NASA CASE NO. LAR 15136-1

PRINT FIG. 3

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Serial No.: 08/325,723
10/14/94

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(NASA-Case-LAR-15136-1) JOINT FOR A VARIABLE GEOMETRY TRUSS AND METHOD OF CONSTRUCTING SAME Patent Application (NASA. Langley Research Center) 18 p

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Unclas

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JOINT FOR A VARIABLE GEOMETRY TRUSS AND METHOD OF CONSTRUCTING SAME

The present invention relates to a joint for a deployable truss structure that can be maneuvered in a serpentine manner.

Referring to FIG. 1, the deployable truss structure according to the invention comprises a number of variable length battens pivotally connected together in a triangular configuration. Each triangle of variable length battens are connected to an adjacent set of variable length battens by six fixed length longerons. The fixed length longerons are arranged in a so-called "Stewart" configuration wherein each point of a triangle is connected to two-points of an adjacent triangle. The longerons are connected to the points of the triangles by universal joints pivotally connected to the pivotal connection between each batten. Multiple triangles of variable length battens can be connected to form a chain-like structure. The terminating ends can either be comprised of another triangle of variable length battens, or can be attached in a fixed length triangular configuration, such as by an end plate. By adjusting the lengths of the variable length battens, the variable geometry truss can be manipulated vertically and laterally to change the orientation of each end with respect to the other end.

The variable geometry truss according to the present invention can be used to statically or dynamically move, in a controlled way, one body with respect to another body. As such, the variable geometry truss is especially suited as a deployable truss, and/or robot-like manipulator in space-borne applications, where its ability to be compactly retracted make it suitable for storage in the U.S. space shuttle.

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JOINT FOR A VARIABLE GEOMETRY TRUSS AND METHOD OF CONSTRUCTING SAME

Origin of the Invention

The invention described herein was made by a U.S. Government employee and may be manufactured and used by or for the government for governmental purposes without the payment of any royalties thereon or therefore.

Background of the Invention

Field of the Invention

This invention relates in general to deployable truss beam structures, and specifically, to a joint suitable for a variable geometry truss able to statically or dynamically move, in a controlled way, one end with respect to the other end.

Description of the Related Art

Deployable truss beam structures that can maneuver in a serpentine manner, i.e., are adaptive, are particularly useful in space-borne applications, such as a robot manipulator, a berthing device between spacecraft, joints in a crane or boom, and as a support structure for other moveable structures. Space-based deployable structures, however, must be transported into space by rocket driven vehicles, such as the U.S. space shuttle, where storage space is limited. In order for a deployable truss beam structure to be useful on such missions, it must be possible to collapse it into a compact package for transportation, and to extend it to its fully extended length during use in space.

Examples of prior deployable trusses include the two-axis gimbal and geodesic trusses. However, two-axis gimbal trusses are limited in terms of the load they can sustain and deployable geodesic trusses are not capable of lateral motion. A deployable truss beam structure that is maneuverable in a serpentine manner is disclosed in a June 1985 paper entitled "Deployable Controllable Geometry Truss Beam" by Marvin D. Rhodes and Martin M. Mikulas. The Rhodes/Mikulas truss consists of cross-longerons and battens. The cross-longerons are of fixed length and attach one corner of a three batten triangle to the next plane defined by another three batten triangle. The length of every other batten triangle can independently vary in length creating a variable geometry truss. When the variable length battens are telescoped from the fully extended position to the fully closed position, the truss goes from a completely collapsed to a fully deployed position. By changing the length of the variable length battens, the truss can be maneuvered in a serpentine manner. Based on the rotational requirement of the joints in the Rhodes/Mikulas truss, two different types of joints are required which limits the useability of the truss.

Summary of the Invention

Accordingly, it is an object of the present invention to provide a joint for a variable geometry truss which allows the truss to statically or dynamically move, in a controlled way, one body with respect to another body.

It is another object of the present invention to provide a single joint suitable for use at every joint location in a variable geometry truss.

It is another object of the present invention to provide a truss joint having significant load capability.

It is a further object of the present invention to provide a simple type of joint structure for a variable geometry truss.

It is still a further object of the present invention to provide a method for constructing a joint for a variable geometry truss.

These and other objects are accomplished by a joint for a truss having battens and longerons comprising a first joint for pivotally connecting at least two battens forming a pivotal axis, and a second joint connected to said first joint for connecting at least two longerons such that each longeron has at least two axes of rotational freedom.

These and other objects are further accomplished by a method for constructing a joint of a truss comprising the steps of pivotally connecting a first and second batten to form a joint having a pivotal axis, and connecting a first and second longeron to one side of the joint such that the first and second longeron has three axes of rotational freedom, the intersection of each axis of rotation of the first and second longeron lying on the pivotal axis of the joint.

