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1020805

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

September 13, 2019

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APPLICATION NUMBER: 16/413,551

FILING DATE: May 15, 2019

RELATED PCT APPLICATION NUMBER: PCT/US19/49272

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS US16/413,551



Certified by

Anders Iversen

Under Secretary of Commerce
for Intellectual Property
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UTILITY PATENT APPLICATION TRANSMITTAL <i>(Only for new nonprovisional applications under 37 CFR 1.53(b))</i>	Attorney Docket No.	NPA02
	First Named Inventor	Jack WEST
	Title	Optimized truss foundations
	Priority Mail Express® Label No.	

APPLICATION ELEMENTS <i>See MPEP chapter 600 concerning utility patent application contents.</i>	ADDRESS TO: Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450
1. ☐ Fee Transmittal Form (PTO/SB/17 or equivalent) 2. ☒ Applicant asserts small entity status. See 37 CFR 1.27 3. ☐ Applicant certifies micro entity status. See 37 CFR 1.29. Applicant must attach form PTO/SB/15A or B or equivalent. 4. ☒ Specification [Total Pages <u>27</u>] Both the claims and abstract must start on a new page. (See MPEP § 608.01(a) for information on the preferred arrangement) 5. ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets <u>16</u>] 6. Inventor's Oath or Declaration [Total Pages <u>2</u>] (including substitute statements under 37 CFR 1.64 and assignments serving as an oath or declaration under 37 CFR 1.63(e)) a. ☒ Newly executed (original or copy) b. ☐ A copy from a prior application (37 CFR 1.63(d)) 7. ☒ Application Data Sheet * See note below. See 37 CFR 1.76 (PTO/AIA/14 or equivalent) 8. CD-ROM or CD-R in duplicate, large table, or Computer Program (Appendix) ☐ Landscape Table on CD 9. Nucleotide and/or Amino Acid Sequence Submission (if applicable, items a. – c. are required) a. ☐ Computer Readable Form (CRF) b. ☐ Specification Sequence Listing on: i. ☐ CD-ROM or CD-R (2 copies); or ii. ☐ Paper c. ☐ Statements verifying identity of above copies	ACCOMPANYING APPLICATION PAPERS 10. ☐ Assignment Papers (cover sheet & document(s)) Name of Assignee _____ 11. ☐ 37 CFR 3.73(c) Statement ☐ Power of Attorney (when there is an assignee) 12. ☐ English Translation Document (if applicable) 13. ☐ Information Disclosure Statement (PTO/SB/08 or PTO-1449) ☐ Copies of citations attached 14. ☐ Preliminary Amendment 15. ☐ Return Receipt Postcard (MPEP § 503) (Should be specifically itemized) 16. ☐ Certified Copy of Priority Document(s) (if foreign priority is claimed) 17. ☐ Nonpublication Request Under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent. 18. ☐ Other: _____ _____ _____ _____ _____

***Note:** (1) Benefit claims under 37 CFR 1.78 and foreign priority claims under 1.55 **must** be included in an Application Data Sheet (ADS).
(2) For applications filed under 35 U.S.C. 111, the application must contain an ADS specifying the applicant if the applicant is an assignee, person to whom the inventor is under an obligation to assign, or person who otherwise shows sufficient proprietary interest in the matter. See 37 CFR 1.46(b).

19. CORRESPONDENCE ADDRESS					
☒ The address associated with Customer Number: <u>157339</u> OR ☐ Correspondence address below					
Name					
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City	State	Zip Code			
Country	Telephone	Email			
Signature	/Phillip D. Mancini/			Date	05/15/2019
Name (Print/Type)	Phillip D. Mancini			Registration No. (Attorney/Agent)	46743

This collection of information is required by 37 CFR 1.53(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

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

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)**Title of
Invention**

Optimized truss foundations, adapters for optimized truss foundations, and related systems and methods

As the below named inventor, I hereby declare that:

This declaration
is directed to:

The attached application, or



United States application or PCT international application number _____

filed on _____

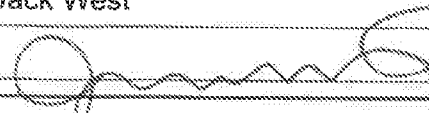
The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTORInventor: Jack WestDate (Optional): 5/15/2019Signature: 

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)**Title of
Invention**

Optimized truss foundations, adapters for optimized truss foundations, and related systems and methods

As the below named inventor, I hereby declare that:

This declaration
is directed to:

The attached application, or



United States application or PCT international application number _____

filed on _____

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

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LEGAL NAME OF INVENTORInventor: Charles AlmyDate (Optional) 5/15/2019

Signature: _____

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

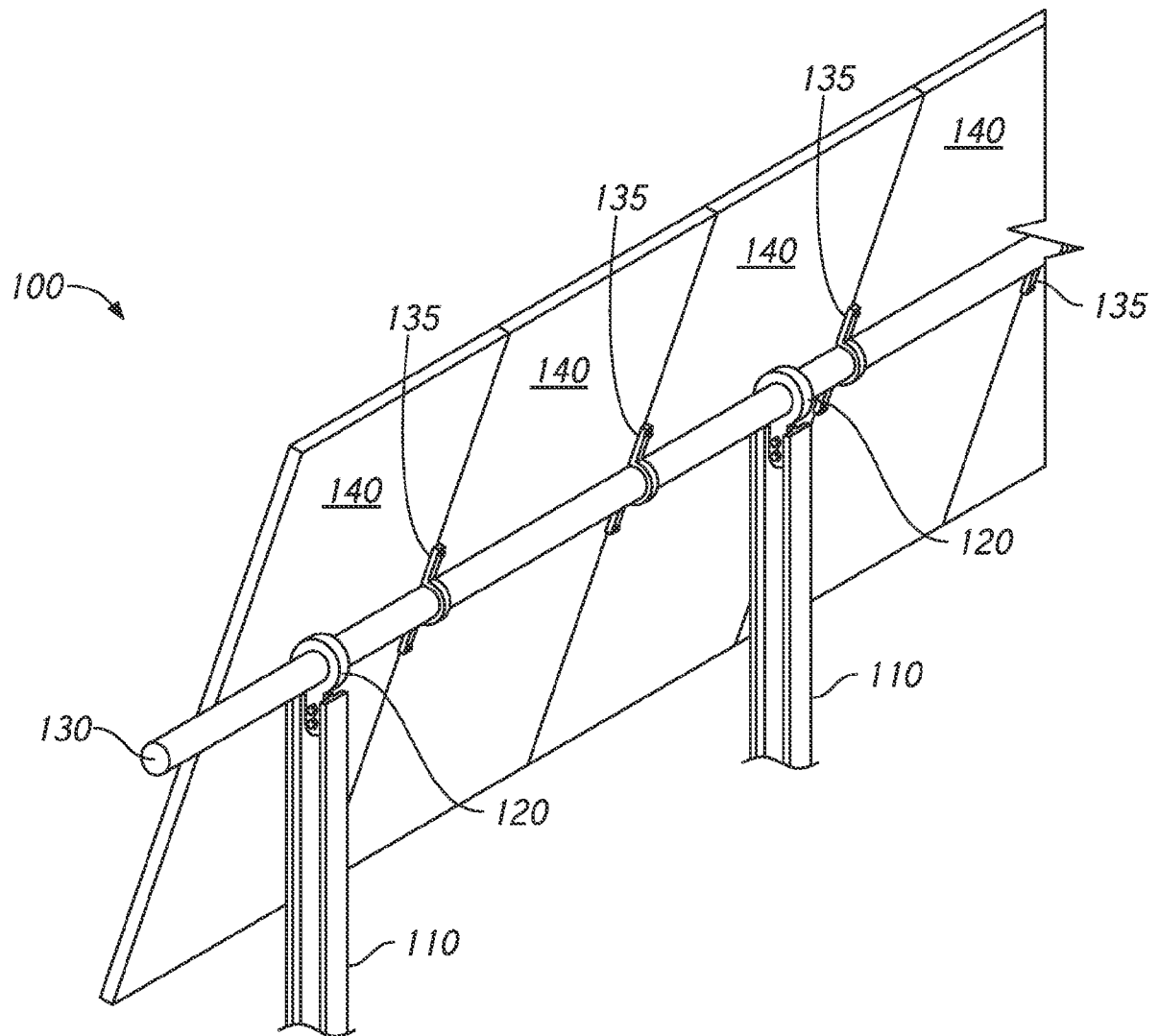


FIG. 1A
(PRIOR ART)

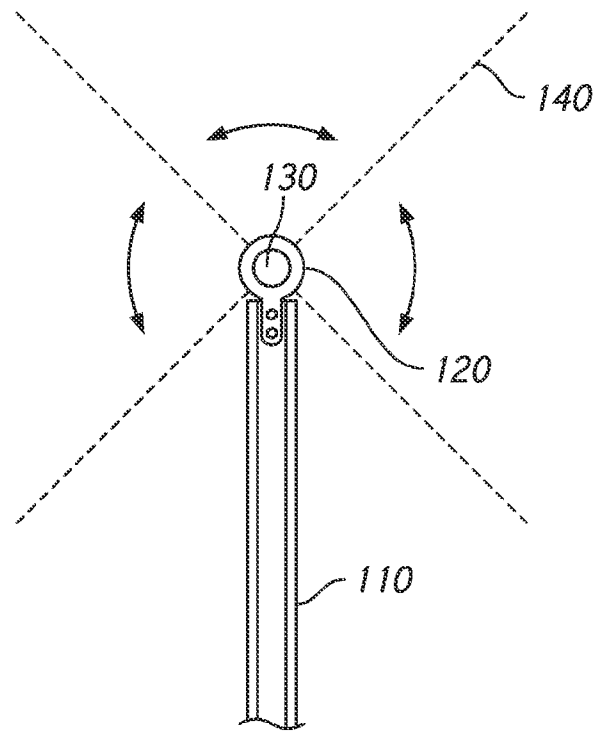


FIG. 1B
(PRIOR ART)

