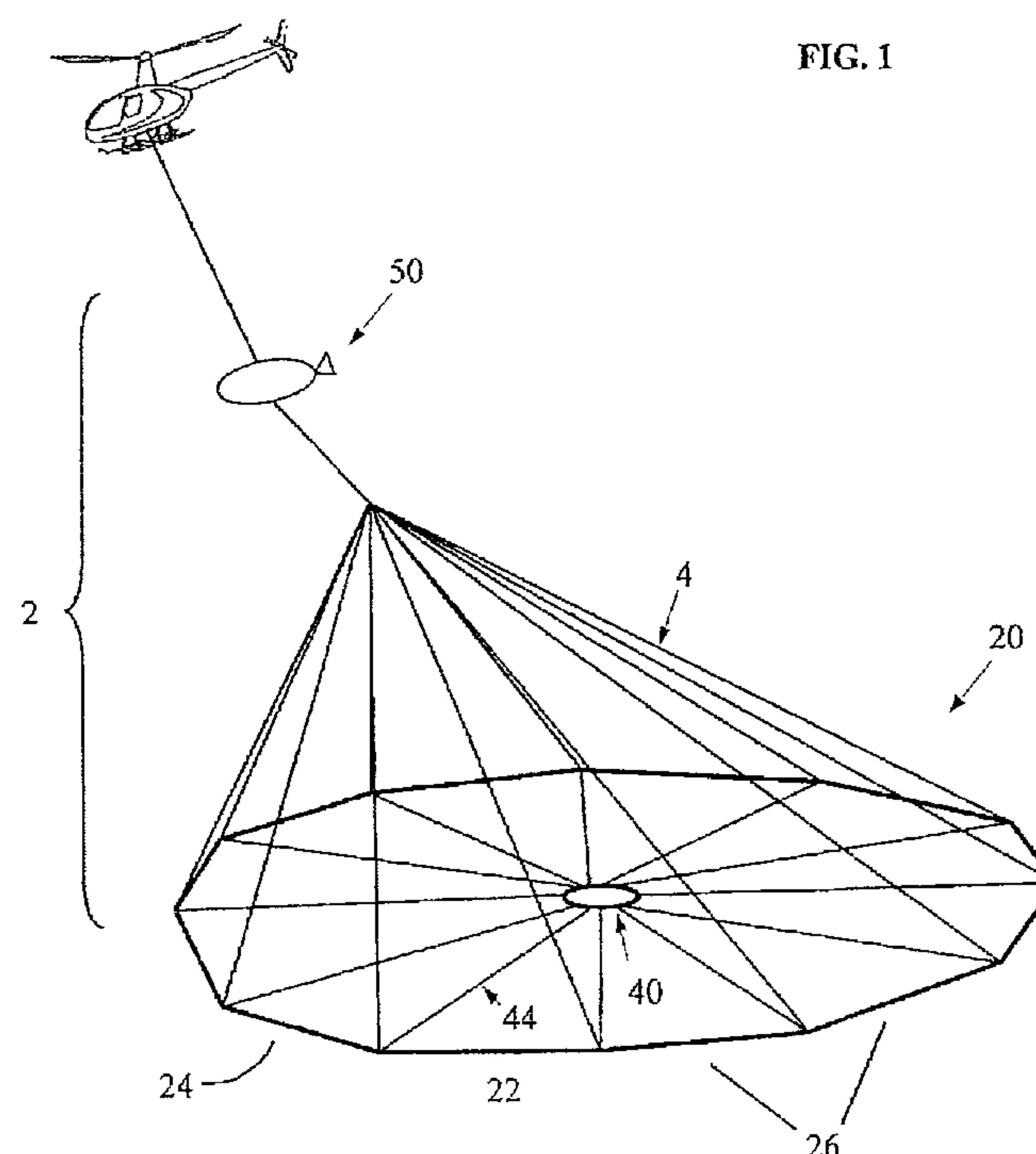




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(54) Title: AIRBORNE ELECTROMAGNETIC SYSTEM WITH RIGID LOOP STRUCTURE COMPRISED OF
LIGHTWEIGHT MODULAR NON-ROTATIONAL FRAMES



(57) **Abrégé/Abstract:**

The present invention provides a light weight, modular and rigid structure for supporting the transmitter loop of an airborne electromagnetic system. The airborne electromagnetic surveying system comprises a tow assembly connected to an aircraft, the tow assembly including a transmitter section comprising a transmitter coil for generating a primary electromagnetic field that induces a secondary electromagnetic field. The transmitter coil is supported by a generally rigid transmitter frame. The transmitter frame comprises a plurality of frame sections assembled in a way such that the generally rigid transmitter frame substantially retains a rigid shape during operation. The system may also include a receiver section located above the generally rigid transmitter frame in between the aircraft and the generally rigid transmitter frame for detecting the secondary electromagnetic field.



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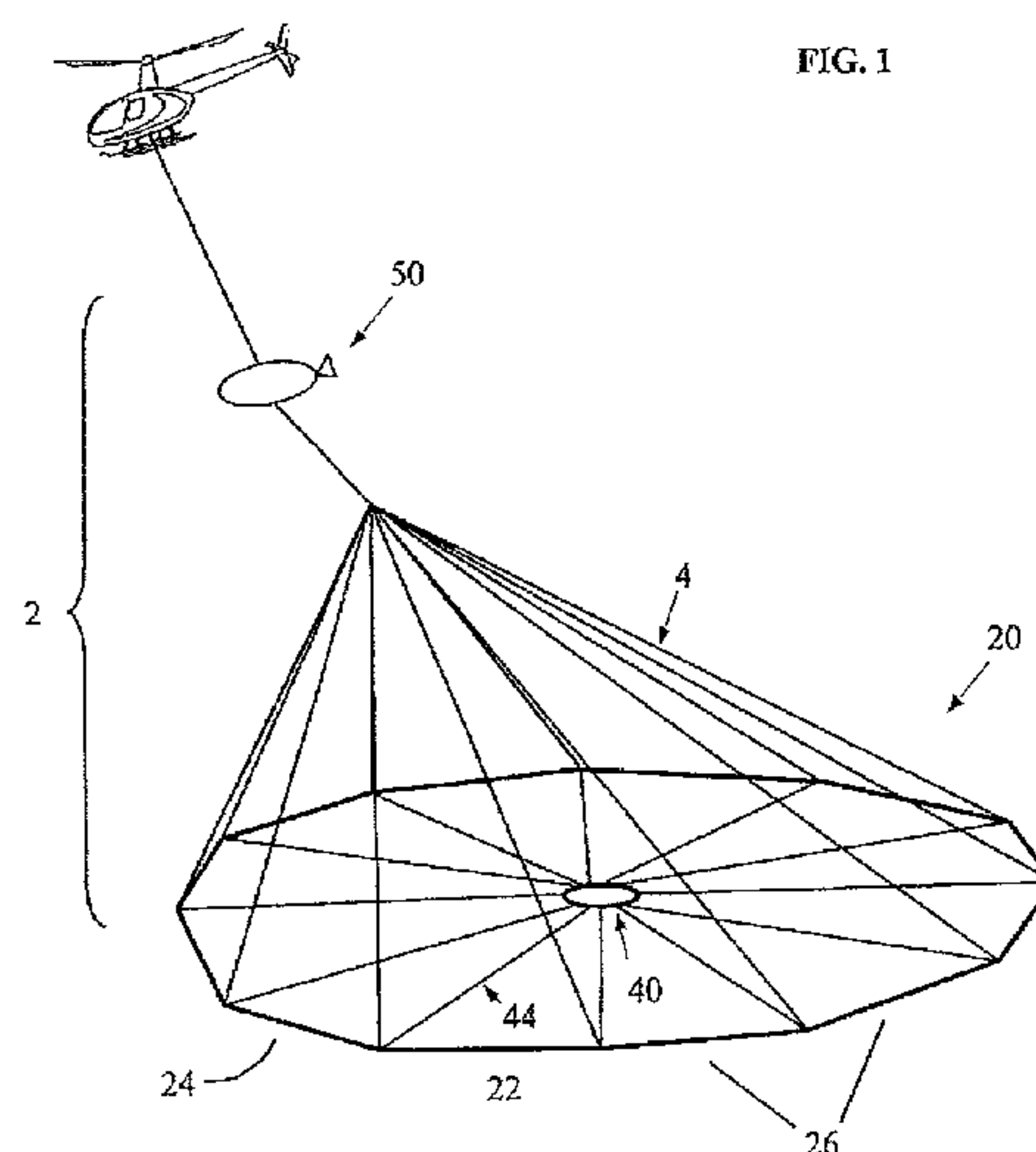
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(54) Title: AIRBORNE ELECTROMAGNETIC SYSTEM WITH RIGID LOOP STRUCTURE COMPRISED OF LIGHTWEIGHT MODULAR NON-ROTATIONAL FRAMES



(57) Abstract: The present invention provides a light weight, modular and rigid structure for supporting the transmitter loop of an airborne electromagnetic system. The airborne electromagnetic surveying system comprises a tow assembly connected to an aircraft, the tow assembly including a transmitter section comprising a transmitter coil for generating a primary electromagnetic field that induces a secondary electromagnetic field. The transmitter coil is supported by a generally rigid transmitter frame. The transmitter frame comprises a plurality of frame sections assembled in a way such that the generally rigid transmitter frame substantially retains a rigid shape during operation. The system may also include a receiver section located above the generally rigid transmitter frame in between the aircraft and the generally rigid transmitter frame for detecting the secondary electromagnetic field.

