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1023799

THE UNITED STATES OF AMERICA

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UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

September 27, 2019

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APPLICATION NUMBER: *62/726,909*

FILING DATE: *September 04, 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 *US62/726,909*



Certified by

Anders Iversen

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	PPA10
		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.)
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Inventor Information:

Inventor 1				
Legal Name				
Prefix	Given Name	Middle Name	Family Name	Suffix
	Almy		Charles	
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service				
City	Berkeley	State/Province	CA	Country of Residence ⁱ US
Mailing Address of Inventor:				
Address 1		1668 Lincoln St.		
Address 2				
City	Berkeley	State/Province	CA	
Postal Code	94703	Country ⁱ	US	
Inventor 2				
Legal Name				
Prefix	Given Name	Middle Name	Family Name	Suffix
	Theodore		Gittings	
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service				
City	Novato	State/Province	CA	Country of Residence ⁱ US
Mailing Address of Inventor:				
Address 1		1110 Ferris Drive		
Address 2				
City	Novato	State/Province	CA	
Postal Code	94945	Country ⁱ	US	
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button. Add				

Correspondence Information:

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PPA10
		Application Number	
Title of Invention	Foundation piers for axial solar arrays and related systems and methods		

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	PPA10	Small Entity Status Claimed	☒
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	7	Suggested Figure for Publication (if any)	

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		

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	PPA10	
		Application Number		
Title of Invention	Foundation piers for axial solar arrays and related systems and methods			

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.

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

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	PPA10
		Application Number	
Title of Invention	Foundation piers for axial solar arrays and related systems and methods		

☐ 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	PPA10
	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.

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	PPA10
		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.

☐ 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

Mailing Address Information For Applicant:

Address 1	47 Mark Drive		
Address 2			
City	San Rafael	State/Province	CA
Country ¹	US	Postal Code	94947
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	PPA10
		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.							

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	PPA10
		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 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

