US012390378B2

(12) United States Patent
St. John et al.

(10) **Patent No.: US 12,390,378 B2**
(45) **Date of Patent: Aug. 19, 2025**

(54) **PATIENT SUPPORT WITH LIFT ASSEMBLY**

(71) Applicant: **Stryker Corporation**, Kalamazoo, MI (US)

(72) Inventors: **Connor Feldpausch St. John**, Kalamazoo, MI (US); **William Dwight Childs**, Plainwell, MI (US); **Gary L. Bartley**, Kalamazoo, MI (US)

(73) Assignee: **Stryker Corporation**

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 31 days.

(21) Appl. No.: **17/116,240**

(22) Filed: **Dec. 9, 2020**

(65) **Prior Publication Data**

US 2021/0177679 A1 Jun. 17, 2021

Related U.S. Application Data

(60) Provisional application No. 62/948,540, filed on Dec. 16, 2019.

(51) **Int. Cl.**

A61G 7/012	(2006.01)
A61G 1/013	(2006.01)
A61G 7/002	(2006.01)
A61G 7/005	(2006.01)
A61G 7/018	(2006.01)

(52) **U.S. Cl.**

CPC ***A61G 7/012*** (2013.01); ***A61G 1/013*** (2013.01); ***A61G 7/018*** (2013.01); *A61G 7/002* (2013.01); *A61G 7/005* (2013.01)

(58) **Field of Classification Search**

CPC A61G 7/002; A61G 7/012; A61G 7/015; A61G 7/018; A61G 1/0562; A61G 1/0567; A47C 20/04; A47C 20/041

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,203,670	A	8/1965	Farris
3,282,566	A	11/1966	Clarke
5,317,769	A	6/1994	Weismiller et al.

(Continued)

FOREIGN PATENT DOCUMENTS

EP	2777672	B1 *	11/2016		A61G 7/012
JP	2016-183876	A	10/2016		
WO	WO-2011021002	A2 *	2/2011		A47C 1/031

OTHER PUBLICATIONS

PCT Written Opinion of the International Searching Authority regarding PCT/US2020/64212, dated May 26, 2021.

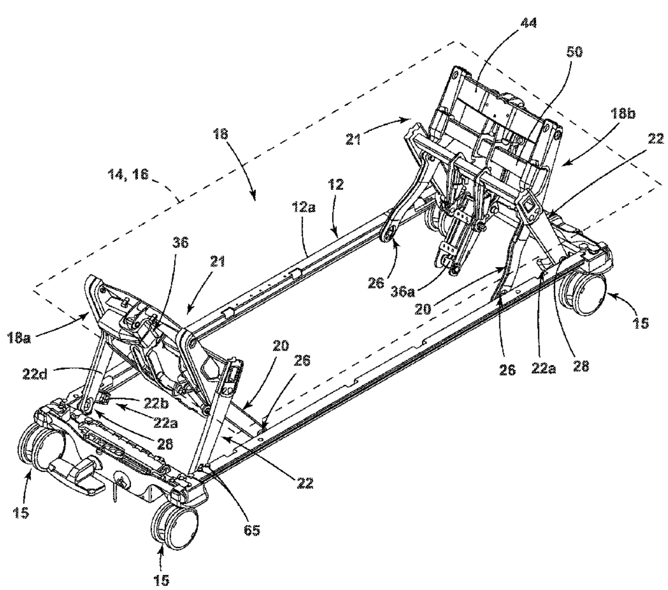
(Continued)

Primary Examiner — Justin C Mikowski
Assistant Examiner — Deborah Talitha Gedeon
(74) *Attorney, Agent, or Firm* — Warner Norcross + Judd LLP

(57) **ABSTRACT**

A patient support apparatus includes a frame supported relative to a floor, the frame configured to support a deck for supporting a patient thereon, and a lift assembly for raising or lowering the frame relative to the floor. The lift assembly includes lifting legs coupled to the frame and an actuator with a body and an extendible member. The actuator is mounted to one of the legs, rather than the frame, and mounted for linear movement with respect to the one leg, with the linear movement translated into rotational movement of the other leg by a link and crank arm arrangement.

19 Claims, 38 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

6,071,228	A	6/2000	Speraw et al.	
7,296,312	B2	11/2007	Menkedick et al.	
7,690,059	B2	4/2010	Lemire et al.	
2005/0120481	A1	6/2005	Farmont et al.	
2006/0021144	A1*	2/2006	Hornbach	A61G 7/018 5/618
2006/0059624	A1	3/2006	Poulos et al.	
2009/0094747	A1*	4/2009	Bly	A61G 7/018 74/522
2014/0033435	A1	2/2014	Jutras	
2014/0325759	A1	11/2014	Bly et al.	
2016/0302985	A1*	10/2016	Tessmer	A61G 7/012
2017/0172309	A1	6/2017	Ahn et al.	
2017/0172829	A1	6/2017	Tessmer et al.	
2017/0258655	A1*	9/2017	Jutras	A61B 5/1115
2019/0133858	A1	5/2019	Tessmer et al.	
2019/0247257	A1	8/2019	Furman et al.	
2019/0322502	A1	10/2019	Lykkegaard	
2024/0082079	A1	3/2024	Souke et al.	

OTHER PUBLICATIONS

PCT International Search Report regarding PCT/US2020/64212, dated May 26, 2021.