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AIRBORNE ELECTROMAGNETIC SYSTEM WITH RIGID LOOP STRUCTURE COMPRISED OF LIGHTWEIGHT MODULAR NON-ROTATIONAL FRAMES

5 FIELD OF THE INVENTION

The present invention relates generally to an airborne electromagnetic system with rigid loop structure in geological mapping and surveying.

10 BACKGROUND OF THE INVENTION

Various systems using electromagnetic ("EM") techniques have been known in the field of airborne subsurface geophysical surveying.

15 EM systems may come in various shapes and sizes, but they generally involve a source of electromagnetic energy (transmitter) and a receiver to detect the response of the ground. Generally speaking, geophysical EM methods involve the generation of a magnetic field by applying a periodic current to a transmitter coil system placed near the surface of the earth. This primary magnetic field induces electrical currents in the ground, and the secondary magnetic
20 field produced by these currents is measured to provide information regarding ground conductivity distributions. By processing and interpreting the received signals, it is possible to make deduction about the distribution of conductivity in the subsurface.

A single or multi-turn loop is generally used as the transmitter element of EM systems. A time
25 varying current passing through the loop can be used to create a time varying magnetic field. One or more receiver coils may be used to measure the response along perpendicular axes.

EM measurements can be done either in frequency domain or time domain. A frequency domain (FD) EM system transmits a magnetic field signal at a single frequency with sinusoidal variation

in amplitude. The response can either be described by its total amplitude and phase with respect to the transmitter signal or by the amplitudes of components in-phase (“in-phase”) and 90° out of phase (“quadrature”) with respect to the transmitter signal. In time-domain (TD) EM systems, a pulse of current may be applied to the transmitter coil during an on-period, generating the primary or transmitted EM field, and then switched off during an off period. The secondary signal may be measured at the receiver coil as a function of time. The signal amplitude decay during the off-period, combined with modeling of the conductivity and geometry of geological bodies in the ground, may be utilized to provide conductivity contour maps.

10 EM methods can encompass both ground-based and airborne applications using airplanes and helicopters, etc.

In designing a helicopter mounted TDEM system, there are a number of desired features, for example, *inter alia*, high signal-to-noise ratio, high conductance discrimination, and high spatial resolution.

High signal-to-noise ratio can be accomplished by lowering system noise, and/or increasing the signal at the receiver coil. One method of increasing the signal is to increase the primary magnetic field. Stronger transmitter signal power, which can be generally obtained by using transmitter loops with large diameters, also assists in obtaining increased signal-to-noise ratio and greater penetration. One method of reducing or limiting noise is to reduce as much as possible the movement of the receiver relative to the transmitter. For example, rigid structures can be used to support and connect the transmitter and the receiver of an EM system.

25 In practice, however, the expected benefit of using a large transmitter loop can be difficult to obtain due to the non-rigidity or over-flexibility of the large transmitter loop structure, which distorts the shape of the transmitter loop during flight and the resulting primary magnetic field during airborne operation which in turn resulting in increased system noise. Therefore, the

stabilization of the transmitter loop will provide less distortion of the receiver itself and better signal-to-noise ratio.

5 The increased weight and size associated with a large transmitter loop also impose mechanical challenges that impede the speed, reduce aerodynamics, and increase drag.

At the same time, using rigid structures existing in the prior art to couple the transmitter and the receiver, however, will increase the weight of the EM system, and therefore resulting in a heavy weight structure and increase the cost of survey operations. For example, it will be a mechanical
10 challenge and may not be economical or practical for a helicopter to tow a transmitter weighing over 500 kg.

As a result, existing EM systems have not been able to satisfactorily take advantage of large transmitter loops. For example, AeroTEM IITM system is an airborne EM system having a rigid
15 transmitter loop and a receiving coil that is mounted at the center of the transmitting loop. The transmitter and the receiver of the AeroTEM IITM system are supported and connected to each other using heavy rigid structures which limit its transmitter loop diameter to about 5 meter in order to have a manageable overall weight of the structure and not exceed tow capacity.

20 Another existing EM system described in Canadian Patent Application No. 2,702,346 proposed a large transmitter loop, where the polygonal receiver coil sits at the centre of the transmitter coil frame. However, the proposed transmitter loop has multiple “articulating joints” and is very flexible as it allows rotation of the frames relative to each other at the “articling joints” and as a result the structure can bend at a plurality of locations about a circumference of the transmitter
25 loop. Therefore, none of these prior art EM systems provide a transmitter loop the size of which can be easily increased while maintaining the overall stability of the loop.

Therefore, there remains a need for an airborne EM system having a rigid supported transmitter loop that will maintain its stability as the size of the transmitter loop varies.

SUMMARY OF THE INVENTION

5 The present invention overcomes the above drawbacks of the prior art EM systems by providing a modular, light weight and rigid structure for supporting the transmitter loop of an airborne EM system.

10 In accordance with one aspect of the present invention, there is provided an airborne electromagnetic surveying system comprising: (a) a tow assembly connected to an aircraft, the tow assembly further comprising (i) a transmitter section comprising: a transmitter means for generating a primary electromagnetic field that induces a secondary electromagnetic field, a generally rigid transmitter frame for supporting the transmitter means, the transmitter frame comprising a plurality of fixedly connected frame sections assembled in a way such that the generally rigid transmitter frame substantially retains its shape during operation; and (ii) a receiver section for detecting the secondary electromagnetic field.

20 In accordance with another aspect of the present invention, there is provided a transmitter section for an airborne electromagnetic survey system, comprising: a transmitter means, and a generally rigid transmitter frame for supporting the transmitter means, the transmitter frame comprising a plurality of fixedly connected frame sections assembled in a way such that the generally rigid transmitter frame substantially retains its shape during operation.

25 In accordance with another aspect of the present invention, there is provided a tow assembly for an airborne electromagnetic surveying system, comprising: means for suspending a transmitter section from an aircraft, the transmitter section comprising: a transmitter means, and a generally rigid transmitter frame for supporting the transmitter means, the transmitter frame comprising a plurality of fixedly connected frame sections assembled in a way such that the generally rigid transmitter frame substantially retains its shape during operation.

Other features and advantages of the present invention will become apparent from the following detailed description and the accompanying drawings, which illustrate, by way of example, the principles of the invention.

5 **BRIEF DESCRIPTION OF THE DRAWINGS**

The invention will now be described by way of reference to the drawings, in which:

10 Figure 1 is a schematic perspective view of an embodiment of the airborne EM system in an airborne position flying at surveying speeds;

Figure 2 is a perspective view of a frame section of the transmitter frame according to an embodiment of the airborne EM system;

15 Figure 3 is an exploded view of two disassembled frame sections and a fastening means according to an embodiment of the airborne EM system;

Figure 4 is a perspective view of two frame sections assembled by a fastening means according to an embodiment of the airborne EM system;

20 Figure 5 is a perspective view of two disassembled frame sections according to an embodiment of the airborne EM system;

25 Figure 6 is a perspective view of two assembled frame sections according to an embodiment of the airborne EM system;

Figure 7 is a perspective view of two frame sections assembled by an interlock according to an embodiment of the airborne EM system;

Figure 8 is a perspective view of two frame sections assembled by an interlock according to an embodiment of the airborne EM system;

Figure 9 is a cross sectional view of two frame sections assembled by an interlock according to an embodiment of the airborne EM system; and

Figure 10 is a perspective view of two frame sections assembled by an interlock according to an embodiment of the airborne EM system.

10 DETAILED DESCRIPTION OF THE INVENTION

Referring to Figure 1, an example embodiment of the airborne electromagnetic surveying system described herein comprises a tow assembly **2** attached to an aircraft. The tow assembly **2** may comprise a transmitter section **20** and a receiver section **50**.

15

The transmitter section **20** is a part of the EM system that generally includes one or more components associated with the task of generating a source electromagnetic field. In this regard, the transmitter section **20** comprises a transmitter means for generating a primary electromagnetic field that induces a secondary electromagnetic field in the ground. Various transmitter means may be used, for example, transmitter loop coils or loop wires **22**. The transmitter loop coil **22** may take various shapes and sizes depending on the particulars of the surveys engaged in. While Figure 1 illustrates a multi-turn polygonal transmitter loop coil **22** as an example, it is understood by a person skilled in the art that similar structure, for example, circular coil or coil of other shape can also be used.

25

The transmitter section **20** may further comprise a “generally rigid” transmitter frame **24** for supporting the transmitter coil **22**. The loop structure or transmitter frame is “generally rigid” in the sense that the loop structure is rigid, other than the mechanical flex caused by the weight of the components, as opposed to flex caused by the rotation between the frame members.

Preferably, the transmitter frame **24** comprises a tubular portion or an enclosure that internally houses the transmitter coil **22**. In Figure 1, the transmitter coil **22** is enclosed within the transmitter frame **24** and therefore is not directly visible. Alternatively, the transmitter coil **22** can be mounted to the transmitter frame **24** or supported thereon in any manner that is known in the art.

The transmitter frame **24** is modular and comprises a plurality of fixedly connected frame sections **26**, forming a substantially circular or polygonal loop. This allows the shape of the transmitter frame **24** to be easily configured for supporting transmitter coils **22** with various shapes. In addition, the modularity of the transmitter frame **24** allows for easy adjustment of the size of the transmitter frame to accommodate or support transmitter coils **22** of various sizes.