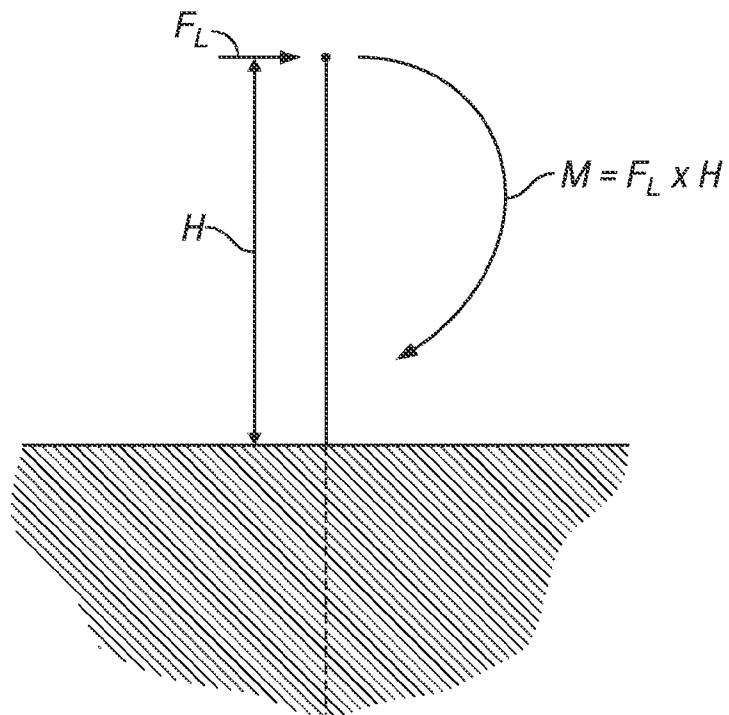


FIG. 1C

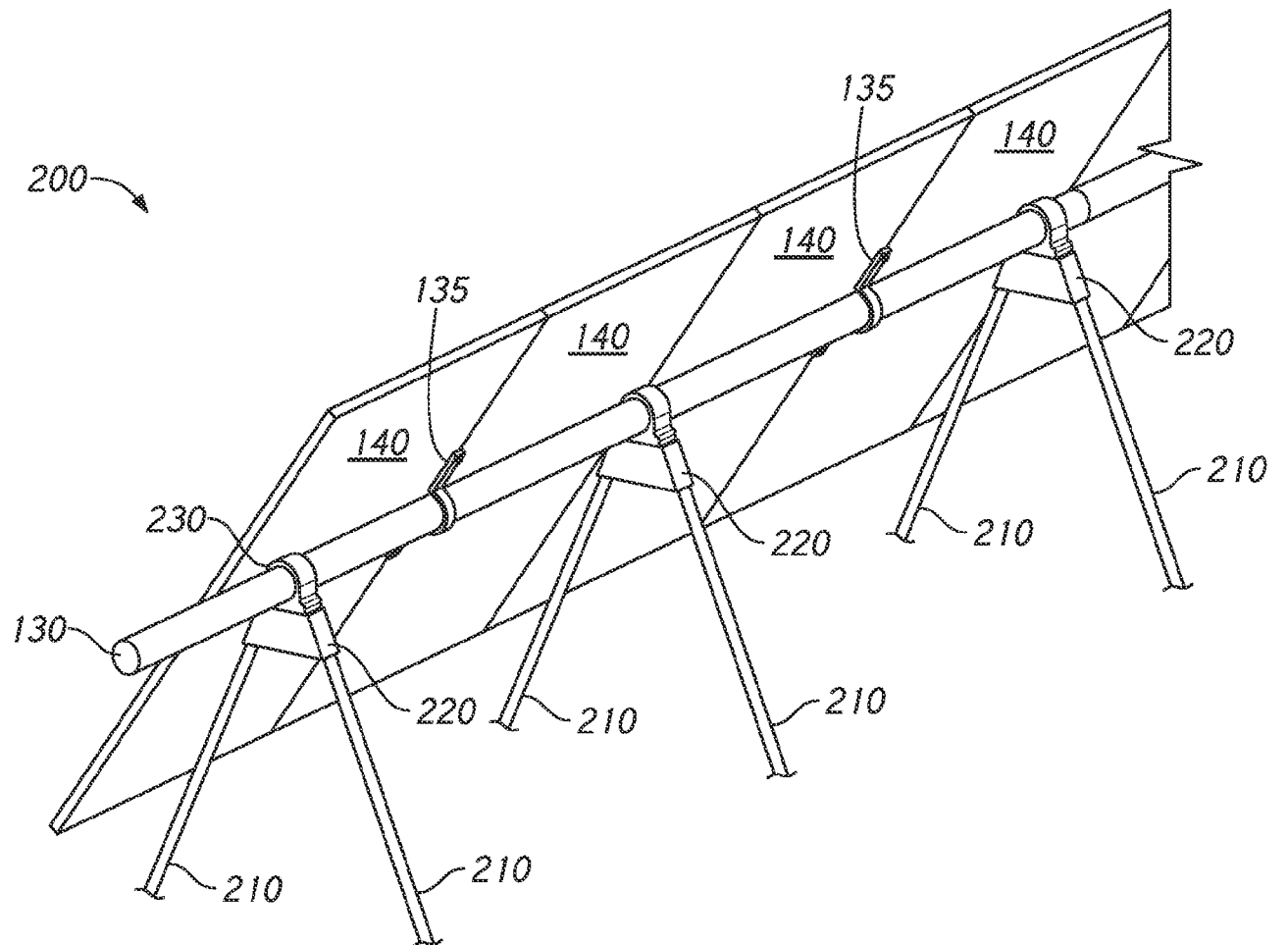


FIG. 2A

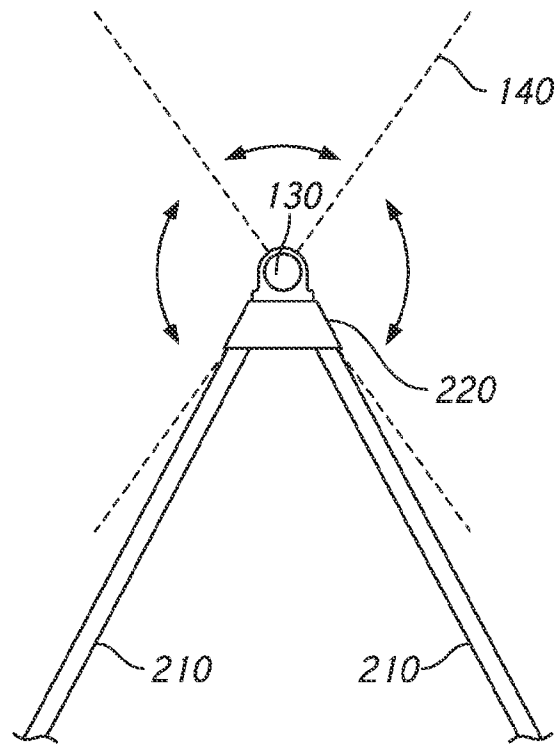


FIG. 2B

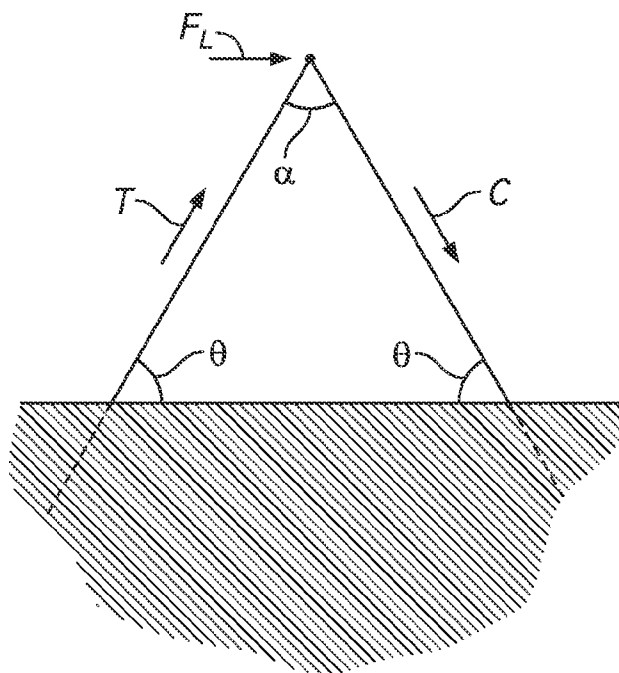


FIG. 2C

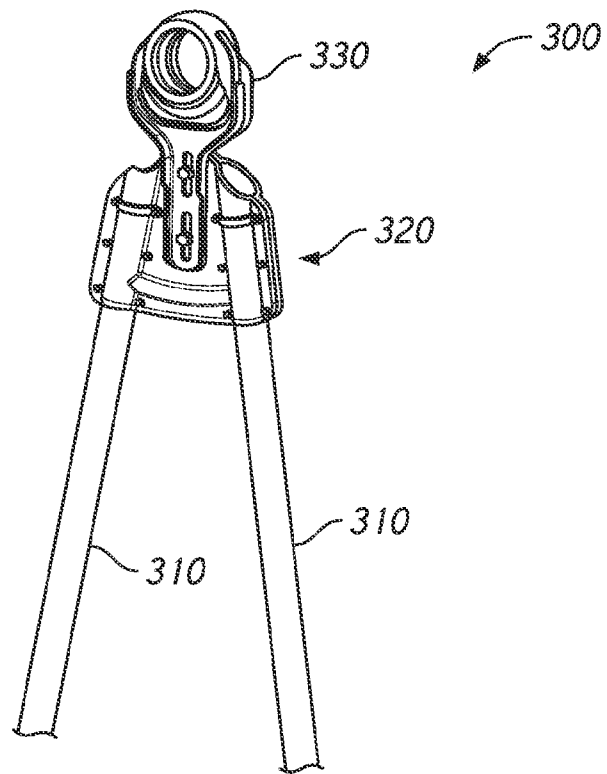


FIG. 3A
(PRIOR ART)

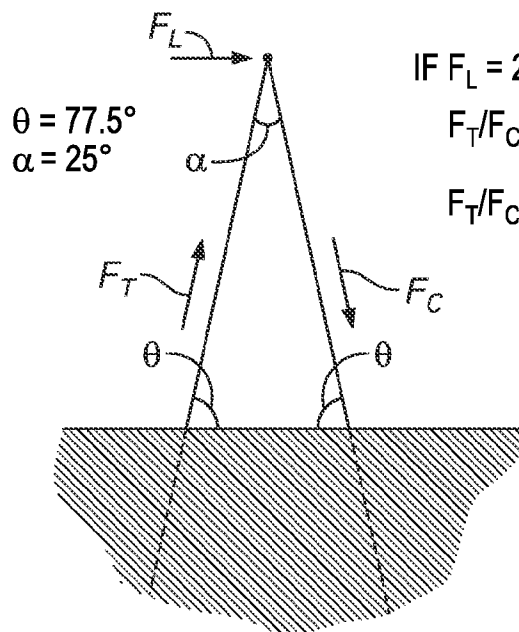


FIG. 3B

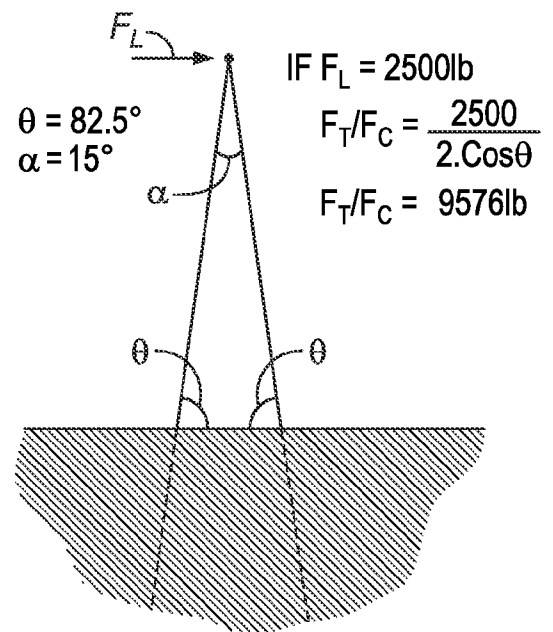
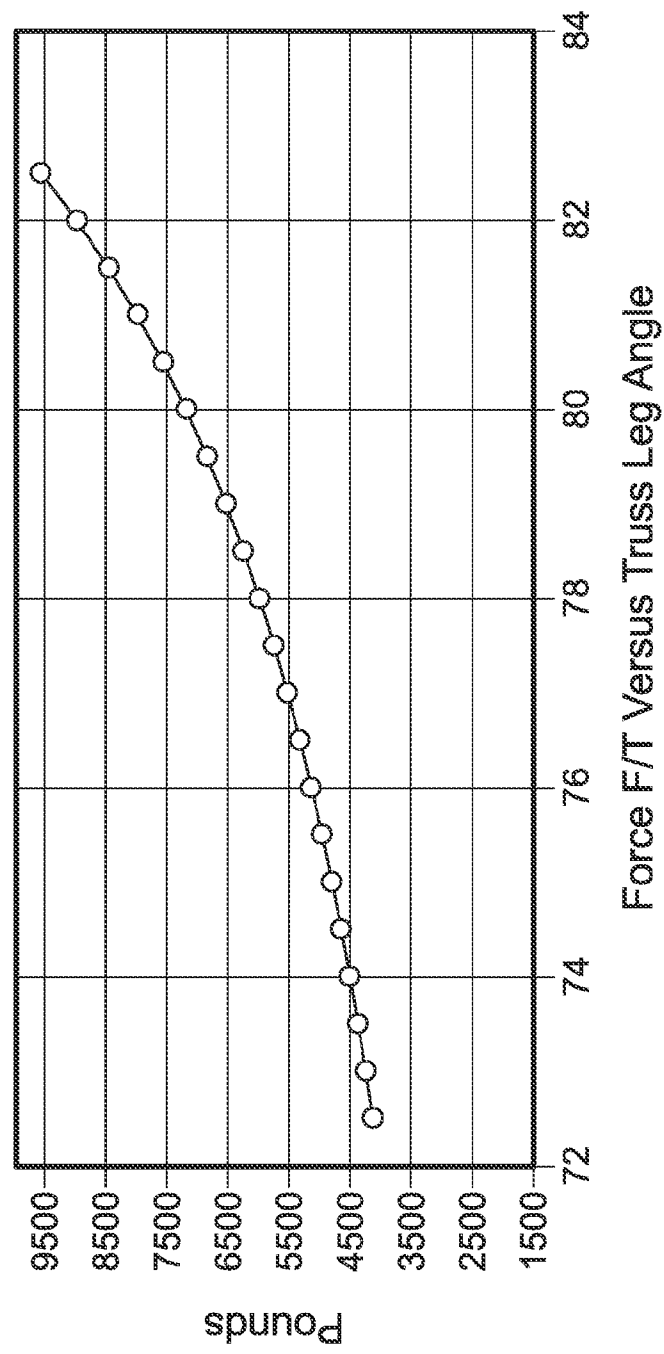