PPA-10

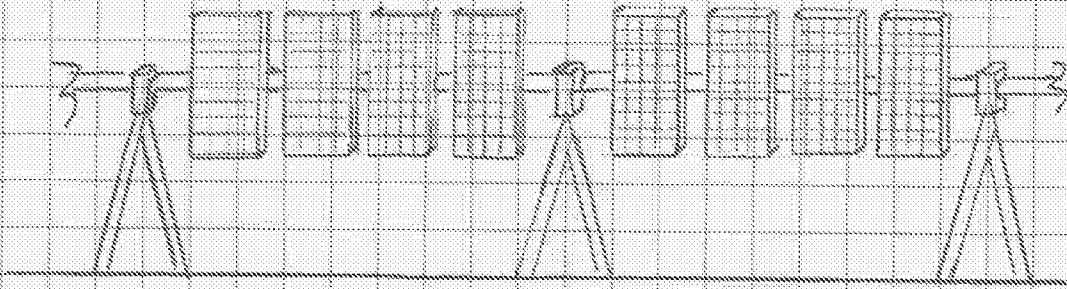


FIG. 2A

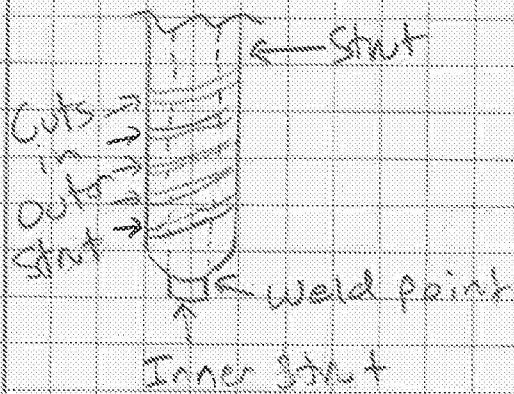


FIG. 2B

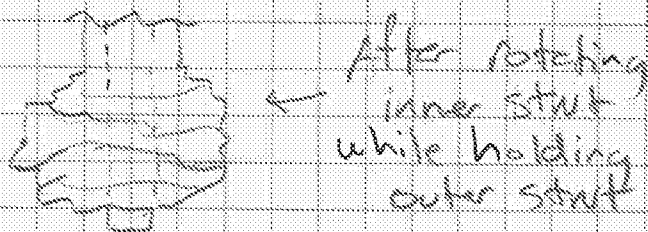


FIG. 3A

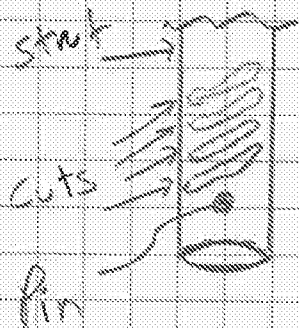


FIG. 3B

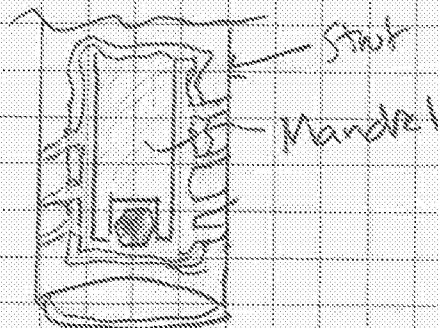


FIG. 3C

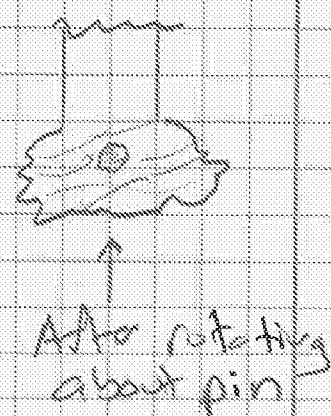


FIG. 4A

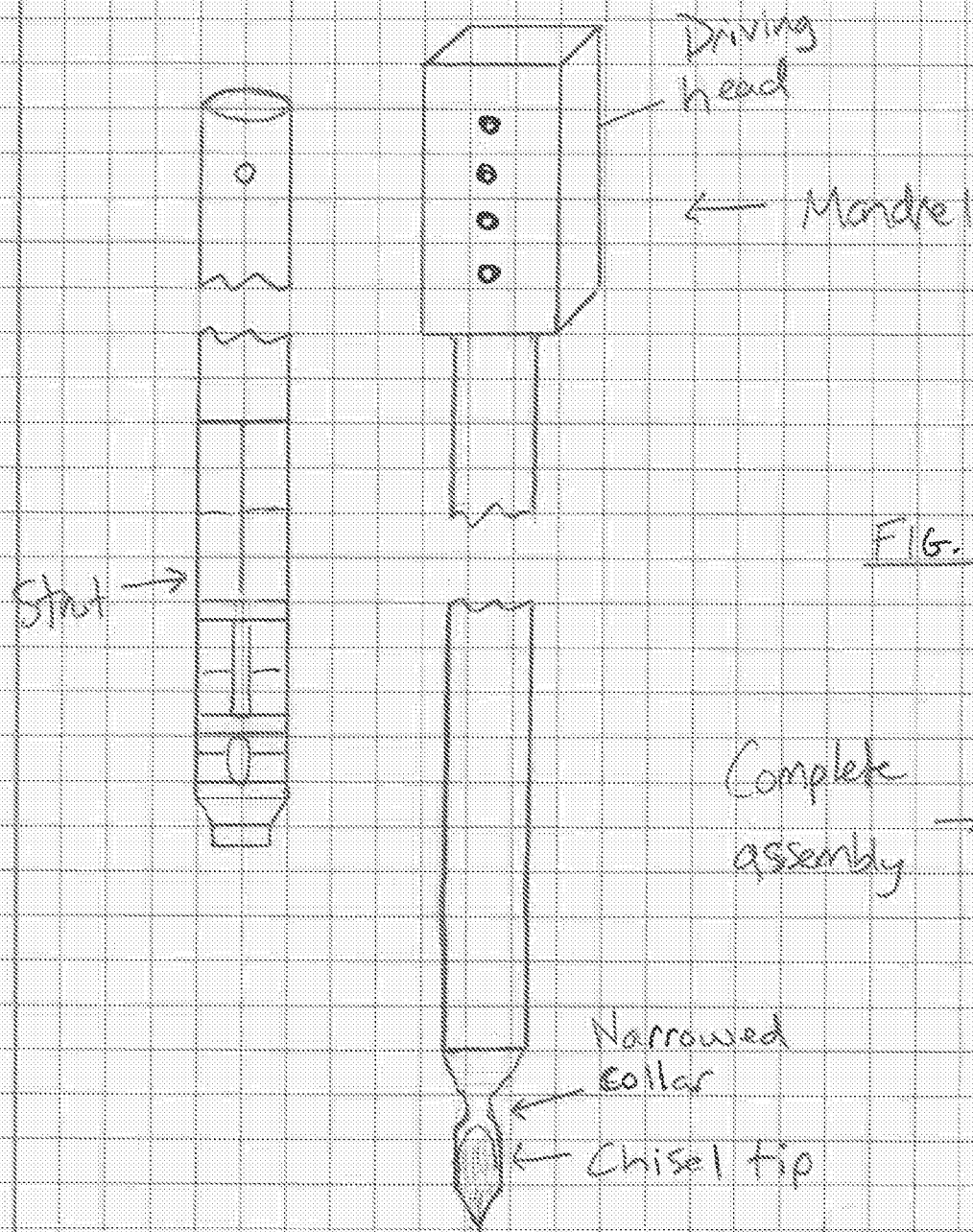


FIG. 4B

Complete assembly →

Narrowed collar

Chisel tip

Stage 3 →

Stage 2 →

Stage 1 →

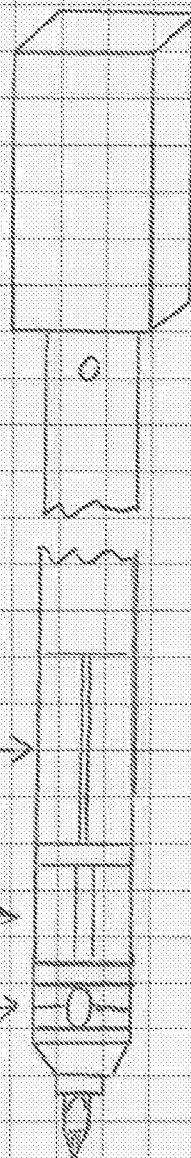


FIG. 5