Preferably, the plurality of frame sections **26** are serially and fixedly connected one to another forming a transmitter loop frame **24** as illustrated in Figure 1. However, in some embodiments according to the present disclosure, the transmitter coil **22** may not be planar and may comprise a 3-dimensional transmitter (such as a cube) generating primary electromagnetic fields in multiple directions. For example, such multi-direction transmission may be used in prospecting along the sides of hills and/or the floor of valleys. As such, in some embodiments, the transmitter loop frame **24** may be non-planar.

Each frame section **26** is made of generally rigid materials. For example, materials such as carbon fiber reinforced plastic, carbon fiber reinforced polymer, unplasticized polyvinyl chloride (uPVC), wood/plastic composite, or any other composite or materials that provide strong rigidity, stability and resistance to deformation, can be used to construct frame sections **26** or portions thereof. Preferably, lightweight materials are used for constructing frame sections **26** or transmitter frame **24** to allow for constructing sizable transmitter frame without significantly increasing the weight thereof.

Advantageously, using rigid materials constructing the transmitter frame **24** allows its size to be increased while maintaining its overall stability and structural integrity.

In comparison, if semi-rigid or flexible materials are used, or that when flexible or rotating joints are engaged, the transmitter frame may become overly-flexible as the size increases due to the increased weight of the frame. The undesirable floppiness or flexibility would result in the distortion of the shape of the transmitter loop during flight and would frustrate the goal of achieving low system noise.

10 In order to provide a generally rigid transmitter frame **24** which minimizes structure distortion during flight, the frame sections **26** are fixedly connected in a manner that substantially eliminates the relative rotation between the connected frame sections **26**, thereby allowing the transmitter frame **24** to retain its shape during operation, or preventing distortion of the shape of the transmitter frame **24**. Various connecting means are provided in accordance with the
15 example embodiments of present invention described herein.

Referring to Figures 2 to 4, a frame section **26** comprises a substantially elongated section **28** and at least one connecting section **30** disposed at the ends of the elongated section **28**.

20 In some embodiments, a connecting section **30** is disposed at each of the ends of the elongated section **28**. The elongated sections **28**, when connected using connecting sections **30**, collectively define a perimeter of the transmitter frame **24** and therefore substantially define the shape and size of transmitter frame **24**.

25 The connecting sections **30** are used to provide modular assembling and disassembling of the transmitter frame **24** and to provide suspension or connection locations for other components of the tow assembly **2**. For example, as shown in Figures 1 and 2, connector means **42** (for example, tow rings) can be mounted around connecting sections **30** for towing the transmitter

frame 24 using tow ropes 4, or for connecting the transmitter driver 40 using cross connecting means such as ropes 44.

5 Preferably, the elongated section 28 and the connecting section 30 are constructed using the same or similar rigid materials for constructing the frame section 26. They can also be constructed using different types of rigid materials noted above to provide alternative overall weight and strength/rigidity balancing of the transmitter frame 24.

10 Different types of frame sections are provided in the embodiment illustrated in Figures 2 to 4. Some frame sections 26 may include at least one connecting section 30 that is constructed as an extension extending from one end of the elongated section 28 and along the length of the elongated section 28. In this type of frame sections 26, the elongated section 28 and the connecting section 30 are substantially co-axial.

15 Other embodiments of frame sections include, for example, at least one connecting section 30 extending from one end of the elongated section 28 and being offset from the length of the elongated section 28. In this type of frame sections 26, the elongated section 28 and the connecting section 30 are angularly disposed forming an elbow around the connecting section 30.

20 Still further, other embodiments of frame sections 26 may comprise at least one non-extruding receiving end 32 that can receive a corresponding extruding connecting section 30.

25 A plurality of the frame sections as described herein can be serially and fixedly connected to form longer, combined frame sections 26 and/or a larger transmitter frame 24. Serial connection can be achieved by inserting a connecting section 30 of a first frame section 26 into a corresponding receiving end 32 of a second frame section 26. The cross-sections of the connecting sections 30 and the receiving ends 32 preferably are constructed so that they fit tightly with each other with substantially no observable relative movement therebetween.

Alternatively, frame sections **26** can be connected by fixedly coupling the connecting sections **30** and/or the receiving ends **32** of the frame sections **26**. For example, the connecting sections **30** and/or the receiving ends **32** may be further coupled by screws.

5 Referring to Figures 5 and 6 and according to one embodiment of the airborne electromagnetic surveying system described herein, the transmitter frame **24** comprises at least one coupling portion **31** for assembling at least two adjacent frame sections **26** such that the shape of transmitter frame **24** is substantially free from distortion being bent during flight operations. For example, a coupling portion **31** comprises a first annular flange **34a** disposed on a first frame
10 section **26** and a second annular flange **34b** disposed on a second frame section **26**. The first flange **34a** is disposed near a connecting section **30** of the first frame section **26**, and the second flange **34b** is disposed on a receiving end **32** of the second frame section **26**, such that when the first and second frame sections **26** are connected, at least a portion of the first flange **34a** is operable to be rigidly or fixedly coupled to at least a portion of the second flange **34b** thereby
15 assembling the first and second frame sections **26** in a way such that there is substantially no relative rotation between the connected frame sections **26**, and that the transmitter frame **24** substantially retains a rigid shape during operation. As shown in Figures 5 and 6, flanges **34a** and **34b** can be coupled using screws, nuts/washers or other fastening devices. Preferably, the flanges **34a** and **34b** are constructed using the same or similar rigid materials as those used for
20 the frame sections **26**.

In one embodiment, to enhance the rigidity of frame sections **26** or transmitter frame **24**, fastening means **36** are applied at the receiving ends **32** and the connecting sections **30** to rigidly or fixedly couple the connected frame sections **26**. Using fastening means **36** ensures a rigid or
25 fixed coupling between frame sections, thus minimizing joint rotation— or rotations between the connected frame sections **26** during take-off, landing, or survey operation.

Referring to Figures 3 and 4, clamps are used to substantially eliminate or minimize relative movements between the connecting sections **30** and the receiving ends **32** of the frame sections **26**.

- 5 While not explicitly shown in the Figures, other fastening means can be used to achieve the rigid or fixed coupling between frame sections. For example, brackets, fasteners, rivets, screws, nuts/washers, clips, bolts, pins, locks, joints, and other rigid connection means may be used to enhance the overall rigidity of the transmitter frame **24**. Preferably, the fastening means **36** are constructed using rigid and strong materials such as steels, metals or alloys.

10

- Referring to Figures 7 and 8 and according to one embodiment of the airborne electromagnetic surveying system described herein, the transmitter frame **24** comprises at least one interlock **37** for interlocking a plurality of adjacent frame sections **26**. For example, at least two frame sections **26** may each comprise an interlocking member such that when the at least two frame sections **26** are connected, the interlocking members engage with each other to substantially eliminate relative movements or rotations between the connected frame sections **26**.

15

- In one embodiment, an interlock comprises at least one tab **38** disposed on a first frame section **26** and at least one slot **39** located on a second frame section **26**, wherein when in a locking position the at least one tab **38** of the first frame section **26** extends into the at least one slot **39** of the second frame section **26**. Such interlocking engagement between tabs **38** and slots **39** of frame sections **26** substantially eliminates or minimizes relative movements or rotations between the connected frame sections **26**.

20

- 25 Preferably, the shape of a tab **38** substantially matches the shape defined by the corresponding slot **39**.

Preferably, the interlocks are constructed using the same or similar rigid materials as those used for the frame sections **26**.

Preferably, tabs **38** or slots **39** are disposed in proximity to the connecting section **30** or receiving end **32** of the frame section **26** such that the frame section **26** is interlocked with an adjacent frame section **26** while being serially connected thereto.

5

In the embodiment shown in Figure 7, the interlock **37** comprises a pair of interlocking bands **37a** and **37b** rigidly fixed to the frame sections **26** and disposed near the connecting section **30** of the first frame section **26** and the receiving end **32** of the second frame section **26** respectively. When two adjacent frame sections **26** are connected, the at least one tab **38** extends into the at least one slot **39** so that bands **37a** and **37b** are interlocked with each other thereby minimizing relative movement and rotation between the frame sections **26**.

10

In the embodiment shown in Figure 8, the interlock **37** comprises at least one tab **38** extending from a first frame section **26** and at least one slot **39** formed on a second frame section **26**. The at least one tab **38** is disposed near a connecting section **30** of the first frame section **26**, and the at least one slot **39** is formed on a receiving end **32** of the second frame section **26**, such that when the first and the second frame sections **26** are serially connected, the at least one tab **38** can extend into the at least one slot **39** thereby interlocking the first and second frame sections **26** and minimizing relative movement and rotation between the frame sections **26**.

15

20

Alternatively, as shown by the cross-sections of the connected frame sections **26** in Figure 9, one or more tabs **38** may take the form of one or more longitudinal ribs extending along the length of the connecting section **30** of the first frame section **26** or a portion thereof; whereas one or more slots **39** may take the form of one or more corresponding grooves inside the receiving end **32** of the second frame section **26** and extending along the length of the receiving end **32** of the second frame section **26** or a portion thereof, wherein when the connecting section **30** is inserted into the receiving end **32**, the one or more tabs **38** extend into one or more slots **39** thereby interlocking the connected first and second frame sections **26**.