* cited by examiner

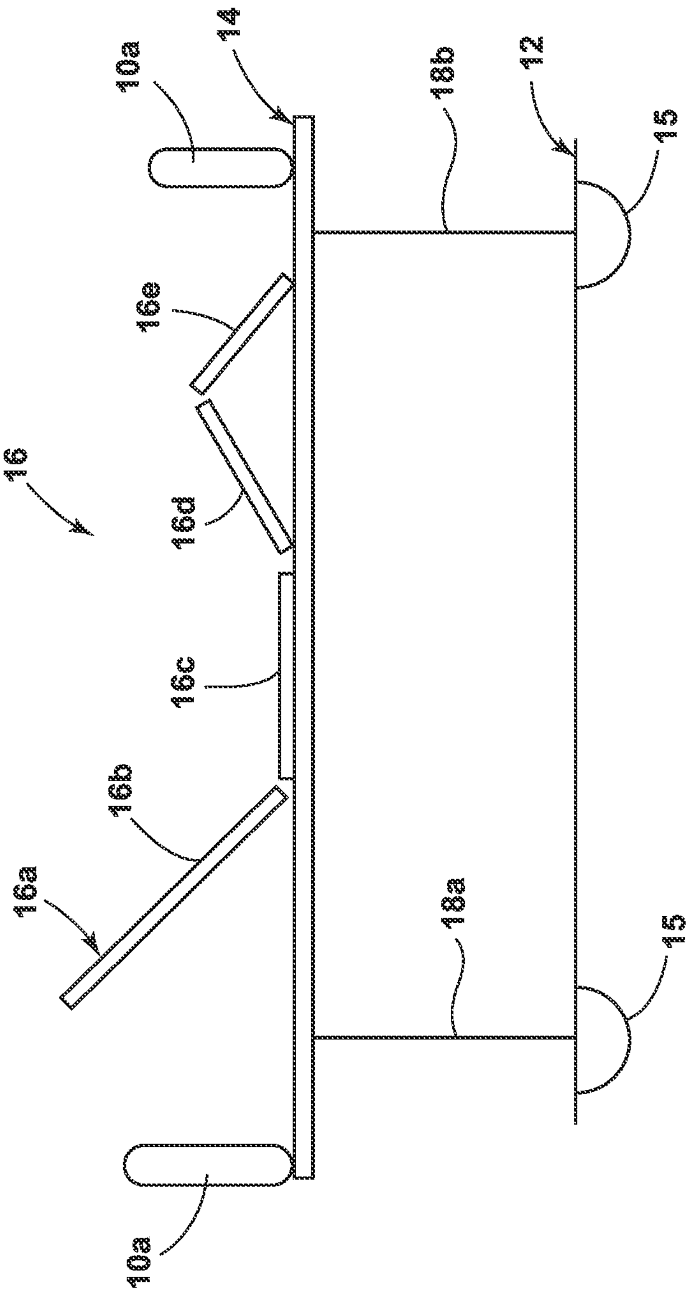


FIG. 1

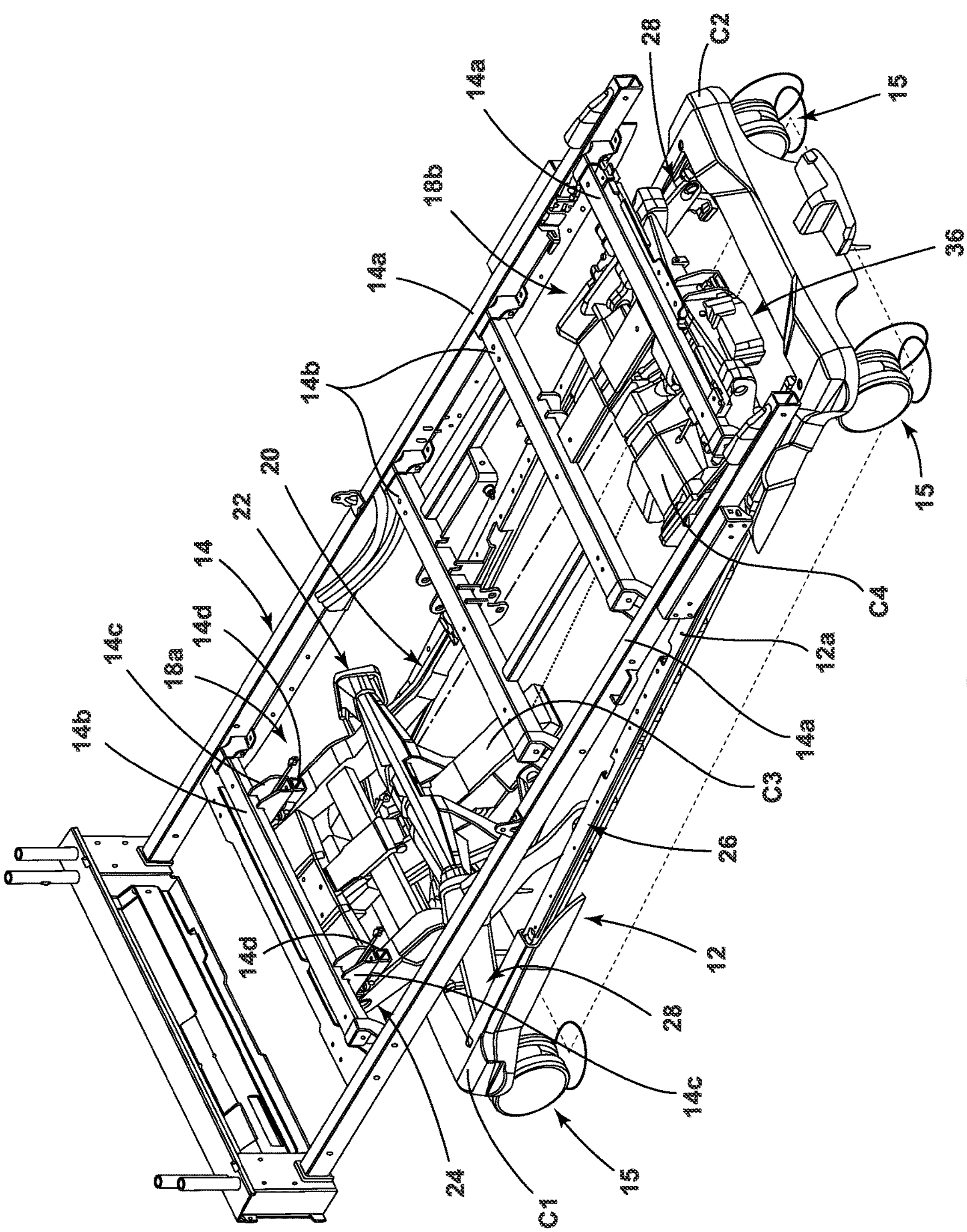

28
C2
15
14a
18b
36
14a
14b
15
20
22
14
C4
14c
14d
18a
14b
12a
14a
C3
26
14d
12
28
14c
24
15
C1

FIG. 1A

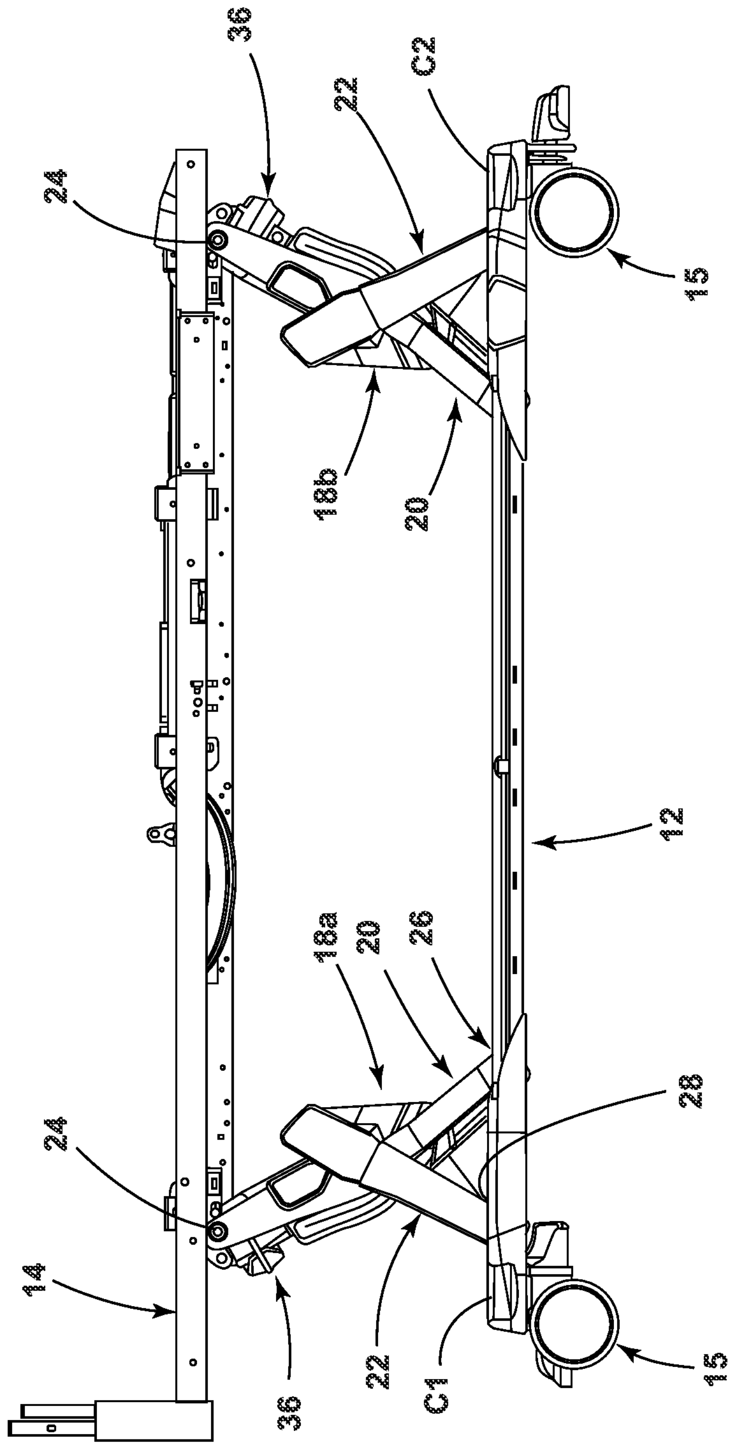


FIG. 1B

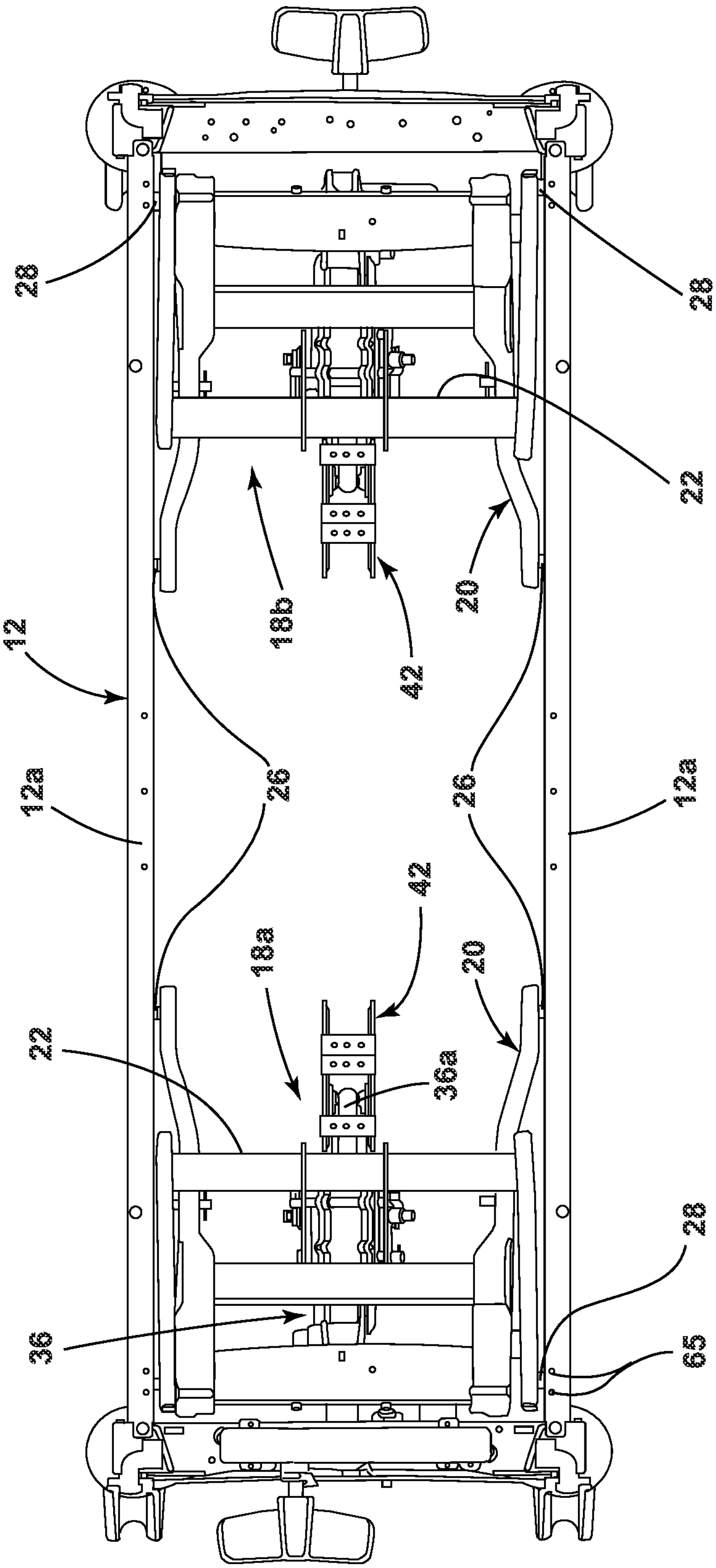


FIG. 1C

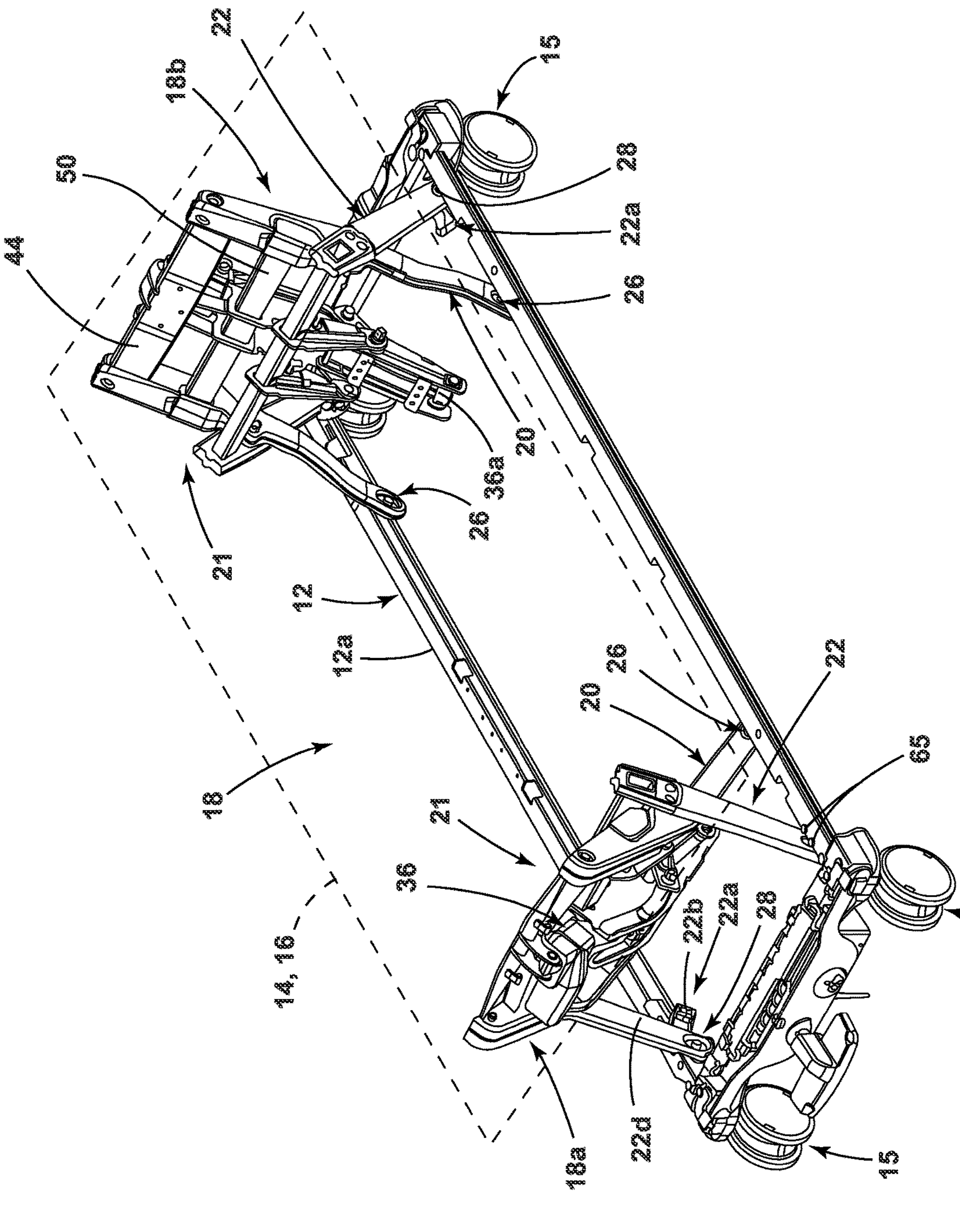

22
18b
50
44
15
28
22a
26
20
36a
26
21
12
12a
18
14, 16
36
21
20
26
22
65
22b
22a
28
15
18a
22d
15

FIG. 2

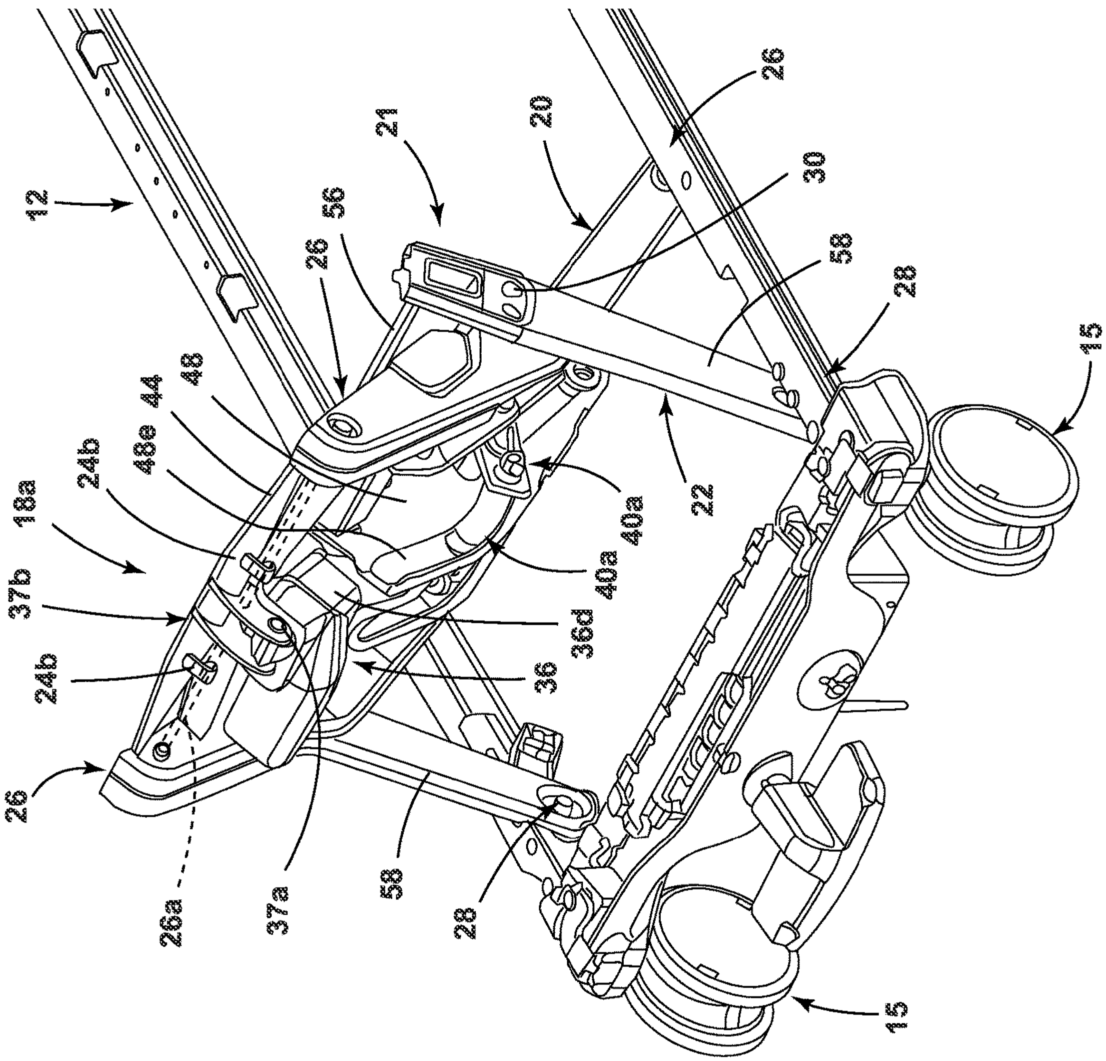

12
21
20
26
30
56
26
58
28
15
48
44
48e
24b
18a
37b
24b
40a
40a
22
36d
36
26
26a
37a
58
28
15

FIG. 2A

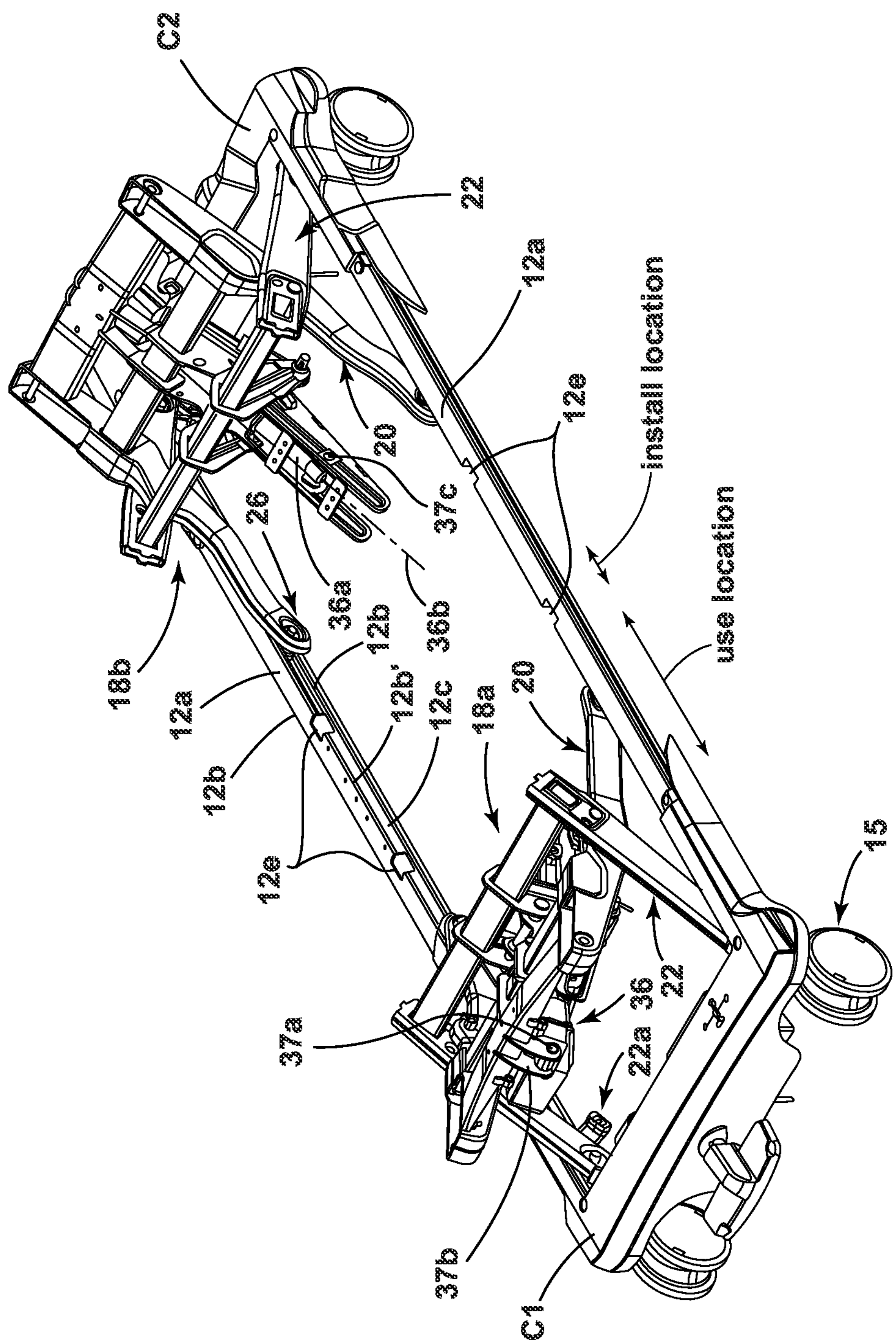

C2
22
12a
12e
install location
use location
20
37c
26
36a
36b
18b
12a
12b
12b'
12b
12c
18a
20
12e
15
22
36
37a
22a
37b
C1