Brief Description of the Drawings

The present invention and the objects achieved by it will be understood from the description herein, with reference to the accompanying drawings, in which:

FIG. 1 is an isometric view of a simplified first embodiment of the invention in a fully deployed variable geometry truss.

FIG. 2 is an isometric view of a simplified first embodiment of the invention as used in a variable geometry truss deployed in a serpentine manner.

FIG. 3 is a lateral cross-sectional view of a joint for a variable length batten in accordance with the first embodiment of the invention.

FIG. 4 is an isometric view of a second embodiment of the invention in a fully deployed variable geometry truss.

FIG. 5 is an isometric view of an alternate joint according to the first or second embodiment of the invention.

FIG. 6 is a lateral cross-sectional view of a joint according Fig. 5.

Detailed Description of the Preferred Embodiments

FIG. 1 is an isometric view of a variable geometry truss 10 having a joint 16 according to a first preferred embodiment of the invention. FIG. 1 is simplified to show only those elements necessary for an understanding of the invention. A variable geometry truss is comprised of three components: a plurality of fixed length longerons 14, a plurality variable length battens 12, and a plurality of joints 16. Three variable length battens 12 are connected together by the joints 16 to form a triangle. Depending on the application and the length requirement, one or more such triangles are formed and connected together by the fixed length longerons 14. In the example, as shown in FIG. 1, and as discussed herein, three such triangles are formed by two end triangles and a center triangle. Each end triangle of variable length battens 12 is connected to the center triangle by six fixed length longerons 14 arranged in a so-called "Steward platform" configuration by the joints 16. In other words, each point of the variable length batten 12 in each end triangle is connected by fixed length longerons 14 to two points of the adjacent variable length battens triangle. Each point in the center triangle is connected to two other triangles by four fixed length longerons 14.

Each variable length batten 12 can be independently lengthened and shortened through the use of a hand-crank 22. The hand-crank 22 is attached to an inner rod 30 (see FIG. 3) of the variable length batten 12 through a cage 25 which forms a main pivot joint, having a main pivotal axis, with bracket 26 of another variable length batten 12. A yoke 18 is pivotally connected to the outside of cage 25. The center triangle has two yokes 18, one on each side of the joints 16. The yoke 18 rotates about the same pivotal axis as the bracket 26 in the cage 25. Each yoke 18 is provided with a rotatable rod 20 which rotates perpendicularly to the rotation of yoke 18 forming a universal joint having two degrees of rotational freedom. Two fixed length longerons 14 are pivotally connected to each rotatable rod 20 by an end bracket 28. In the first preferred embodiment of the invention, the end bracket 28 is free to rotate in a direction perpendicular to the rotation of both the rotatable rod 20 and the yoke 18 thereby providing each fixed length longeron 14 with three intersecting degrees of rotational freedom. At one end of each fixed length longeron 14 is a revolute joint 19 which allows rotation about the longitudinal axis of the longeron 14.

FIG. 2 is an isometric view of the variable geometry truss 10 deployed in a serpentine manner. The variable length battens 12 allow the orientation of one end triangle with respect to the other end triangle to be changed in a controlled manner. The length of each variable length battens 12 is controlled by rotating the hand crank 22. By rotating the hand crank 22, an inner threaded rod 30 is made to rotate against a threaded joint 24 connected to an outer rod 29. Thus, the length of each variable length batten 12 can be precisely controlled to displace the end triangles of the variable geometry truss 10 in both a vertical and lateral manner.

FIG. 3 is a lateral cross-section view of a variable length batten 12 with joint 16. The hand crank 22 is connected to the inner rod 30 via a bolt 22b. The inner rod 30 extends through the cage 25 and inside the outer rod 29. The outer rod 29 is capped with the threaded joint 24. Threads 23 on the inner rod 30 engage the threads on the threaded joint 24. A bracket 26 is connected to the opposite end of the outer rod 23. The bracket 26 has two end arms 27. Each end arm 27 is provided with a hole 27a to allow attachment to the cage 25 of an adjacent variable length batten 12. The cage 25 of the variable length batten 12 is provided with holes 25a for pivotally connecting, about the same axis, the yoke 18 and the end arms 27 of another variable length batten 12 via bolt 25b. The yoke 18 is provided with opposing holes 18a for attachment of the rotatable rod 20 via bolts 20b. The rotatable rod 20 is provided with a throughhole 20a, intersecting the pivotal axis of the yoke 18, for pivotally attaching the end brackets 28 of the fixed length longerons 14. The cage 25, the bracket 26, the yoke 18, and the rotatable rod 20 form the joint 16.

The joint 16 pivotally connects two variable length battens 12 about a main pivotal axis. The joint 16 further connects at least two fixed length longerons 14 such that each fixed length longeron 14 has three intersecting axes of rotation. At one end of each fixed length longeron 14 is a revolute joint 19 which allows rotation about the longitudinal axis of the longeron 14.