25

Other interlocking devices that can be used include but are not limited to: projection/cavity, screws, latches, and any other similar apparatus.

Furthermore, the mechanism for eliminating relative movement and rotation between adjacent
5 frame sections **26** described herein can be provided by frictionally engaged structures or means.

For example, in one embodiment shown in Figure 10, an interlock **37** comprises a first member
37a disposed on a first frame section **26** and a second member **37b** disposed on a second frame
section **26** that is adjacent to the first frame section **26**. The first member **37a** is disposed near a
10 connecting section **30** of the first frame section **26**, and the second member **37b** is disposed on a
receiving end **32** of the second frame section **26**, such that when the first and the second frame
sections **26** are serially connected, at least a portion of the first member **37a** frictionally engages
with at least a portion of the second member **37b** thereby interlocking the first and second frame
sections **26** and minimizing relative movement and rotation between the first and second frame
15 sections **26**.

According to one embodiment illustrated in Figure 10, the first member **37a** comprises a first
slanted portion **38** disposed near a connecting section **30** of the first frame section **26**, and the
second member **37b** comprises a second slanted portion **39** extending from a receiving end **32** of
20 the second frame section **26**, such that when the first and the second frame sections **26** are
serially connected, at least a portion of the first slanted portion **38** frictionally engages with at
least a portion of the second slanted portion **39** thereby minimizing relative movement and
rotation between the first and the second frame sections **26**.

25 Advantageously, the interlocking mechanism described herein may substantially minimize
relative movements and rotations between the connected frame sections **26**. This in turn
improves the planar rigidity and stability, and thereby minimizes the distortion of the shape of
the transmitter frame **24** as the size of the transmitter frame **24** increases.

The generally rigid, light weight and modular transmitter frame described herein therefore provides stable support for large transmitter loop and will maintain its rigidity and stability as the size of the transmitter loop varies. As the fastening means **36** are used only at a limited number of locations around the connecting sections **30** of the transmitter frame **24**, the added weight of the fastening means are negligible in practice. Using the generally rigid transmitter frame described above, transmitter loop having diameter in excess of about 30 meters with a manageable overall weight of the structure not exceeding tow capacity can be achieved. Therefore, the rigid transmitter frame **24** significantly improves the mechanical agility of the tow assembly **2** of the airborne EM system.

Another advantage of the rigid transmitter frame **24** is that the load bearing capability around the connecting sections **30** can be enhanced by the fastening means **36**. As such, it is now possible to support the transmitter platform including the transmitter driver **40** using the rigid transmitter frame **24**.

In one embodiment, the transmitter driver **40** is located centrally at or centrally above the transmitter loop and is connected to the transmitter frame **24** using cross ropes **44** coupled at a plurality of connecting sections **30** along the transmitter frame **24**. This frees up the real estate in the aircraft that usually is taken to house the transmitter driver **40**.

In addition, in contrast with those prior art EM systems where the receiver is located at the center of the transmitter loop, the receiver section **50** of the present invention can be spaced away from the transmitter section **20**, thus further improves the signal-to-noise ratio of the airborne EM system.

The receiver section **50** generally comprises one or more receivers and associated support structures for mounting the receivers. A receiver generally comprises at least one receiver coil of any kind that is suitable for sensing the secondary fields induced in the subsurface of the ground.

The transmitter section **20** and receiver section **50** may cooperate with each other during flight in any suitable configuration. For example, they can be configured to cooperate in a spaced apart relationship. Depending on the surveying tasks, system load capacity, and the availability of operating space, they can also be deployed in relatively close proximity, or substantially co-located or supported by common supporting means.

Preferably, the receiver section **50** is positioned above or below the transmitter section **20**, and is offset from the center of the transmitter section **20**. However, it is to be understood that the spacing between the transmitter section **20** and the receiver section **50** can also be maintained by a concentric configuration, or in a coplanar fashion. For example, in one embodiment, the receiver section **50** is positioned above the generally rigid transmitter frame **24** and in between the aircraft and the transmitter frame **24**.

In one embodiment, the receiver section **50** is located at the center of the transmitter frame **24**. The transmitter driver **40** can be co-located with the receiver section **50** or can be placed at a different location. In case the receiver section **50** and the transmitter driver **40** are both located at the center of the transmitter loop, it is preferable that a transmitter platform rope is used to support the transmitter driver **40** from the tow assembly **4** to maintain the planar stability of the transmitter loop.

In some embodiments, flexible means, such as tow ropes, tension cables can be used to connect the transmitter section **20** and the receiver section **50**. Alternatively, the transmitter section **20** is connected or coupled to the receiver section **50** by rigid means such as connecting rods, bars, struts or other similar structures. Any other rigid, semi-rigid or flexible connections can also be used to provide the spacing or association between the transmitter section **20** and the receiver section **50**.

The transmitter frame **24** is supported by a cone, or shroud, comprised of a plurality of suspension means, for example, suspension ropes **4**, each being connected to a suspension

position along the circumference of the transmitter frame 24, and suspended from a main suspension location above the transmitter frame 24. The rope length has been designed to allow the transmitter frame 24 to fly horizontally leveled in forward flight. For this flight dynamic, the ropes are shorter at the forward side of the transmitter frame 24, and longer at the tail end of the transmitter loop.

In one embodiment, at least one suspension rope 4 is split at a split point into two legs forming a reversed Y-shaped suspension rope as the suspension rope 4 approaches the suspension position along the transmitter frame 24, wherein each of the two ends of the Y-shaped ropes (not shown) is connected to a connector means 42 disposed along the transmitter frame 24. The two legs of a Y-rope may have the same length or may have different lengths. This type of Y-shaped suspension arrangement allows the Y-ropes to adjust to the flight angle set by the suspension ropes 4. Advantageously, as each Y-rope connects to two suspension positions of the transmitter loop from a split point that is lower than the main suspension location, the Y-rope arrangement reduces the number of ropes required to connect to the main suspension position for towing the transmitter frame 24 while providing a balanced suspension of the transmitter loop at the same time, thereby reducing the drag created by the suspension means and enhancing the planar stability of the transmitter loop.

Although the present invention has been described in considerable detail with reference to certain preferred embodiments thereof, other embodiments and modifications are possible. Therefore, the scope of the appended claims should not be limited by the preferred embodiments set forth in the examples, but should be given the broadest interpretation consistent with the description as a whole.

CLAIMS

1. An airborne electromagnetic surveying system comprising:
 - (a) a tow assembly connected to an aircraft, the tow assembly further comprising
 - 5 (i) a transmitter section comprising:

a transmitter means for generating a primary electromagnetic field that induces a secondary electromagnetic field,

a generally rigid transmitter frame for supporting the transmitter means, the transmitter frame comprising a plurality of fixedly connected frame sections

10 assembled in a way such that the generally rigid transmitter frame substantially retains its shape during operation; and

(ii) a receiver section for detecting the secondary electromagnetic field.
2. The airborne electromagnetic surveying system of claim 1, wherein the receiver section is
15 located above the generally rigid transmitter frame in between the aircraft and the generally rigid transmitter frame.
3. The airborne electromagnetic surveying system of claim 1, wherein the receiver section is
20 located at the center of the generally rigid transmitter frame.
4. The airborne electromagnetic surveying system of claim 1, wherein the plurality of frame sections are connected using fastening means to substantially eliminate or minimize relative movements therebetween.
- 25 5. The airborne electromagnetic surveying system of claim 1, wherein the generally rigid transmitter frame comprises at least a first frame section having a first interlocking member and a second frame section having a second interlocking member, wherein when the first and the second frame sections are connected, the first and the second interlocking

members engage with each other to substantially eliminate or minimize relative movements or rotations between the first and the second frame sections.

- 5 6. The airborne electromagnetic surveying system of claim 1, wherein the generally rigid transmitter frame has a diameter in excess of 30 meters.
7. The airborne electromagnetic surveying system of claim 1, wherein the plurality of frame sections are serially connected to form the generally rigid transmitter frame.
- 10 8. The airborne electromagnetic surveying system of claim 1, wherein the frame sections are connected in a manner that substantially eliminates the relative rotation therebetween, thereby preventing distortion of the shape of the transmitter frame during operation.
- 15 9. The airborne electromagnetic surveying system of claim 1 or claim 6, wherein the generally rigid transmitter frame is constructed using lightweight materials.
10. A transmitter section for an airborne electromagnetic survey system, comprising:
a transmitter means, and
a generally rigid transmitter frame for supporting the transmitter means, the transmitter
20 frame comprising a plurality of fixedly connected frame sections assembled in a way such that the generally rigid transmitter frame substantially retains its shape during operation.
- 25 11. A tow assembly for an airborne electromagnetic surveying system, comprising:
means for suspending a transmitter section from an aircraft, the transmitter section comprising:
a transmitter means, and
a generally rigid transmitter frame for supporting the transmitter means, the transmitter
frame comprising a plurality of fixedly connected frame sections assembled in a way

such that the generally rigid transmitter frame substantially retains its shape during operation.