FIG. 3

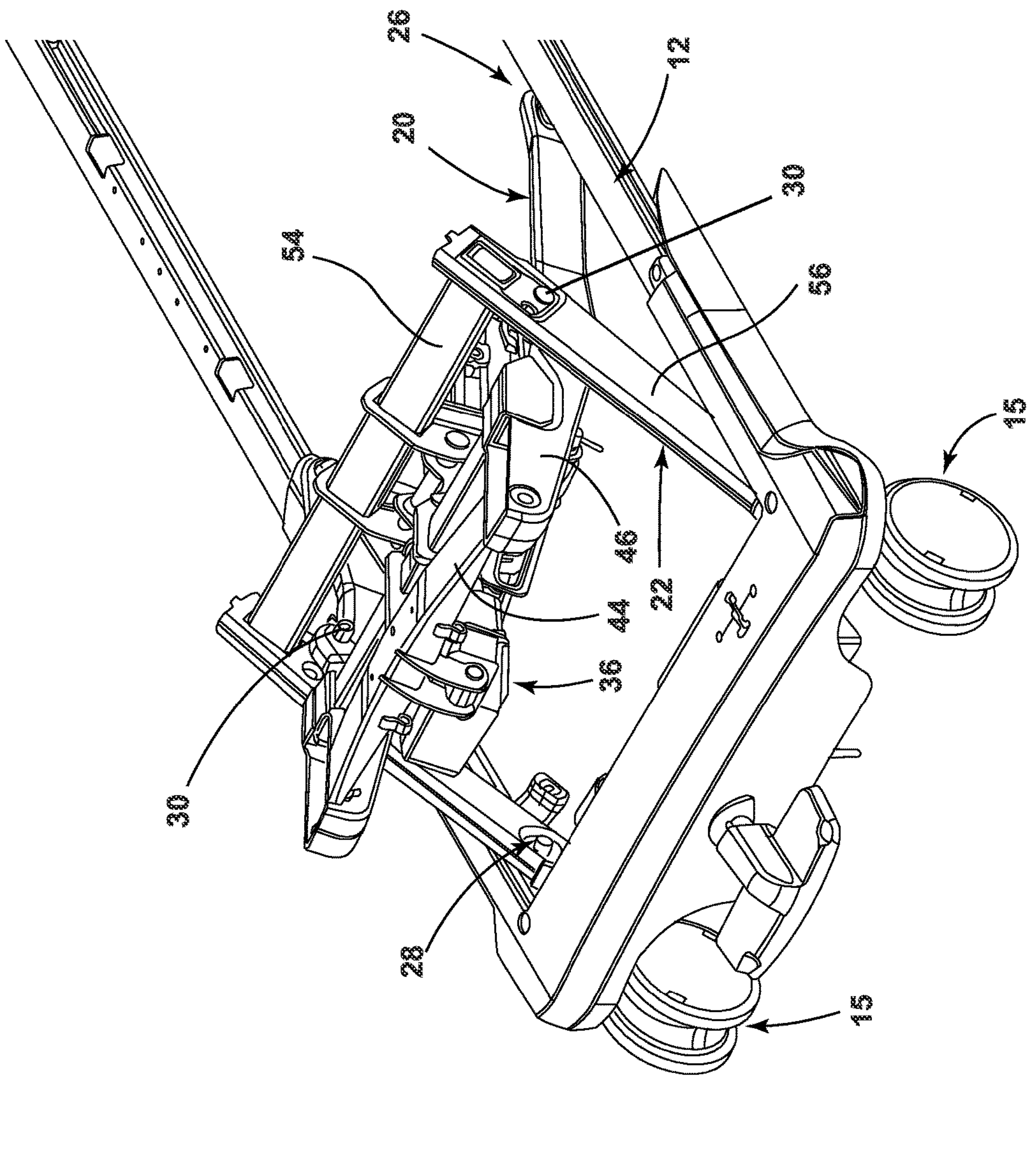


FIG. 3A

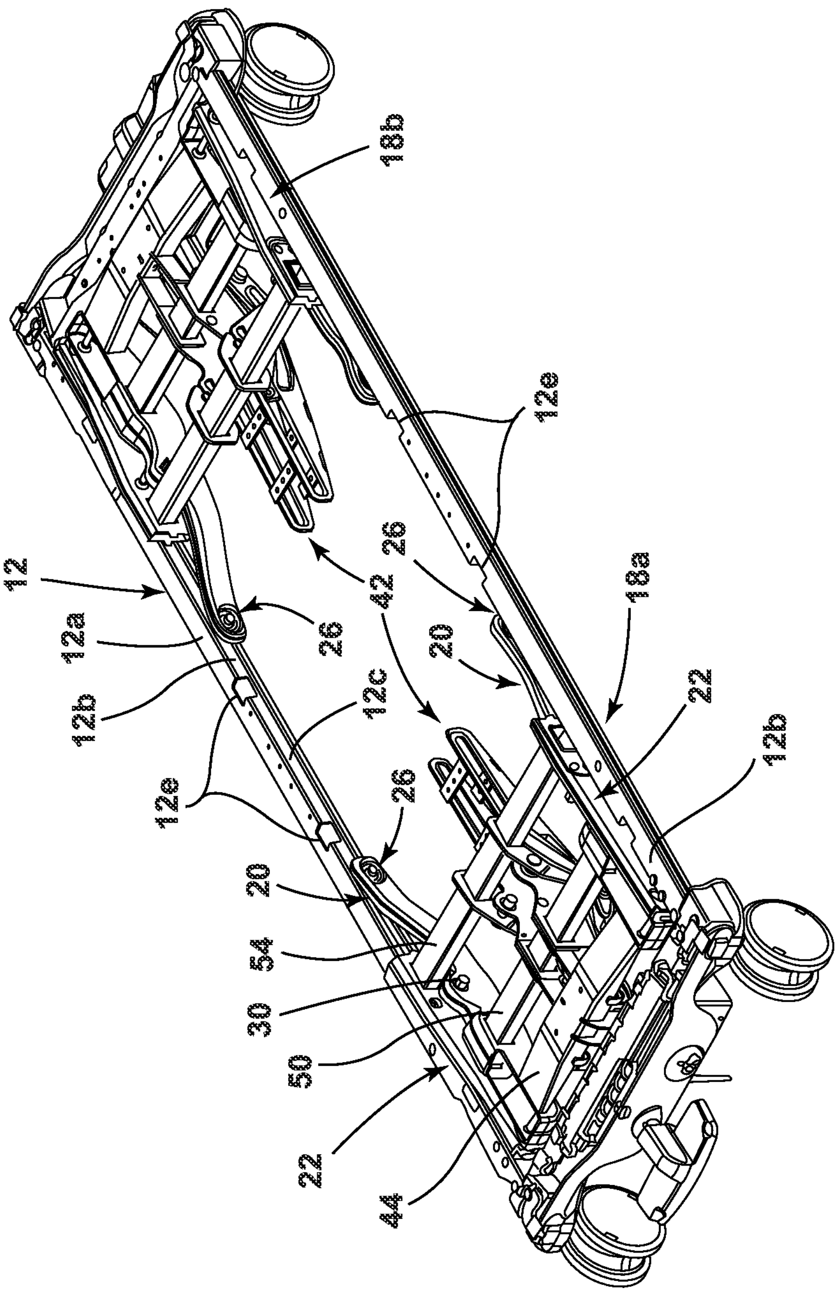

18b
12e
26
42
18a
12
12a
26
20
22
12b
12c
12b
12e
26
20
54
30
50
22
44

FIG. 4

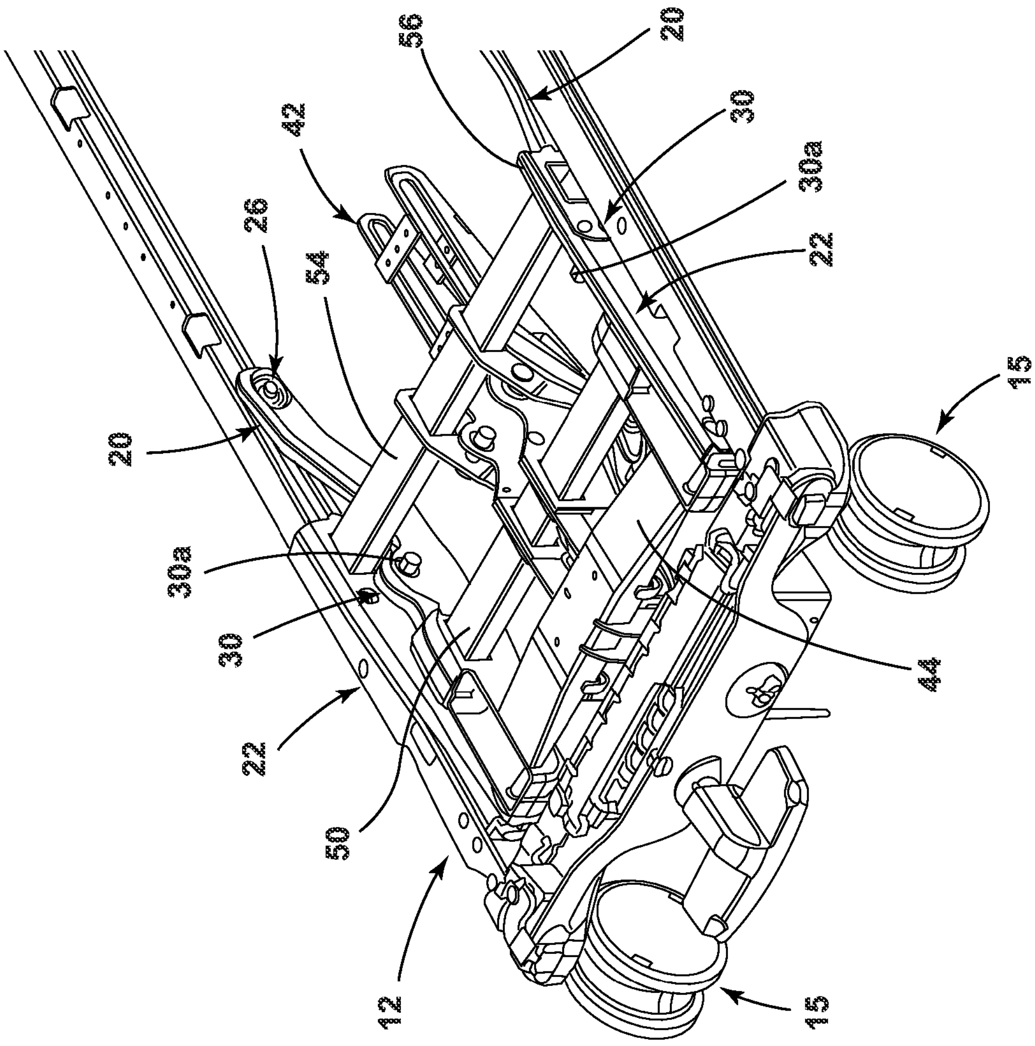


FIG. 4A

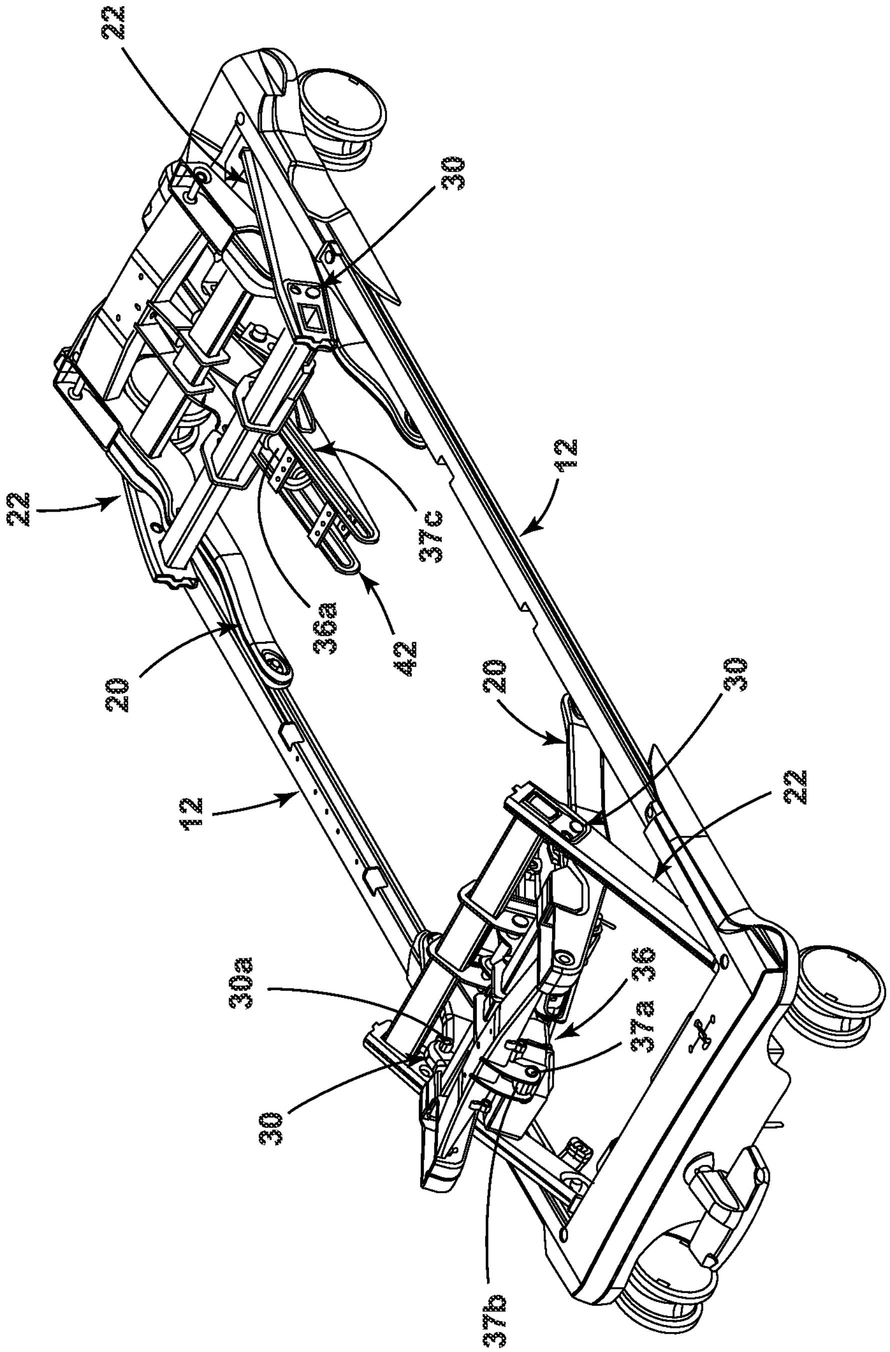


FIG. 5

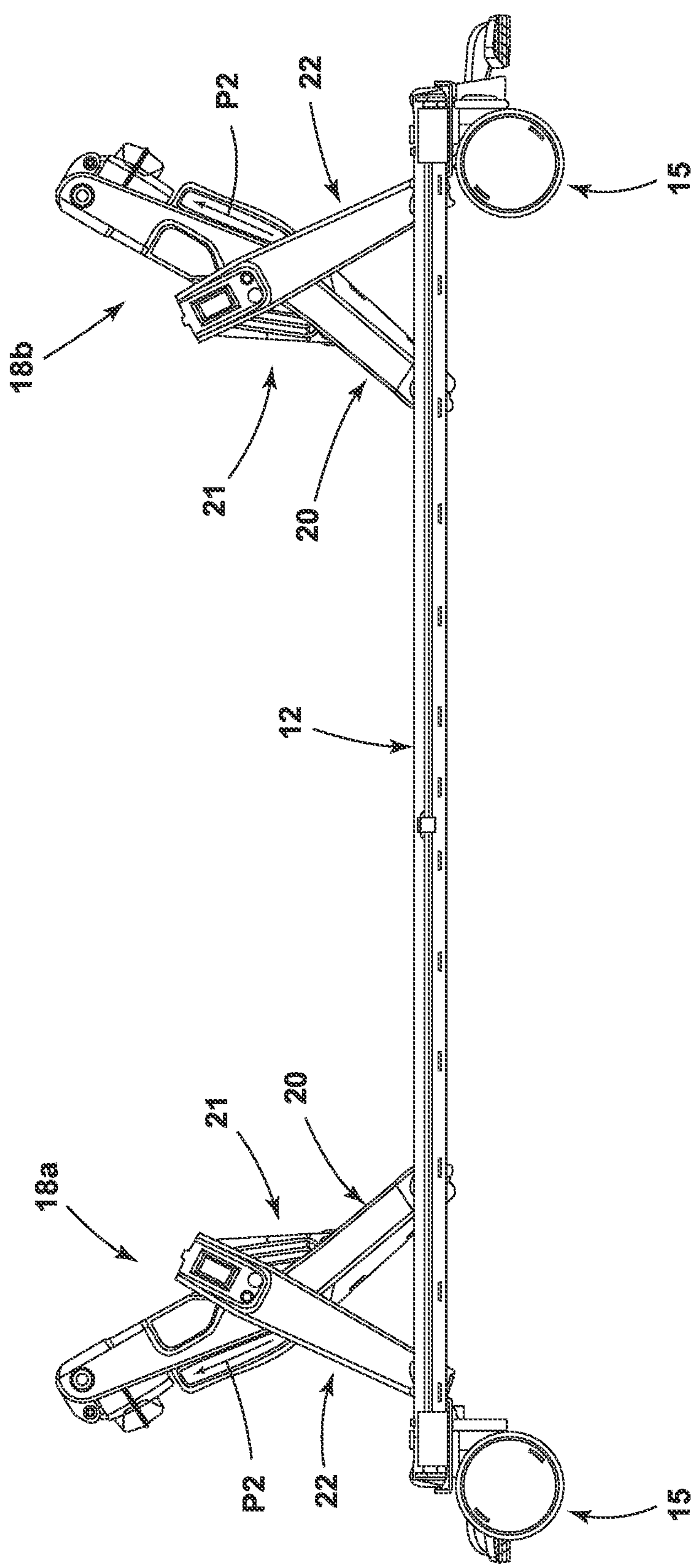


FIG. 6

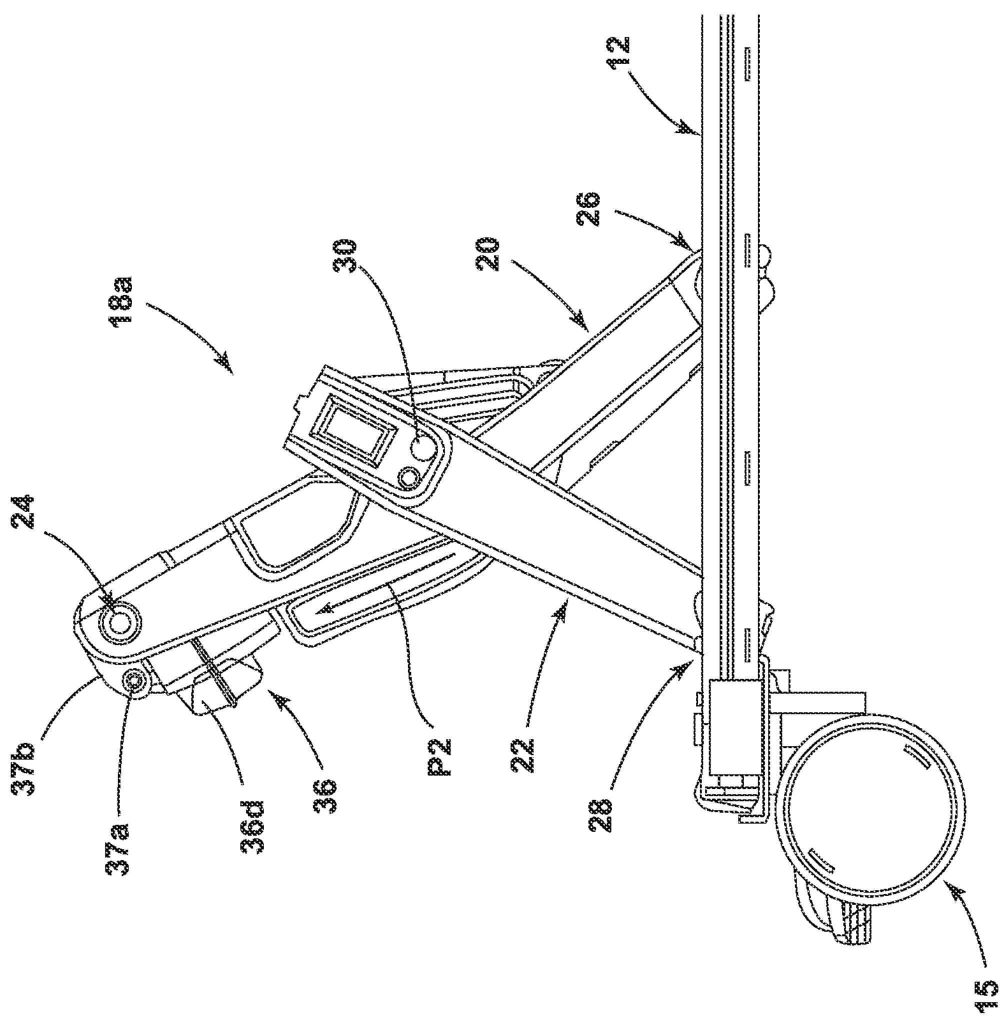


FIG. 6A

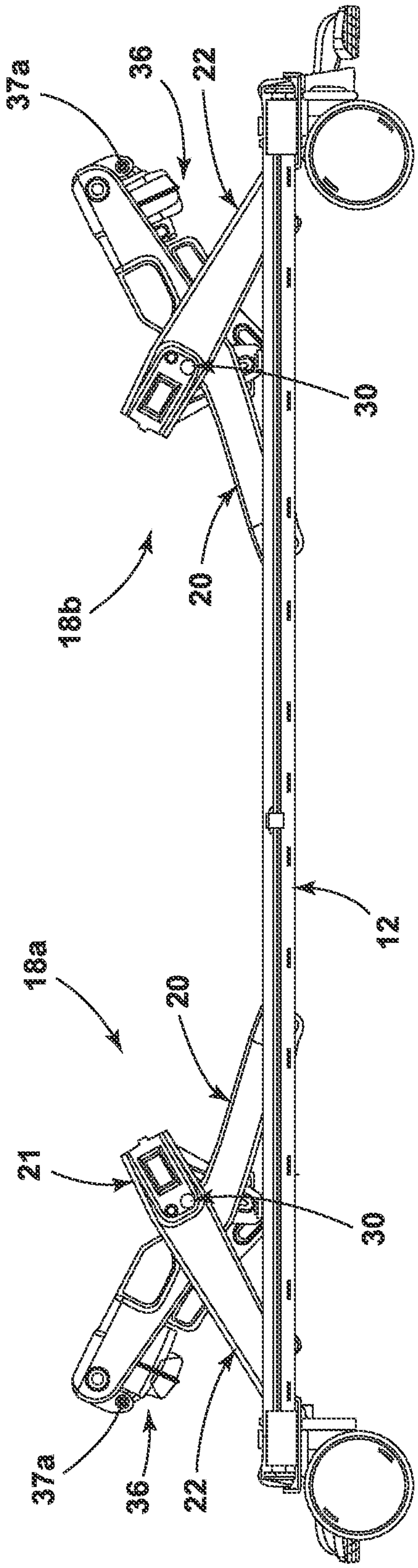


FIG. 7

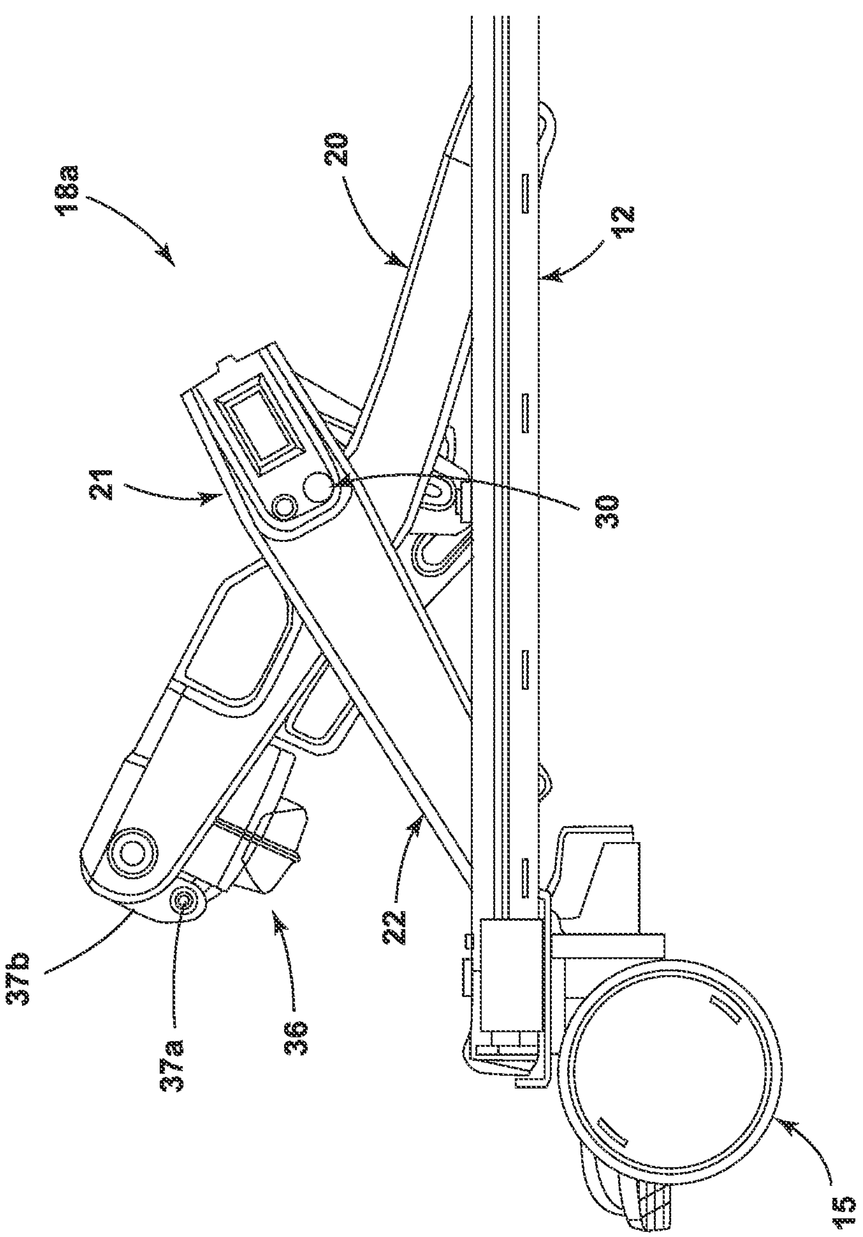


FIG. 7A

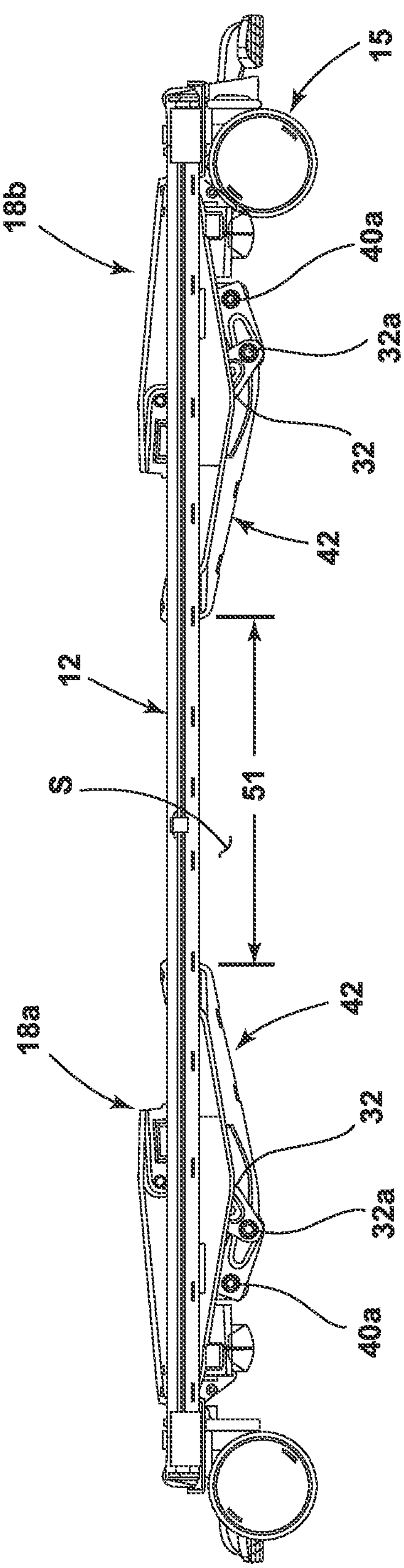


FIG. 8

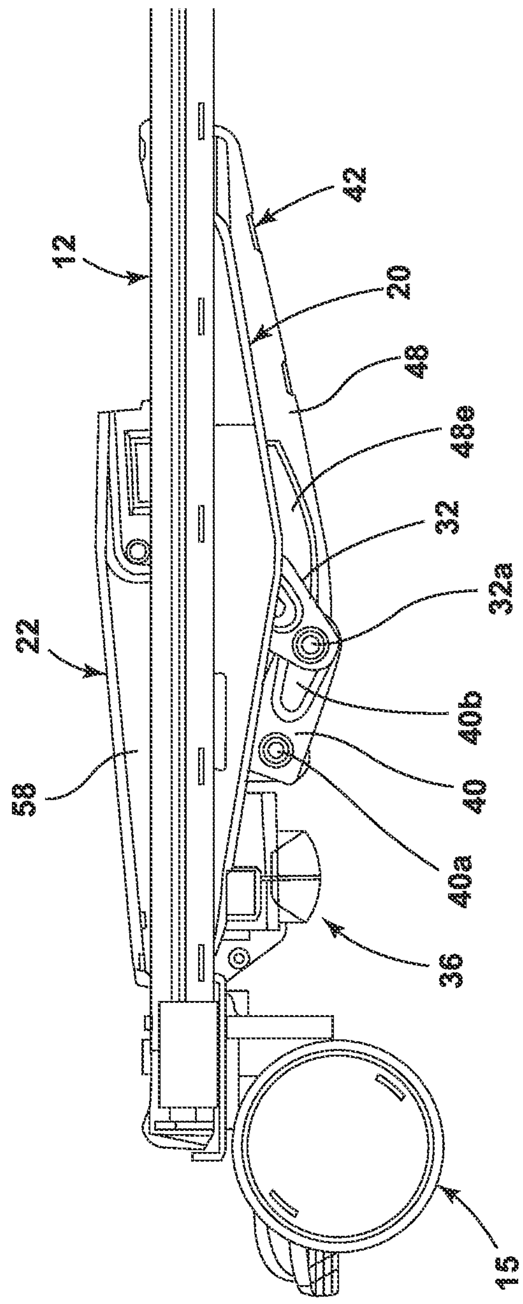