FIG. 3C

*FIG. 3D*

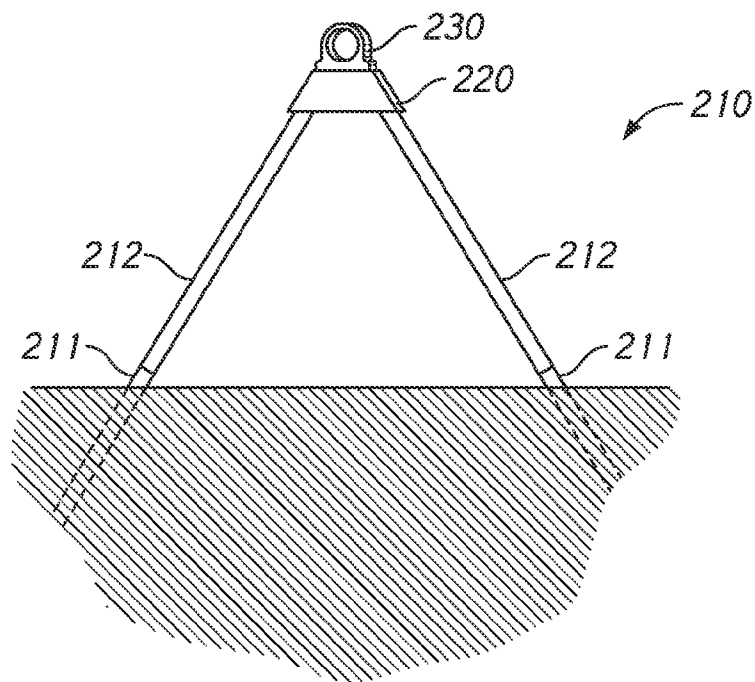


FIG. 4A

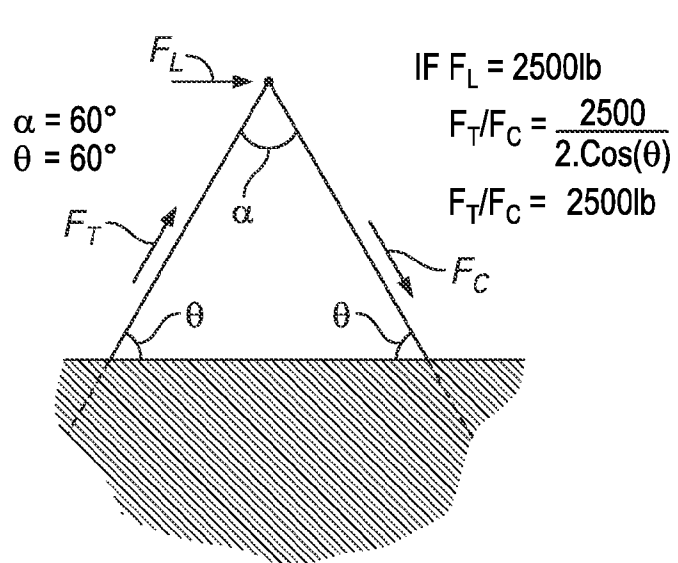


FIG. 4B

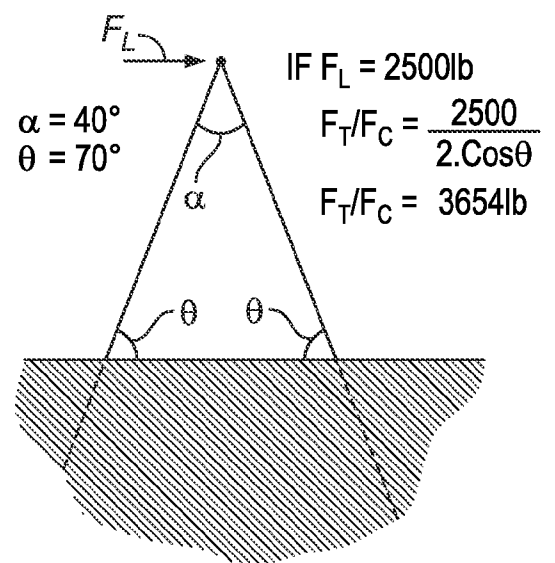


FIG. 4C

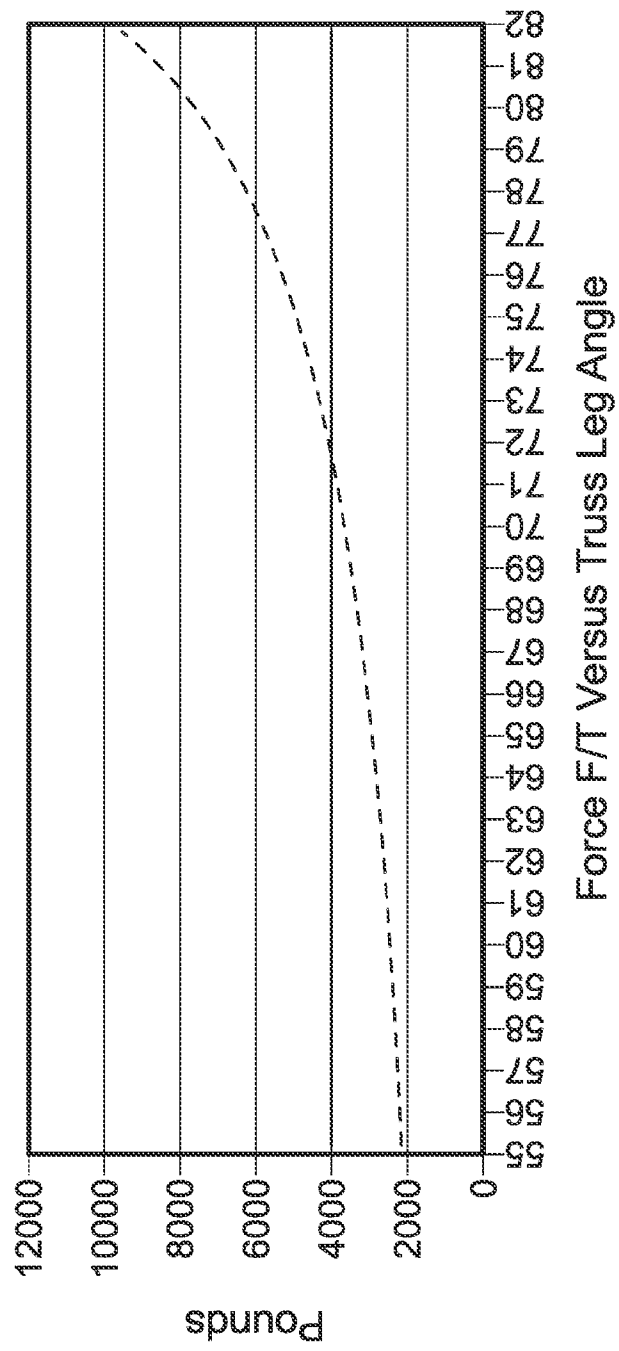


FIG. 4D

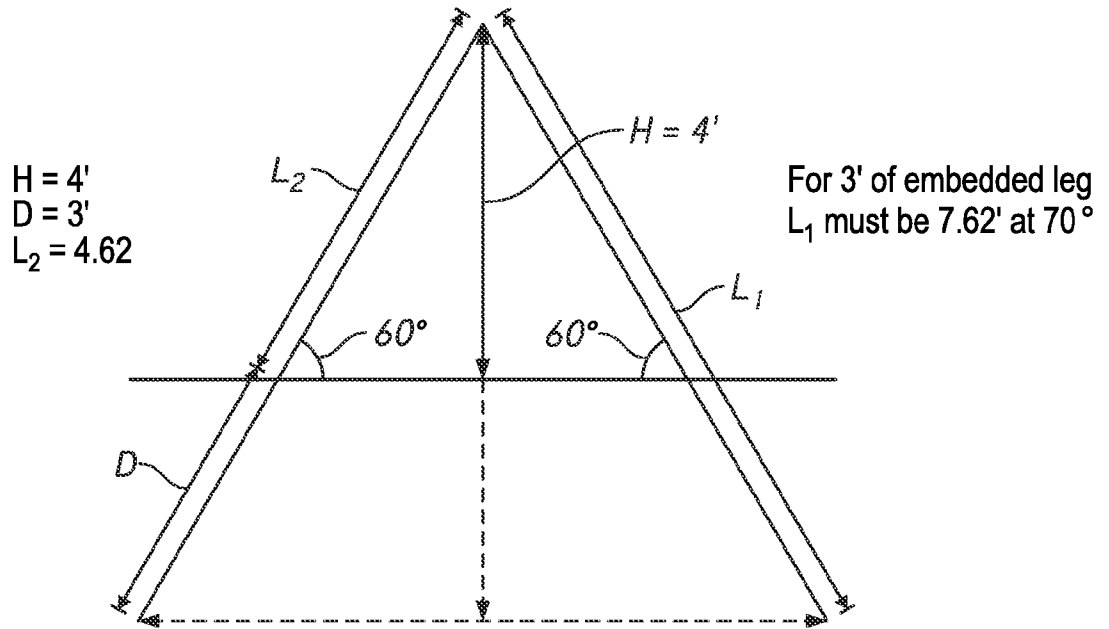


FIG. 5A

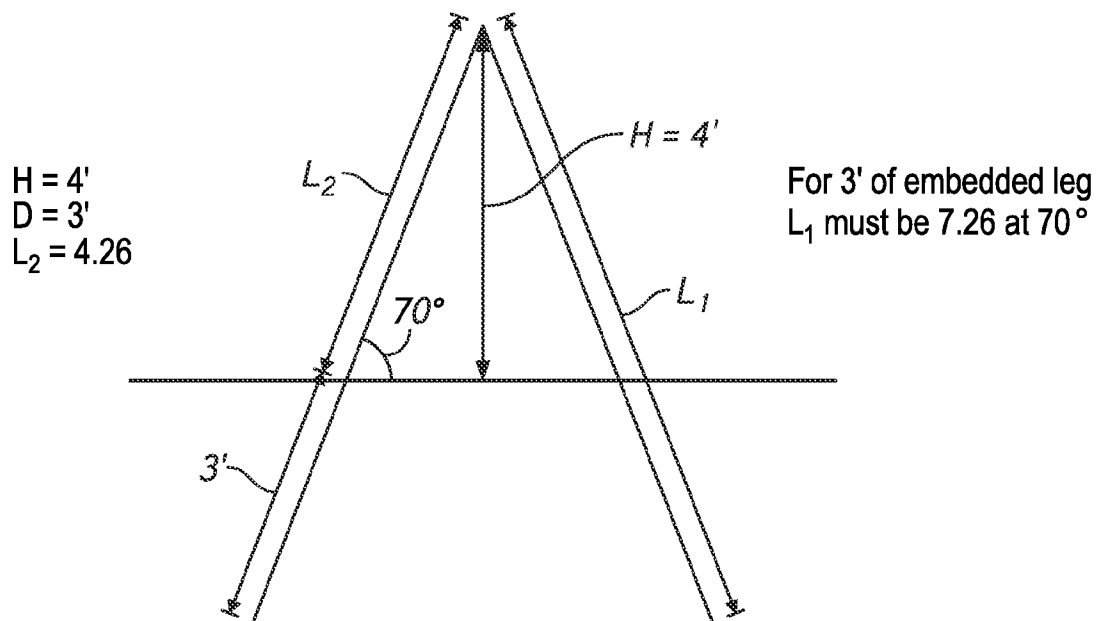
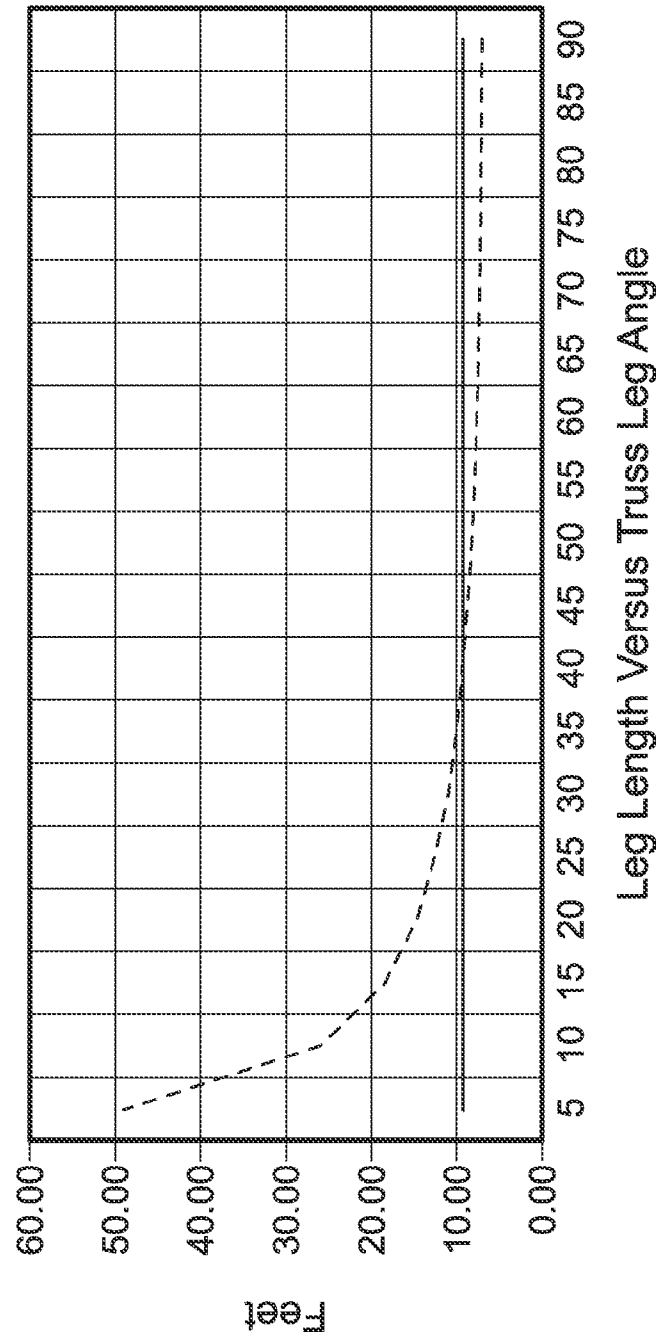