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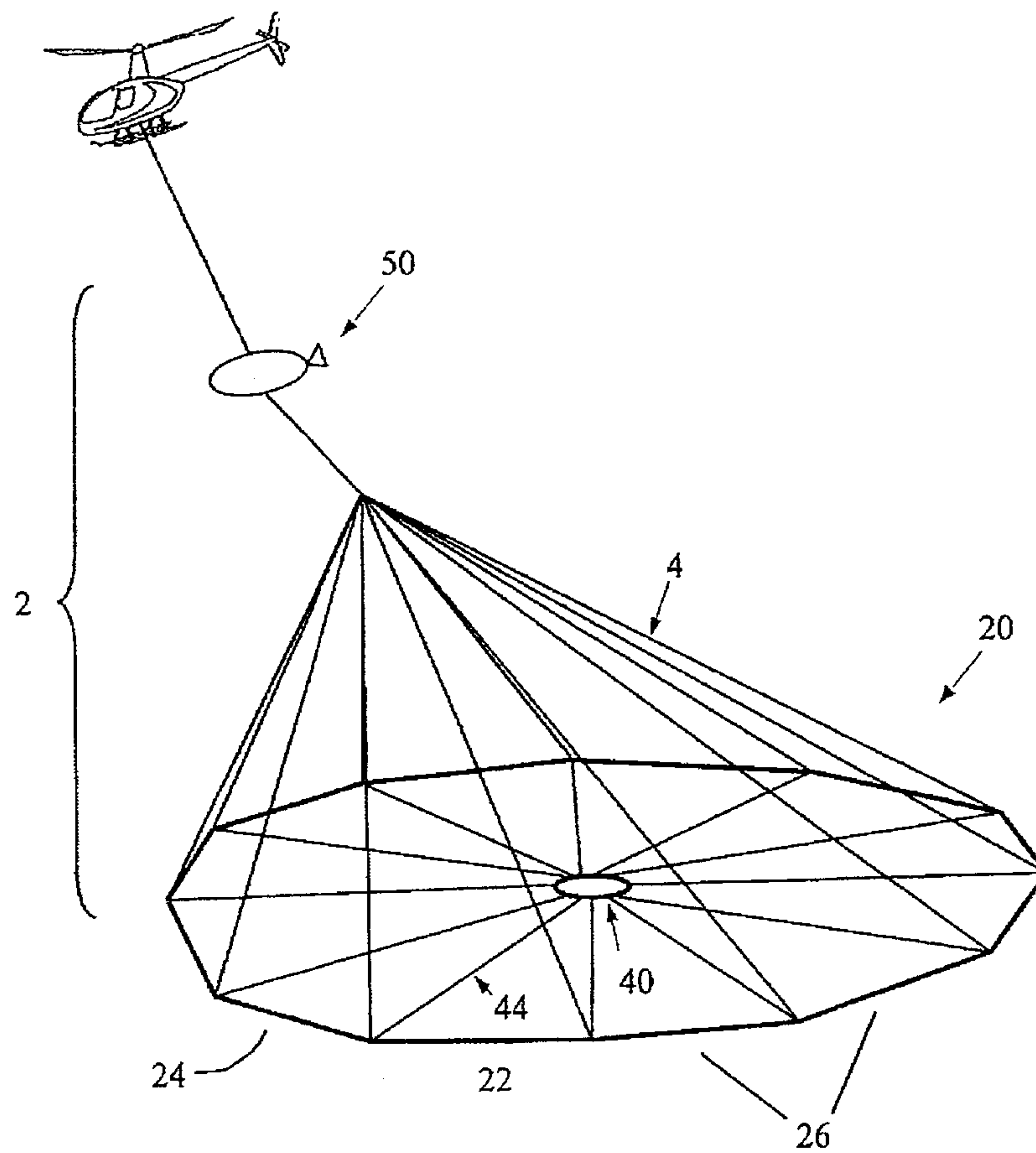


FIG. 1

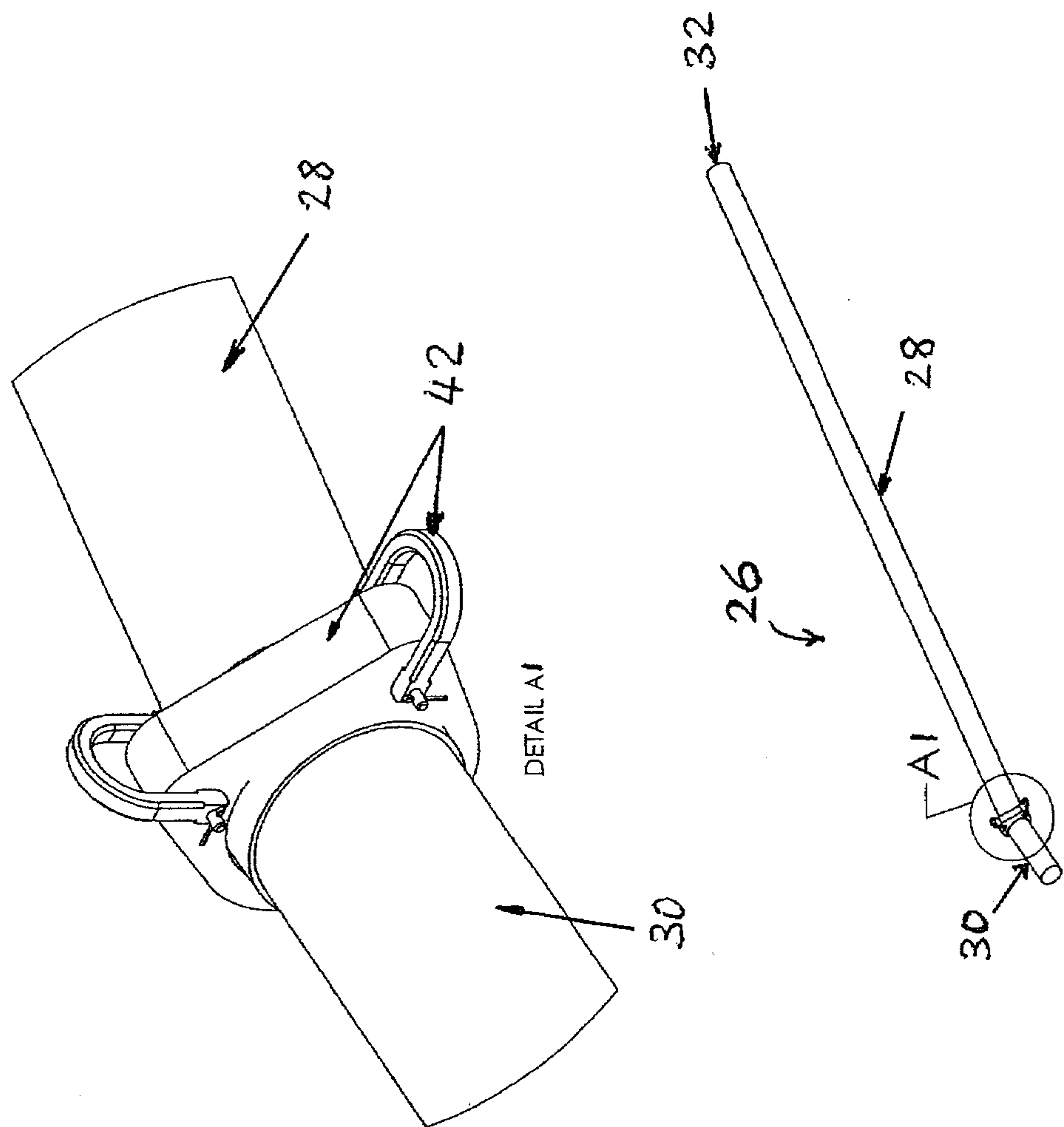


FIG. 2

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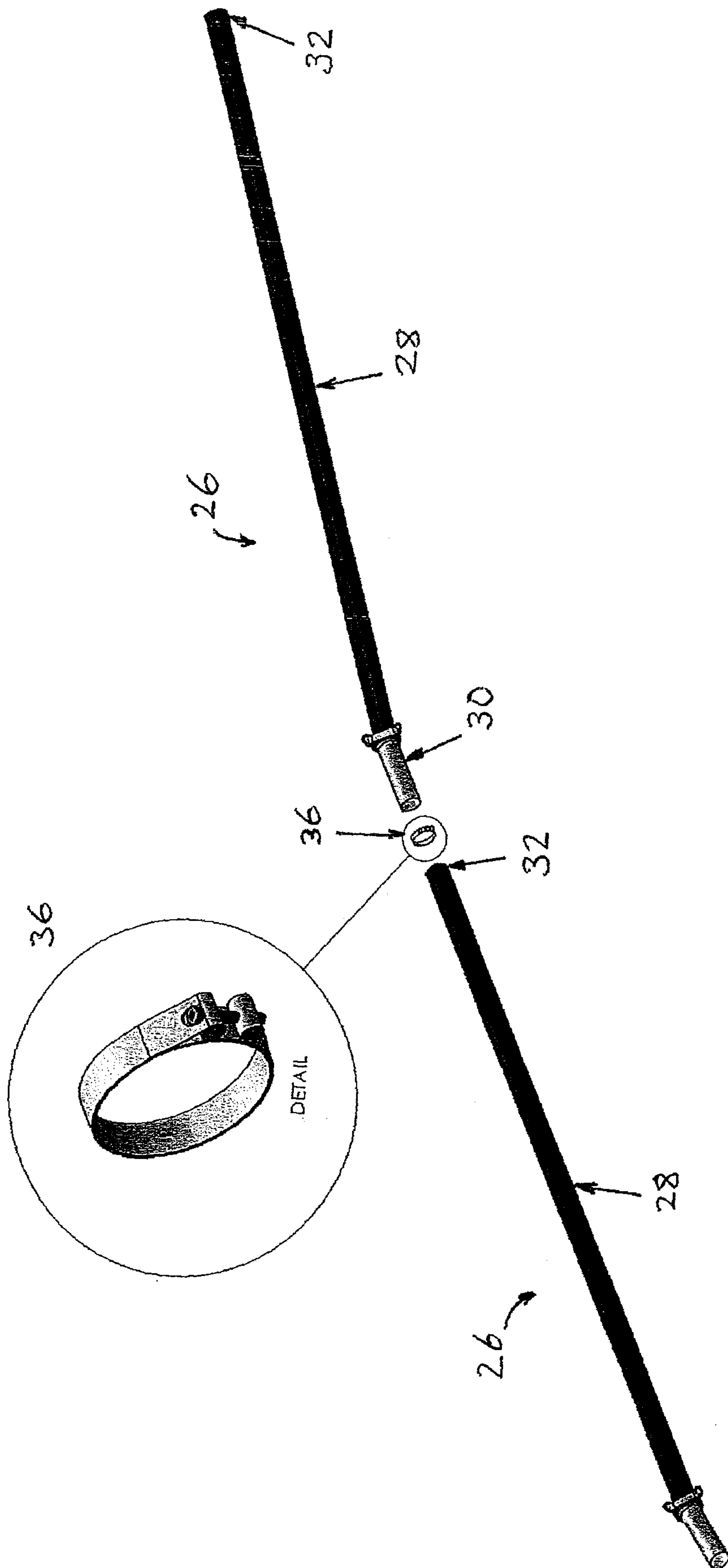