FIG. 8A

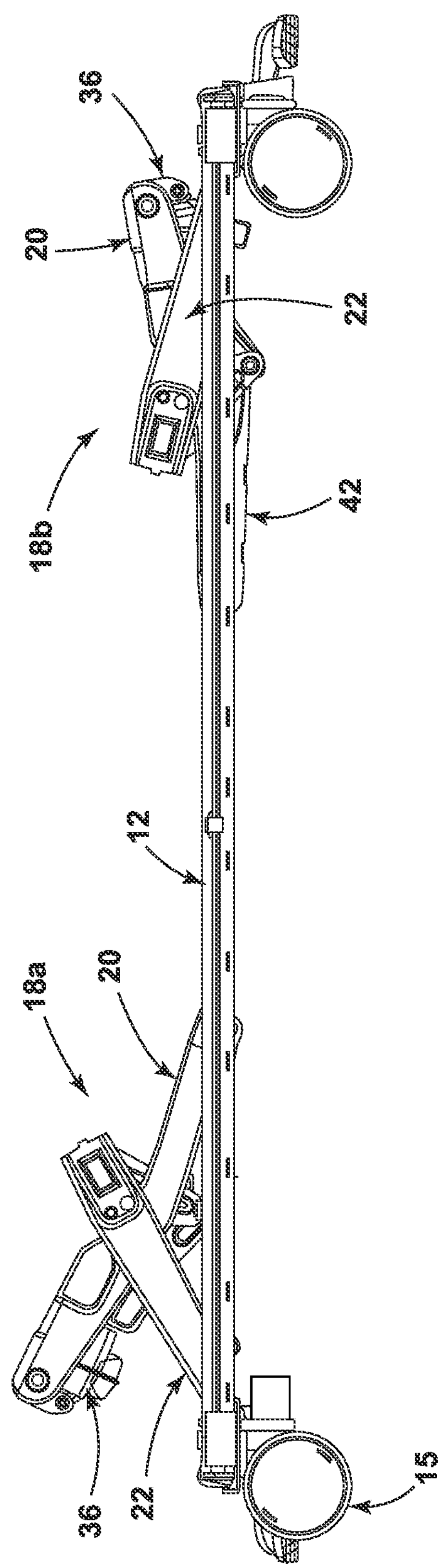


FIG. 9

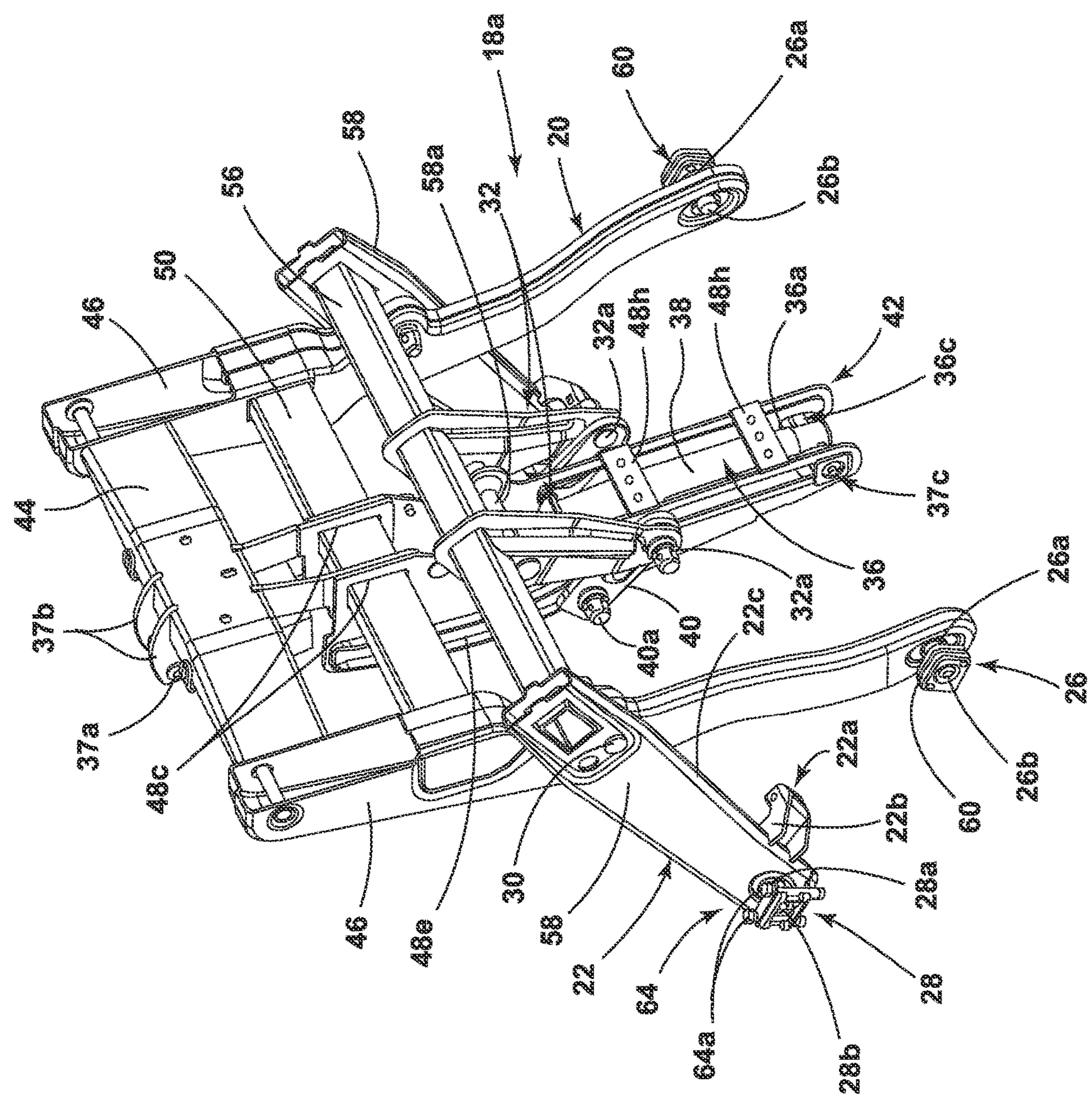

18a
60
26a
20
58
56
58a
32
26b
50
46
32a
48h
38
48h
36a
42
36c
37c
44
36
32a
40
40a
22c
26a
37b
37a
48c
26
22a
22b
60
26b
46
48e
30
58
22
64
64a
28b
28
28a

FIG. 9A

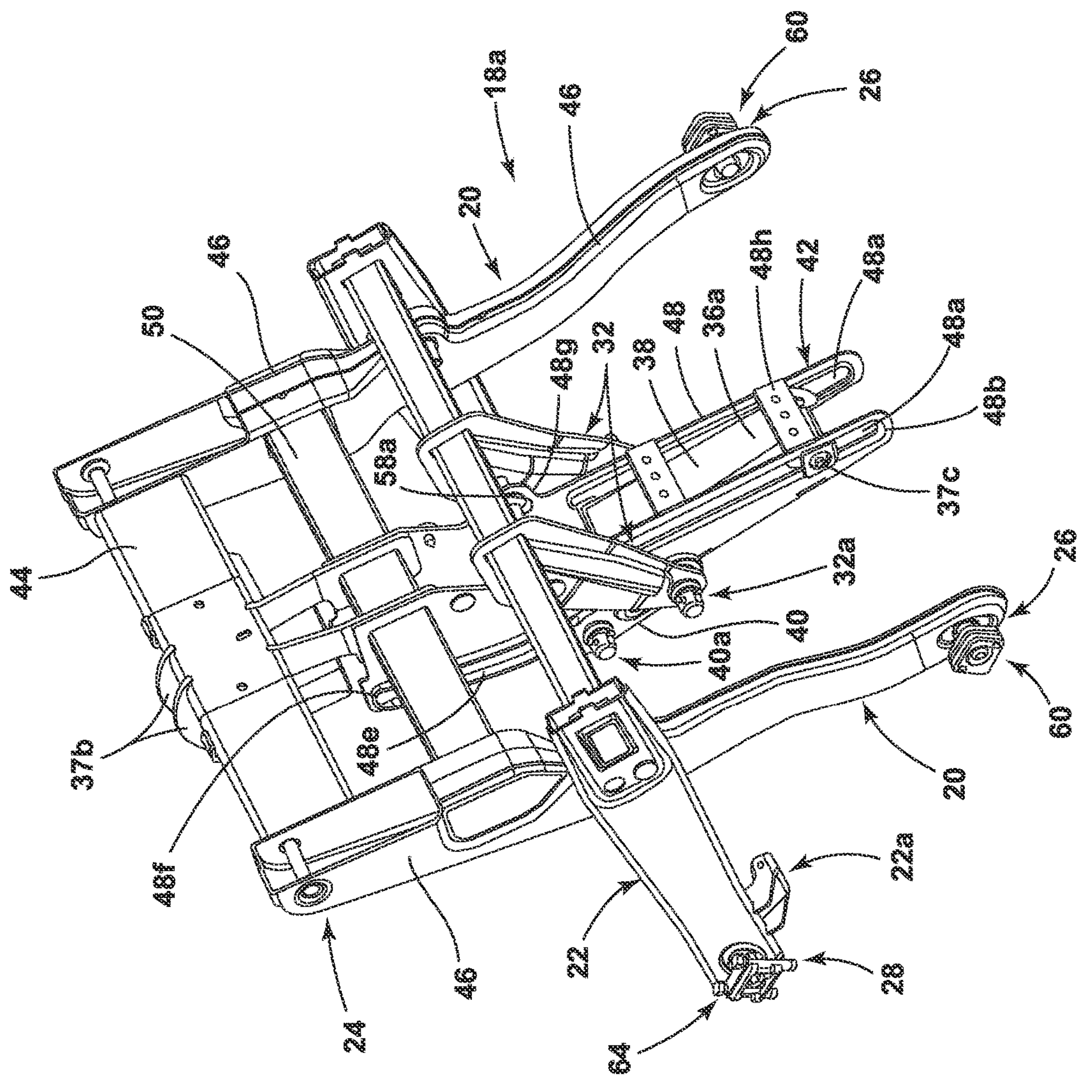

60
26
18a
46
20
46
50
48h
42
48a
36a
48
38
32
48g
48a
48b
58a
37c
44
32a
40
40a
26
37b
48e
60
20
48f
22a
24
46
22
28
64

FIG. 9B

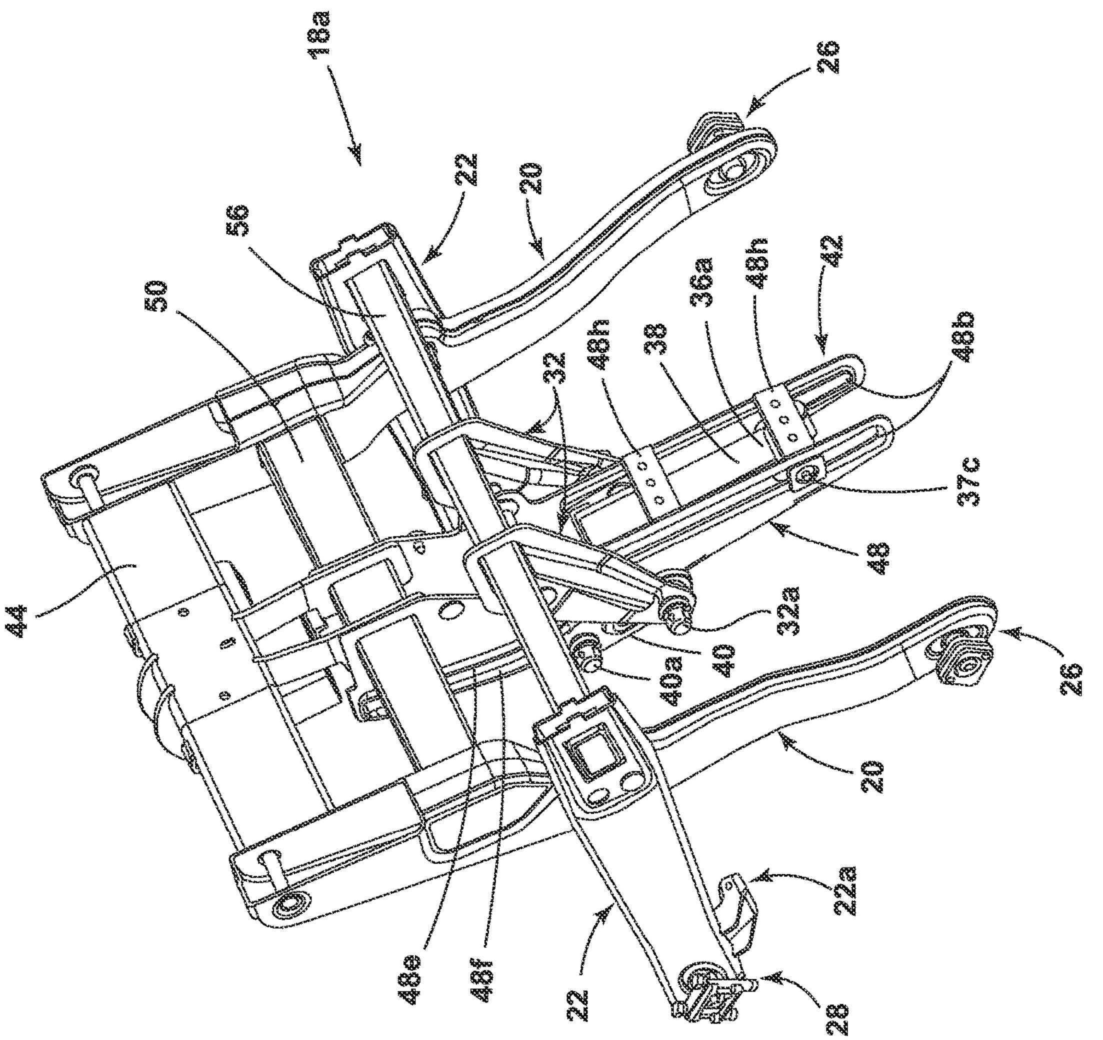

18a
26
22
20
56
50
42
48h
36a
38
48h
32
48b
37c
44
48
32a
40
40a
26
20
22a
48e
48f
22
28