FIG. 5B

*FIG. 5C*

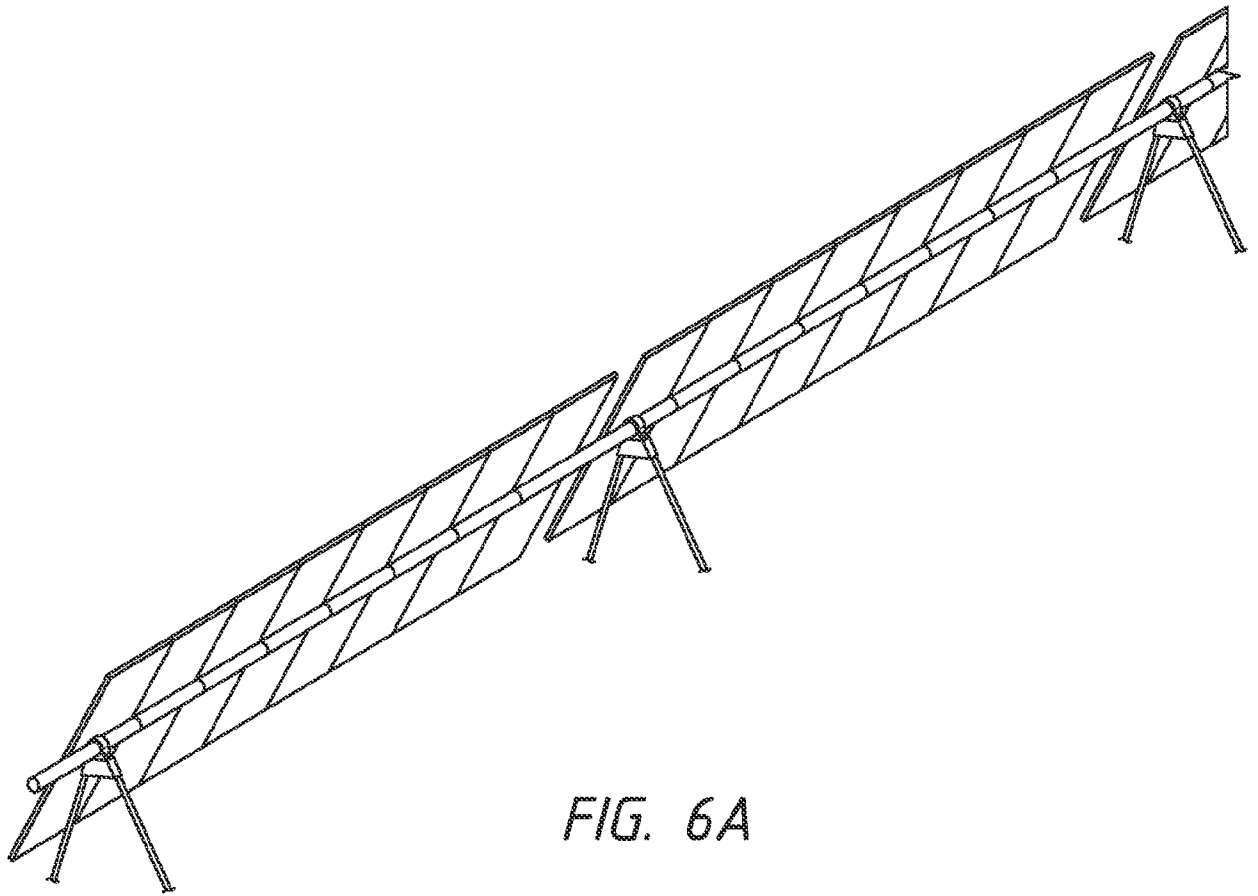


FIG. 6A

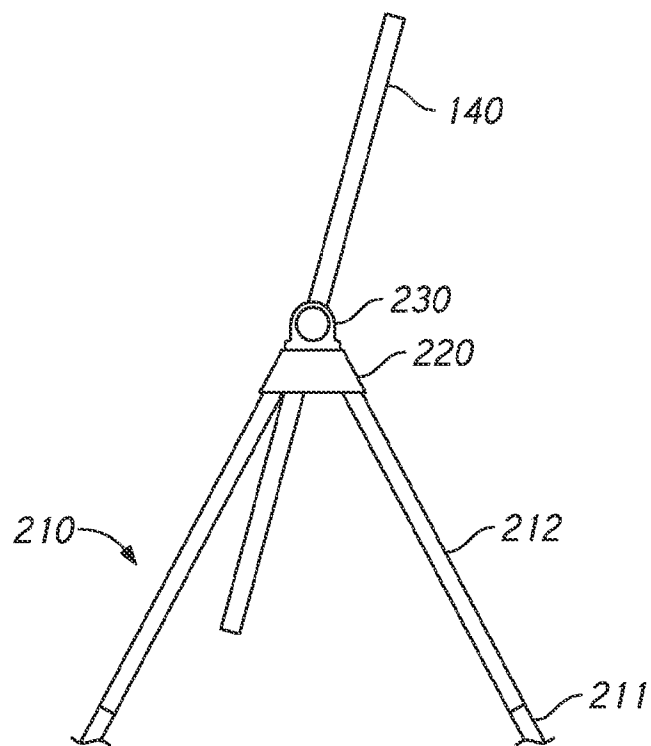


FIG. 6B

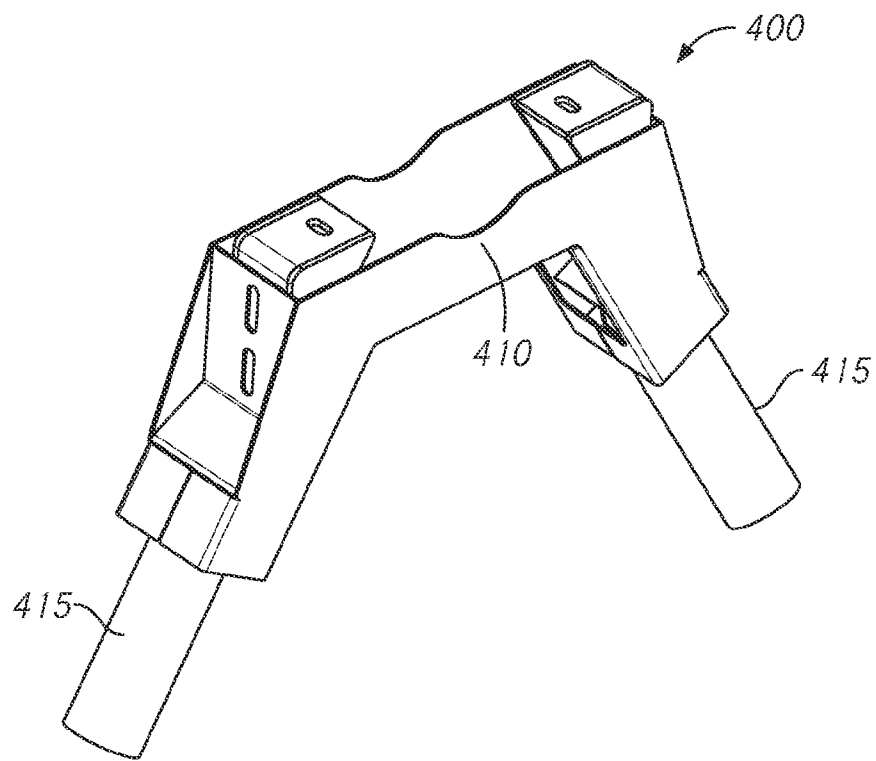


FIG. 7A

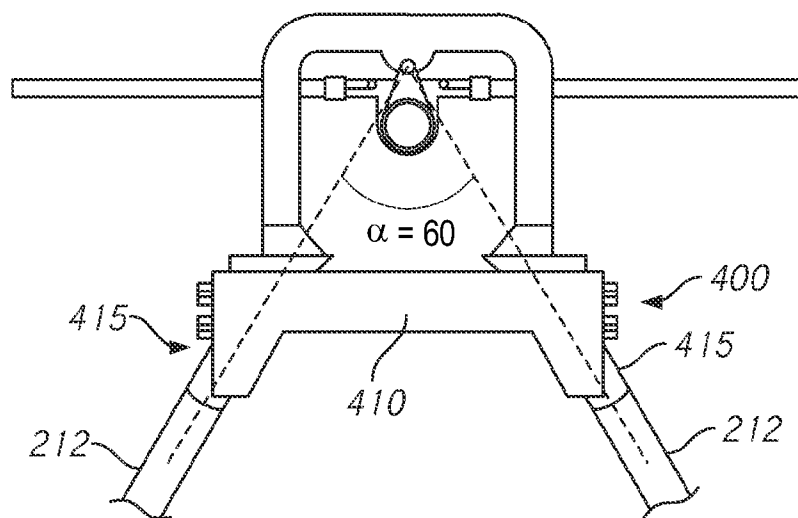


FIG. 7B

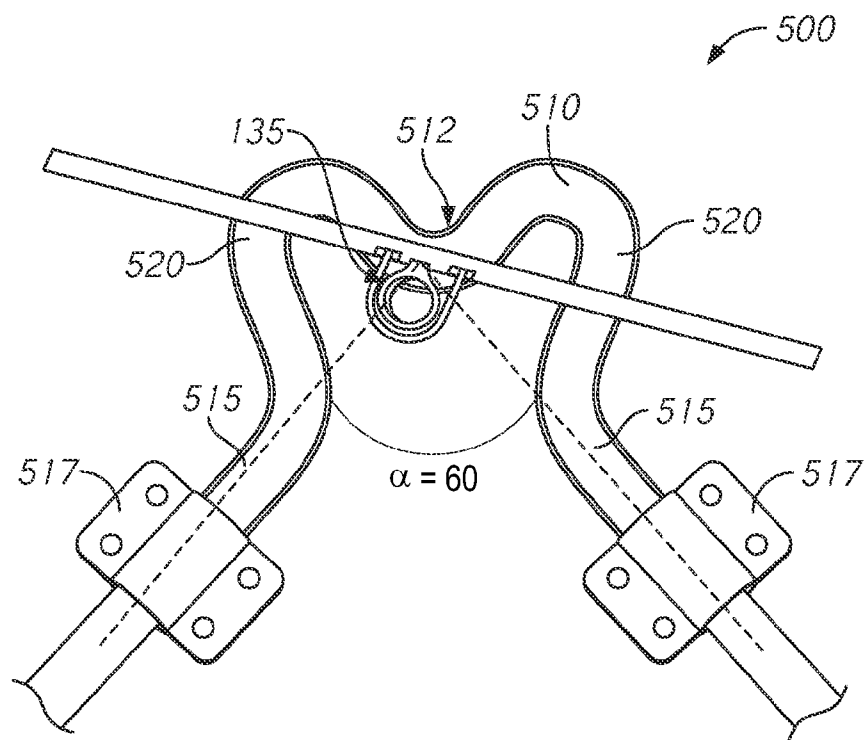


FIG. 8

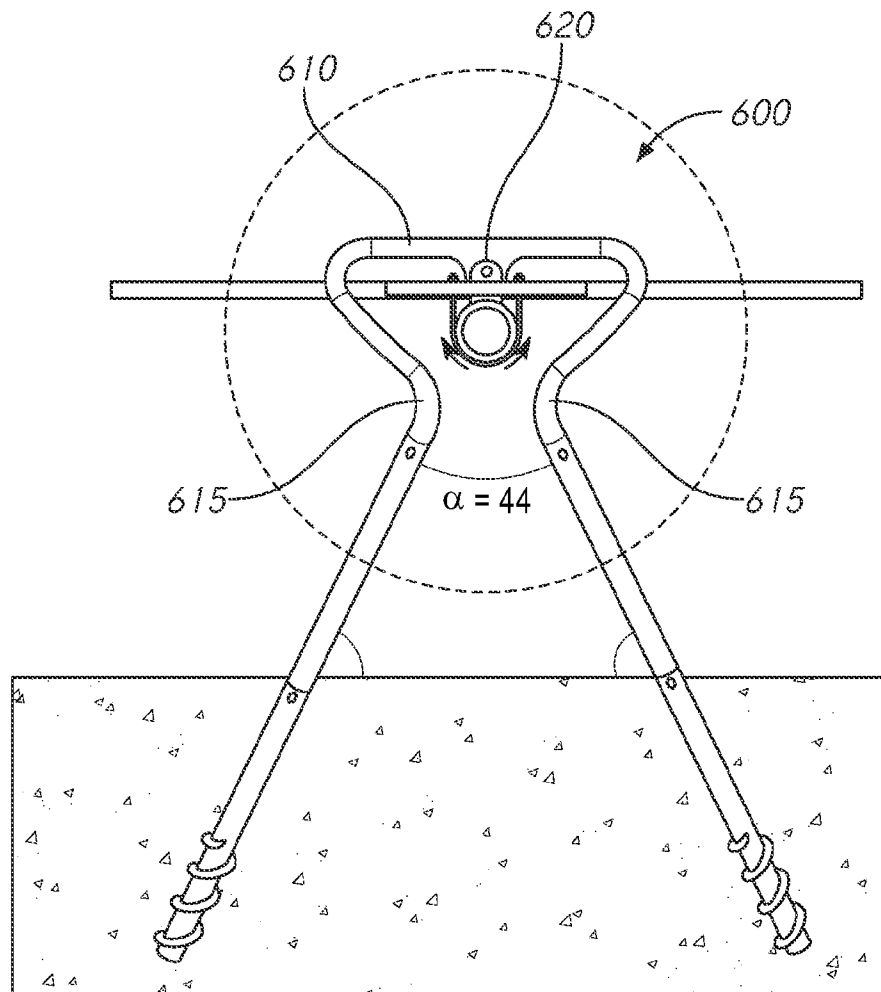


FIG. 9

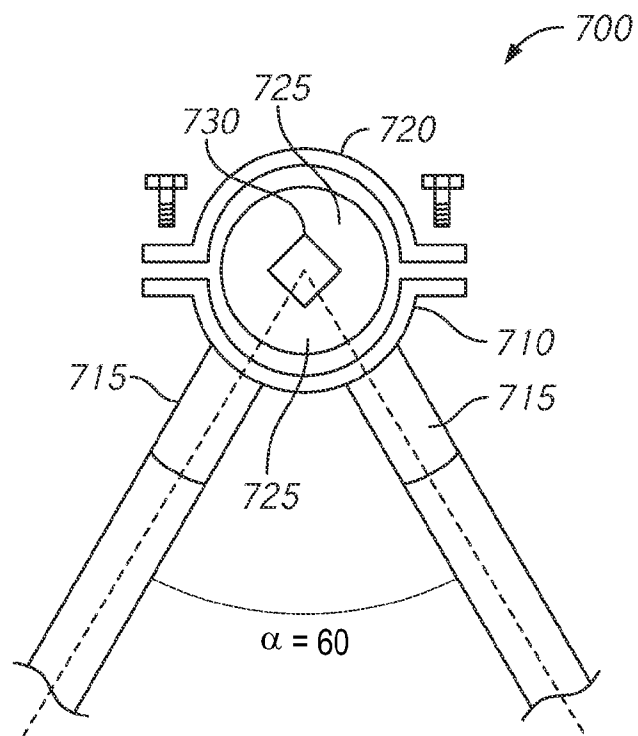


FIG. 10

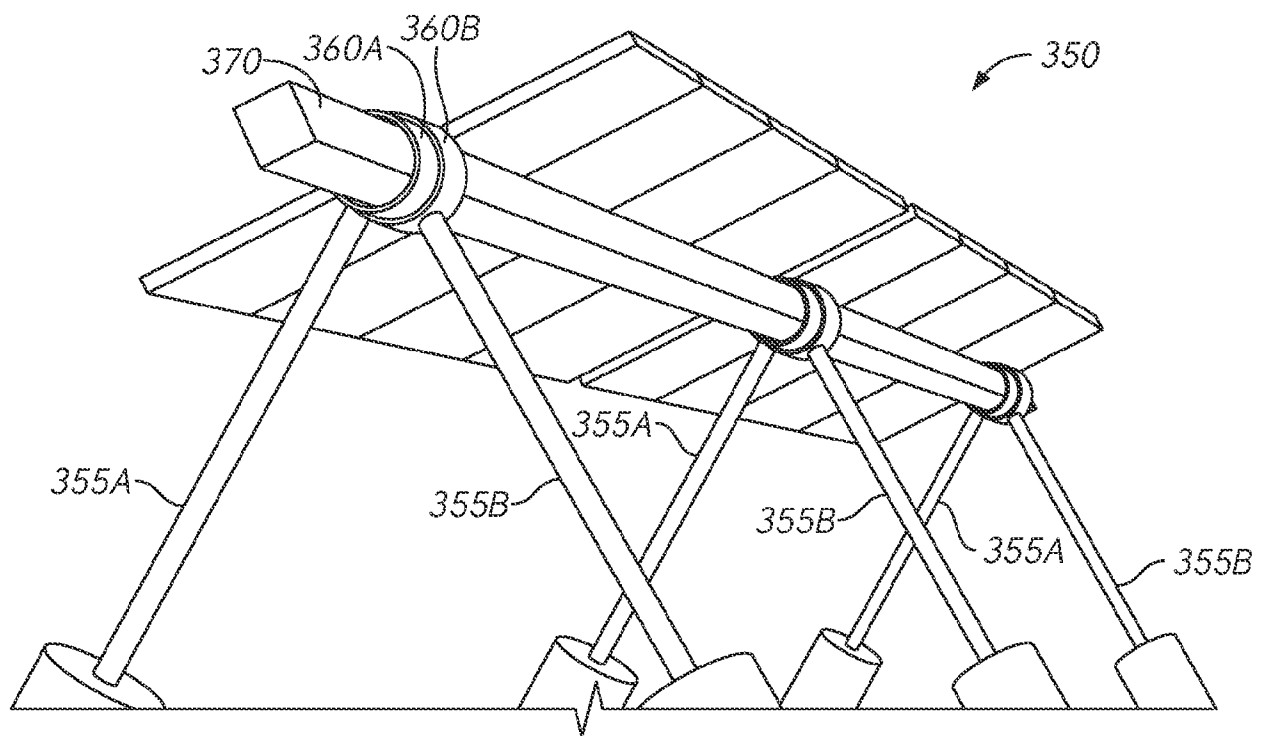


FIG. 11A
(PRIOR ART)

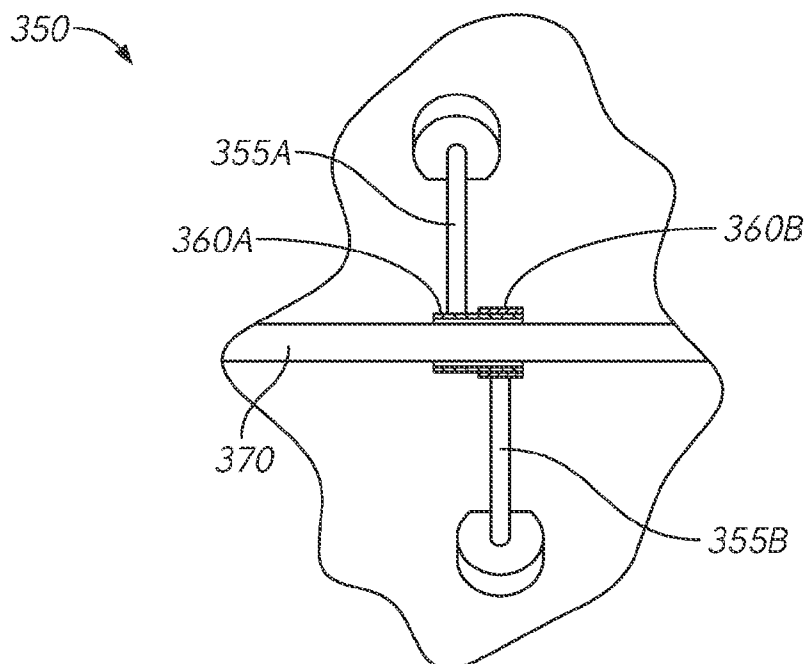


FIG. 11B
(PRIOR ART)

Electronic Acknowledgement Receipt

EFS ID:	36026949
Application Number:	16413551
International Application Number:	
Confirmation Number:	6542
Title of Invention:	Optimized truss foundations, adapters for optimized truss foundations, 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:	NPA02
Receipt Date:	15-MAY-2019
Filing Date:	
Time Stamp:	21:21:06
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	\$2855
RAM confirmation Number	051619INTEFSW21225000
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	127675	no	8
			9c6cbb397101925366233a8a0787376a6d20b0cf		
Warnings:					
Information:					
2	Transmittal of New Application	Transmittal.pdf	235224	no	2
			028ffc0529275303e6f90cc7b2b9f50a5e06e833		
Warnings:					
Information:					
3	TrackOne Request	T1.pdf	147721	no	1
			db8c3ef3f2ca726a4b1e6118a4240d20814604cf		
Warnings:					
Information:					
4	Oath or Declaration filed	Decs.pdf	161786	no	2
			4c961fdb5da235b2488b365c80c87b8ac7647151		
Warnings:					
Information:					
5	Specification	NPA02.pdf	221383	no	27
			bd1f49a64f16a280d7b8eefad04e8ad86936f381		
Warnings:					
Information:					
6	Drawings-only black and white line drawings	NPA02DWGS.pdf	1473835	no	16
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Warnings:					
Information:					

7	Fee Worksheet (SB06)	fee-info.pdf	40306 24f07efef7c5f79c7eec4b9632e634f2e15cd1d5	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			2407930		
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. <u>New Applications Under 35 U.S.C. 111</u> 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. <u>National Stage of an International Application under 35 U.S.C. 371</u> 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. <u>New International Application Filed with the USPTO as a Receiving Office</u> 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.					

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	NPA02
		Application Number	
Title of Invention	Optimized truss foundations, adapters for optimized truss foundations, 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
	Charles		Almy	
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		1668 Lincoln Street		
Address 2				
City	Berkeley	State/Province	CA	
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	NPA02
		Application Number	
Title of Invention	Optimized truss foundations, adapters for optimized truss foundations, and related systems and methods		

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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	Optimized truss foundations, adapters for optimized truss foundations, and related systems and methods		
Attorney Docket Number	NPA02	Small Entity Status Claimed	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	16	Suggested Figure for Publication (if any)	9

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.

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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.

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	NPA02	
		Application Number		
Title of Invention	Optimized truss foundations, adapters for optimized truss foundations, and related systems and methods			

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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	Pending	Remove	
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	Claims benefit of provisional	62745188	2018-10-12
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)
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Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	NPA02
		Application Number	
Title of Invention	Optimized truss foundations, adapters for optimized truss foundations, 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.

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	NPA02
		Application Number	
Title of Invention	Optimized truss foundations, adapters for optimized truss foundations, 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.

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☐ 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.

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

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	NPA02
		Application Number	
Title of Invention	Optimized truss foundations, adapters for optimized truss foundations, 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.

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	NPA02
		Application Number	
Title of Invention	Optimized truss foundations, adapters for optimized truss foundations, and related systems and methods		

Assignee Information including Non-Applicant Assignee Information:

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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. ☐				
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Mailing Address Information For Assignee including Non-Applicant Assignee:				
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City		State/Province		
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	NPA02
		Application Number	