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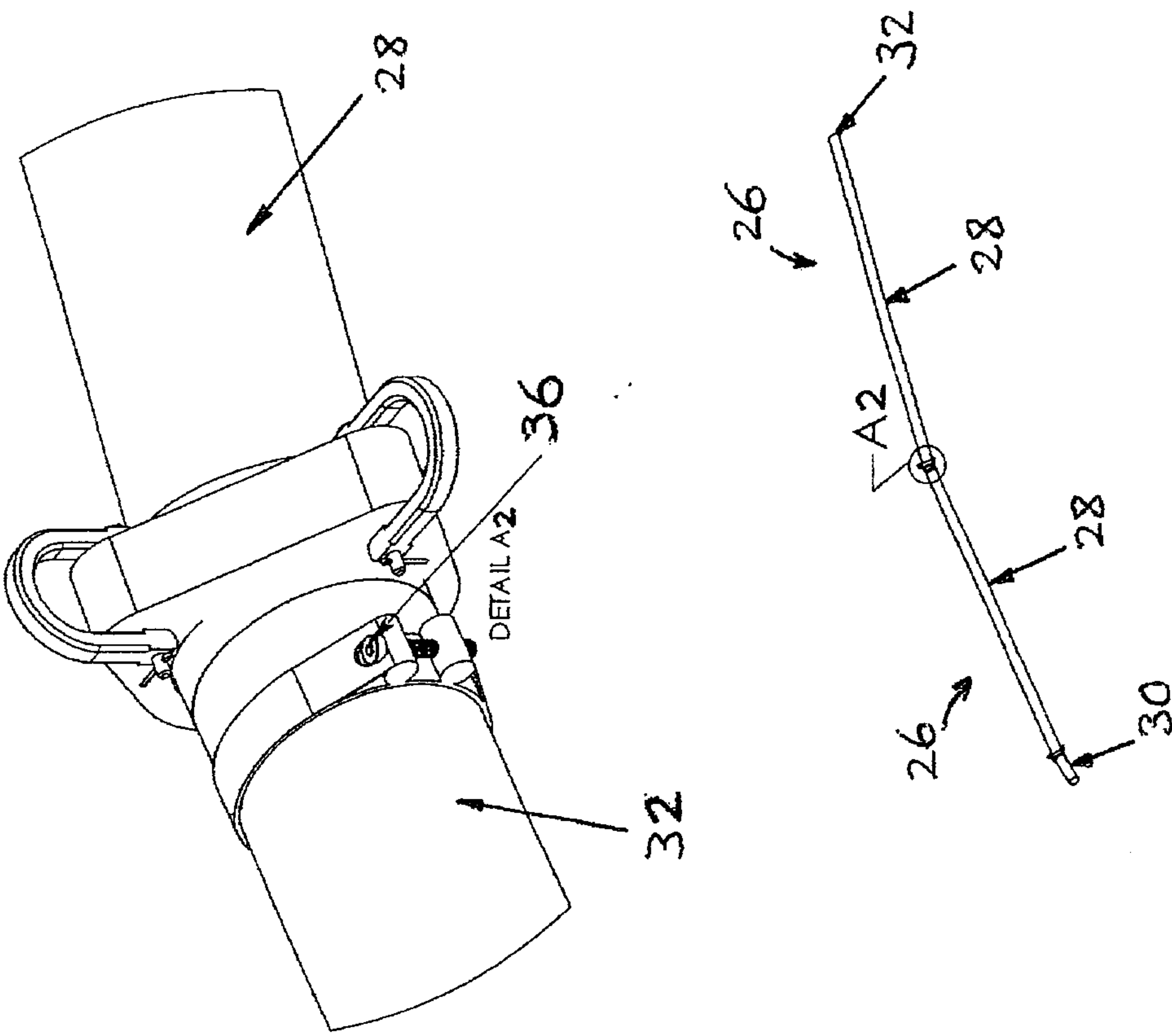


FIG. 4

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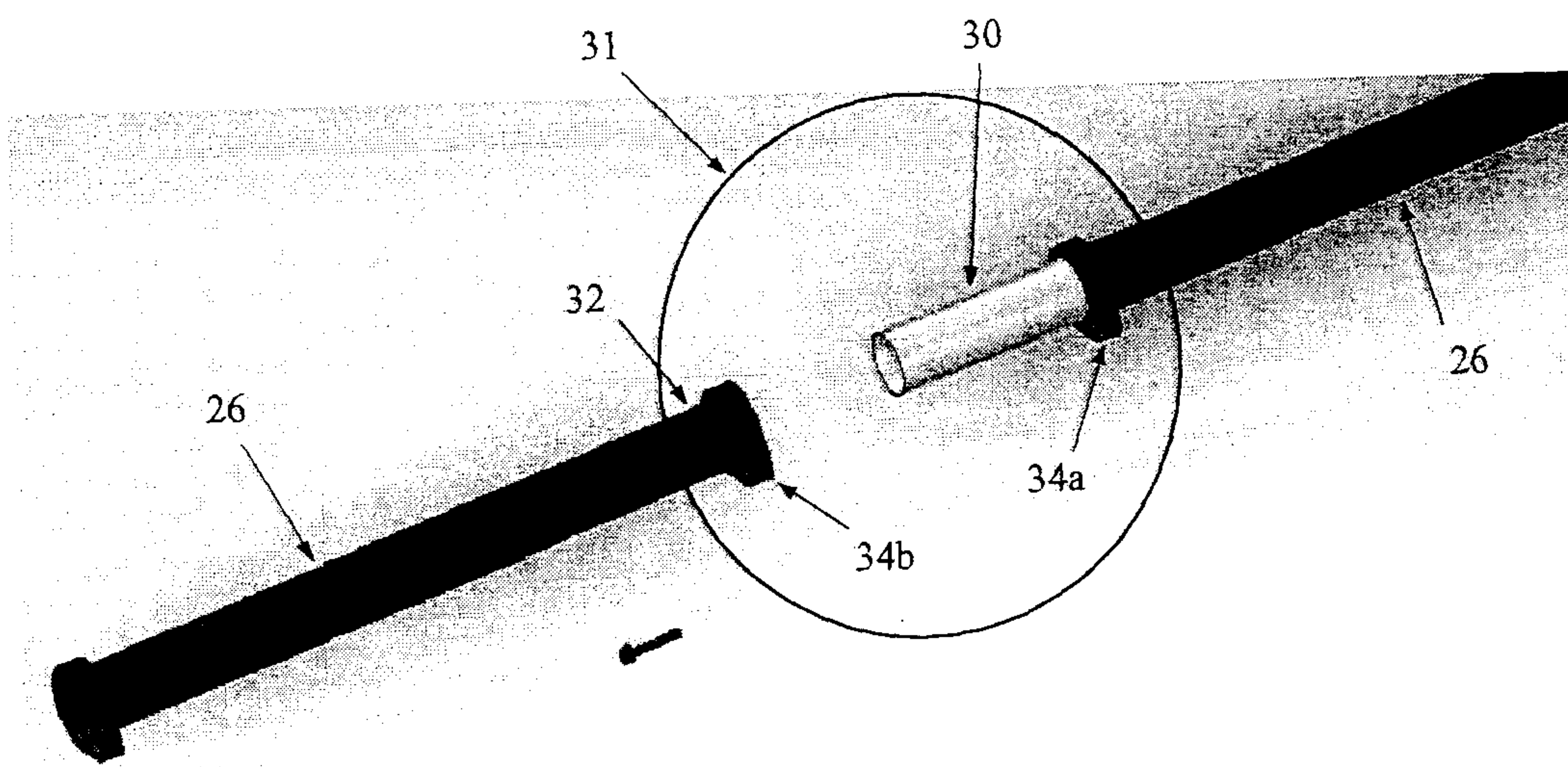