FIG. 9C

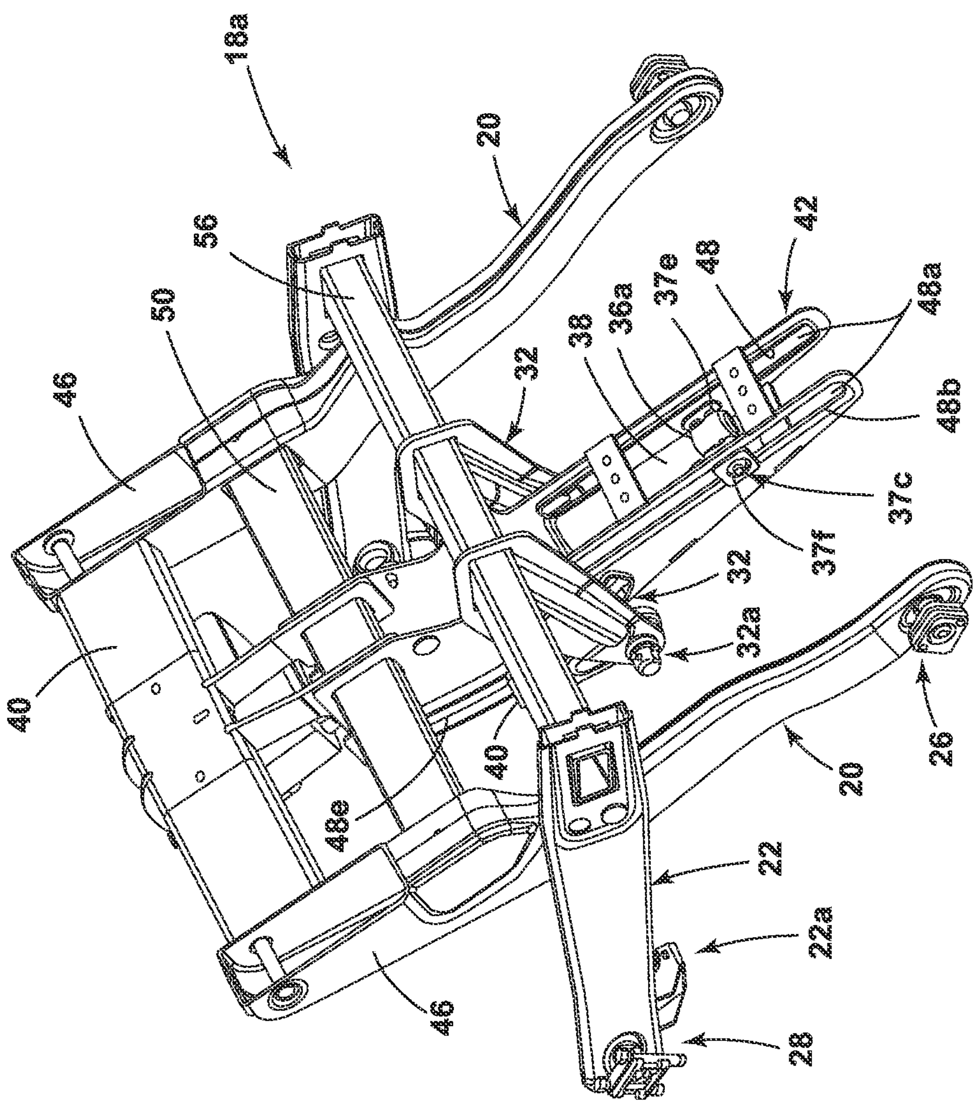

18a
20
56
50
46
42
48
37e
36a
38
32
48a
48b
37c
37f
32
32a
40
40
48e
26
20
22
22a
46
28

FIG. 9D

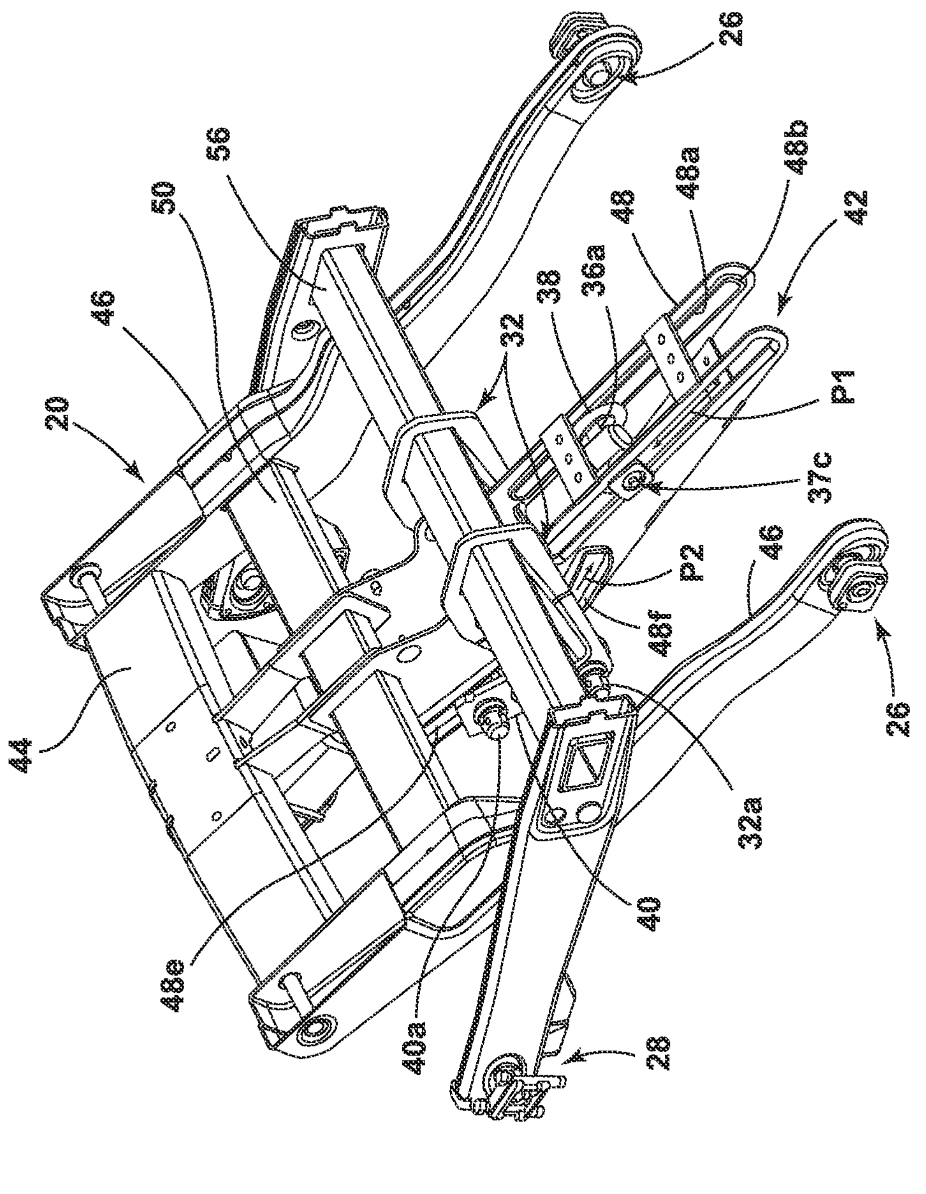

20
46
50
56
26
48
48a
48b
42
38
36a
32
P1
37c
P2
46
48f
26
32a
40
44
48e
40a
28

FIG. 9E

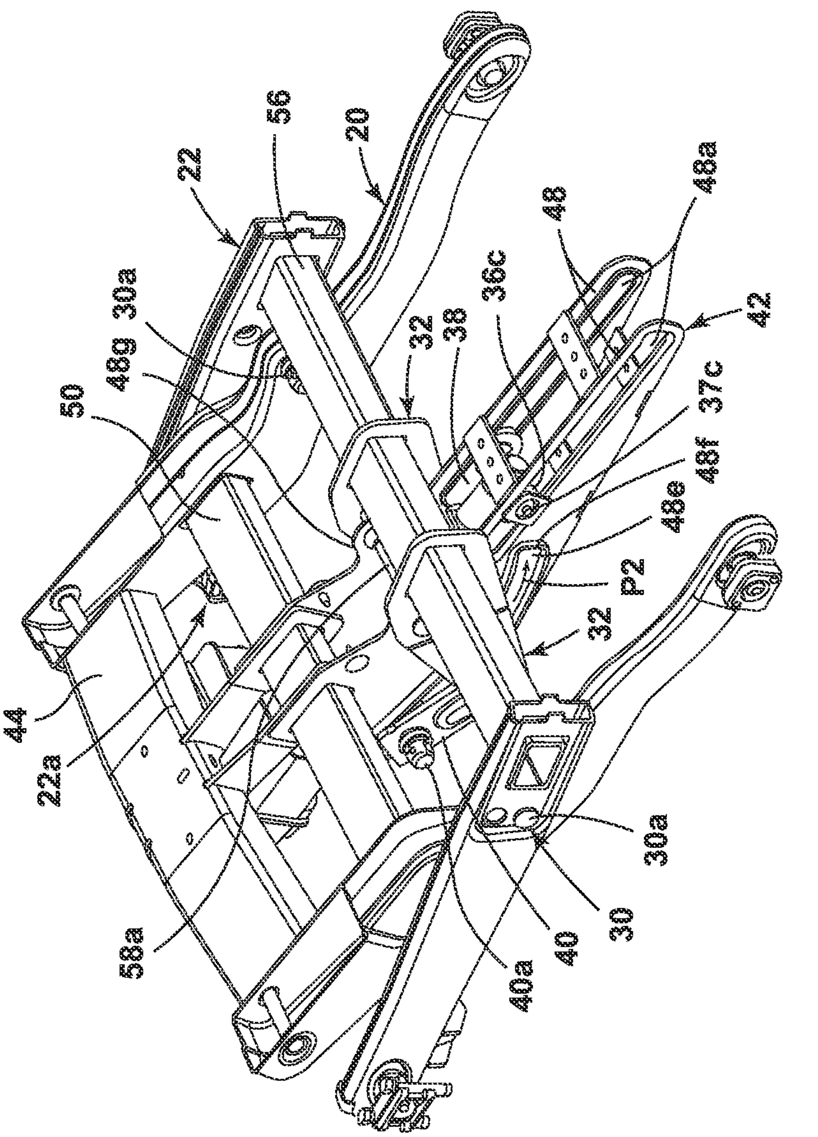

22
56
20
30a
48g
50
32
38
36c
48
48a
42
37c
48f
48e
P2
32
44
22a
58a
40a
40
30
30a

FIG. 9F

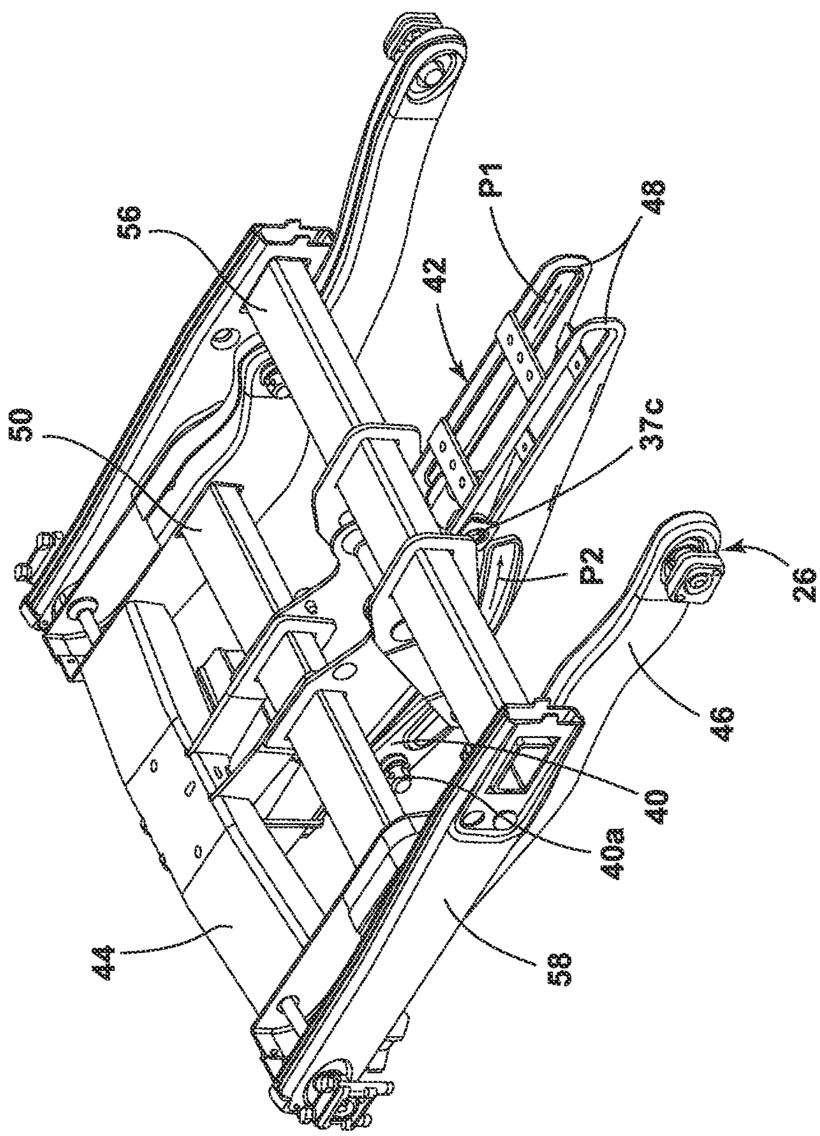


FIG. 9G

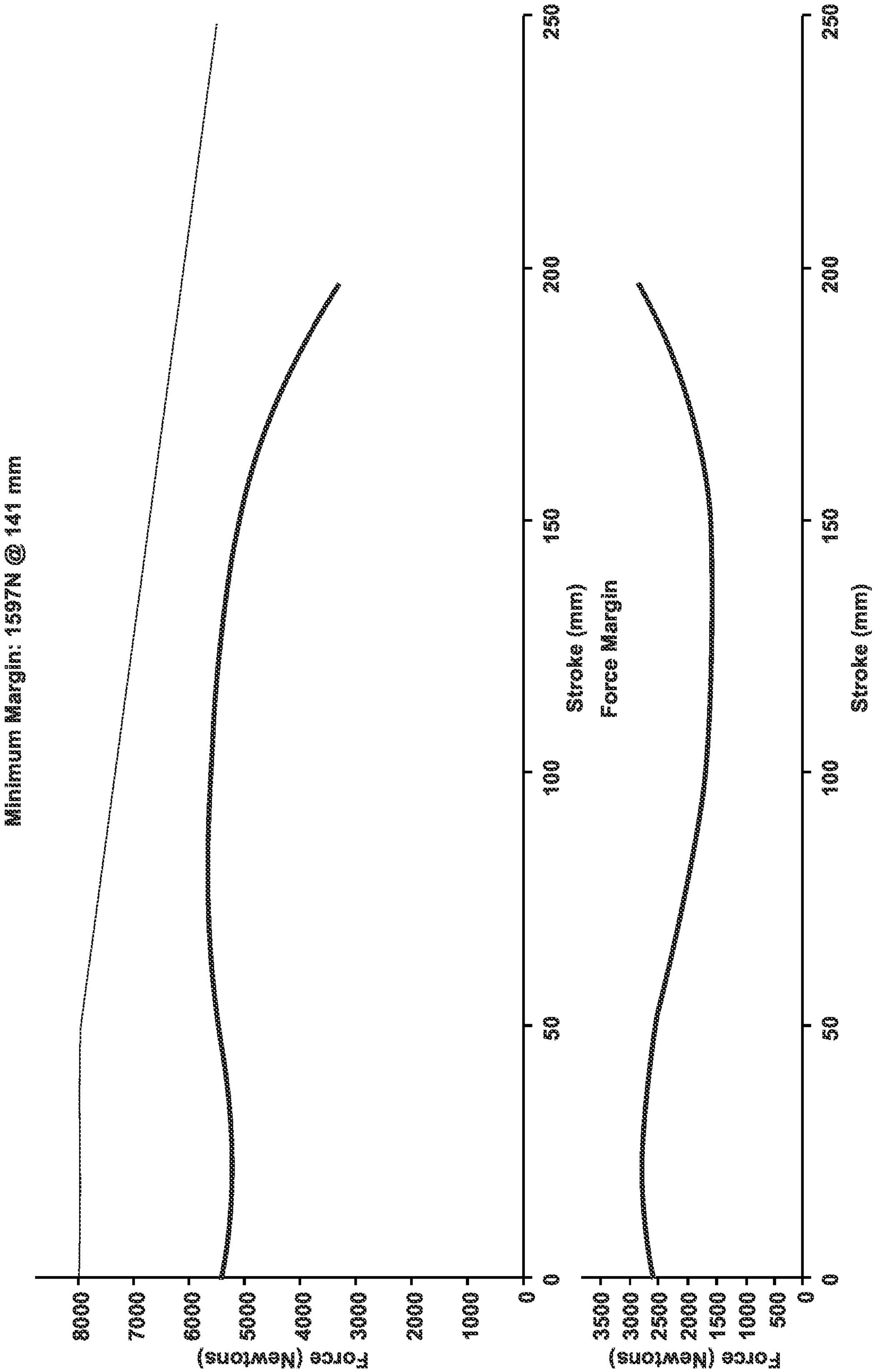

Minimum Margin: 1597N @ 141 mm
Force (Newtons)
8000
7000
6000
5000
4000
3000
2000
1000
0
50
100
150
200
250
Stroke (mm)
Force Margin
Force (Newtons)
3500
3000
2500
2000
1500
1000
500
0
50
100
150
200
250
Stroke (mm)