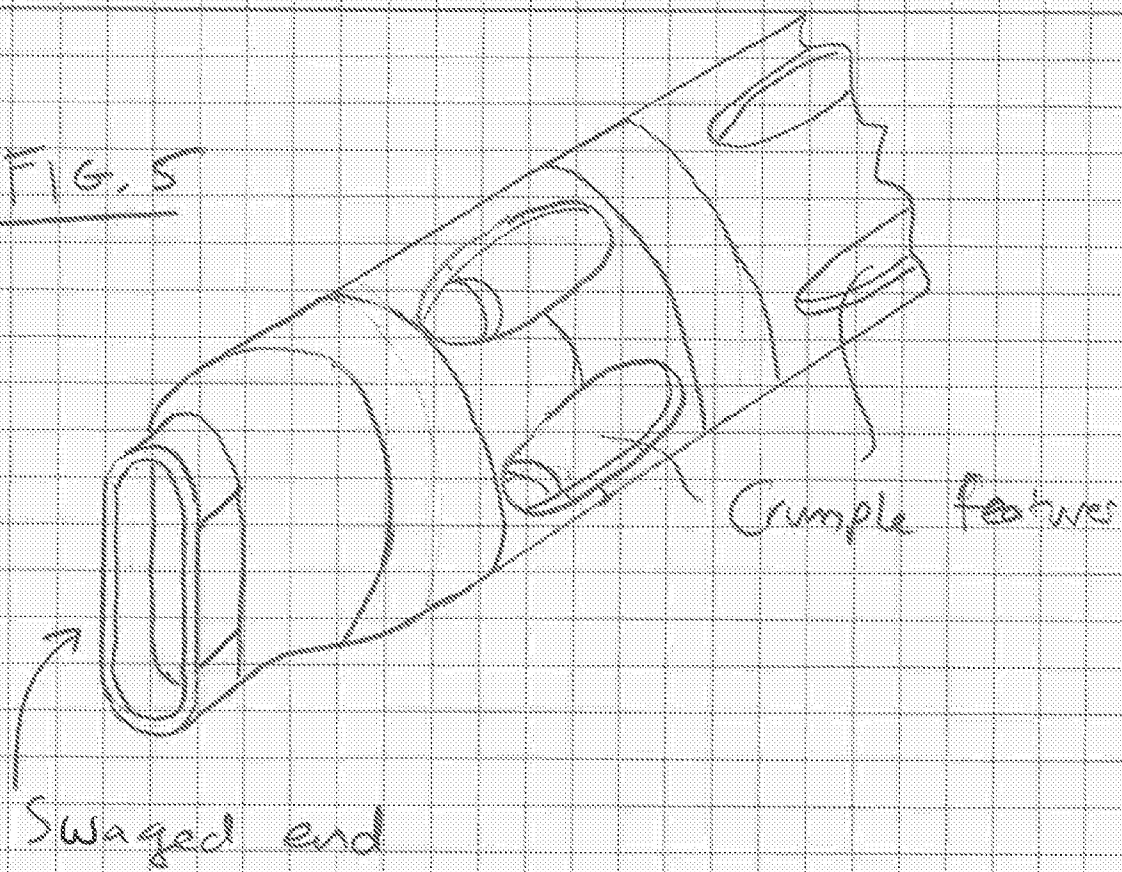


FIG. 6A

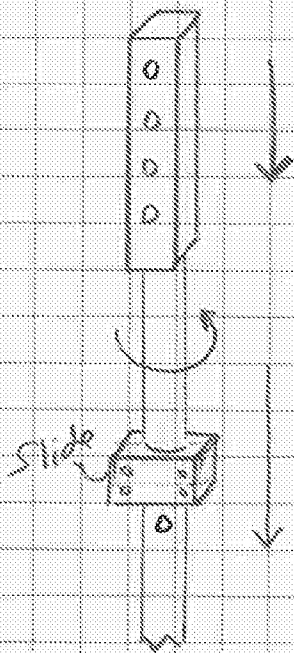


FIG. 6B

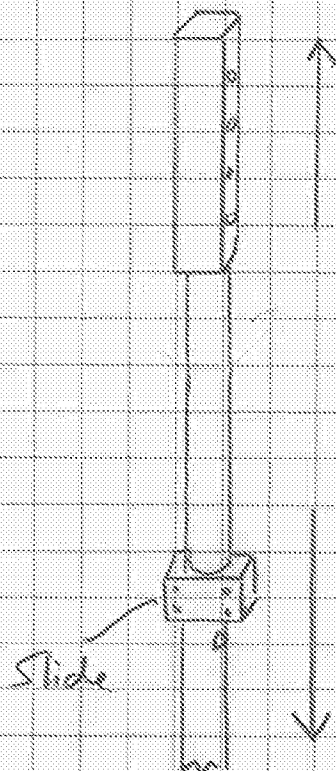


FIG. 6C



FIG. 7A

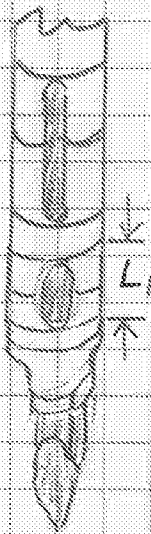


FIG. 7B

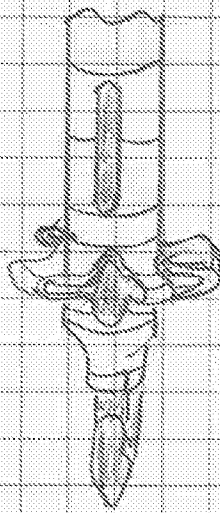


FIG. 7C

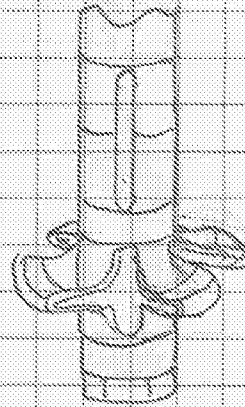


FIG. 8A

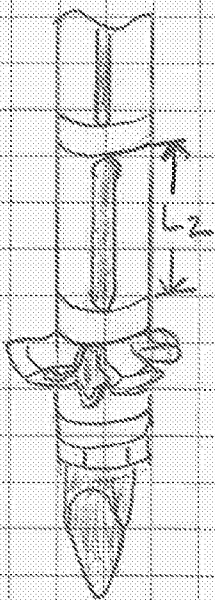


FIG. 8B

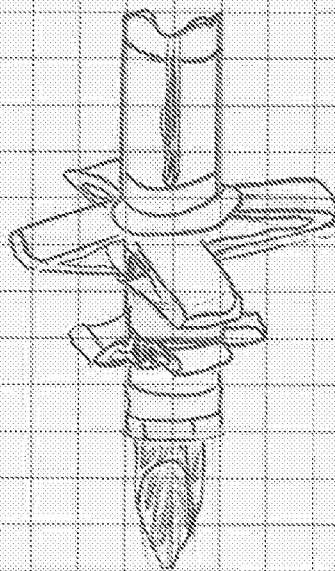


FIG. 8C

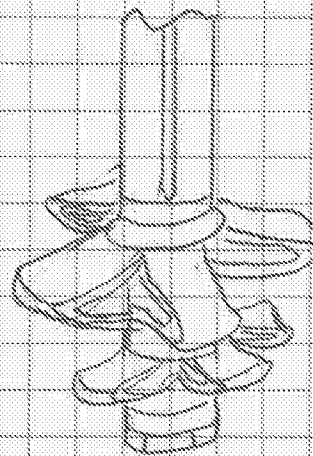


FIG. 9A

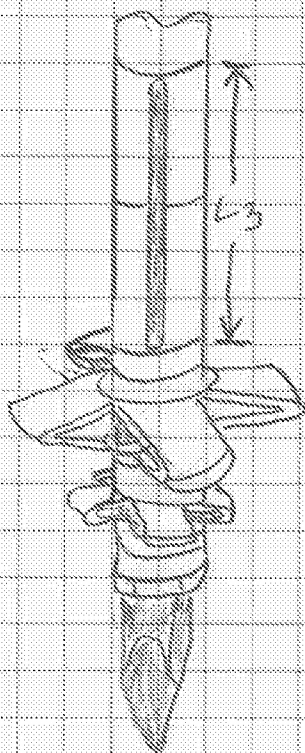