Title of Invention	Optimized truss foundations, adapters for optimized truss foundations, 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).**

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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
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OPTIMIZED TRUSS FOUNDATIONS, ADAPTERS FOR OPTIMIZED TRUSS FOUNDATIONS, AND RELATED SYSTEMS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This claims priority to U.S. provisional patent application no. 62/745,188 filed on October 12, 2018, titled "OPTIMIZED A-FRAME FOUNDATIONS FOR AXIAL SOLAR ARRAYS AND RELATED SYSTEMS AND METHODS", the disclosure of which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] Solar energy is one of Earth's largest potential sources of energy. Above the atmosphere, solar irradiance per unit area is 1.361 kilowatts per square meter. At sea level, the usable energy density is reduced to 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 continuously strikes Earth's surface. Assuming the sun continues to burn and emit photons for a billion more years, the survival of human life ultimately depends on harnessing this essentially unlimited, source of clean energy.

[0003] The main impediment to widescale solar adoption thus far has been cost. Unlike other energy sources, solar energy costs are frontloaded while the operating costs are comparatively low. Fossil fuel-based energy sources require up-front costs as well as pay-as-you-go costs from consuming fuel. Unfortunately, not all the ongoing costs are reflected in the price of energy generated from fossil-fuel sources. These "dirty" energy sources have significant external costs stemming from CO₂ emissions that, in the absence of a carbon tax, are not reflected in the cost. In addition to this cost advantage, entrenched utilities and fossil fuel producers have lobbied effectively to stymie the progress of solar, even in states with the greatest solar potential.

[0004] Notwithstanding these headwinds, the cost of solar has now dropped low enough that even when coupled with energy storage, solar power is equivalent to or less expensive than power generated from coal, oil and even natural gas. In the context

of the electricity market, the relative cost difference between competing sources is quantified in terms of the cost per unit, typically a kilowatt hour (kWh). Large scale solar arrays, so called “utility-scale” arrays, may have tens to hundreds of megawatts of power generating capacity, putting them on the same scale as small coal and natural gas-fueled power plants. These arrays generate power that is fed into the grid and sold at wholesale prices on the order of a few cents per kWh.

[0005] The development of utility-scale solar projects is typically funded against power purchase agreements (PPAs). With a PPA, an off-taker (e.g., utility, grid operator, etc.) agrees to purchase all the power generated by the system at a fixed rate for the operational life of the array (e.g., 30 years). This enables a bank or other investor to accurately value the future revenue stream and to loan money against it to finance construction of the array.

[0006] Utility-scale solar power plants are predominantly configured as fixed-tilt ground mounted arrays or single-axis trackers. Fixed-tilt arrays are arranged in East-West oriented rows of panels tilted South at an angle dictated by the latitude of the array site – the further away from the equator, the steeper the tilt angle. By contrast, single-axis trackers are installed in North-South rows with the solar panels attached to a rotating axis called a torque tube that moves the panels from an East-facing orientation to a West-facing orientation throughout the course of each day, following the sun’s progression through the sky. For purposes of this disclosure, both fixed-tilt and single-axis trackers are referred to collectively as axial solar arrays.

[0007] Excluding land acquisitions costs, overall costs for building utility-scale arrays include site preparation (road building, leveling, grid and water connections etc.), foundations, tracker or fixed-tilt hardware, solar panels, inverters and electrical connections (conduit, wiring, trenching, grid interface, etc.). Many of these have come down in price over the past few years due to ongoing innovation and economies of scale, however, one area that has been largely ignored is foundations. Foundations provide a uniform structural interface that couples the system to the ground. When installing a conventional single-axis tracker, after the site has been prepared, plumb

monopiles are usually driven into the ground at regular intervals dictated by the tracker manufacturer and/or site plan; the tracker system components are subsequently attached to the head of those piles. Most often, these monopiles have an H-shaped profile, but they may also be C-shaped or even box-shaped. In conventional, large-scale single-axis tracker arrays, the procurement and construction of the foundations may represent up to 5-10 percent of the total system cost. Despite this relatively small share of the total cost, any savings in steel and labor associated with foundations will amount to a significant amount of money over a large portfolio of solar projects. Also, tracker development deals are often locked-in a year or more before the installation costs are actually incurred, so any post-deal foundation savings that can be realized will be on top of the profits already factored into calculations that supported the construction of the project.