FIG. 5

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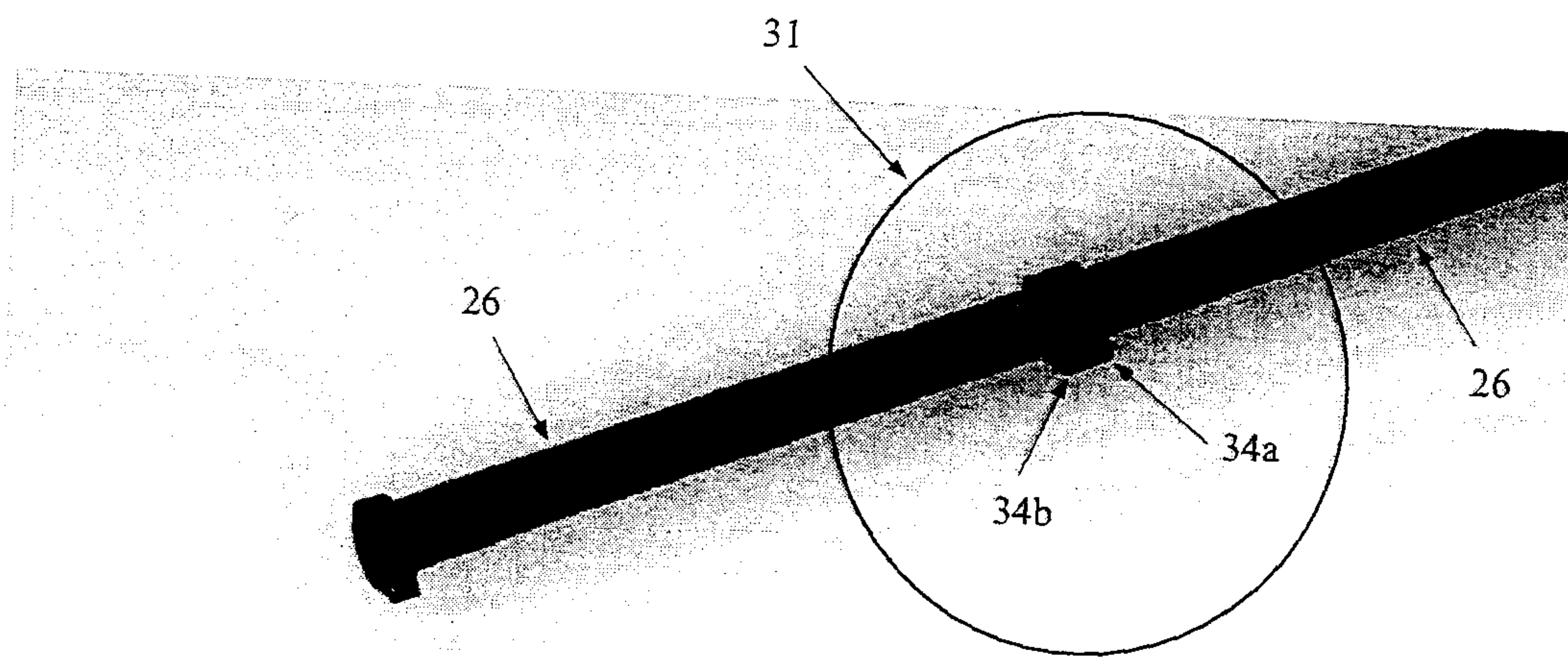


FIG. 6

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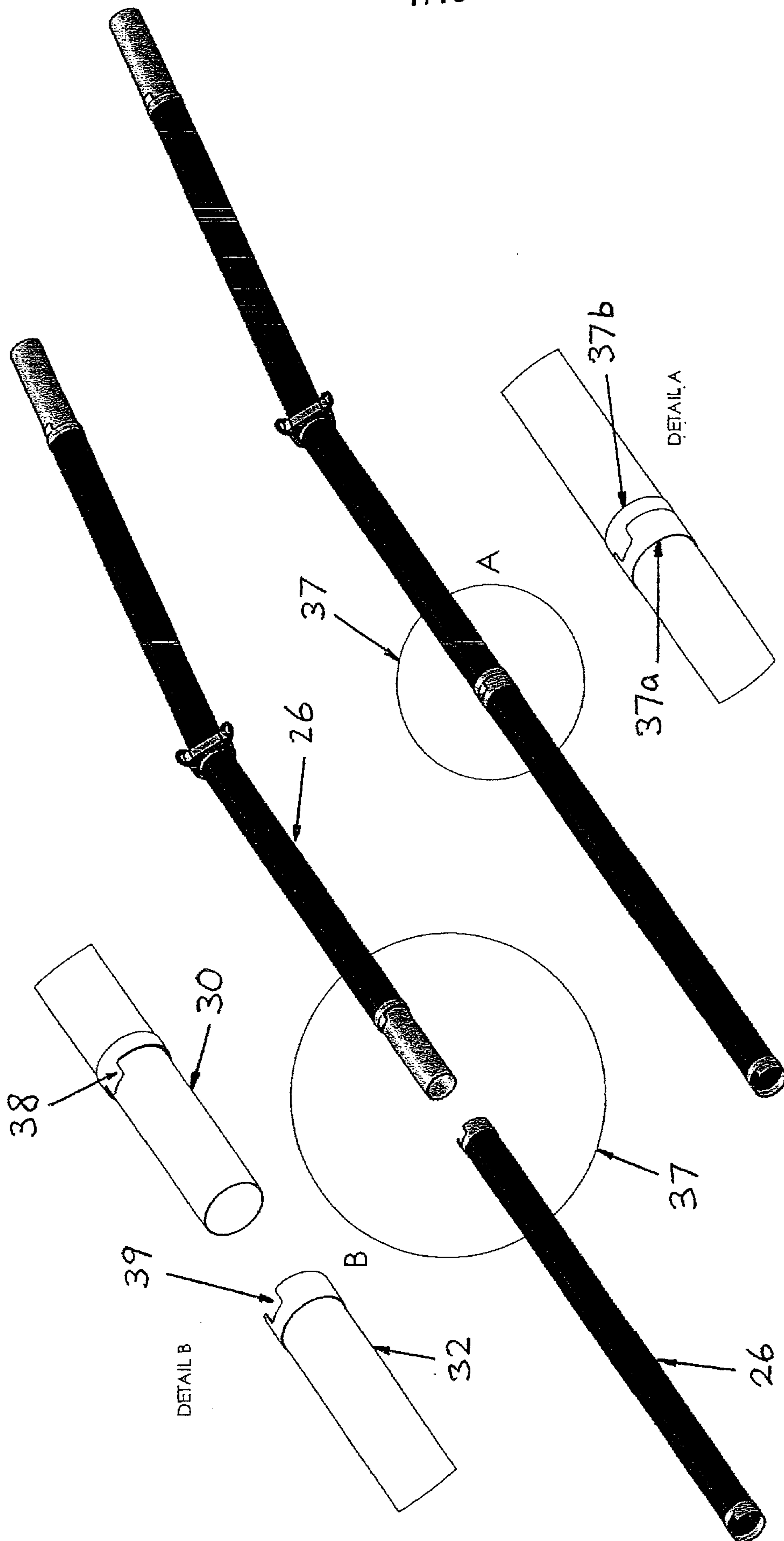


FIG. 7

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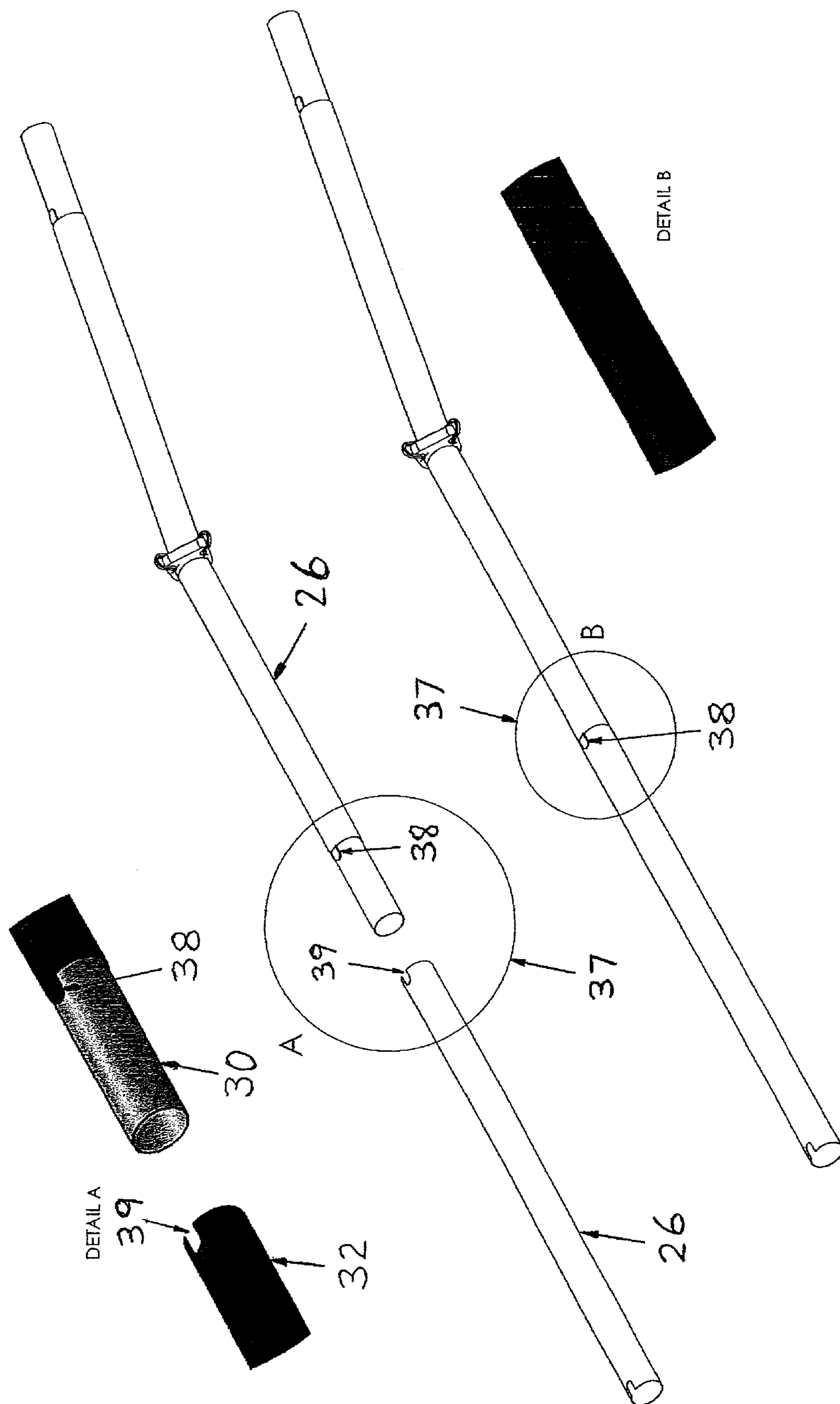