FIG. 9H

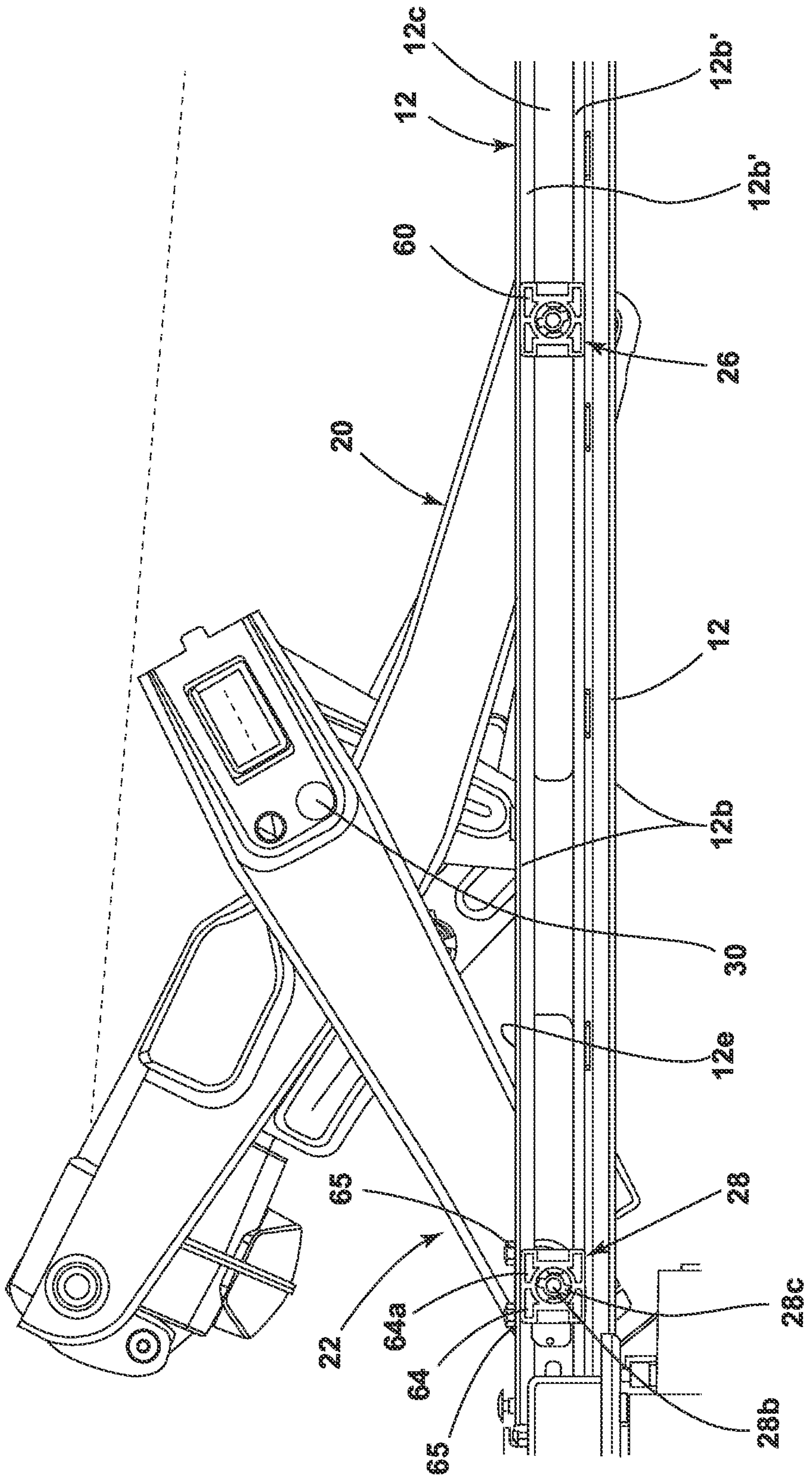


FIG. 10

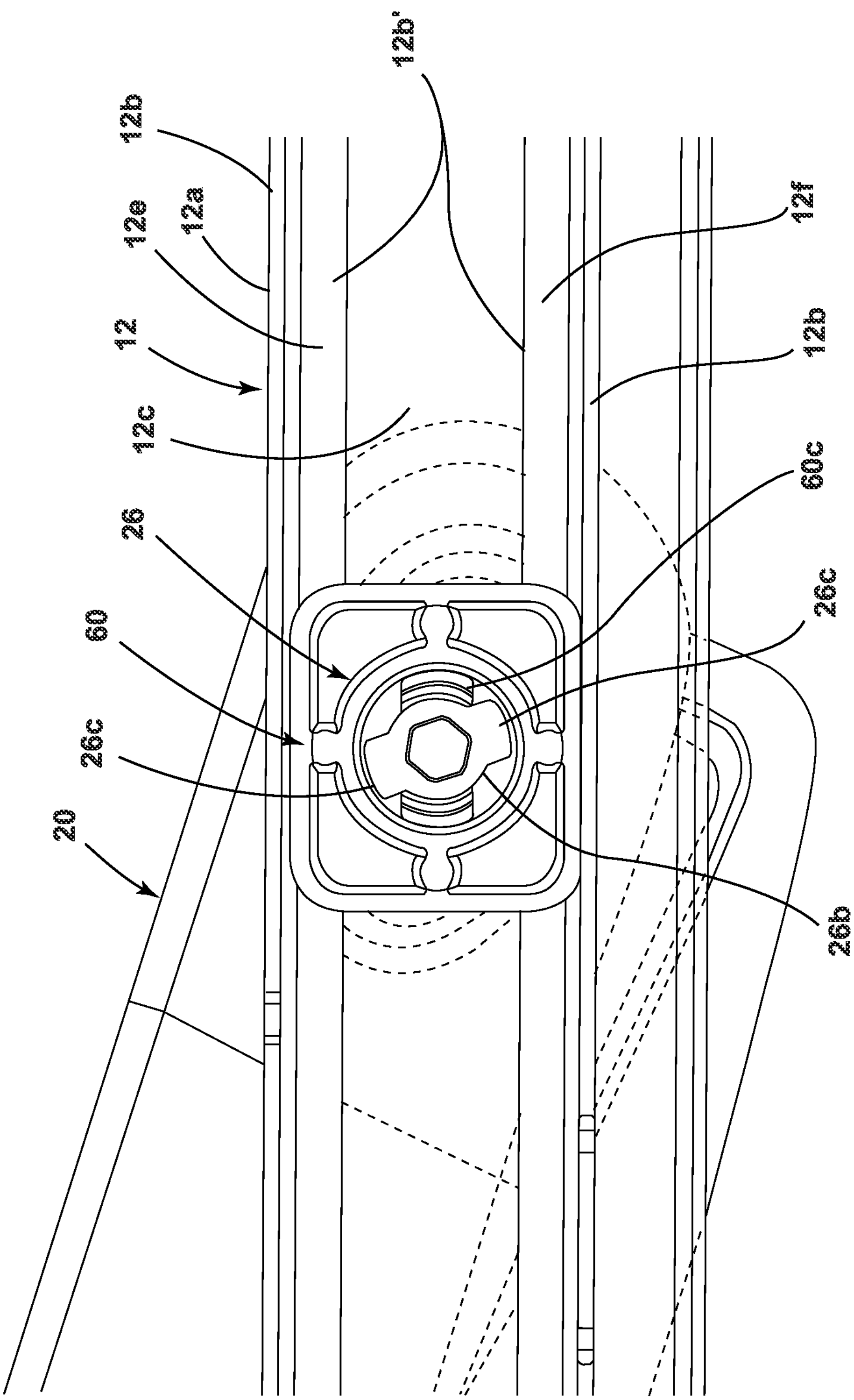


FIG. 10A

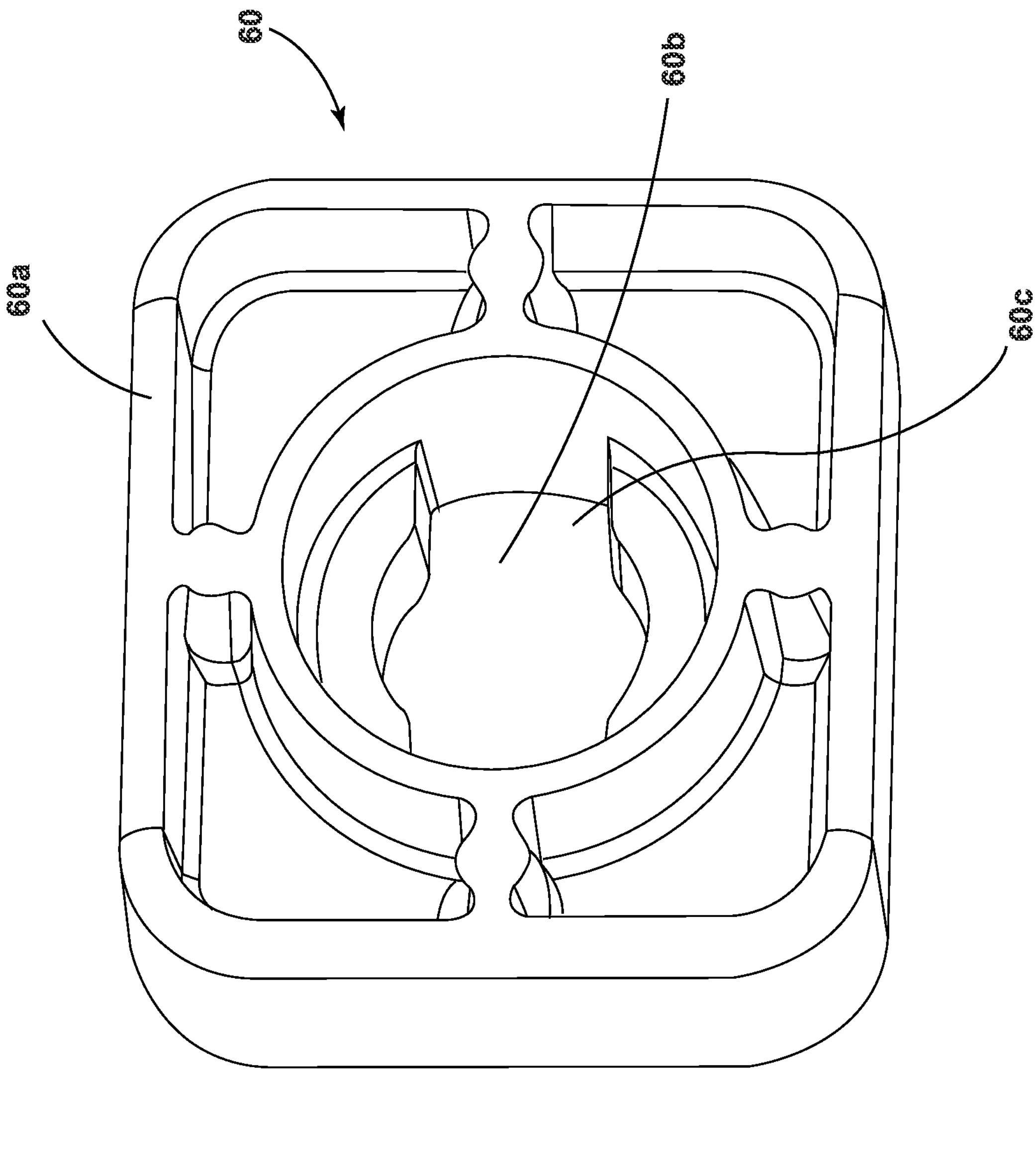


FIG. 10B

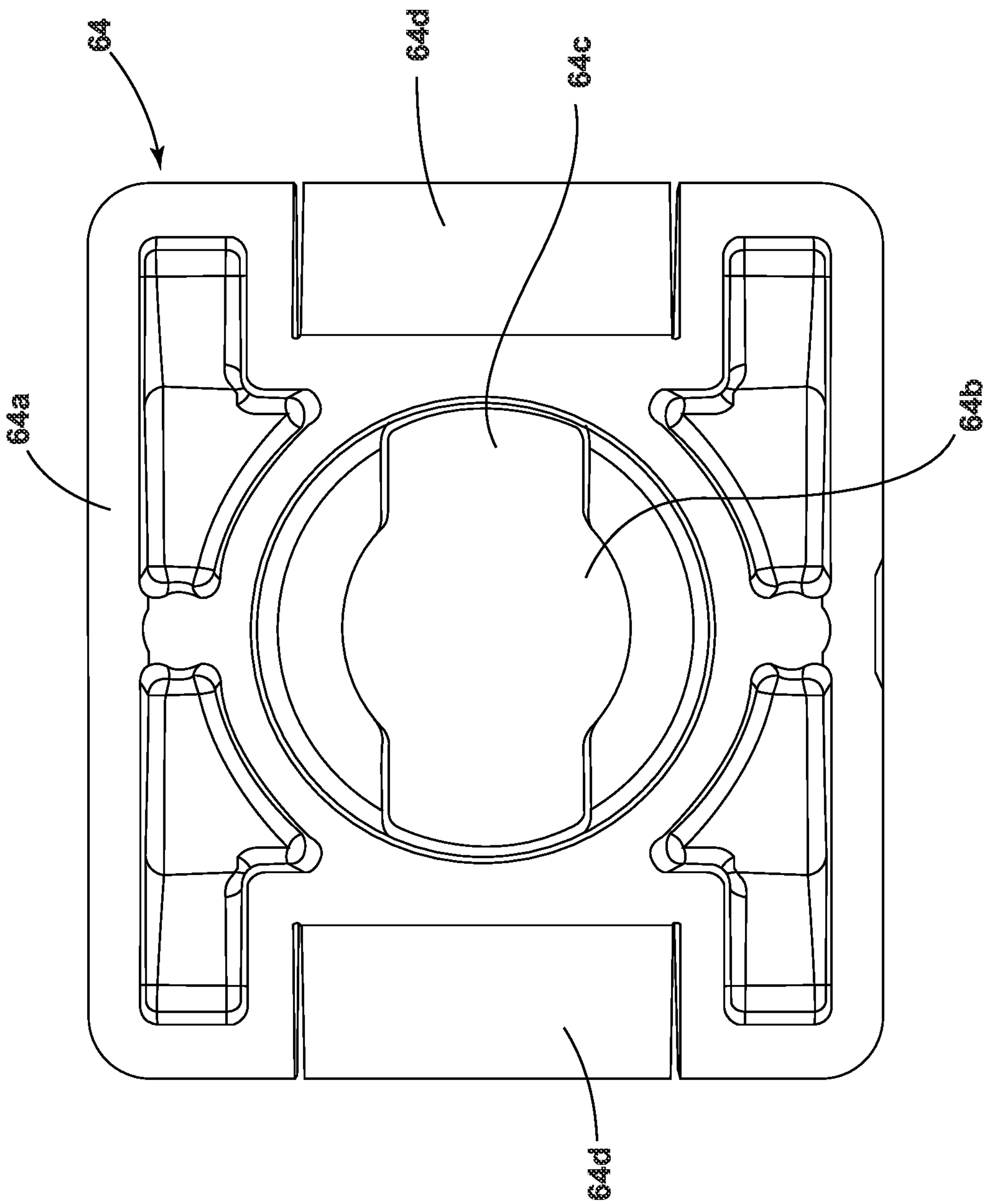


FIG. 10C

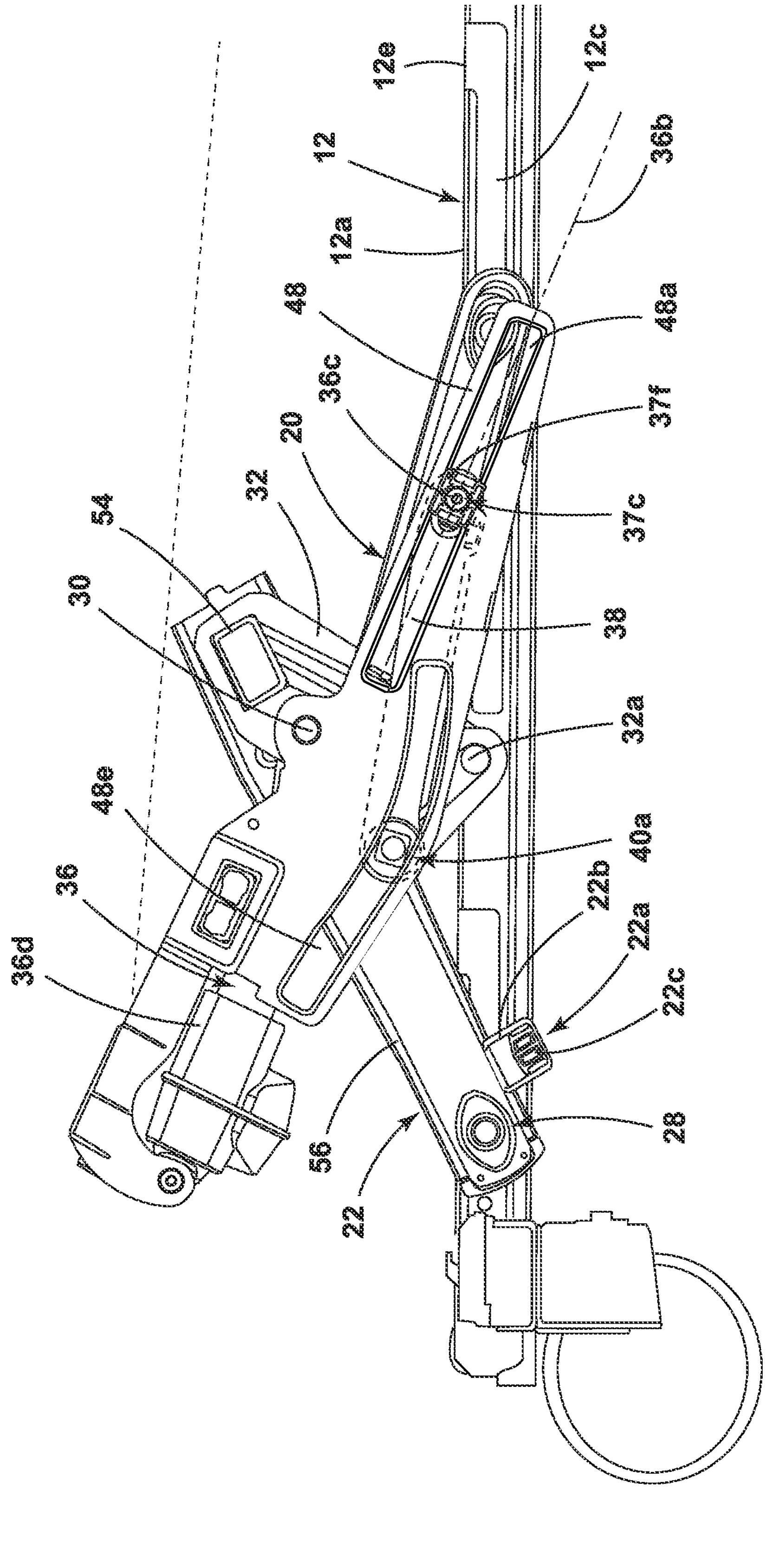

12e
12c
12
36b
12a
48
48a
36c
20
37f
32
54
37c
30
38
32a
48e
40a
36
22b
36d
22a
22c
56
28
22