[0008] One reason monopiles continue to dominate the market for single-axis tracker foundations is simplicity. It is relatively easy to drive monopiles into the ground along a straight line with existing technology even though their design is inherently wasteful. The physics of a monopile mandates that it be oversized because single structural members are not good at resisting bending forces. When used to support a single-axis tracker, the largest forces on the foundation are not from the weight of the components, but rather the combined lateral force of wind striking the solar panels. This lateral force gets translated into the foundation as a bending moment. The magnitude of the bending moment is much greater than the static loading attributable to the weight of the panels and tracker components. It acts like a lever arm trying to bend the pile, and the longer the lever arm, the greater the magnitude of the force. Many tracker companies specify a minimum foundation height of 40-inches or more. Therefore, in the context of single-axis trackers, monopile foundations must be oversized and driven deeply into the ground to withstand lateral loads.

[0009] One proposed alternative to monopile foundations is to use a pair of steeply angled legs to form an A-frame or truss-like foundation. An A-frame has the advantage of converting lateral loads into axial forces of tension and compression in the legs. As

an example, this is seen in published U.S. Patent Application, 2018/0051915 (herein after, “the ’915 application”). The ’915 application teaches a support device for solar panels that consists of a pair of ground screws driven into the ground either parallel or at steep angles to one another and joined above ground with a bridge. According to the disclosure, in the angled embodiments, the legs are inclined towards one another at an angle that is preferably between 10 and 35-degrees, and more preferably between 15 and 25-degrees. That angle is the separation of the legs at the apex of the A-frame and corresponds to a leg angle in a range of ± 72.5 -degrees to ± 85 -degrees and more preferably ± 78.5 -degrees to ± 82.5 -degrees with respect to horizontal. As discussed in greater detail herein, such steep angles, while still capable of translating lateral loads into tension and compression, will result in tensile and compressive forces much larger than the underlying lateral load. The magnitude of the tensile and compressive forces generated by lateral loads is non-linearly correlated to leg angle, a fact that is not recognized by the teaching of the ’915 application. As a result, at such steep angles, the legs must be oversized or include additional orthogonal features to resist the large values of tension and compression that are generated. Otherwise, the foundation will fail. This is part of the reason why ground screw-based A-frames have failed to gain traction in the utility scale solar industry, other than in the most difficult soils where costly refusals dominate.

[0010] In recognition of this problem, it is an object of various embodiments of this disclosure to provide a truss or A-frame foundation for single-axis trackers that is limited to a range of angles that reduces the non-linear magnitude of tensile and compressive forces imparted to the truss from lateral loads and thereby optimizes the amount of steel and depth of embedment needed for a given diameter leg.

BRIEF DESCRIPTION OF THE DRAWINGS

[0001] FIG. 1A shows a portion of an exemplary single-axis tracker system supported by multiple conventional monopile foundations;

[0002] FIG. 1B is an end view of the system of FIG. 1A showing the range of angles of the solar panels as the torque tube rotates;

- [0003] FIG. 1C is a force diagram showing how lateral loads are translated into a bending moment in a conventional monopile foundation of FIG. 1A;
- [0004] FIG. 2A shows a portion of an exemplary single-axis tracker system supported by a moderately sloped A-frame foundation;
- [0005] FIG. 2B is an end view of the system of FIG. 2A showing the range of angles of the solar panels as the torque tube rotates;
- [0006] FIG. 2C is a force diagram showing how lateral loads are translated into tension and compression in the moderately sloped A-frame foundation of FIG. 2A;
- [0007] FIG. 3A shows a portion of a single-axis tracker system supported by a conventional steeply sloped A-frame foundation;
- [0008] FIG. 3B is a force diagram showing the magnitude of tensile and compressive forces in the steeply sloped A-frame of 3A at 77.5-degrees in response to a 2,500-pound lateral load;
- [0009] FIG. 3C is a force diagram showing the magnitude of tensile and compressive forces in the steeply sloped A-frame of 3A at 82.5-degrees in response to a 2,500-pound lateral load;
- [0010] FIG. 3D is a graph of tensile and compressive forces through a range of steep angles for a 2,500-pound lateral load;
- [0011] FIG. 4A is a moderately sloped A-frame foundation system according to various embodiments of the invention;
- [0012] FIG. 4B is a force diagram showing the magnitude of tensile and compressive forces in the moderately sloped A-frame of 2A and 2B at ± 60 -degree in response to a 2,500-pound lateral load;
- [0013] FIG. 4C is a force diagram showing the magnitude of tensile and compressive forces in the moderately sloped A-frame of 2A and 2B at ± 65 -degrees in response to a 2,500-pound lateral load;
- [0014] FIG. 4D is a graph of tensile and compressive forces through a range of moderately sloped and steep angles in response to a 2,500-pound lateral load;

- [0015] FIG. 5A is a diagram showing the correlation between truss angle and A-frame leg length at ± 60 -degrees.
- [0016] FIG. 5B is a diagram showing the correlation between truss angle and A-frame leg length at ± 70 -degrees;
- [0017] FIG. 6A is a perspective view of a portion of a single-axis tracker and A-frame foundation according to various embodiments of the invention;
- [0018] FIG. 6B is an end view of the portion of single-axis tracker and A-frame foundation shown in Figure 6A;
- [0019] FIG. 7A is a perspective view of a further adapter for a top-down single-axis tracker that orients lateral loads at the work point of an A-frame-shaped truss foundation according to various embodiments of the invention;
- [0020] FIG. 7B is an end view of the adapter for the top-down single-axis tracker of FIG. 7A supporting a single-axis tracker;
- [0021] FIG. 8 is an end view of a bearing adapter supporting a top-down single-axis tracker according to various embodiments of the invention;
- [0022] FIG. 9 is an end view of a bearing adapter supporting a top-down single-axis tracker according to various embodiments of the invention;
- [0023] FIG. 10 is an end view of a bearing adapter supporting a bottom-up single-axis tracker according to various embodiments of the invention; and
- [0024] FIGS. 11A and are perspective and top views respectively of a conventional single-axis tracker.

DETAILED DESCRIPTION

- [0025] The following description is intended to convey a thorough understanding of the embodiments described by providing a number of specific embodiments and details involving A-frame foundations used to support single-axis solar trackers. It should be appreciated, however, that the present invention is not limited to these specific embodiments and details, which are exemplary only. It is further understood that one possessing ordinary skill in the art in light of known systems and methods, would appreciate the use of the invention for its intended purpose.

[0026] As discussed in the background, when a single-axis tracker is supported by monopile foundations, lateral loads induced by wind striking the array generate large bending moments that must be resisted by the foundation. Figure 1A shows a portion of single-axis tracker 100 supported by a series of aligned monopile foundations 100. Exemplary tracker 100 in this figure consists of solar panels 140, attached to torque tube 130 via panel brackets 135. Torque tube 130 is captured within multiple aligned cylindrical bearing assemblies 120 that are each attached atop respective H-piles 110. Though not shown, one pile will also typically support a drive motor or gear assembly that moves the torque tube. Also, electrical interconnections between the solar panels have been intentionally omitted. In real world conditions, the panels would be connected serially to form high voltage direct current (DC) strings that are fed into one or more combiner boxes and/or inverters.

[0027] Single-axis tracker 100 shown in Figure 1 is a conventional bottom-up design where the bearing assembly is attached the head of the pile and the torque tube rotates within the bearing about its own main axis. Other tracker systems may employ a top-down design where the torque tube hangs from a hinge received in the bearing housing so that the torque tube can sweep through an arc like a pendulum. In such systems, the drive motor is offset from the torque tube's main axis so that the tracker's axis of rotation is about the hinge point. The bearing housing is still attached to the head of each pile, but the axis of rotation is offset from the torque tube's main axis. One such top-down tracker is disclosed, for example, in U.S. Patent No. 10,222,446, which is hereby incorporated by reference in its entirety. The various embodiments of the invention are compatible with bottom-up as well as top-down or off-set single-axis trackers.

[0028] Figure 1B is an end view of the portion of the conventional tracker shown in Figure 1A. The Figure shows foundation pile 110, bearing assembly 120 and torque tube 130. Rotation of torque tube 130 causes solar panels 140 to sweep through a range of angles from East to West shown by the dotted lines in the figure. The extent of angular rotation is specified by the tracker maker but currently as much as ± 55 -degrees to ± 60 -

degrees with respect to horizontal (0-degrees). Because the pile is plumb (i.e., oriented at 90-degrees), there is ample clearance for the panels to achieve their maximum rotation angle without mechanical interference from the foundation.

[0029] Figure 1C is a force diagram showing the effect of lateral loads on such a tracker. Lateral load F_L imparts a bending moment on the foundation at the point where the torque tube is attached to the pile (e.g., at the bearing assembly). The magnitude of the resulting moment M is equivalent to the magnitude of the force F_L multiplied by the height H above the point where the foundation is pinned to the ground. If the pile extends four feet above ground and the lateral load is 2,500 pounds, the resultant moment M will be at least 2500×4 or 10,000 lb./ft. The pin point will often be more than one foot below ground because the top layer of soil provides little resistance to moments so the safety factor of the pile must be increased to account for that reality. Therefore, to achieve the necessary structural rating, the piles used to support the array must be rated to resist that moment and driven deep enough to keep it pinned when subjected to such a moment. This requires the use of a strong monopile, such as the commonly used W6x9 or W6x12 H-pile, which have a six-inch flange and nine or twelve pounds of steel per linear foot respectively, with as much as five to seven feet of below ground embedment.

[0030] The inventors and applicant of this disclosure have proposed an alternative to plumb monopile foundations that aims to significantly reduce the total amount of steel required to support axial solar arrays. This alternative foundation system, referred to commercially as EARTHTRUSS™, consists of a pair of moderately sloped, substantially aligned legs configured as an A-frame or truss that extend above and below ground and are joined at the apex with an adapter, bearing assembly, or other torque tube support element. The truss architecture offers several advantages over conventional monopile foundations. First, if properly designed, the A-frame will translate lateral loads into axial forces of tension and compression in the legs rather than bending. Individual structural members are poor at resisting bending but relatively good at resisting axial forces. The A-frame or truss takes advantage of this by directing those forces along the axis of the

legs where it is best applied. Therefore, the size and gauge of the steel that makes up the legs may be much smaller than an equivalent monopile. Also, without needing to resist bending, the legs do not need to be driven as deep as a conventional monopiles. This saves steel but also reduces the likelihood of encountering a refusal. A refusal occurs when additional impacts of a pile driver fail to result in additional embedment of the pile. Usually, this is the result of striking rock or cementious soil and requires an expensive, labor-intensive mitigation process. The shallower piles are driven, the less likely it is that they will encounter rock or cementious soil.

[0031] Turning now to Figure 2A, this figure shows a single-axis tracker like that of Figure 1A, except that the monopile foundations have been replaced with multiple aligned A-frame or truss foundations 200. Each truss foundation 200 consists of a pair of adjacent legs 210 driven into the ground at angles to each other so that they are substantially aligned with each other. In various embodiments, the legs may be angled symmetrically (e.g., ± 60 -degrees) with respect to horizontal. In other cases, they may be at somewhat different angles due to variations in grade and terrain and misalignment during driving. Surface variations can make measurement of the legs with respect to grade or a horizontal reference difficult. Therefore, throughout the disclosure, A-frame or truss foundations are characterized in terms of their top angle, even though this implies a corresponding leg angle.

[0032] In various embodiments, legs 210 may be beaten into the ground with a pile driver, rotated into the ground with a rotary driver, pushed into the ground, or otherwise driven. Also, legs 210 may consist of a single member or multiple interconnected members extending along a substantially common axis. Truss foundations 200 are installed along a North-South row at regular intervals specified by the tracker maker. In this exemplary system, the above ground ends of each leg 210 are joined by adapter 220. As shown, bearing assembly 230 sits atop adapter 220. Torque tube 130 passes orthogonally through each bearing assembly 230. It should be appreciated that in other embodiments, and as discussed in greater detail herein, the

bearing assembly and adapter may be combined into a single structure to reduce part count, cost and for other reasons.

[0033] Figure 2B is an end view of tracker system 200 of Figure 2A. As seen in this figure, clearance between the panels and the foundation is tighter than in the case of the monopile array of Figures 1A and B due to angled legs 210. If the tracker can orient the panels all the way down to ± 60 -degrees, the legs may have to be separated by a smaller top angle to prevent interference. It is not uncommon for the angle of panels on a torque tube to vary along its length by as much as 5-degrees due to bending and manufacturing tolerances, so an additional buffer of 5-degrees may be necessary to avoid interference.

[0034] Figure 2C is a force diagram showing how lateral loads are translated in a truss or A-frame foundation. As discussed herein, the truss architecture directs lateral forces along the main axis of each structural member instead of trying to bend them. In general, the column loading capacity of the legs is much greater than the tensile and compressive forces generated by lateral loads so loading capacity is not the limiting factor. Rather, a combination of skin friction between the leg surface and the soil and resistance from orthogonal threads or other below-ground features will control the truss' ability to resist lateral loads. If designed properly, the primary failure mode should be pulling up on the windward leg and sinking of the leeward leg. As seen in 2C, when lateral load F_L strikes the array, the forces are translated into the truss legs as tension and compression labeled T and C. For the truss not to fail, the sum of all forces must be zero. In this case, that means that the sum of forces in the direction of the lateral load, labeled X direction in the figure, must be zero. In other words, the X-component of the resistance provided by the legs to the lateral load, labeled as $F_{T/C}$, must be equivalent to the lateral load F_L . The actual value of these forces will also be impacted by the vertical load from the weight of the tracker system, which will resist tension in the windward leg and add to compression in the leeward leg, however, for purpose of angle comparison that load has been ignored. The X-component of resistive forces $F_{T/C}$ is proportional to the cosine of the truss leg angle θ by equation (1):

$$(1) F_L = 2F_{T/C} \cos(\theta).$$

Therefore, the required resistive force for each leg $F_{T/C}$ in response to F_L is equal to

$\frac{F_L}{2 \cos(\theta)}$. As θ approaches 90-degrees, the $\cos(\theta)$ will approach zero and the required resistive force $F_{T/C}$ in each leg will approach infinity.