FIG. 9B

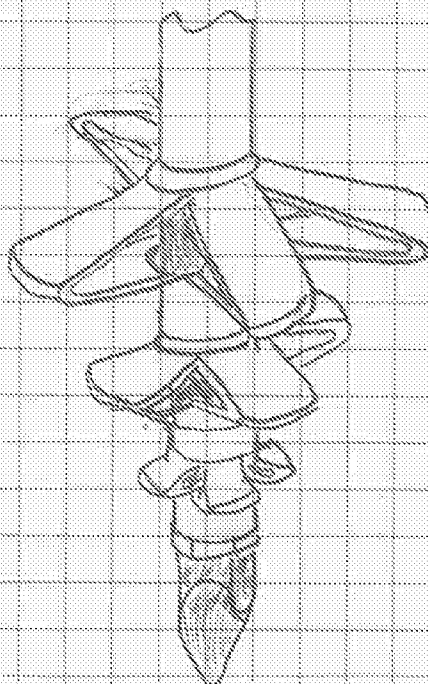


FIG. 9C

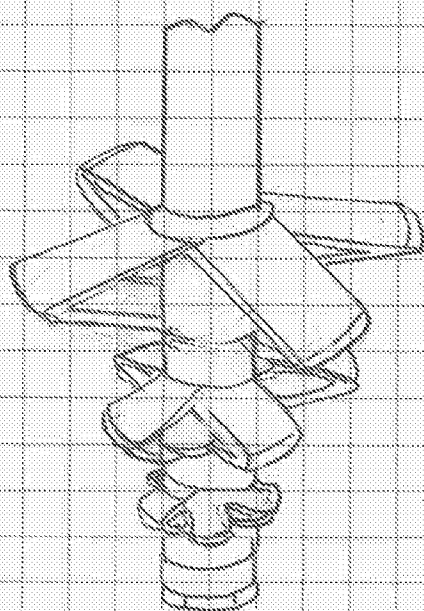


FIG. 10

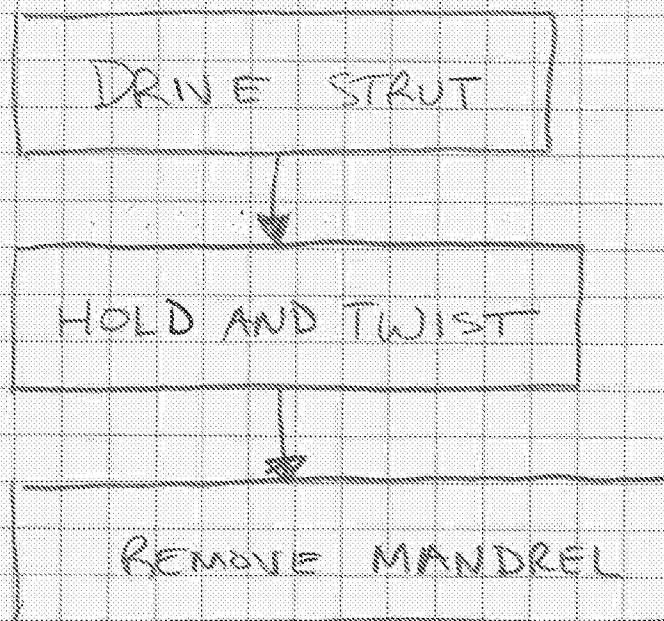


FIG. 11

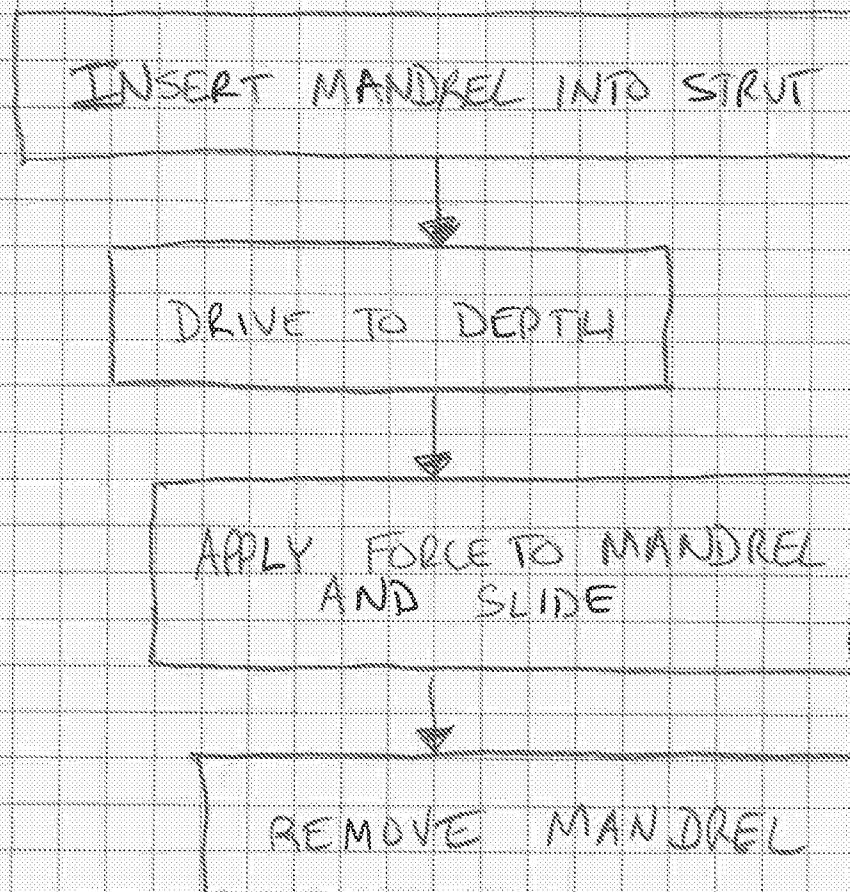


FIG. 12A

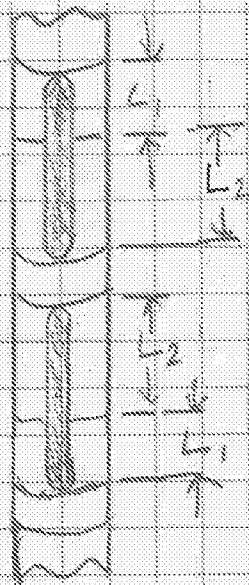


FIG. 12B

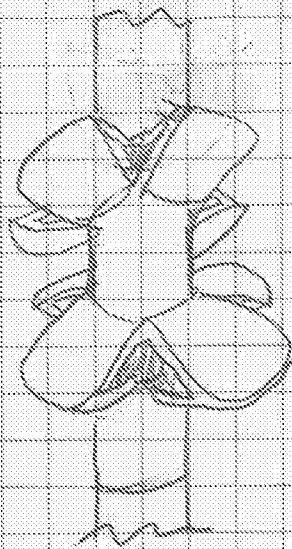


FIG. 12C

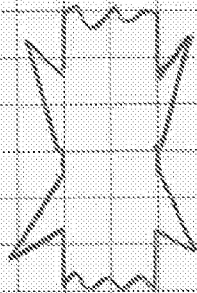


FIG. 13A

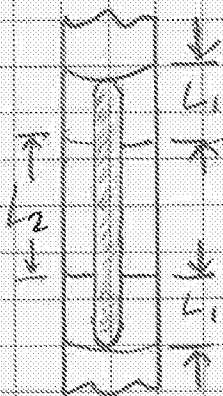


FIG. 13B

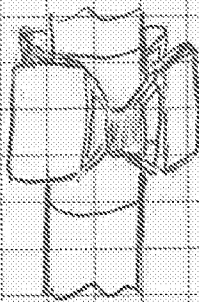
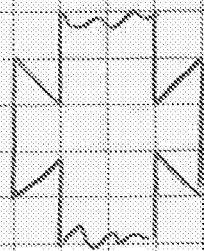