FIG. 4 is an isometric view of a variable geometry truss with a joint 16 according to a second embodiment of the invention. FIG. 4 is simplified to show only those elements necessary for an understanding of the invention. In the second embodiment of the invention, the variable length battens 12 are provided with motors 32 to allow for automatic lengthening and shortening of the variable length battens 12. The variable length battens 12 are lengthened and shortened by the motor 32 via a standard ball screw mechanism (not shown). It will be recognized by one skilled in the art that other mechanisms may be used, such as pneumatic or hydraulic actuators. It will also be recognized that the invention according to the first embodiment can be automated by replacing the hand crank 22 by an automatic drill-like mechanism. One advantage of using the ball screw mechanism in the variable length batten 12 is that the inner rod 30 is not required to extend through the joint 26, and thus allows the use of a much more compact joint structure.

In the second embodiment, as shown in FIG. 4, the variable geometry truss 10 is only provided with one triangle of variable length battens 12. A pair of fixed end plates 34, upon which various structures can be attached, is provided to form end planes for the variable geometry truss 10. The fixed length longerons 14 are connected to the end plates via joints 38 which provide two degrees of rotational freedom. In this configuration, the fixed length longerons 14 can be attached to the rotatable rod 20 via a fixed-angle bracket 36 which restricts the movement of the fixed length longerons 14 by maintaining a constant angle between them. Due to the limited range of available motion in this configuration, the joint 16 is provided with restriction plates 42 to prevent over-extension of the variable geometry truss.

FIG. 5 is an isometric view of an alternate joint 16, constructed in accordance with the first or second preferred embodiment of the invention. As shown in FIG. 5, the joint 16 is configured to allow for multiple planes of variable length batten triangles by allowing rotation as between the fixed length longerons 14, similar to the first embodiment as shown in FIG. 1. In this configuration, a bracket 45, forming the main pivot joint of joint 16, is provided to rotatably connect the end brackets 26 of two variable length battens 12 with two yokes 18 via a common center pin 44. Each yoke holds a rotatable rod 20, via bolt 48, whose axis of rotation is perpendicular to and intersects with the centerline of center pin 44. The fixed length longerons 14 are rotatably connected to the rotatable rod 20 via a bolt 50 whose axis of rotation intersects the axis of rotation of center pin 44. For use in the second embodiment, a restriction plate 42 is attached to adjacent yokes 18 to cause the variable length battens 12 to rotate simultaneously about the center pin 44. This in turn causes the battens 12 in the adjacent batten planes to become fixed length battens of equal length.

As can be seen in FIG. 5, the variable length battens 12 are driven by a motor 32 via a belt 52. The motor 32 is held in place via a bracket 54. The variable length battens 12 are provided with an expansion joint 46 which protects the gap between the inner rod 30 (not shown) and the outer rod 29, allowing for deployment in environmentally hostile situations.

FIG. 6 is a lateral partial cross-sectional side view of the joint 16 in accordance with Fig. 5. An axis of rotation 56 of the common centerpin 44 lies perpendicular to and intersects with an axis of rotation 58 of the rotatable rod 20 (not shown). Because the variable length battens 12 are activated via motors 32, the joint 16 is compactly designed using easily machined parts.

The use of motors 32 to automatically adjust the length of the variable length battens 12 enables the use of remote controllers for deployment in environmentally hostile situations. The remote controllers can be embodied in computerized controls that automatically adjust the relationship between the end planes of the variable geometry truss 10.

In all of the embodiments of the joint 16 for the variable geometry truss 10, according to the preferred embodiments of the invention described above, the variable length battens 12 and the fixed length longerons 14 share a common axis of rotation 56. Further, the axis of any other degree of rotational freedom provided to the fixed length longerons 14 preferably intersects at the same point on the common axis of rotation 56. This common axis of rotation 56 is provided by the structure of joint 16. While two specific embodiments have been described, it will be recognized by one skilled in the art that other configurations can be used. Specifically, any joint that provides rotations about two axes, just as if there were an actual two-axis gimbal operating at the joint, can be used. The embodiments of the invention provide a single joint for variable geometry truss that can be retracted compactly for storage and transportation, and has excellent structural stability during and after deployment, while displaying great dexterity.

Numerous modifications and adaptations of the present invention will be apparent to those skilled in the art. Thus, the following claims and their equivalents are intended to cover all such modifications and adaptations which fall within the true spirit and the scope of the present invention.