[0035] As discussed in the background above, the '915 application teaches one example of an A-frame or truss foundation used to support a single-axis tracker. Figure 3A is a reproduction of the foundation described in the '915 application. System 300 consists of a pair of angled legs 310, in this case ground screws, joined above ground by a two-piece bridge that clamps down on the end of each leg. A conventional bearing assembly 330 is bolted onto the bridge to complete the assembly. The disclosure describes a range for the top angle α between each leg that is preferably between 10 and 35-degrees, and more preferably between 15 and 25-degrees. These ranges for the angle α correspond to truss legs that are angled in a range of ± 72.5 -degrees to ± 85 -degrees (assuming they are symmetric with respect to horizontal), and more preferably truss leg angles θ of ± 77.5 -degrees to ± 82.5 -degrees. Figures 3B and 3C are force diagrams showing the magnitude of the required $F_{T/C}$ at the steep leg angles and corresponding small apex angles suggested in the '915 application for a 2,500-pound lateral load. Starting with 3B, the chosen angle α is 25-degrees corresponding to a leg angle $\theta = 77.5$ -degrees, the high end of the preferred range for α specified in the '915 application. The resistive force required in each leg $F_{T/C}$ is equal to 5,775 pounds or $2500/2 \cdot \cos(77.5)$. Although still under the column capacity of the leg, this results in substantially increased axial forces to be resisted with skin friction and orthogonal threads. In Figure 3C, the apex angle α is set to 15-degrees, corresponding to a leg angle θ of ± 82.5 -degrees, the lower end of the '915 application's preferred range for α . At this angle, assuming the same 2,500-pound lateral load, $F_{T/C}$ increase to 9,576 pounds or $2500/2 \cdot \cos(82.5)$, nearly a four-fold increase. Table 1 below shows the resistive force required in each leg ($F_{T/C}$) for the entire range of angles proposed in the '915 application. Figure 3D is a graph of the same. The first column of Table 1 is the truss leg

angle Θ and ranges from 72.5-degrees to 82.5-degrees in half-degree increments. The second column is the top angle α between the legs when they are joined at the apex for each given leg angle and changes in one-degree increments. The third column is the resultant tensile and compressive forces $F_{T/C}$ that must be generated to resist the 2,500-pound lateral load.

Table 1. Resistive force for range of angles in '915 application.

Angle Θ	Angle α	Force $F_{T/C}$ (lbs.)
72.5	35	4157
73	34	4275
73.5	33	4401
74	32	4535
74.5	31	4677
75	30	4830
75.5	29	4992
76	28	5167
76.5	27	5355
77	26	5557
77.5	25	5775
78	24	6012
78.5	23	6270
79	22	6551
79.5	21	6859
80	20	7198
80.5	19	7574
81	18	7991
81.5	17	8457
82	16	8982
82.5	15	9577

As Table 1 and the corresponding graph at Figure 3D show, the resultant force increases in a non-linear fashion in the range for α proposed in the '915 application, negating the benefits of using an A-frame or truss foundation. To resist the large tensile and compressive forces at these shallow apex angles (steep leg angles), the truss components must be overbuilt, driven deeply and/or include additional orthogonal features. This will undermine the advantages that can be provided by replacing monopiles with A-frames by making them relatively more expensive. Though not

stated, module interference with the legs may be one reason for the recommended range of angles in the '915 application.

[0036] Turning now to Figure 4A, this figure shows a truss foundation 200 for a single axis tracker according to various exemplary embodiments of the invention. The exemplary truss shown here consists of adjacent legs 210 driven into the ground to be substantially aligned with each other and along the torque tube. The significance of this is that if the legs are not substantially aligned, that is their respective axes don't extend to substantially the same place on the torque tube, lateral loads will introduce a twisting moment to the foundation in addition to tension and compression. This twisting moment will require additional reinforcing of the apex hardware to withstand these twisting forces.

[0037] This is seen in the prior art, for example, in U.S. Patent No. 9,207,000 (hereinafter, the '000 patent). Figures 11A and B, are reproduced from the '000 patent. Tracker 350 has an A-frame-shaped foundation with legs 355A/B supporting torque tube 370. The bearing assembly consists of respective bearings 360A/B welded to the top of each leg 355A/B to make them into unitary structures. The bearings are nested one within the other along torque tube 370 resulting in an offset geometry as seen in the overhead view of 11B. Because legs 355A/B are offset, that is not substantially aligned with respect to the torque tube, or symmetric with respect to each other, lateral loads will tend to twist the legs, bearings and torque tube. Tracker 350 compensates for this by nesting one bearing within the other, however, this requires a double thickness of metal at the bearing and that the legs be thicker and/or heavier than they would need to be if no twisting moment was generated.

[0038] Returning to the system of 4A, in this system, legs 210 are joined at the top by adapter 220 so that they are substantially aligned with respect to each other and the torque tube. Bearing assembly 230 sits atop adapter 220. As a result of the legs alignment, lateral loads will result in axial forces only and no twisting moment. Also, in contrast to truss 300 of FIG. 3A, truss 200 of this figure is optimized to an angle that significantly limits the tensile and compressive forces, in this case a 60-degree apex

angle α and 60-degree leg angle Θ . The dramatic effects of this are shown in the force diagram of 4B. Assuming the same 2,500-pound lateral load as in the force diagrams of Figures 3B and 3C, the forces $F_{T/C}$ in each leg drop to 2,500 pounds at 60-degrees, or $2500/2*\cos(60)$, a 57-percent reduction over the 25-degree apex angle (77.5-degree truss leg angle) of Figure 3B, and a staggering 74-percent reduction over the 15-degree apex angle (82.5-degree truss leg angle) of Figure 3C.

[0039] Figure 4C is force diagram repeating the analysis of Figure 4B for a 30-degree apex angle (70-degree truss leg angle). Assuming the same 2,500-pound lateral load, with the legs oriented at 70-degrees, the value of the resistive force required in each leg ($F_{T/C}$) increases to 3654 pounds, or $2500/2*\cos(70)$, a 37-percent reduction over the 25-degree apex angle (77.5-degree truss angle) of Figure 3B and a 62-percent reduction over the 15-degree apex angle (82.5-degree truss angle) shown in Figure 3C. Table 2 below shows the resistive force required in each leg ($F_{T/C}$) for the entire range of angles proposed by the inventors of this application. Figure 4D is a graph of the of the data in Table 2 as well as the data in Table 1. The first column is the truss leg angle Θ and ranges from 55-degrees to 72.5-degrees in half-degree increments. The second column is the apex or top angle between the legs, α , and the third column is the resultant tensile and compressive forces $F_{T/C}$ that must be generated to resist the 2,500-pound lateral load.

Table 2. Resistive force for range of angles according to embodiments of the invention.

Angle Θ	Angle α	Force $F_{T/C}$ (lbs.)
55	70	2179
55.5	69	2207
56	68	2235
56.5	67	2265
57	66	2295
57.5	65	2326
58	64	2359
58.5	63	2392
59	62	2427
59.5	61	2463
60	60	2500
60.5	59	2538

61	58	2578
61.5	57	2620
62	56	2663
62.5	55	2707
63	54	2753
63.5	53	2801
64	52	2851
64.5	51	2904
65	50	2958
65.5	49	3014
66	48	3073
66.5	47	3135
67	46	3199
67.5	45	3266
68	44	3337
68.5	43	3411
69	42	3488
69.5	41	3569
70	40	3655
70.5	39	3745
71	38	3839
71.5	37	3939
72	36	4045
72.5	35	4157

Table 2 and the corresponding combination graph at Figure 4D show that the resultant force increases in a non-linear fashion. The range of angles proposed in the '915 application massively increase the required resistive forces, negating the benefits of using an A-frame or truss foundation. The horizontal line drawn at 4000 pounds in Figure 4D shows the range of leg angles required to limit $F_{T/C}$ to 4000 pounds or less. To stay below 4000 pounds, the leg angle Θ must be below 72.5 degrees and the apex angle α above 35-degrees. For apex angles below that, or truss leg angles above that, the tensile and compressive forces begin to increase sharply, which has significant cost-impacting consequences for the truss design. Therefore, the preferred apex angle range is 35-degree to 70-degrees corresponding to a leg angle below 72.5 degrees. The ideal apex angle is above 49-degrees corresponding to a leg angle below 65.5 degrees. Angles in this range will keep the resultant forces below 3000 pounds.

[0040] Another consideration in angle selection is material usage. For a given fixed depth of embedment, steeper angles will require less material. Turning to Figures 5A and 5B, these figures present two scenarios that seek to achieve a four-foot apex height, labeled H in the figures, and three feet of embedment for each truss leg. By setting the opposite side of the truss triangle to 4, the desired height of the apex above ground, the hypotenuse (L_2) may be solved for using equation (2):

$$(2) L_2 = 4/\sin(\Theta).$$

For the 60-degree apex and truss leg angle assumption in Figure 5A, this results in a value for L_2 of 4.62 feet. Adding 3 feet for the desired embedment length, requires a leg that is 7.62 feet or approximately 1935mm long for a 60-degree truss. In Figure 5B, the apex angle is decreased to 40-degree and the truss leg angle increased to 70-degrees. In this case, L_2 drops to 4.26 feet, $4/\sin(70)$, resulting in a required leg length of 7.26 feet or 1844mm. Therefore, as between the two, steeper angles allow for shorter legs to be used, reducing the amount of steel required. However, as with the required resistive forces, the rate of change of leg length with decreasing angle is not linear, and as noted above, steeper leg angles (narrower apex angles) may require greater length of embedment for each leg due to the exponentially increasing forces $F_{T/C}$. Table 3 below shows the pile length for various leg and apex angles assuming a four-foot apex height and three feet of embedded length.

Table 3. Leg length as a function of truss angle.

Angle α	Angle Θ	Leg Length
170	5	48.89
160	10	26.04
150	15	18.45
140	20	14.70
130	25	12.46
120	30	11.00
110	35	9.97
100	40	9.22
90	45	8.66
80	50	8.22
70	55	7.88
60	60	7.62
50	65	7.41

40	70	7.26
30	75	7.14
20	80	7.06
10	85	7.02
0	90	7.00

As the leg angle increases and the apex angle decreases, the leg length goes down to the minimum, the straight-line length of 7-feet where the truss becomes a monopile. As the leg angle is reduced and apex angle increased, the leg length begins to increase slightly and then takes off for angles below 40-degrees. For nearly all leg angles above 40-degrees (apex angles below 100), there is relatively little variance in the length, ≈ 2 feet or 29-percent above the minimum of 7-feet. For leg angles of 55-degrees or greater, apex angles of 70-degrees or less, there is less than one foot of variance, or 14-percent longer than the minimum. Therefore, the preferred leg angle from a material usage perspective is one that is at least 40-degrees and ideally 55-degrees or greater, corresponding to a preferred apex angle less than 100-degrees, and ideally less than 70-degrees.

[0041] Taken together, the information in Tables 1, 2, and 3 and Figures 3D, 4D, and 5D show that there are optimal ranges for α and Θ that balance competing goals of minimizing $F_{T/C}$ against minimizing material usage. To the first point, the preferred apex angle α is more than 35-degrees up to 70-degrees, while the ideal range is from 55-60-degrees, corresponding to a preferred truss leg angle Θ from 55 to less than 72.5-degrees, with an ideal range from 60 to 65-degrees. From a material usage perspective, any angle α below 100-degrees or angle Θ above 40-degrees is acceptable but angles for α below 70-degrees and angles Θ above 55-degrees are preferred. These ranges overlap with the optimal range of the apex angles α and truss leg angles Θ to minimizing $F_{T/C}$.

[0042] Referring now to FIGS 6A and 6B, these figures show a single-axis tracker array and an A-frame foundation for a single-axis tracker array or other axial solar array according to various embodiments of the invention. As discussed above in the context of Figures 2A and 2B, one potential disadvantage of an A-frame type foundation relative

to a conventional H-pile is that as the torque tube rotates the panels into steep angles (greater than ± 50 degrees), the legs of the A-frames may interfere with the panels. This could require using a smaller apex angle or steeper leg angle for the A-frame, as taught in the '915 application, but this is not optimal due to the rapidly and non-linearly increasing value of $F_{T/C}$. Another mitigation technique is to limit the range of motion for the tracker, but this too is untenable because it eliminates the ability to harvest so-called "shoulder power" obtained at the beginning and end of each day, when the sun is rising from or setting towards the horizon. Tracker manufacturers design their systems to harvest shoulder power and advertise this feature, so limiting rotation of the tracker is impractical from a business perspective.