FIG. 13C



Electronic Acknowledgement Receipt

EFS ID:	33624500
Application Number:	62726909
International Application Number:	
Confirmation Number:	7933
Title of Invention:	Foundation piers for axial solar arrays and related systems and methods
First Named Inventor/Applicant Name:	Almy Charles
Customer Number:	157339
Filer:	Phillip Mancini
Filer Authorized By:	
Attorney Docket Number:	PPA10
Receipt Date:	04-SEP-2018
Filing Date:	
Time Stamp:	20:10:47
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	\$ 140
RAM confirmation Number	090518INTEFSW20115800
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	127230	no	8
			290fe2d1b87bc681bf6da254617b2ae87816c8e2		
Warnings:					
Information:					
2	Specification	PPA10.pdf	127313	no	16
			82835164edce06ecbc29f96ab43338b79161c9d4		
Warnings:					
Information:					
3	Drawings-other than black and white line drawings	PPA10DrawingFigures.pdf	1164213	no	7
			acb3fb5b8935f9b820af547c4b3866fe570f27bd		
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	29271	no	2
			dba28fc7daa32ccbcc7d85e54bd045c270c6a57d		
Warnings:					
Information:					
Total Files Size (in bytes):			1448027		

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

SCORE Placeholder Sheet for IFW Content

Application Number: 62726909

Document Date: 09/04/2018

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

At the time of document entry (noted above):

- USPTO employees may access SCORE content via eDAN using the Supplemental Content tab, or via the SCORE web page.
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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 particular 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, in particular, 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 especially 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] Contrary to conventional H or I pile foundations used in most axial solar array installations, A-frame style foundations may provide similar resistance to vertical loads and lateral wind forces while using far less steel and being driven less deep. Experimentation has shown that resistance to lateral forces by an A-frame foundation formed from two adjacent angled struts driven into the ground is dictated by tension and soil friction on the windward leg, buckling of the above-ground portion of the leeward leg, and compression (sinking) of the leeward leg. Because of the soil's large pressure on the submerged legs, buckling does not typically occur underground in such foundations other than in the first few inches of loose topsoil. Therefore, structures that increase the surface area or outside diameter of the strut normal to its axis deep

below ground will provide greater resistance to lateral loads versus straight struts. This explains why helical anchors are often used in applications where large weights need to be supported (retaining walls, building foundations, etc.) or massive resistance to pull-out is required (e.g., securing communication towers and poles).

[007] Referring now to FIG. 1, this figure shows a portion of an axial solar array, in this case, a single axis tracker array, supported by A-frame foundation piers according to various embodiments of the invention. The portion shown in FIG. 1 includes three A-frame foundations, each consisting of two adjacent struts driven into the ground at reciprocal angles with respect to normal (i.e., 90 degrees). Each adjacent strut pair is capped off with a saddle member that converts the struts into a unitary A-frame structure. Though not shown, a mounting plate may be attached to the saddle member. The mounting plate may provide some adjustment in both the vertical and horizontal planes for aligning to other A-frames supporting the torque tube. A bearing, such as that shown in FIG. 1 may be attached to the mounting plates, as is done with conventional H and I-beam foundations to insure interoperability with commercial single-axis trackers. The adjacent foundation piers making up each A-frame are oriented along a North-South axis so that when the torque tube is rotated, the panels cycle from facing East to facing West each day. Each torque tube may have more than a dozen A-frame supports and may hold as many as one hundred solar panels. A utility scale sized array may consist of many such torque tubes.

[008] FIGS. 2A and 2B show details of one exemplary configuration of strut for use with an A-frame foundation pier system for an axial solar array according to various embodiments of the invention. The strut of FIGS. 2A and 2B consists of a full-length inner strut and an outer strut enclosed around a portion of the inner strut forming a sleeve around the latter. In various embodiments, outer strut may be joined to the inner strut at the distal below-ground end of the inner strut with a weld or other suitable bond. Also, in various embodiments, the portion of the outer strut proximate to the below-ground end of inner strut may be pre-distressed or formed with a plurality of cuts, making it predisposed to deformation upon twisting. In various embodiments, the strut, including

the inner and outer portions, will be driven into the ground using a mandrel, pile driver or other suitable driving device until the desired depth is achieved. In various embodiments, this may be to the point where the opposing end of the outer strut reaches grade. In various embodiments, this point will be somewhere along the length of the inner strut.

- [009] In various embodiments, once the desired depth has been achieved, the mandrel used to drive the inner strut will rotate the strut while the above-ground end of the outer strut is held in place (i.e., prevented from rotating). In various embodiments, rotation of the inner strut will tend to rotate the attached portion of the outer strut, unfolding it about the cuts or pre-distress marks made in the outer strut, expanding its outside diameter from its original diameter during driving. This will have the effect of increasing the strut's resistance to axial forces (e.g., tension and compression) experienced by an A-frame support. Although the degree to which this expansion occurs will be random and dependent on the speed and pressure of rotation as well as the density and condition of the soil surrounding the below-ground end of the strut, twisting of the inner strut while holding the above-ground end of the outer strut in place will cause some deformation at the strut's below-ground tip. In various embodiments, the cuts or distress marks formed in the outer strut will be cut and/or formed at diagonals with respect to the strut's axis, angled in the direction of rotation to increase the extent to which the outer strut unfolds when torque is applied to the inner strut.
- [010] In various embodiments, if the inner strut is hollow, the mandrel may engage with a bolt or other feature orthogonal to the strut's axis to push it into the ground as well as to rotate it. In other embodiments, for example, if the inner strut is solid, this feature may be formed in the above-ground end of the strut. In such cases, downward pressure will drive the strut while rotation of the mandrel while holding outer strut will unfold the outer strut. This will result in the end of the strut deforming to a larger diameter shape such as that shown in FIG. 2B. The larger diameter shape at or near the deepest point below ground will increase the strut's resistance to axial forces for compression and tension.