What is claimed is:

Abstract of the Disclosure

A joint and a method of constructing a joint for a variable geometry truss having a variable number of planes of variable length battens connected together in a triangular configuration, each plane being connected by six fixed length longerons in a Stewart platform configuration. The variable length battens allow the orientation of one end plane of the variable geometry truss to be changed to the other end plane in a controlled manner by selectively adjusting the lengths of the variable length battens. A main pivot joint pivotally connects two battens about a pivotal axis. A universal joint is pivotally connected to the main joint such that the pivotal axis of the universal joint is coextensive with the pivotal axis at the main joint. Two longerons are pivotally connected to the universal joint. Each longeron is thereby provided with three intersecting axis of rotation. Each longeron may include a revolute joint, allowing rotation about the longitudinal axis of the longeron.

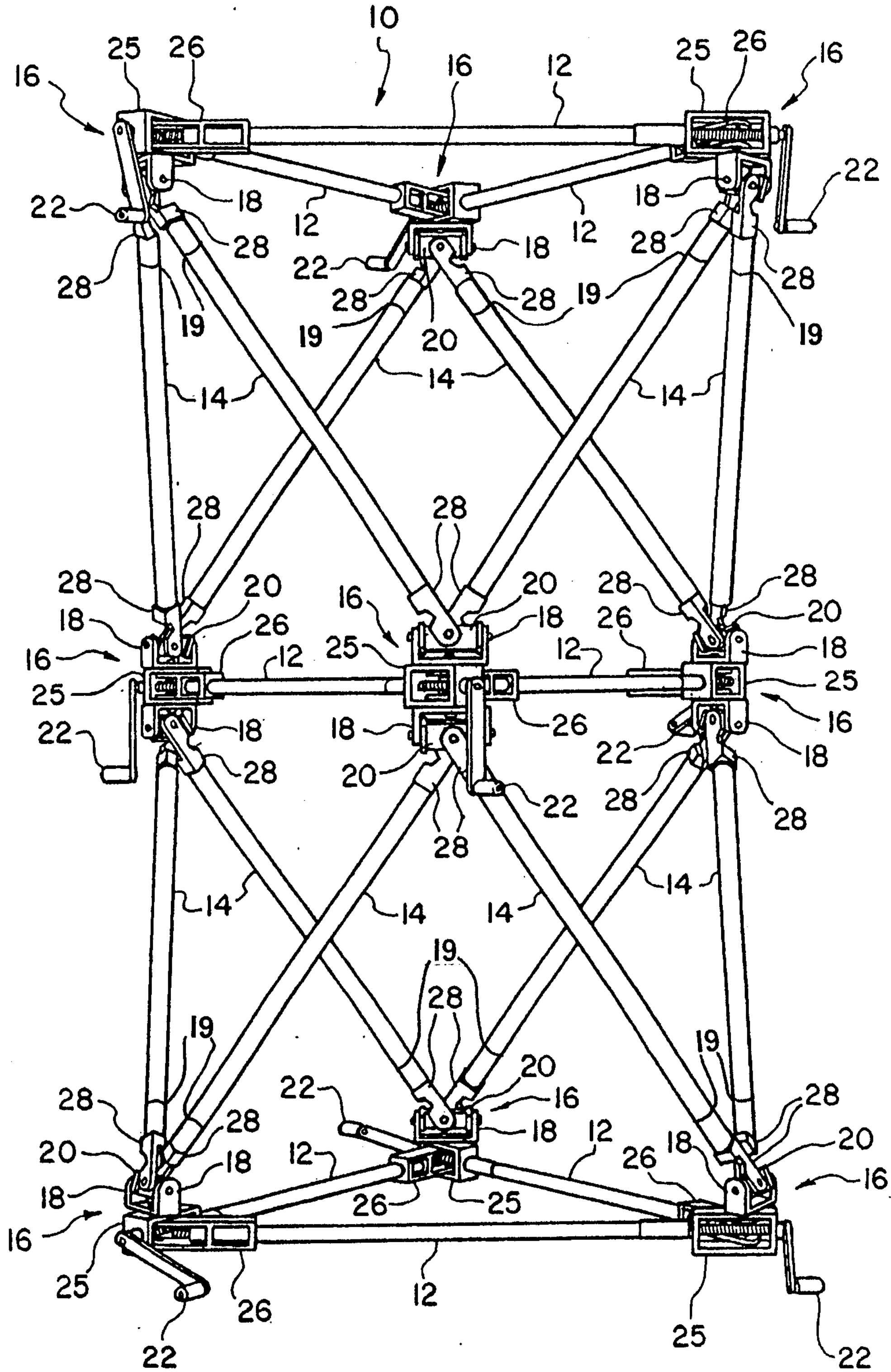

FIG. 1

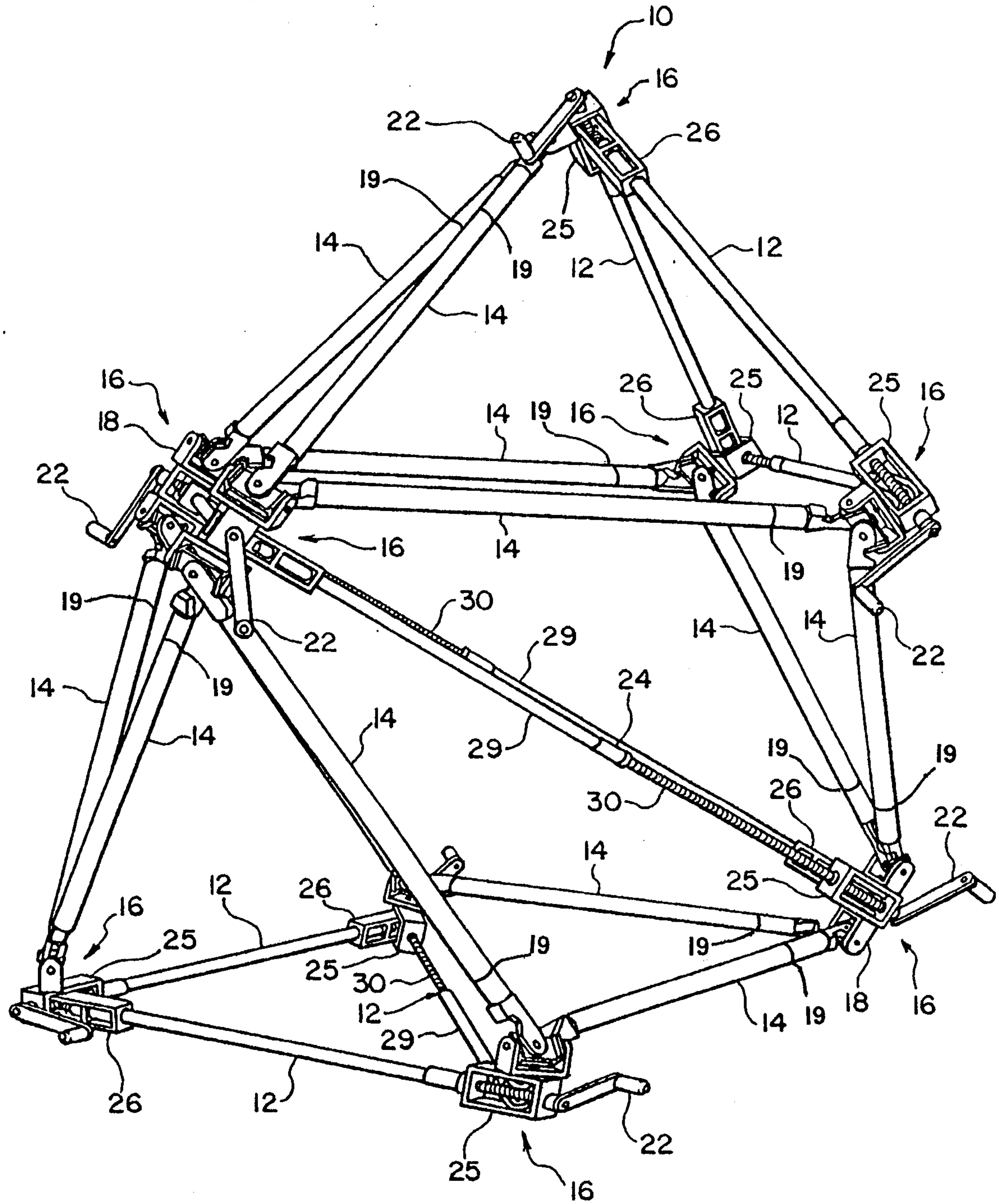

FIG. 2

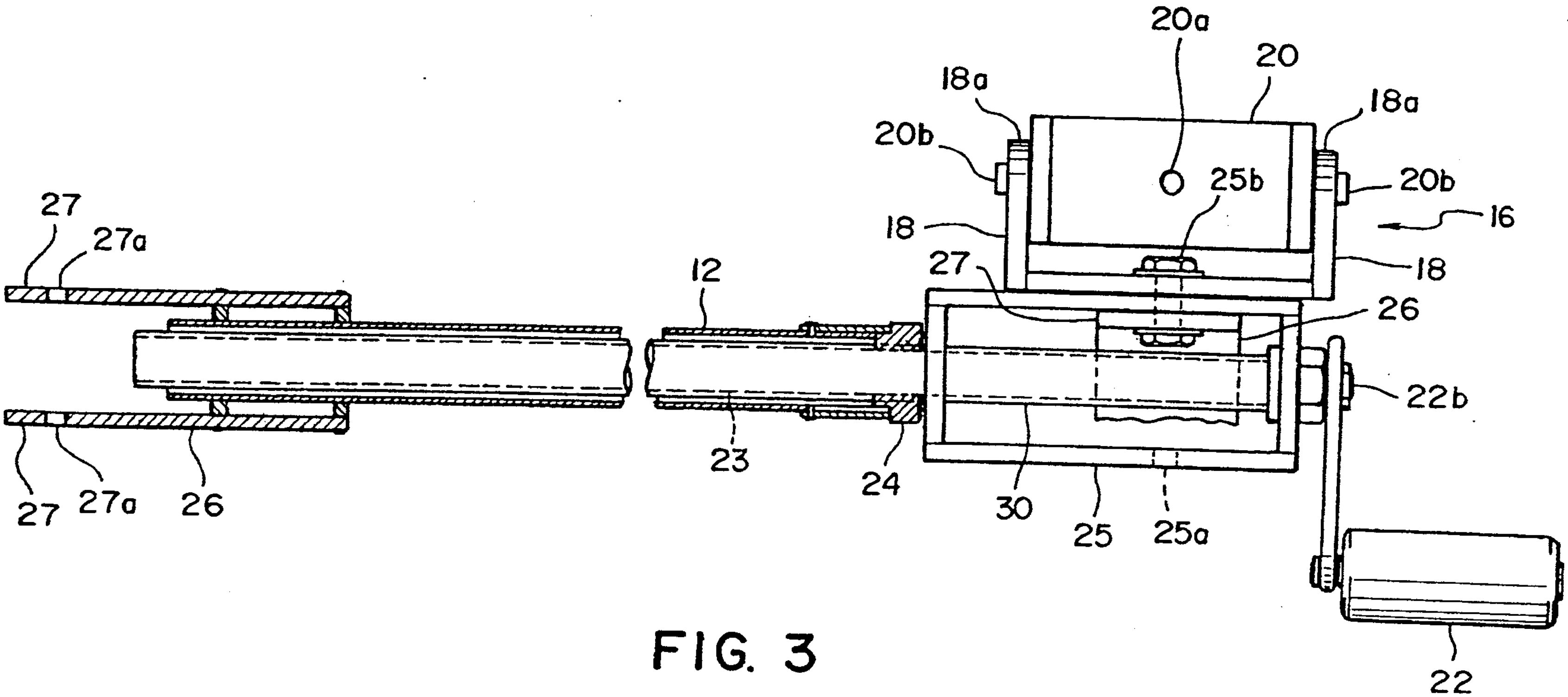

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FIG. 3

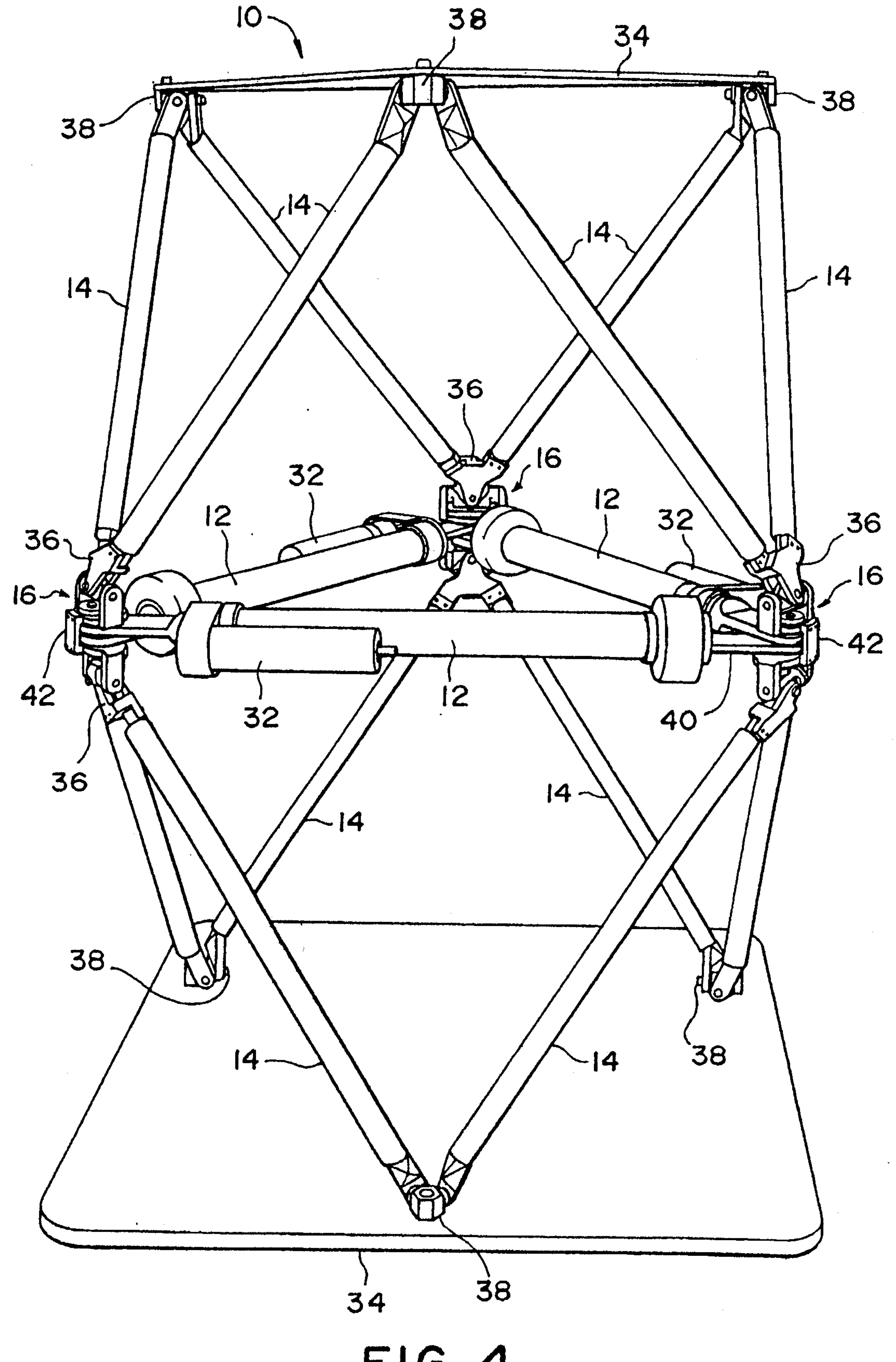
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FIG. 4