FIG. 8

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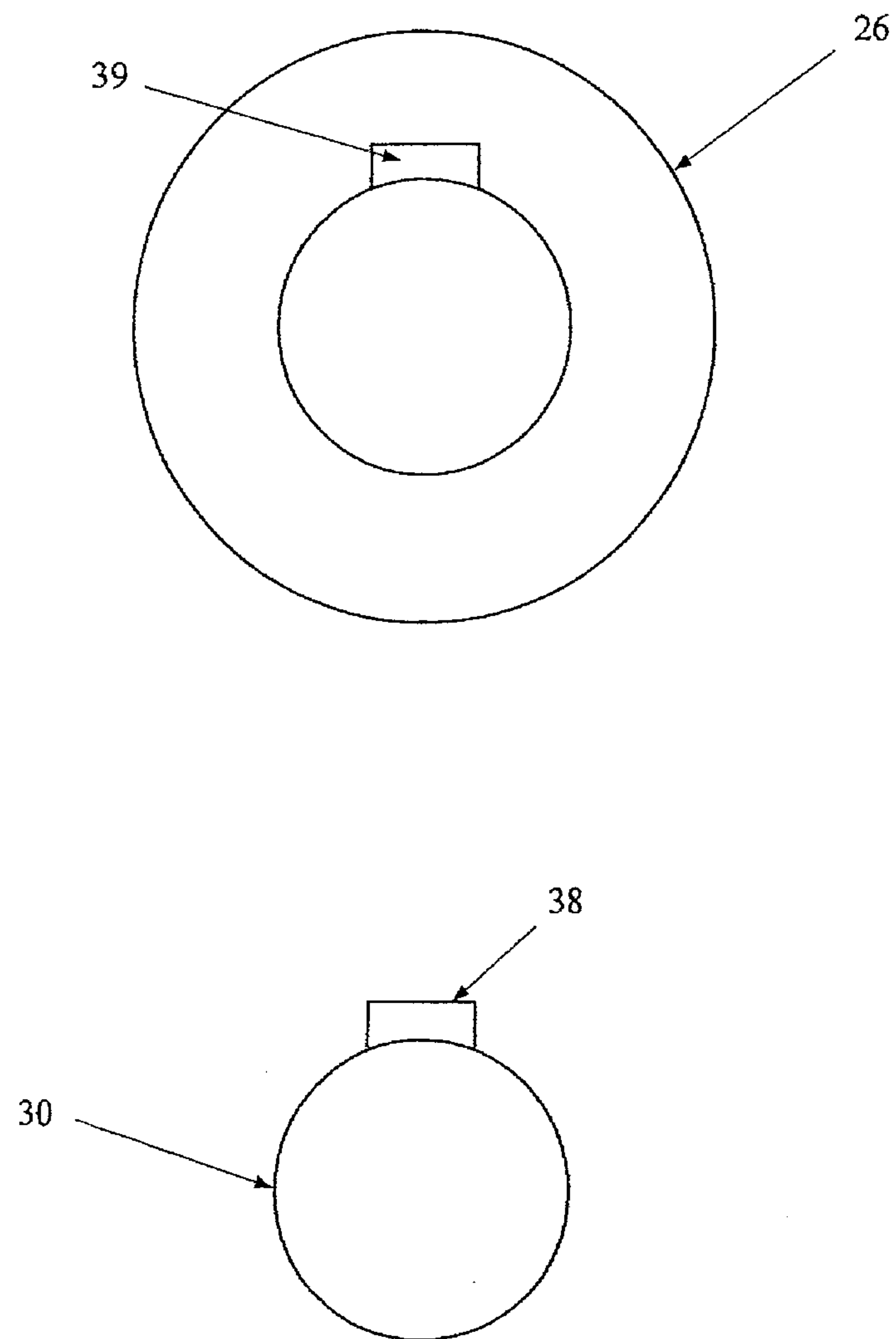


FIG. 9

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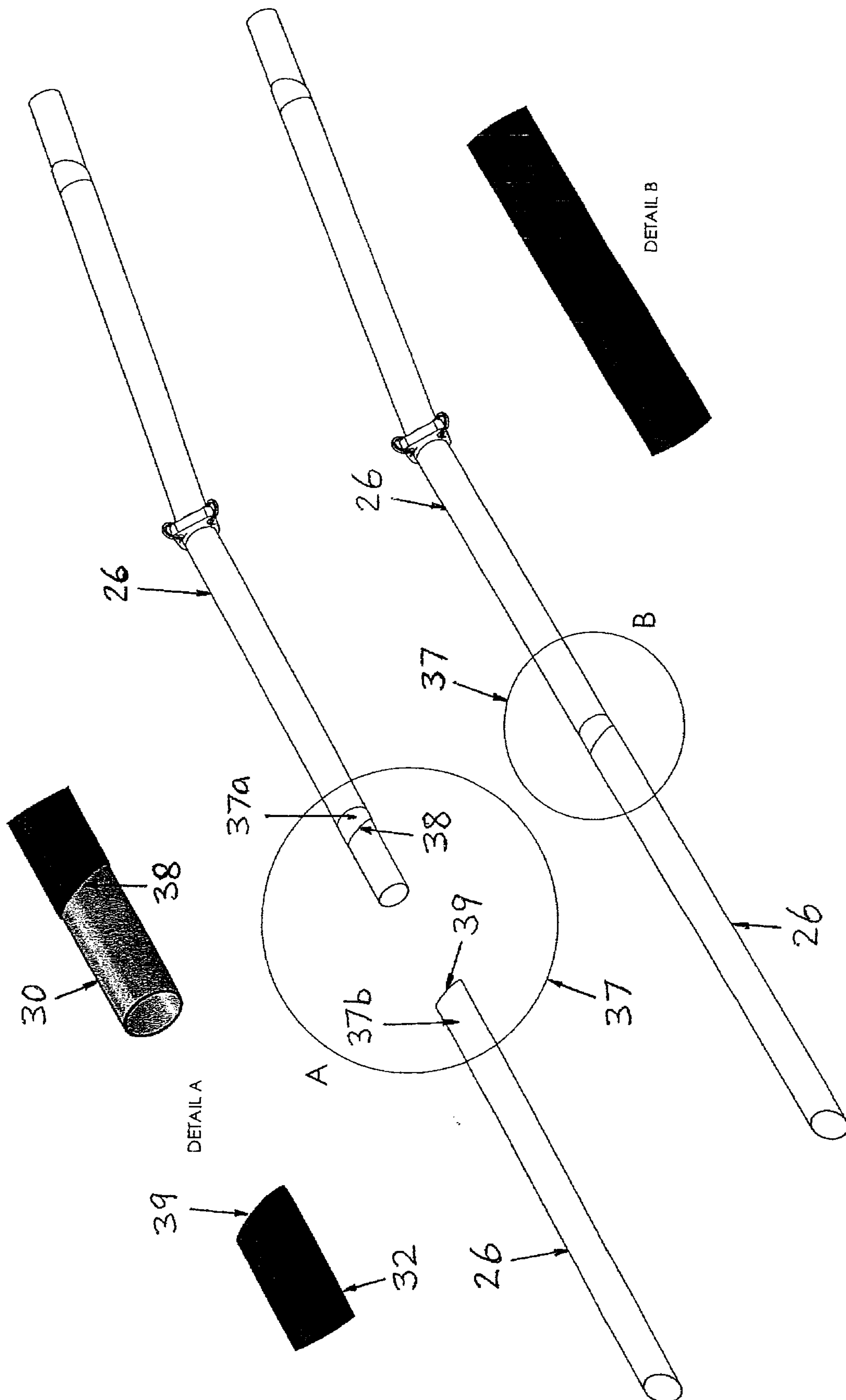


FIG. 10

FIG. 1