FIG. 11

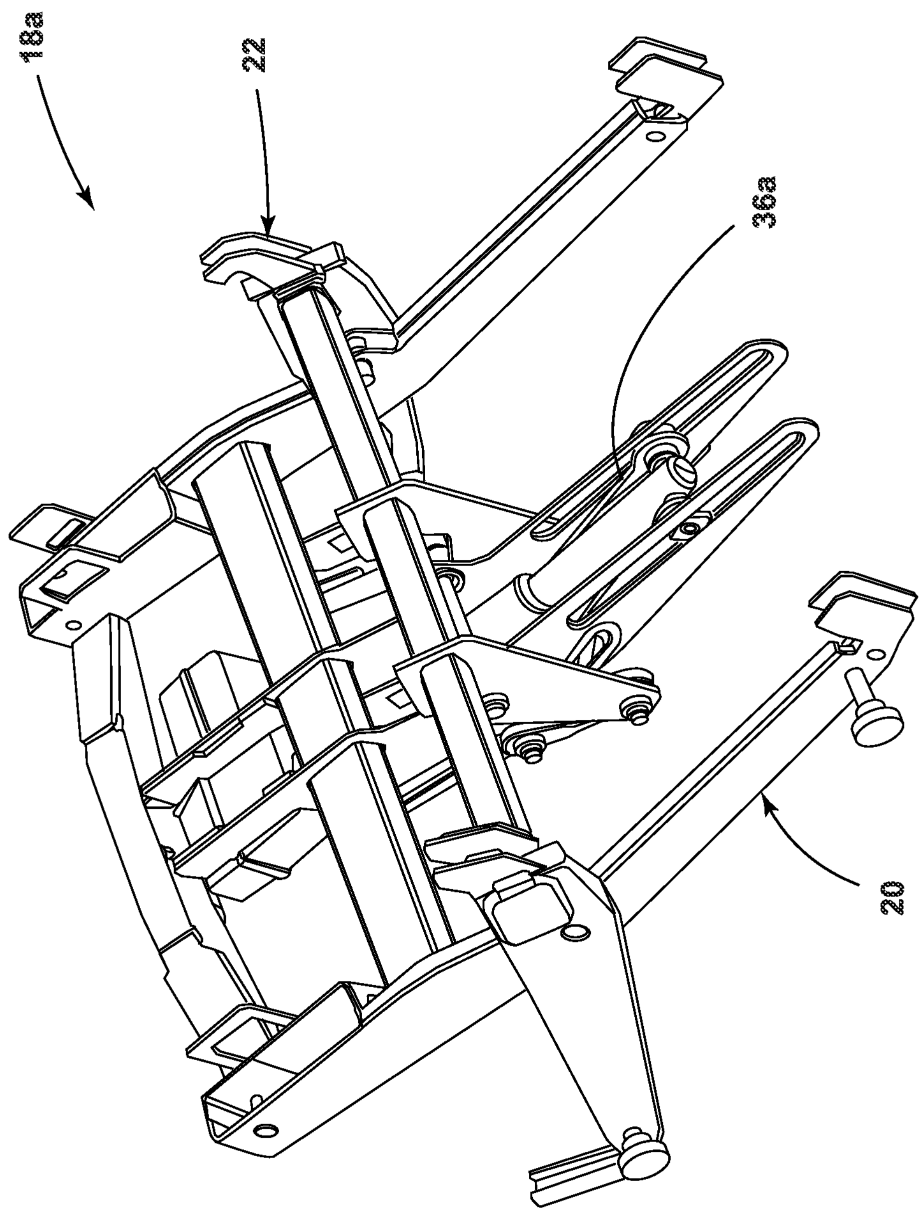


FIG. 12

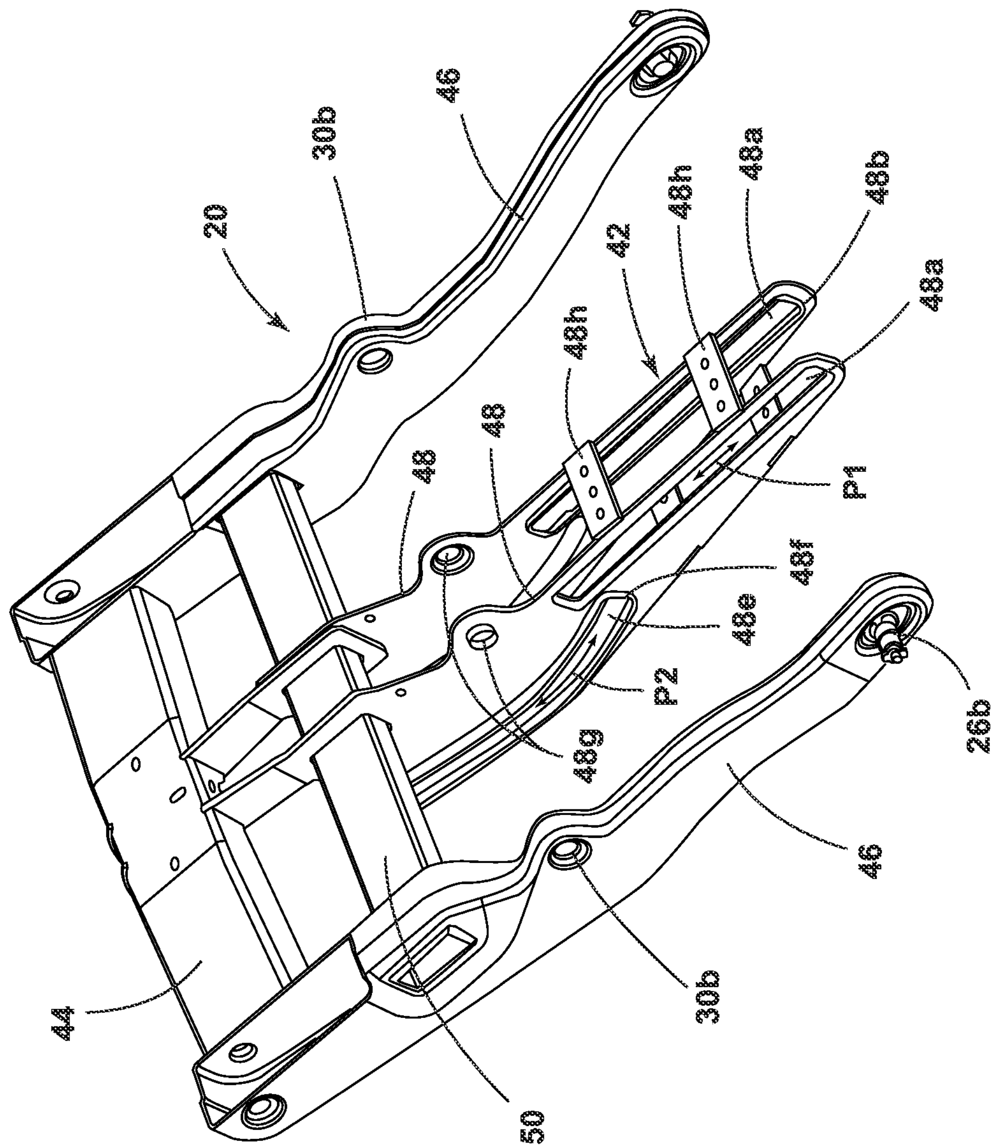

20
30b
46
42
48h
48a
48b
48h
48a
48
48
P1
48f
48e
P2
48g
26b
46
30b
44
50

FIG. 12A

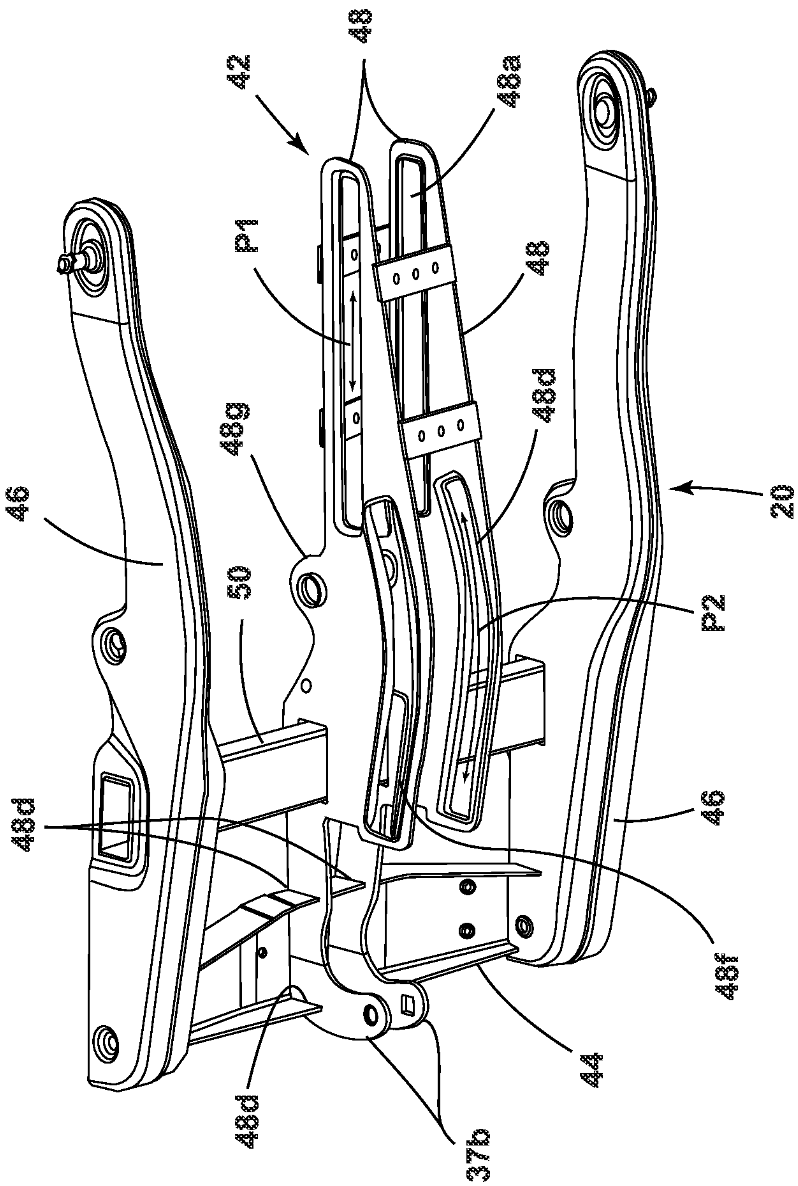


FIG. 12B

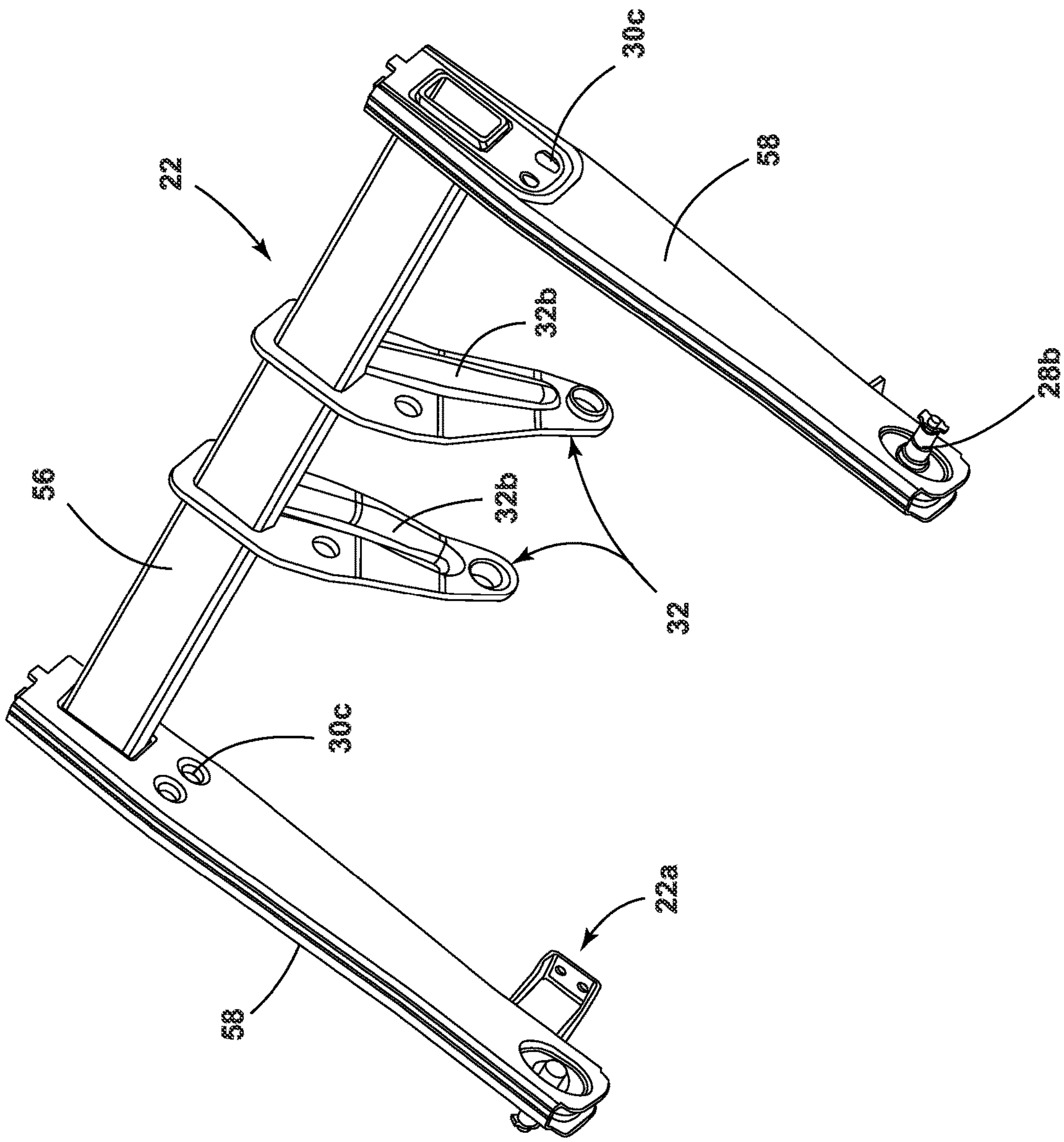


FIG. 12C

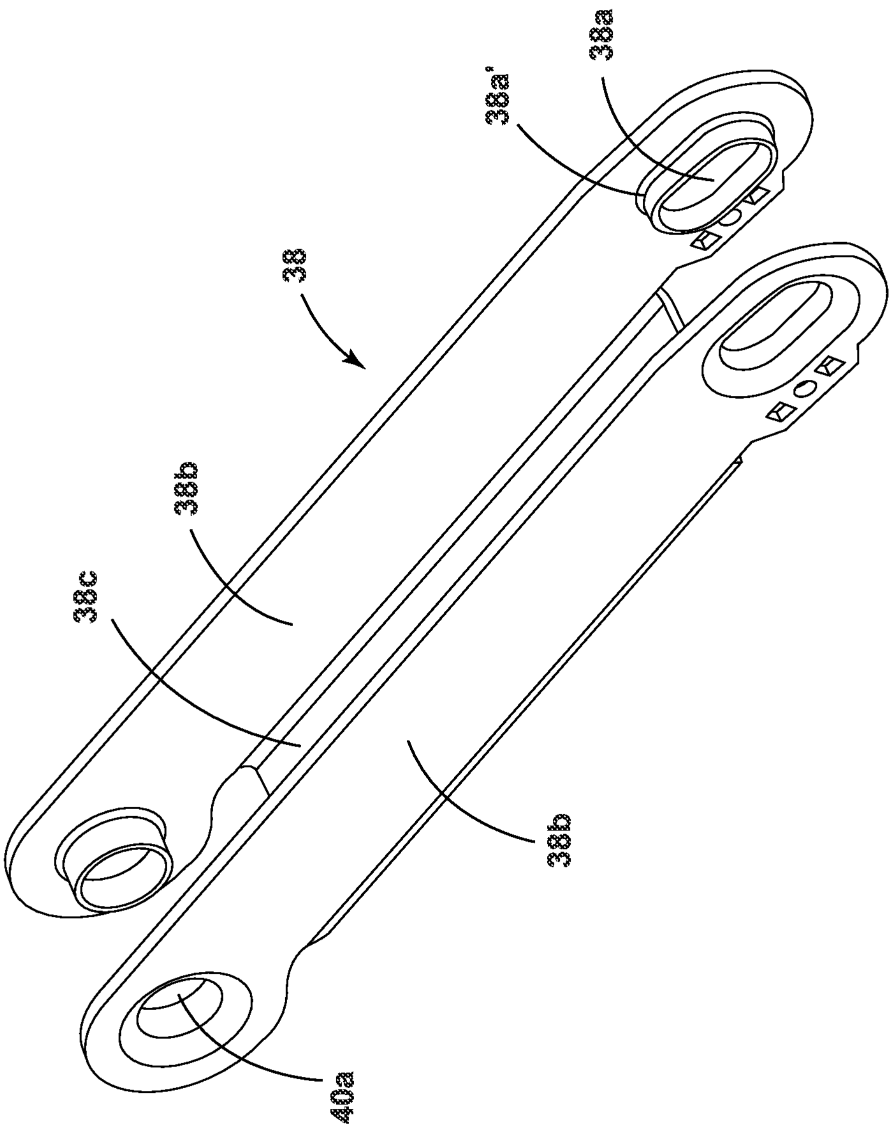


FIG. 12D

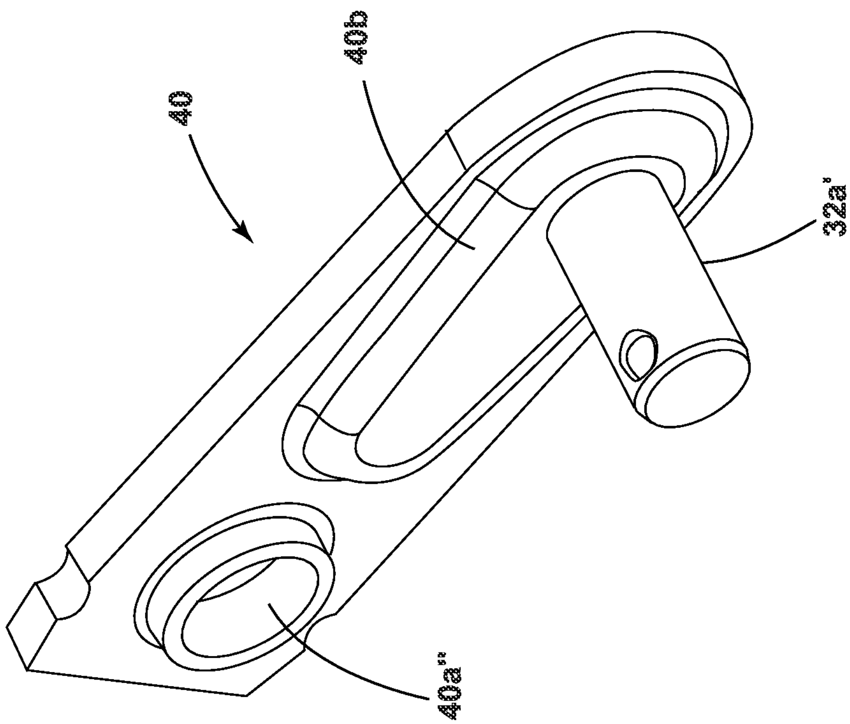


FIG. 12E

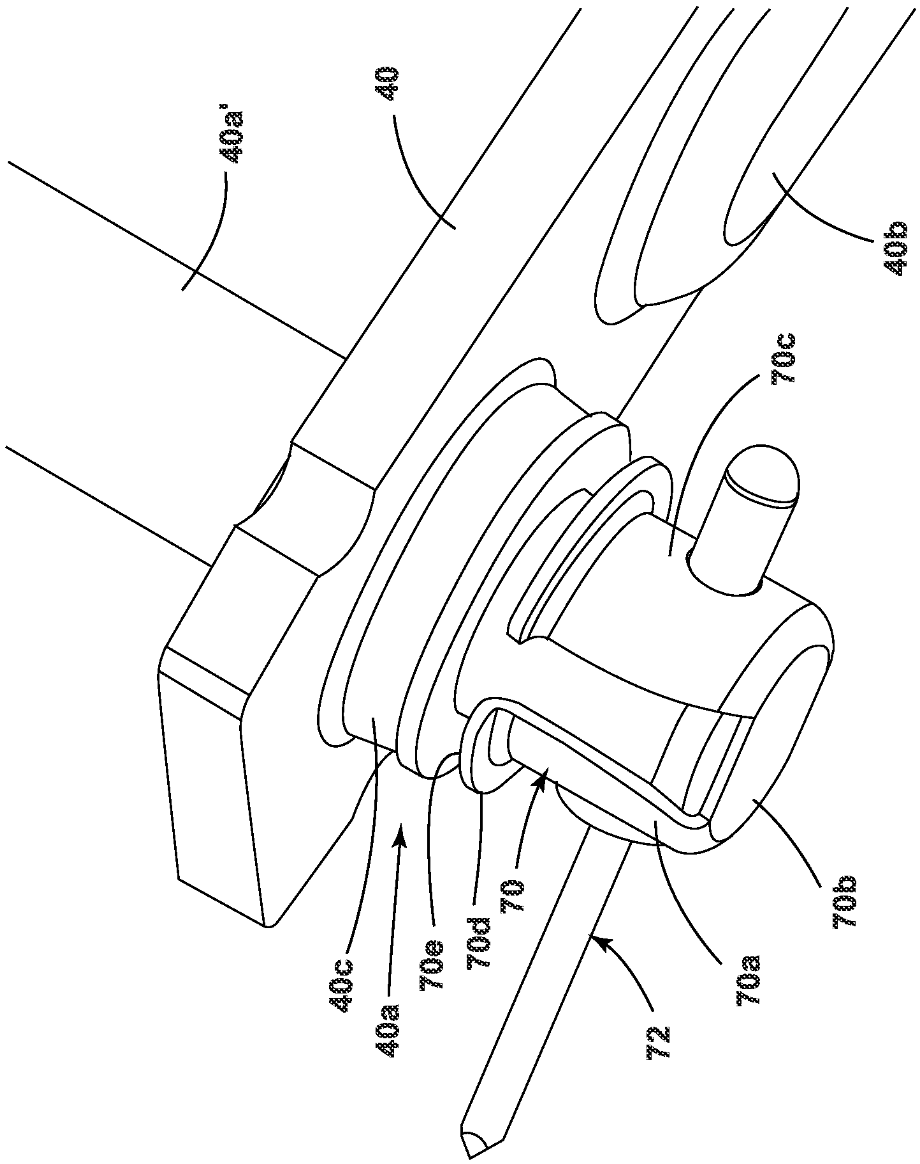


FIG. 12F

PATIENT SUPPORT WITH LIFT ASSEMBLY

This application claims the benefit of U.S. Prov. App. Ser. No. 62/948,540, entitled PATIENT SUPPORT WITH LIFT ASSEMBLY, filed on Dec. 16, 2019 (P-600), which is incorporated by reference in its entirety herein.

BACKGROUND

The present disclosure relates to a patient support apparatus with a lift assembly for raising or lowering a patient support apparatus deck relative to a floor surface. More specifically, the present disclosure relates to a patient support apparatus with a lift assembly that can lower the patient support apparatus deck to a very low height while still providing a full range of motion to a height where a caregiver can access the patient.

SUMMARY

A lift mechanism is described that is compact at a very low height while still providing a long range of travel to raise the patient support apparatus deck to a height that is suitable for caregivers. Further, the lift mechanism is configured so that it can raise or lower one end of the patient support deck to orient the patient in a Trendelenburg or reverse Trendelenburg position.

In one form, a patient support apparatus includes a base, a frame supported relative the base, with the frame configured to support a deck for supporting a patient thereon. The patient support apparatus further includes a lift assembly for raising or lowering the frame relative to the base. The lift assembly includes a first leg and a second leg, with the first leg being pivotally coupled to the frame at an upper end thereof and pivotally and slidably coupled to the base at a lower end thereof. The second leg is pivotally at its upper end mounted to the first leg at a medial portion thereof to form an inverted Y-shaped leg assembly when unfolded. The lift assembly further includes an actuator mounted in the leg assembly with a mounting configuration to produce a maximum force F1 when raising the frame occurring after the lift assembly is raised from its lowermost configuration. For example, the maximum force F1 may occur approximately at mid-stroke of the lift assembly.

In one embodiment, the actuator is mounted in the leg assembly with a mounting configuration to produce a starting force SF wherein the starting force SF is in a range of 95% to 99% of or 96% to 98% of or about 97% of the maximum force F1.

In one aspect, the actuator is mounted with a mounting configuration to produce a minimum force F2 when raising or lowering the frame wherein the minimum force F2 is in a range of 50% to 70% of the maximum force F1 and, optionally, about 60% of the maximum force F1.

In another embodiment, a patient support apparatus includes a base, a frame supported relative to the base, which is configured to support a deck for supporting a patient thereon, and a lift assembly for raising or lowering the frame relative to the base. The lift assembly is pivotally coupled to the frame at an upper end thereof and pivotally coupled to the base at a lower end thereof. The lift assembly includes a first leg and a second leg, with the second leg being pivotally mounted to the first leg at a medial portion thereof to form an inverted Y-shaped leg assembly when unfolded. An actuator is mounted in the leg assembly with a mounting configuration to produce a maximum force F1 and a minimum force F2 when raising or lowering the frame wherein the minimum force F2 is a range of 55% to 65% of the maximum force F1. For example, the minimum force F2 may occur at a maximum height of the lift assembly.

In one aspect, the actuator is mounted in the leg assembly with a mounting configuration to produce a starting force SF wherein the minimum force F2 is in a range of 55% to 65% of the starting force SF.

In another embodiment, a patient support apparatus includes a base, a frame supported relative to the base, which is configured to support a deck for supporting a patient thereon, and a lift assembly for raising or lowering the frame relative to the base. The lift assembly is pivotally coupled to the frame at an upper end thereof and pivotally coupled to the base at a lower end thereof. The lift assembly includes an actuator and a first leg and a second leg, with the second leg being pivotally mounted to the first leg at a medial portion thereof to form an inverted Y-shaped leg assembly when unfolded. The actuator is mounted in the leg assembly to the first leg on one end by a first connection and at its opposed end by a second sliding pivotal connection to the first leg.

In one aspect, the second sliding pivot connection is linked to the second leg wherein when the actuator extends or contracts, the first leg and the second leg are unfolded or folded with respect to each other.

In a further aspect, the first leg includes an upper pivot connection to the frame, a lower pivot connection to the base, and further comprises a drive link coupled on one end to the actuator and coupled at its opposed end to the first leg by a sliding link pivot connection. The drive link is eccentrically coupled to the second leg.

In one aspect, the sliding link pivot connection between the drive link and the first leg comprises a non-linear sliding pivot connection.

In another aspect, the sliding link pivot connection between the drive link and the first leg extends below the lower pivot connection of the first leg when the lift assembly is in its lowermost position.

In yet another embodiment, a patient support apparatus includes a base, a frame supported relative to the base, which is configured to support a deck for supporting a patient thereon, and a lift assembly for raising or lowering the frame relative to the base. The lift assembly is pivotally coupled to the frame at an upper end thereof and pivotally coupled to the base at a lower end thereof. The lift assembly includes an actuator and a first leg and a second leg, with the second leg being pivotally mounted to the first leg at a medial portion thereof to form an inverted Y-shaped leg assembly when unfolded. The second leg has a crank arm. The lift assembly further includes a drive link having first and second ends, with the first end of the drive link pivotally coupled to actuator and the second end of the drive link coupled to the crank arm and configured to move in a nonlinear path to thereby to push or pull on the crank arm from a range of angles and thereby unfold or fold the first leg and the second leg with respect to each other to contract or extend the lift assembly.

In one aspect, the first leg includes an upper pivot connection to the frame, a lower pivot connection to the base, and the driving link is slidingly coupled to the first leg by a sliding pivot connection and eccentrically coupled the crank arm.

In another aspect, the sliding pivot connection comprises a non-linear sliding pivot connection.

According to yet another embodiment, a patient support apparatus includes a base, a frame supported relative to the base, which is configured to support a deck for supporting a patient thereon, a head end actuator, and a foot end actuator. The patient support further includes a lift assembly for raising or lowering the frame relative to the base, which includes a head end leg assembly and a foot end leg assembly. Each of the leg assemblies has a pair of legs, with each pair of legs including a first leg and a second leg forming an inverted Y-shaped configuration when raising the frame and being folded generally flat when lowering the frame. The first legs are pivotally mounted at their upper ends to the frame and pivotally mounted at their lower ends to the base. Each pair of legs has a folding pivot axis, and each of the head end and foot end actuators has a first connection to its respective first leg and a sliding lower pivot connection to its respective first leg, wherein the first and second legs of each leg assembly are linked such that extension and contraction of their respective actuators will unfold or fold the leg assemblies to raise or lower the frame.

In one aspect, each of the first legs is linked to its respective second leg by a drive link, which are eccentrically mounted to their respective second legs.

In a further aspect, one end of each of the drive links is coupled to its respective first leg by a sliding pivot connection with an arcuate path.

In another aspect, the sliding pivot connections of the actuators to the first legs have linear paths.

According to another aspect, the head end leg assembly is independent from the foot end leg assembly.

In yet another embodiment, the lifting leg of the head end leg assembly is pivotally mounted at a head end pivot connection at or near the head end of the frame, and the lifting leg of the foot end leg assembly is pivotally mounted at a foot end pivot connection at or near the foot end of the frame.

In a further aspect, the head end and foot end pivot connections are offset below the frame.

In another embodiment, a patient support apparatus includes a base, a support frame supported relative to the base, which is configured to support a deck for supporting a patient thereon, and a lift assembly. The lift assembly includes a head end leg assembly and a foot end leg assembly. Each of the leg assemblies has an actuator and forms an independent assembly that can be mounted between the base and the support frame as an assembled unit simply inserting the pivot connections between the leg assembly and the base and coupling the pivot connections between the leg assembly and the support frame.

For example, in one aspect, the head end leg assembly and the foot end leg assembly each have an inverted Y-shaped configuration when the lift assembly moves the support frame to a raised position.

In yet further aspects, at least one of the leg assemblies includes first and second lifting legs. Optionally, the first lifting leg comprises an inverted U-shaped frame. Similarly, the second lifting leg may comprise a second inverted U-shaped frame. In another embodiment, one or both lifting legs may be L-shaped.