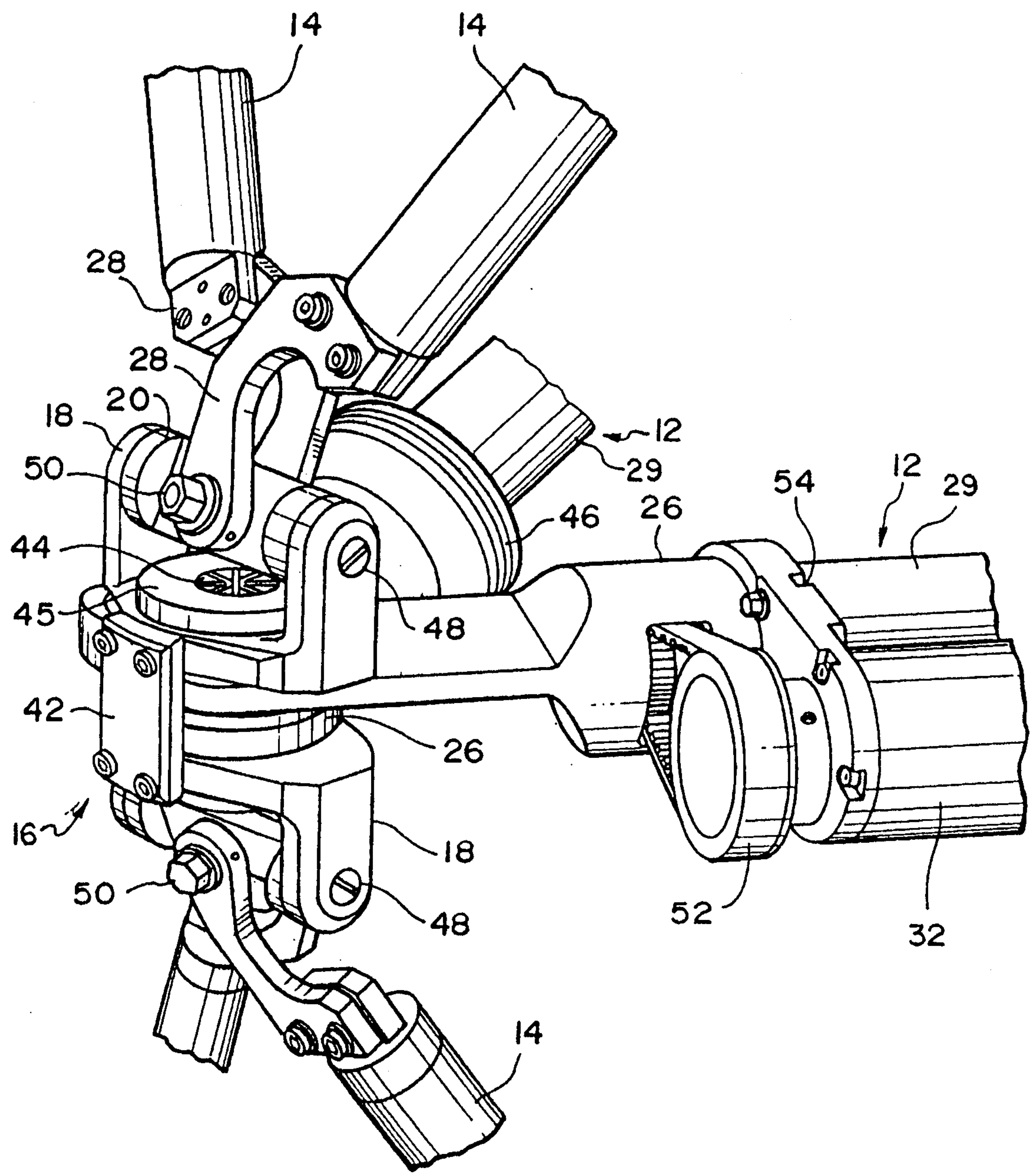
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FIG. 5

