system according to claim 7, wherein the internal threads of the helical nut are conical.

9. The system according to claim 7, further comprising a mandrel located inside the elongated pile member projecting out of the tapered end, the mandrel operable to hammer a path ahead of the elongated pile member through reciprocation when it is rotated into supporting soil.

10. The system according to claim 7, further comprising a rock drill located inside the elongated pile member, the rock drill operable to drill through the elongated pile member to form a cavity in submerged rock ahead of the pile member to receive the tapered portion if the pile encounters a refusal.

11. The system according to claim 7, further comprising a helix operable to thread onto the thread form of the elongated pile member to form a helical anchor.

Claim Set Three

12. A feedback-controlled system for driving a foundation pile for an axial solar array, the system comprising:

an elongated foundation pile;

a rotary driver having an engagement portion for selectively engaging the elongated foundation pile to drive the pile into supporting soil;

a rotary driver controller for controlling operation of the rotary driver;

a mandrel located within the elongated foundation pile, the mandrel operable to reciprocate at one end of the pile to forge a path ahead of the foundation pile during driving;

a mandrel controller for controlling operation of the mandrel; and

a feedback controller, the feedback controller sending a signal to at least one of the mandrel controller and the rotary driver controller to adjust an operation thereof based on at least one operating parameter monitored by the feedback controller during driving.

13. The system according to claim 12, wherein the at least one operating parameter comprises a parameter selected from the group consisting of a rotational speed of the rotary driver, a rate of penetration of the foundation pile, a level of vibration of the foundation pile, a downward force exerted on the mandrel, a rate of penetration of the mandrel, a level of vibration of the mandrel, and a reciprocation speed of the mandrel.
14. The system according to claim 12, wherein adjusting an operation of the rotary driver comprises adjusting an operation selected from the group consisting of a speed of rotation, a direction of rotation, and a pressure exerted by the driver on the pile.
15. The system according to claim 12, wherein adjusting an operation of the mandrel comprises adjusting an operation selected from the group consisting of a speed of reciprocation, a reciprocating force, an axial force, and a position of mandrel within the pile.
16. The system according to claim 12, further comprising a rock drill operable to fit within the elongated pile member and to drill a cavity in rock ahead of the pile member if the pile member encounters a refusal during driving.

Claim Set Four

17. A foundation pile for an axial solar array comprising:
- an elongated pile member having a first end and an opposing second end; and
 - a thread form beginning at the first end and extending along a portion of the elongated pile member, wherein a profile of the thread form increases as it travels away from the first end along a main axis of the pile member while an inside diameter of the elongated pile member remains constant.
18. The pile according to claim 17, further comprising a helical nut, the helical nut having a nut portion at the center of a helical flight, the nut portion having a set of internal threads dimensioned to engage with the thread form of the elongated pile member to form a helical pile.
19. The pile according to claim 17, further comprising a helix operable to thread onto the thread form of the elongated pile member.
20. The pile according to claim 19, further comprising a separate nut that engages the thread form of the pile member to secure the helix.

Claim Set Five

21. A method of installing a foundation pile for an axial solar array comprising:
rotating one end of an elongated foundation pile into supporting soil with a rotary driver; and
simultaneously reciprocating a mandrel within the foundation pile to clear a path ahead of the foundation pile with a mandrel driver.
22. The method according to claim 21, further comprising monitoring a performance parameter of at least one of the rotary driver and the mandrel with a feedback controller and adjusting an operation of at least one the rotary driver the mandrel driver based on the monitored performance parameter.
23. The method according to claim 22, wherein the at least performance parameter comprises a parameter selected from the group consisting of a rotational speed of the rotary driver, a rate of penetration of the foundation pile, a level of vibration of the foundation pile, a level of vibration of the mandrel, a reciprocation speed of the mandrel, and reciprocation force of the mandrel.
24. The method according to claim 21, further comprising:
in the event of a refusal, removing the mandrel from the foundation pile and inserting a rock drill one end of the pile until it reaches the other end;
drilling a cavity below the foundation pile with the rock drill; and
joining the foundation pile to the cavity.
25. The method according to claim 24, wherein joining the foundation pile to the cavity comprises driving the foundation pile into the cavity with the rotary driver.
26. The method according to claim 24, wherein joining the foundation pile to the cavity comprises inserting a coupling into the cavity via the foundation pile so that it spans from a bottom of the cavity into the foundation pile and injecting pressurized fluid around the coupler.
27. The method according to claim 26, wherein the pressurized fluid is selected from the group consisting of grout, cement, resin, and epoxy.

Claim Set Six

28. A helical nut for a foundation pile comprising:

a center hub portion, the center hub portion comprising an external face and opposing internal face, the internal face having a set of threads formed thereon; and

at least one helical flight attached to the external face, the helical flight circumscribing the center hub portion.

29. The helical nut according to claim 25, wherein the threads are conical threads.

Claim Set Seven

30. A method of installing a foundation pier for an axial solar array comprising:

attaching an elongated foundation pile to a driving tamper so that a first helix at a distal end of the elongated pile is aligned with a second helix formed on the driving tamper to form an assembly;

driving the assembly to a target depth in supporting soil with a rotary driver;

decoupling the driving tamper from the elongated foundation pile;

rotating the driving tamper in an opposite direction to move it away from elongated foundation pile; and

intermittently tamping down on soil between the driving tamper and the first helix with the second helix while moving the tamper away from the foundation pile until the driving tamper is completely out of the supporting soil.

31. The method according to claim 30, further comprising reciprocating a mandrel within the elongated pile as the assembly is being rotated into the supporting soil to clear a path in the soil ahead of it.

32. The method according to claim 30, further comprising inserting a mandrel in the elongated pile so that the mandrel projects out of the distal end, the mandrel set to relieve soil pressure at the distal end exceeding a predetermined limit by retracting within the pile member.

33. The method according to claim 30, further comprising:

in the event of a refusal, removing the mandrel from the pile and inserting a rock drill in its place until the rock drill emerges from the distal end;

drilling a cavity below the distal end; and

- securing the distal end of the pile to the cavity.
34. The method according to claim 30, wherein securing the distal end of the pile to the cavity comprises rotating the pile into the cavity with the rotary driver.
35. The method according to claim 30, wherein securing the distal end of the pile to the cavity comprises inserting a coupling into the cavity via an above-ground end of the pile so that it passes out of the distal end, spanning the cavity and the pile member, and injecting pressurized fluid around the coupling.
36. The method according to claim 35, wherein the pressurized fluid is selected from the group consisting of grout, cement, resin, and epoxy.