- [011] Referring now to FIGS. 3A, B and C, these figures show various details of an exemplary strut usable to create an A-frame foundation according to various other embodiments of the invention. In the exemplary strut of FIG. 3A, the strut is formed from an elongated section of rounded pipe. An engagement pin is located near the below-ground end of the strut. In various embodiments, the engagement pin will provide a connection point for the mandrel to drive the strut into the ground and will also provide a mechanism for the mandrel to grip the strut and rotate it about its primary axis. As seen in FIG. 3A, as with the embodiment shown in FIGS. 2A and 2B, in various embodiments, the strut of FIGS. 3A-C may have a series of cuts formed near its distal end. When the desired depth has been achieved and the mandrel rotates the strut about its below-ground end while holding the above-ground end in place, the cuts will cause the below-ground end to unravel to some extent, increasing its outside diameter which in turn will increase the strut's resistance to axial forces of compression and tension. The degree to which the outer strut unfolds will be a function of the rotation force applied to the strut as well as the density of the surrounding soil
- [012] FIG. 3B is a partial cut-away view showing a portion of the strut cut-away to reveal the shape of the mandrel and its interface to the pin bisecting the strut. In this example, the mandrel has a notched tip that receives the pin. In various embodiments, the strut and mandrel are dimensioned so that when the strut is slid on the to the mandrel, the pin will sit in the notch simultaneous to the driving head of the mandrel contacting the top of the strut allowing the strut to be pushed from both ends simultaneously. In other embodiments, the pushing force may be applied to the pin only. After the desired driving depth has been achieved, the mandrel is rotated while the top of the strut is held in place. In various embodiments, this will cause the strut end to unravel about the cuts or pre-formed distress lines so that it cuts into the surrounding soil expanding its outside diameter. The larger outside diameter will help the strut resist the types of axial forces (tension and compression) that it will be subjected to when configured as an A-frame to support an axial solar array.

- [013] Referring now to FIGS. 4A/B, 5, 6A/B/C, 7A/B/C, 8A/C, and 9A/B, these figures show elements of foundation pier system and related methods for installing a foundation pier for an axial solar array according to various embodiments of the invention. The exemplary system shown here consists of a strut and a mandrel. The strut according to these embodiments is an elongated tubular member having a first below-ground end and a second, opposite end. As seen in FIG. 5, the below-ground end of the strut has a generally rectangular-shaped opening with rounded ends that may be formed by swaging or with some other deforming process. This geometry allows the tip of a mandrel that is wider than it is thick to fit through the opening at only one orientation. Once the mandrel emerges from the end of the strut, if the strut is rotated by 90 degrees with respect to the mandrel, the narrowed collar portion of the mandrel allows the mandrel to rotate within swaged opening of the strut, effectively coupling the mandrel and strut together as an assembly for driving.
- [014] Moving away from the opening, the strut has a series of crumple zones preformed in it. Each crumple zone comprises a plurality of holes or openings that are longer in the direction of the axis of the strut than they are wide. In various embodiments, these openings are repeated all the way around the strut, dividing it into multiple crumple sections (e.g., two, three, or four). In various embodiments, each crumple zone may be separated from the next by a spacer – a continuous section of the strut. Also, as shown, each crumple zone has a crumple line orthogonal to the axis of the strut interconnecting each opening at approximately the midpoint of the opening. The combination of the openings and crumple lines will cause each section of the crumple zone to fold in half about each side of the crumple lines cutting into the surrounding soil to form a series of anchors spanning around the diameter of the strut. In the example of FIGS. 4A/B, the extent to which each crumple section anchors into the surrounding earth after compression will be roughly one half the length of the opening or one half the length of that crumple zone.
- [015] In various embodiments, the axial length of the crumple zones formed in the strut will increase moving away from the end of the strut as reflected by the increasing length of

the openings of each successive crumple zone. At the same time, the width of the openings will decrease, requiring relatively more pressure to deploy because more material must be bent and must be forced deeper into the surrounding soil. With this geometry, for a given level of soil density, the smallest crumple zone with the largest opening will be easier to crumple than the smaller ones. At the same time, because the size (e.g., length) of the crumple zone gets increasingly larger moving away from the below-ground end of the strut, denser soils such as clay will prevent the larger crumple zones that displace more soil from deploying (e.g., deforming). By contrast, in less dense soil such as sand or silt, the same amount of compressive pressure will cause multiple ones of the crumple zones to deform, and preferably all of them, massively increasing the cross-sectional geometry of the strut and its corresponding resistance to axial forces.

- [016] FIGS. 6A-C visually detail the steps of driving the strut of FIGS. 4A/B and 5 and deploying the crumple zone anchors. After the mandrel is loaded onto the strut and the rotated by 90 degrees to lock in into the strut, the mandrel and strut assembly are driven into the ground with downward pressure from the driving equipment supporting the mandrel. Once the desired depth has been achieved, downward (i.e., axial) pressure is maintained on the top of the strut with a slide or other device while strong upward pressure is applied to the mandrel as indicated by the directional arrows. In various embodiments, the mandrel may apply a fixed amount of upward pressure (e.g., 3000 pounds) for a predetermined time. In other embodiments, upward pressure may be applied to the mandrel until the mandrel moves up a predetermined amount. In either case, after either of these conditions have been achieved, the mandrel is relaxed so that tension between the mandrel and strut is released and the mandrel can be rotated back or forwards 90 degrees so that it can fit back through the opening in the end of the strut. Upward pressure is again applied to draw it out of the strut. In looser soils it may be advantageous to hold the top of the strut while removing the mandrel.
- [017] FIGS. 7A-C show various stages of crumple zone compression in relative hard (i.e., high density) soils. When the mandrel and strut assembly reach the desired depth, and the

mandrel is pulled up while applying downward force or at least resistance to the other end of the strut, the mandrel will push against the swaged end of the strut causing that pressure to be translated up the strut to the weakest point, the stage 1 crumple zone. Ideally, and as shown in 7B, upward pressure compresses the strut, crumpling stage 1 and causing the four crumple sections to splay outward orthogonally to the strut axis an approximate distance equal to one half the length of that crumple zone (L_1). When the mandrel is withdrawn the bottom of the strut remaining in the ground will look like that shown in FIG. 7C. In very dense soil, this should be enough to achieve the axial force resistance required for the array.

- [018] FIGS. 8A-C show stages of crumple zone compression in soil that is less dense than that of FIGS. 7A-C. In these figures, both the stage 1 and stage 2 crumple zones have been deformed. 8A starts with the image of 7B where the stage 1 has been deformed. In relatively softer soil, that is soil that is less dense than hard clay, the same amount of compression on the strut will cause additional crumple zone deformation. This is reflected in FIG. 8B where both stage 1 and stage 2 crumple zones have been deformed by the upward pulling pressure of the mandrel combined with downward pressure on the strut. The relatively larger sections of stage 2 will provide greater surface area perpendicular to the axis of the strut compensating for the lower density of the soil. This lower density will allow the crumple sections to fold about their crumple lines causing them to anchor outward into the surrounding earth a distance approximately equal to one half of the length of the stage 2 crumple zone (L_2). When the tension between the mandrel and strut is relieved and the mandrel is rotated back or forward 90 degrees, it can be withdrawn from the strut leaving behind the deformed shape shown in FIG. 8C. The advantage of this system is that by applying a uniform degree of compression force, the strut will anchor itself to a lesser or greater degree depending on the density of the soil resulting in greater anchoring in less dense soils but sufficient anchoring in relative denser soils.
- [019] Referring now to FIGS. 9A-9C, these figures illustrate a strut according to various embodiments of the invention that has been driven and compressed in relatively soft

soil such as sand. In soft soils, resistance to tension and compression is more difficult to achieve because of the relatively low soil density reduces skin friction making it easier to pull out and/or push in the struts. As a result, when solar foundation piers are installed in such soils they typically have to be driven much deeper than in dense soil types in the absence of an anchor or other resistance enhancing feature.