[0043] The inventors of this disclosure have proposed a solution that overcomes this problem without limiting the torque tube's range of rotation. The solution introduces a gap at each point on the torque tube above one of the A-frame foundations (e.g., at the torque tube bearing locations). Because the legs of each truss define a substantially common East-West oriented plane, the amount of spacing required is little more than the outside diameter of the legs themselves or the thickness of the bearing assembly. In this way, the torque tube can rotate through a full range of angles (up to and beyond the leg angle) and is limited only by the length of slack wire interconnecting the modules to non-rotating components. As seen, in 6B, with a 60-degree truss leg and apex angles, the torque tube can rotate the panels all the way to 70-degrees or even steeper without interference.

[0044] The remaining figures 7A-B, 8, 9, and 10 show various truss adapters and bearing adapters that separate the legs by an apex angle in the desired range of more than 35-degrees up to 70-degrees according to various embodiments of the invention. Starting with Figures 7A-B, these figures show adapter 400 with a main body portion 410 and a pair of aligned connecting portions 415 extending down and away from main body portion 410 to couple to truss legs 210. The connecting portions 415 are preferably symmetric, meaning that straight lines through their respective centers will intersect at a common point. Adapter 400 could support a bottom-up or top-down style tracker. 7B

shows adapter 400 attached to upper legs 212 via connecting portions 415. In various embodiments connection portions 415 are oriented so that upper legs 212 are angled apart from each other at the apex at an angle in a range of more than 35-degrees up to 70-degrees. In various embodiments, fitment between connecting portions 415 and upper legs 212 will allow for adjustment between these structures to enable the adapter's height relative to upper legs 212 to be adjusted before permanently connecting it to upper legs 212. The dotted lines extending through the center of each leg 210 show that connection portions 415 are aligned in the vertical direction. Though not shown, a top view would also show that the lines through their respective centers intersecting, showing that they are also horizontally aligned, i.e., intersecting at substantially the same point along the torque tube. The tracker shown in 7B is a top-down tracker, such as that shown in Figures 2C and D.

[0045] Figure 8 shows cardioid-shaped bearing adapter 500 specifically adapted for a top-down single-axis tracker. As used in this disclosure and claims, the term bearing adapter is used generically to refer to structures that combine the function of an adapter, i.e., joining the legs of the A-frame so that they are aligned and at the correct angle, and the functions of a bearing assembly, i.e., supporting the torque tube as well as providing a cylindrical bearing that receives a rotational member that serves as the tracker's axis of rotation. Bearing adapters are not limited to only bottom-up or only top-down trackers, and instead may accommodate either, as is shown and discussed in greater detail below. Bearing adapter 500 of Figure 8 performs at least three functions. First, it unifies the adjacent legs of the A-frame to form a rigid truss structure. Second, it provides a cylindrical bearing opening for a bearing pin to hang the torque tube from and clearance for it to swing through its East-West arc while reducing the steel and components needed to do so. Finally, it aligns upper legs 212 so that their respective axes are aligned with respect to each other and the torque tube sets the apex angle between them in a range of greater than 35-degrees up to 70-degrees, and ideally in a range of 50-degrees to 60-degrees.

[0046] Bearing adapter 500 is formed from one or more cast metal pieces. It should be appreciated, however, that other manufacturing techniques may be employed without departing from the spirit or scope of the invention. It consists of cardioid-shaped hoop 510 with cusp 512 and symmetric S-shaped arms 520, located on either side of cusp 512. S-shaped arms 520 terminate in respective tubular connecting portions 517. S-shaped arms 520 project away from cusp 515, then curve back inwards before curving back out to match the angle and spacing of the truss legs (e.g., ± 60 -degrees). In various embodiments, the desired angle truss leg angle Θ and apex angle α will be known in advance and the bearing adapter 500 will be manufactured to set that angle.

[0047] Connecting portions 517 shown in the example of these figures are drawn as partial tubes. In various embodiments, separate cover plates that are also tubular may fit over the upper legs 212 of the A-frame and mate with connecting portions 517 to capture the upper legs. Bolts, rivets, or other known mechanical fasteners and their functional equivalents may be used to secure the cover plates to connecting portions 517. It should be appreciated that other embodiments may have a complete tube at the end of each S-shaped arm 520 that is dimensioned to receive or fit inside the free ends of each adjacent upper leg 212, or a completely different geometry. Such modifications are within the scope of the various embodiments of the invention as long as they don't undermine the functions of the adapter. A cylindrical bearing opening in cusp 512 receives the bearing pin from which torque tube 130 is suspended. Module brackets 135 couple the solar panels (photovoltaic modules) to torque tube 130. Because a monopile foundation is not used, the ends of S-shaped members 520 do not need to intersect at a horizontal mounting platform. This design takes more efficient advantage of the truss architecture and may simplify installation. For example, if after each pair of adjacent truss legs is installed, the torque tube or torque tube sections may be laid on the ground between the adjacent unconnected legs. Once bearing adapters, such as adapter 500, are attached to torque tube 130 at the appropriate locations, the entire tube or tube sections can be lifted with a forklift or other equipment so that individual

connections between adjacent legs and their respective bearing adapters can be completed.

[0048] Turning now to Figure 9, this figure shows an end view of a top-down single-axis tracker and bearing adapter 600 for such a tracker that joins the truss to form a A-frame foundation and aligns the legs so that they are separated from each other at the apex by an angle α in a range of more than 35-degrees up to 70-degrees, and ideally in a range of 50 to 60-degrees. The top-down tracker could be a mechanically balanced tracker system such as that available from NEXTRACKER or other a different top-down tracker from another tracker maker. Bearing adapter 600 provides the functionality of conventional torque tube clamp supports (e.g., elements 124/126 in Figures 2C/2D) but in a form factor optimized for truss foundations.

[0049] Starting with the foundation, as with those shown in conjunction with the other truss adapters and bearing adapters discussed herein, it consists of legs 210 each formed from screw anchors 211 and upper legs 212. Screw anchors 211 have been rotated into the underlying soil at reciprocal angles with respect to horizontal, in this example ± 68 -degrees so that they are separated at the top by an angle α of 44-degrees. In various embodiments, each screw anchor 211 has a thread form at its distal end to help it resist axial forces and keep it on track during driving. The thread form may be uniformly wide or may have a tapered lead-in. Upper leg 212 is axially coupled to the above-ground end of each screw anchor 211 to form a partial A-frame using one of the various joining methods discussed herein.

[0050] Bearing adapter 600 is like bearing adapter 500 of figure 8 but is tubular rather than cast. Connecting portions 615 are connected to respective ends of each upper leg 212 to complete the A-frame. In various embodiments, a collar, pin, coupler, crimp or their functional equivalents may be used to join the second connecting portion 615 to the second upper leg 212 after the first connecting portion 615 has been connected to the first upper leg 212. The hinge and clamp assembly holding the torque tube are supported by bearing adapter 600 via bearing pin 620 extending through the cylindrical bearing opening in bridge section 610. As in other top-down systems shown herein, the

clamp assembly holds the torque tube and suspends it so that it can rotate about bearing pin 620. In addition, in this system a pair of U-bolts straddle the torque tube to pin the module support bracket to torque tube 130. Photovoltaic modules, otherwise known as solar panels, are then attached along the torque tube 130 to each module support bracket, with each bracket joining the edges of two adjacent modules. In various embodiments, the connection between bearing adapter 600 and upper legs 212 will allow for some relative height and angular adjustment. In various embodiments, installation of adapter 600 shown in Figure 9 may be like that described in the context of bearing adapter 500 of Figure 8.

[0051] Turning now to Figure 10, this figure shows bearing adapter 700 according to various other embodiments of the invention. Unlike the bearing adapters shown in Figures 8 and 9, adapter 700 is designed for a bottom-up style of single-axis tracker. Functionally it is equivalent to adapter 500/600 because it aligns and connects the truss legs to complete the A-frame, provides a cylindrical bearing for receiving a rotating member, in this case the torque tube, and sets the apex angle to the desired range. However, the geometry of adapter 700 is different because the bearing receives the torque tube rather than a hinge and therefore no clearance is required for the torque tube to swing through an arc.

[0052] Bearing adapter 700 consists of lower body portion 710 with aligned connecting portions 715 projecting down and away from lower body portion 710 to connect to upper legs 212. As with the adapters of various other embodiments, connecting portions 715 are angled down and away from lower body portion 710 so that the truss legs will be separated from each other by an angle α of more than 35-degrees to 70-degrees, and preferably at about 50 to 60-degrees. Lower body portion 710 has a semicircular cross section because it serves as the lower half of a cylindrical bearing. Upper portion 720 fits over lower body portion 710 via upper flanges that sit on corresponding lower flanges in lower body portion 710. Bolts, screws, or other known fasteners or their functional equivalents may secure upper portion 720 to lower body portion 710. In this example, torque tube 730 is shown with a boxed cross section. It is

surrounded by bearing insert 725 which, translates the boxed tube to a circular cross-sectional shape to match the profile of the cylindrical bearing formed from the union of upper portion 720 and lower portion 710. Bearing adapter 700 is optimized from a material usage perspective to work with an A-frame-shaped truss foundation by joining the legs of the A-frame, keeping them at the desired angle and spacing, and aligning them with respect each other. It also provides a cylindrical bearing so that a separate bearing assembly is not needed.

[0053] The embodiments of the present inventions are not to be limited in scope by the specific embodiments described herein. Indeed, various modifications of the embodiments of the present inventions, 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. Further, although some of the embodiments of the present invention have been described herein in the context of a particular implementation in a particular environment for a particular purpose, those of ordinary skill in the art will recognize that its usefulness is not limited thereto and that the embodiments of the present inventions can be beneficially implemented in any number of environments for any number of purposes. 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

1. An adapter for joining legs of an A-frame-shaped truss foundation comprising:
a main body portion, the main body portion having a bearing support for supporting a bearing assembly; and
a pair of substantially aligned connecting portions for connecting to legs of the A-frame extending above and below ground along a substantially common axis, the connecting portions separating the legs by an apex angle in a range of greater than 35-degrees up to 70-degrees.
2. The adapter according to claim 1, the connecting portions separating the A-frame legs by an apex angle in a range of 50-degrees to 60-degrees.
3. The adapter according to claim 1, further comprising a bearing assembly coupled to the bearing support, the bearing assembly comprising a cylindrical bearing portion capable of receiving a rotating member.
4. The adapter according to claim 3, wherein the rotating member is a torque tube.
5. The adapter according to claim 3, wherein the rotating member is a bearing pin
6. An assembly comprising:
means for rotatably supporting a torque tube; and
means for joining a pair of adjacent truss legs extending below and above ground along substantially the same axis so that they are substantially aligned with respect to the main body portion and separated from each other by an angle in a range of greater than 35-degrees up to 70-degrees.
7. The assembly according to claim 6, further comprising means for joining a pair of adjacent truss legs so that they are substantially aligned with respect to the main body portion and separated by an angle in a range of 50-degrees up to 60-degrees.
8. The assembly according to claim 6, wherein the means for rotatably supporting a torque tube and the means for joining a pair of adjacent truss legs both comprising an adapter.

9. The assembly according to claim 8, wherein the adapter is a bearing adapter, the means for rotatably supporting a torque tube comprises a cylindrical bearing in the bearing adapter, and the means for joining a pair of adjacent truss legs comprises a pair of connecting portions in the adapter.

10. The assembly according to claim 6, wherein the means for rotatably supporting a torque tube comprising a bearing assembly, and the means for joining a pair of adjacent truss legs comprising an adapter connected to and supporting the bearing assembly.

11. A single-axis tracker comprising:
a torque tube;
a plurality of solar panels attached to the torque tube;
a plurality of bearing assemblies rotatably supporting the torque tube; and
a plurality of truss foundations, one supporting each of the plurality of bearing assemblies, wherein each truss foundation comprises a pair of adjacent substantially aligned legs extending into underlying ground and separated from each other by an angle in a range of more than 35-degrees up to 70-degrees.

12. The single-axis tracker according to claim 11, wherein each truss foundation comprises a pair of adjacent substantially aligned legs extending into underlying ground and separated from each other by an angle in a range of 50-degrees to 60-degrees.

13. The single-axis tracker according to claim 11, further comprising a plurality of module clamps, the module clamps securing the plurality of solar panels to the torque tube.

14. The single-axis tracker according to claim 12, further comprising a gap without any module clamps between adjacent solar panels at each location on the torque tube supported by one of the plurality of truss foundations, the gap enabling the plurality of solar panels to rotate without mechanical interference from the plurality of truss foundations.

15. The single-axis tracker according to claim 11, the plurality of bearing assemblies rotatably supporting the torque tube to rotate about its own axis.

16. The single-axis tracker according to claim 11, the plurality of bearing assemblies rotatably supporting the torque tube to rotate about a bearing pin.

17. The single-axis tracker according to claim 11, further comprising a plurality of adapters joining each bearing assembly to one of the plurality of truss foundations, each adapter having a pair of substantially aligned connecting portions, the connecting portions joining each adjacent leg pair and providing a mounting platform for the bearing assembly.

18. The single-axis tracker according to claim 14, the connecting portions of the adapter joining each one pair of adjacent substantially aligned legs by an angle in a range of 50-degree to 60-degrees.

ABSTRACT

An A-frame shaped truss foundation system for a single axis tracker with moderately sloped legs that translate lateral loads into tension and compression without substantially increasing the magnitude of the lateral load force while optimizing material usage. Several such truss foundation systems are installed in a row to support a torque tube of a single-axis solar tracker. An adapter joins ends of adjacent upper legs and separates the truss legs by an angle more than 35-degrees up to 70-degrees.