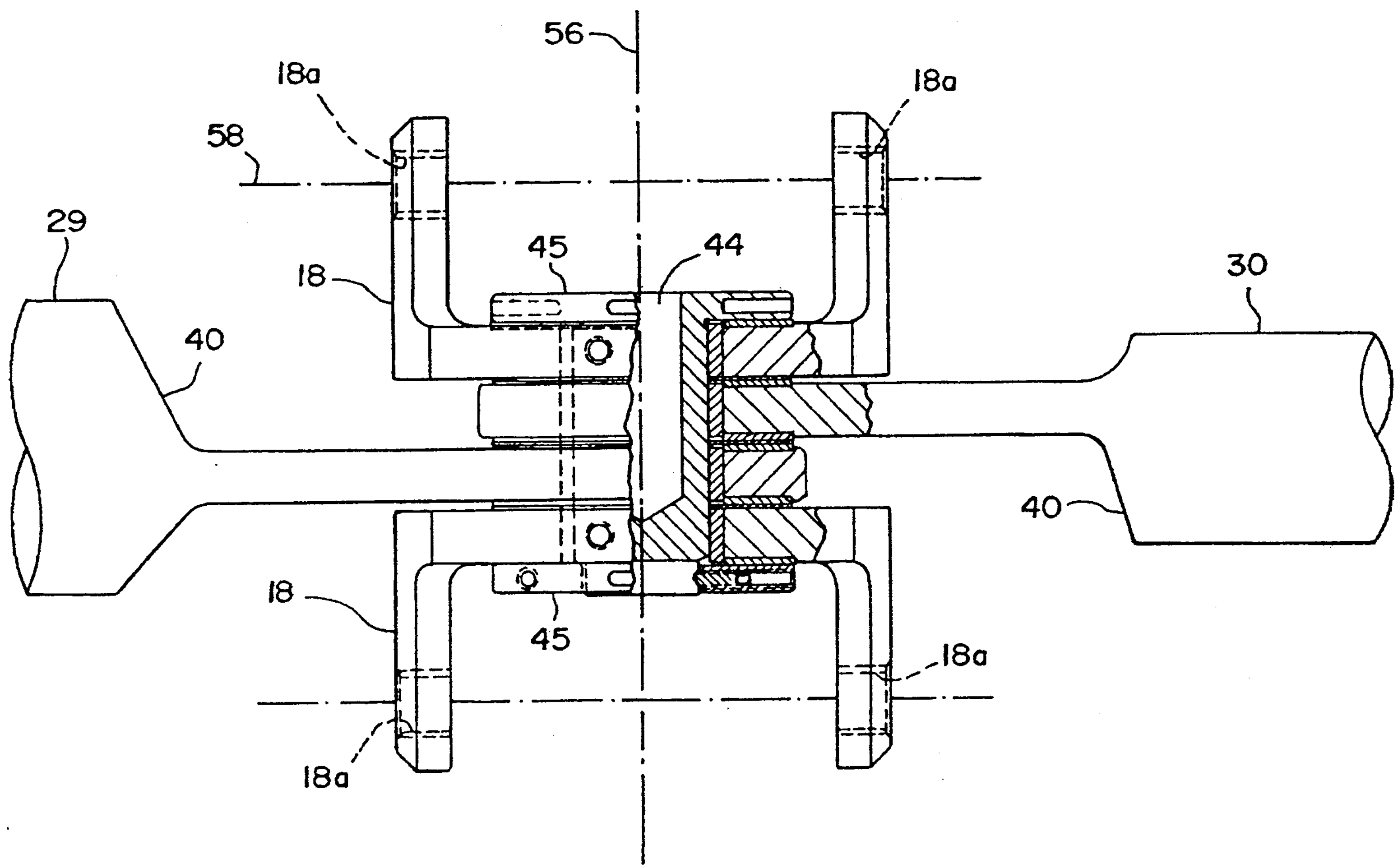

FIG. 6