- [020] FIG. 9A starts with the stage 2 deployment shown in FIG. 8B with stages 1 and 2 deformed. In the softest soil types, pressure against the strut will be reduced so that the longer crumple zone of stage 3 (L_3) with its relatively small opening can be forced into the surrounding soil as the sections of the crumple zone fold about the crumple line projecting outward, orthogonal to the main axis of the strut, into the surrounding soil.
- [021] As seen in FIG. 9B, upward pulling on the mandrel combined with downward pressure on the top of the strut will deform all three crumple zones, providing the largest underground footprint. For a given amount of compressive pressure, stage 3 deployment will only happen in the softest soils because of the relatively large size of the crumple sections (one half of L_3). Soil resistance rather than the steel's rigidity is the controlling factor. In this way, the installer doesn't need to know the properties of the soil. Rather, by using the same compressive pressure every time, the required crumple zones will always deform.
- [022] Though not shown, in various embodiments, stages 1-3 will be offset from one another by misaligning the crumple zone openings so that when they are deformed, the crumple sections project out into the surrounding soil at different radial angles. For example, stage 1 may project out at $0, \pi/2, \pi$, and $3\pi/2$ radians, stage 2 may project out at $\pi/6, 2\pi/3, 7\pi/6$, and $5\pi/3$ radians, and stage 3 may project out at $\pi/3, 5\pi/6, 4\pi/3$, and $11\pi/6$ radians. Offsetting the position of the crumple sections will reduce spatial redundancy which provides very little additional resistance to axial forces. Also, it should be appreciated that although each crumple zone in the FIGS. is shown having four crumple sections, in various embodiments each crumple zone may have fewer than four sections (e.g., two or three).

- [023] Referring now to FIGS. 12A-C, and 13A-C, these figures show other possible crumple zone geometries. FIGS. 12A-C show a strut with a pair of adjacent crumple zones that are offset in opposing directions. This is accomplished by placement of the crumple lines that govern where the metal bends. In this example, the lines are placed at distance L_1 from beginning of the first zone and at from the end of the second zone respectively (see, e.g., FIG. 12A). Because the crumple zones are not divided into equal halves, they will deform unevenly causing the short section to fold back on itself as the long section folds out (see, e.g., FIG. 12C). As seen here, the upper crumple zone deforms upward while the lower one deforms downward. FIG. 12B shows what the strut will look like below ground after deformation. In various embodiments, having one crumple zone pointing upward and one point downward may provide improved performance over the symmetric crumple zones shown in FIGS. 7, 8 and 9. This is due to small voids that are created above and below each crumple section when the zones deform. These voids could allow a small amount of axial movement before the crumple sections contact the earth above and below within the voids, assuming a force strong enough to overcome skin friction is applied to the strut.
- [024] FIGS. 13A-C show another strut according to various embodiments of the invention. The portion of strut shown in these figures has a crumple zone divided into two sections having respective lengths L_1 , L_2 and L_1 . Deformation of this crumple zone will result in a generally bow-tie shaped profile seen in the simplified 2-D line drawing of FIG. 13B. FIG. 13B shows this same strut portion in three dimensions after deformation. Each section of the crumple zone having this configuration will deform into a relatively long flat section oriented parallel to the strut axis with two shorter, angled connecting sections as seen in 13D, which will provide increased resistance to both tensile and compressive forces on the strut.
- [025] It should be appreciated that various combinations and numbers of the crumple zones shown and described herein may be made without departing from the spirit or scope of the invention. In various embodiments it may be desirable to have at least two different

sized zones to facilitate the ability to deform fewer or more zones with the same compressive force depending on the relative density of the soil surrounding the strut.

- [026] FIGS. 10 and 11 are flow charts detailing steps of respective methods for installing and deploying a self-anchoring strut for an axial solar array according to various embodiments of the invention. Starting with FIG. 10, this figure describes a method of installing a strut consistent with the embodiments shown in FIGS. 2A/B and 3A-C. The method begins by joining the strut to the mandrel, such as by sliding it over the penetrating end above ground until the mandrel projects out of the bottom end the strut. In various embodiments, and as shown in FIGS. 2A/B and 3A-C, the below-ground end of the strut may have cuts or other features formed in it that can be expanded with twisting forces. This may be accomplished with a two-layer strut as in FIGS. 2A/B or with a single layer strut as in FIGS. 3A-C.
- [027] In various embodiments, the mandrel will engage with a feature formed in the strut to hold it in place. In other embodiments, a widening of the mandrel will prevent the strut from sliding any further up the mandrel. In still further embodiments, the mandrel and strut may be joined near the above-ground end of the strut with a pin or other easily detachable fastener. The mandrel and strut assembly are driven into the ground using downward pressure on the driving head of the mandrel. This will force both structures into the ground simultaneously. Once the desired depth has been achieved, a condition that may be realized when the entire strut has been buried or when it has been driven down to the point that an indicator on the strut reaches grade, the strut is subjected to a rotational force at its below-ground end by twisting the mandrel while holding the top of the strut in place. In various embodiments, a fixed amount of twisting pressure may be applied for a predetermined time to deform the tip. In other embodiments, the mandrel may be spun a predetermined number of rotations or fractional rotations. Once this has been achieved, the mandrel is pulled out leaving the anchored strut in place and the process repeats for the next strut in the array.
- [028] FIG. 11 details the steps of a method for installing a strut according to the remaining figures in the application (e.g., 4A/B, 5, 6A-C, 7A-C, 8A-C, 9A-C, 12A/B and 13A/B). The

method begins again by inserting the mandrel into the strut. In various embodiments, and as seen in FIG. 5, the strut will slide up the mandrel until the mandrel's tip and the narrower collar portion exits the swaged opening. At that point, rotating the strut by 90 degree will prevent the strut from falling off mandrel. The machine holding the mandrel then applies downward pressure to the mandrel which takes the strut down with it until it achieves the desired depth. Then, a pulling force is applied to the mandrel to pull up on the below-ground end of the mandrel while downward pressure is applied to the top of the strut via a slide or other device to effectively compress the strut. In various embodiments, a predetermined amount of compressive pressure will be applied to the strut, regardless of the type of soil the strut is driven in to. This will cause one or more of the crumple zones formed proximate to the below-ground end of the strut to deform, deploying them into the surrounding earth. The degree of deformation (i.e., the number of crumple zones that are deformed) will depend on the soil density for a given amount of compressive force. After compression is complete, a slight downward pressure may be applied to the strut to release the tension between the strut and the mandrel so that the collar reaches the swaged opening and the mandrel can be rotated 90 degrees and then removed from the anchored strut.

CLAIM SET 1:

1. A foundation system for an axial solar array comprising:
 - an inner strut having a first earth-penetrating end and a second opposing end;
 - a relatively shorter outer strut surrounding a portion of the inner strut, a first end of the outer strut rigidly attached to the first end of the inner strut at and a second end of the outer strut terminating at a point on the inner's strut's length; and
 - a plurality of cuts formed in the outer strut proximate to its first end such that application of rotational force to the inner strut while holding the outer strut causes the first end of the outer strut to splay outward into surround earth via the plurality of cuts.
2. The system according to claim 1, wherein the application of rotational force comprises rotation of a mandrel used to drive the inner and outer struts, the mandrel directly engaging only the inner strut proximate to the first end.
3. A foundation system for an axial solar array comprising:
 - an inner strut; and
 - a relatively shorter outer strut surrounding a portion of the inner strut, wherein after driving the inner and outer struts together, movement of the inner strut relative to the outer strut causes the outer strut to change its geometry deploying an anchor into surrounding earth.
4. The system according to claim 3, wherein movement comprises rotation of the inner strut.
5. The system according to claim 3, wherein movement comprises movement in the direction of an axis defined by the inner and outer struts.
6. The system according to claim 3, wherein driving comprises driving with a mandrel.
7. A method of installing a foundation for an axial solar array comprising:
 - pushing a two-part strut formed of an inner strut and an outer strut arranged as a sleeve around a portion of the inner strut into the ground with a mandrel positioned inside the inner strut;
 - with the mandrel, moving the inner strut with respect to the outer strut, thereby expanding an outside diameter of the outer strut by splaying it outward into the ground.

8. The method according to claim 7, wherein moving the inner strut with respect to the outer strut comprises pulling up on the inner strut while holding the outer strut in place.
9. The method according to claim 7, wherein moving the inner strut with respect to the outer strut comprises rotating the inner strut about an in-ground end of the inner strut while holding an above ground end of the outer strut in place.
10. The method according to claim 7, wherein the outer strut comprises a plurality of pre-formed features that expand the outside diameter of the outer strut when the inner strut is moved with respect to the outer strut.
11. A foundation for an axial solar array comprising:
 - a pair of adjacent struts driven into earth at reciprocal angles with respect to normal;
 - a saddle portion interconnecting respective above-ground ends of the adjacent struts; and
 - a mounting plate attached to the saddle portion, the mounting plate having a plurality of mounting holes for attaching components of an axial solar array, wherein each strut of the pair of adjacent struts comprises an inner strut having a first in-ground end and a second above-ground end, and an outer strut connected to the inner strut proximate to the first in-ground end and surrounding a portion of the inner strut, the outer strut having a plurality of pre-formed splaying features that deploy after the struts are driven into the ground by moving each inner strut with respect to its corresponding outer strut.
12. The foundation according to claim 11, wherein moving each inner strut with respect to its respective outer strut comprises rotating the inner strut with a mandrel used to drive the pair of adjacent struts while holding the outer strut in place.
13. The foundation according to claim 11, wherein moving each inner strut with respect to its respective outer strut comprises pulling up on the inner strut with a mandrel used to drive the pair of adjacent struts while holding the outer strut in place.
14. A strut for an axial solar array comprising an elongated tube having a first in-ground end and a second end opposite to the first end, wherein the first end that defines a two-

dimensional opening that has a first dimension and a second dimension different than the first dimension, and at least one crumple zone, proximate to the first end, wherein compression of the first end toward the second end causes the strut to deform the at least one crumple zone, widening a cross section of the strut at the at least one crumple zone.

15. The strut according to claim 14, further comprising a plurality of successive crumple zones.
16. The strut according to claim, 15 wherein each of the plurality of successive crumple zones increases in size progressing away from the first end of the strut.
17. The strut according to claim 15, wherein each of the plurality of successive crumple zones comprises a plurality of openings and a plurality of crumple lines.
18. The strut according to claim 15, wherein the number of successive crumple zones deformed by a given compressive force will be determined by a density of soil surrounding the strut.
19. The strut according to claim 14, wherein the first dimension and second dimension are orthogonal to one another.
20. A system for forming a foundation pier for an axial solar array comprising:
 - a mandrel having a substantially uniform geometry along its length, a driving head and a tip portion, the tip portion having a cross section that is wider in a first dimension than in a second orthogonal dimension; and
 - an elongated strut member, the strut member having a first in-ground end a second opposite end, the first end comprising an opening dimensioned to receive the tip portion of the mandrel at a first orientation and to capture the mandrel at a second orientation, the second orientation 90 degrees rotated from the first orientation, the strut member further comprising at least one crumple zone proximate to the first end.
21. The system according to claim 19, wherein pulling upward on the mandrel while at the second orientation while pressing down on the strut deforms the at least one crumple zone, causing it to expand its diameter.
22. The system according to claim 19, further comprising a plurality of crumple zones.

23. The system according to claim 22, wherein the plurality of crumple zones increase in size moving away from the first end of the strut.
24. The system according to claim 22, wherein each crumple zone comprises a plurality of axial openings and a plurality of corresponding crumple lines, wherein each crumple line is orthogonal to an axis defined by the strut.
25. The system according to claim 24, wherein deforming at least one of the crumple zones comprises folding it half about the plurality of crumple lines.
26. A method of installing a foundation for an axial solar array comprising:
- inserting an end of a mandrel into a strut member until it exits an in-ground end of the strut member;
 - rotating the mandrel by approximately 90 degrees to capture it within the strut;
 - driving the strut member into the ground with the mandrel;
 - pulling up on the mandrel with respect to the strut with a pulling force to deform at least one crumple zone formed in the strut member;
 - rotating the mandrel by approximately 90 degrees to free it from the strut; and
 - removing the mandrel from the ground while preventing the strut from moving in the axial direction.
27. The method according to claim 26, wherein the steps of driving, pulling, and removing are performed with a piece of hydraulic equipment connected to a driving head of the mandrel.
28. The method according to claim 26, wherein pulling upon the mandrel with a given amount of pulling pressure compresses the at least one crumple zone in the axial direction causing an outside diameter of the at least one crumple zone to increase.
29. The method according to claim 26, wherein pulling up on the mandrel with respect to the strut comprises simultaneously pushing down on the strut from above-ground.