In another embodiment, the second lifting leg forms a stop for the first lifting leg when the lift assembly is folded to it lowermost configuration.

According to yet another embodiment, a patient support apparatus includes a base, a frame supported relative to the base, with the frame configured to support a cushion for supporting a patient thereon, and a lift assembly for raising or lowering the frame relative to the base. The lift assembly includes a first lifting leg and a second lifting leg. A linear actuator is mounted to the first lifting leg on one end and mounted to the first lifting leg at another end for linear movement relative to the first leg. The second lifting leg is linked to the actuator in a manner to cause the second lifting leg to pivot about the first lifting leg when the linear actuator is extended or contracted.

In yet another aspect, the second lifting leg includes a crank arm that is coupled to the actuator by a link so that extension or retraction of the actuator induces rotation of the second lifting leg.

These and other objects, advantages, and features of the disclosure will be more fully understood and appreciated by reference to the description of the current embodiment and the drawings.

Before the embodiments of the disclosure are explained in detail, it is to be understood that the disclosure is not limited to the details of operation or to the details of construction and the arrangement of the components set forth in the following description or illustrated in the drawings. The disclosure may be implemented in various other embodiments and is capable of being practiced or being carried out in alternative ways not expressly disclosed herein. In addition, it is to be understood that the phraseology and terminology used herein are for the purpose of description and should not be regarded as limiting. The use of "including" and "comprising" and variations thereof is meant to encompass the items listed thereafter and equivalents thereof as well as additional items and equivalents thereof. Further, enumeration may be used in the description of various embodiments. Unless otherwise expressly stated, the use of enumeration should not be construed as limiting the disclosure to any specific order or number of components. Nor should the use of enumeration be construed as excluding from the scope of the disclosure any additional steps or components that might be combined with or into the enumerated steps or components.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevation view of a patient support apparatus;

FIG. **1**A is a perspective view of the patient support apparatus of FIG. **1** with the deck, headboard, and footboard removed to show the mounting arrangement of the lift assembly;

FIG. **1**B is a side elevation view of the patient support apparatus of FIG. **1** with the deck, headboard, and footboard removed to show the mounting arrangement of the lift assembly;

FIG. **1**C is a plan view of the patient support apparatus of FIG. **1** with the deck, headboard, and footboard removed to show the mounting arrangement of the lift assembly in its fully lowered position;

FIG. **2** is a perspective view of the patient support apparatus of FIG. **1** with the deck, frame, headboard, and footboard removed to show the lift assembly in a full height position;

FIG. **2**A is an enlarged view of the foot end leg assembly of the lift assembly of FIG. **2**;

FIG. **3** is another perspective view of the patient support apparatus similar to FIG. **2** illustrating the lift assembly in a mid-height position;

FIG. **3**A is an enlarged view of the foot end leg assembly of the lift assembly of FIG. **3**;

FIG. **4** is another perspective view of the patient support apparatus similar to FIG. **2** illustrating the lift assembly in a lowermost position;

FIG. **4**A is an enlarged view of the foot end leg assembly of the lift assembly of FIG. **4**;

FIG. **5** is another perspective view of the patient support apparatus similar to FIG. **2** illustrating the lift assembly in a Trendelenburg position;

FIG. **6** is a side elevation view of the patient support apparatus with the deck, frame, headboard, and footboard removed to show the lift assembly in its full height configuration;

FIG. **6**A is an enlarged view of the foot end leg assembly of the lift assembly of FIG. **6**;

FIG. **7** is a side elevation view similar to FIG. **6** with the lift assembly in its mid-height position;

FIG. **7**A is an enlarged view of the foot end leg assembly of the lift assembly of FIG. **7**;

FIG. **8** is a side elevation view similar to FIG. **6** with the lift assembly in its lowermost position;

FIG. **8**A is an enlarged view of the foot end leg assembly of the lift assembly of FIG. **8**;

FIG. **9** is a side elevation view similar to FIG. **6** with the lift assembly in its Trendelenburg position;

FIG. **9**A is an enlarged perspective view of the lift assembly;

FIG. **9**B is an enlarged perspective view of the lift assembly;

FIG. **9**C is an enlarged perspective view of the lift assembly with actuator removed;

FIG. **9**D is an enlarged perspective view of the lift assembly with actuator removed;

FIG. **9**E is an enlarged perspective view of the lift assembly with actuator removed;

FIG. **9**F is an enlarged perspective view of the lift assembly with actuator removed;

FIG. **9**G is an enlarged perspective view of the lift assembly with actuator removed;

FIG. **9**H are graphs of the force and force margin versus stroke of the actuator;

FIG. **10** is an enlarged fragmentary outside elevation view of the mounting arrangement of one of the leg assemblies of the lift assembly to the base of the patient support apparatus;

FIG. **10**A is an enlarged cut-away of the base frame member illustrating a slide block of the lifting assembly;

FIG. **10**B is an enlarged perspective view of the slide block of FIG. **10**A;

FIG. **10**C is an enlarged elevation view of a mounting block;

FIG. **11** is an enlarged fragmentary inside elevation view of the mounting arrangement of one of the leg assemblies to the base of the patient support apparatus;

FIG. **12** is an enlarged perspective view of one of the leg assemblies and actuator of the lift assembly;

FIG. **12**A is an enlarged perspective view of one of the lifting legs of the lift assembly;

FIG. **12**B is a second enlarged perspective view of the lifting leg of FIG. **12**A;

FIG. **12**C is a perspective view of the other lifting leg of the lift assembly;

FIG. **12**D is an enlarged perspective view of one of the links of the lift assembly;

FIG. **12**E is an enlarged perspective view of another link of the lift assembly; and

FIG. **12**F is an enlarged perspective view of an exemplary pivot connection of the lift assembly.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Referring to FIG. **1**, the numeral **10** generally designates a patient support apparatus. In the illustrated embodiment, patient support apparatus **10** is configured as a bed, such as a hospital bed, with head and foot boards **10***a*, **10***b*, side rails (not shown), and an articulating deck **16**. However, it should be understood the patient support apparatus **10** may take on other forms, including a stretcher, a cot, or the like. In general, patient support apparatus **10** is used whenever a patient is to be supported and it is desirable to raise and lower the patient relative to a floor surface or other supporting surface. As will be more fully described below, patient support apparatus **10** includes a lift assembly for raising and lowering the patient support apparatus surface, such as a mattress or other cushioning device, which supports a patient thereon, between a fully raised position and a lowermost position, while still leaving clearance sufficient to allow a base of an over bed table or a patient lift to be extended under the patient support apparatus.

As best seen in FIG. **2**, patient support apparatus **10** includes a base **12**, a support frame **14** for supporting deck **16** (FIG. **1**), and a lift assembly **18** for raising or lowering support frame **14** (and deck **16**, see FIG. **1**) relative to base **12**. It should be understood that frame **14** may also support a load frame beneath deck **16**, which is used for mounting sensors, such as load cells, to measure the weight of a patient supported on the deck. However, the load frame may be eliminated and, instead, load cells may be placed in frame **14** due to the reduction of forces, especially the reduction of torque on the frame **14**, which is achieved the arrangement of the lift assembly components described more fully below.

As best seen in FIG. **2**, base **12** is a wheeled base with a plurality of caster wheels **15** to facilitate movement of the bed across a floor surface. In the illustrated embodiment, again referring to FIG. **1**, deck **16** includes a plurality of articulating deck sections **16***a*, **16***b*, **16***c*, **16***d*, and **16***e*. It should be understood, however, that the number of deck sections may vary. Each deck section may be articulated by an actuator (not shown) to raise or lower the deck sections, for example, to orient the deck sections in a flat configuration or in a chair configuration (and various other configurations in between). The construction of any of base **12**, support frame **14**, the headboard **10***a*, footboard **10***b*, and/or the side rails may take on any known designs, such as, for example, those disclosed in U.S. Pat. No. 7,690,059 issued to Lemire et al., and entitled HOSPITAL BED, commonly assigned to Stryker Corp., the complete disclosure of which is incorporated herein by reference herein in its entirety; or U.S. Pat. No. 8,689,376 entitled PATIENT HANDLING DEVICE INCLUDING LOCAL STATUS INDICATION, ONE-TOUCH FOWLER ANGLE ADJUSTMENT, AND POWER-ON ALARM CONFIGURATION, also commonly assigned to Stryker Corp., the complete disclosure of which is also hereby incorporated by reference herein in its entirety. The construction of any of base **12**, support frame **14**, the headboard **10***a*, footboard **10***b*, and/or the side rails may also take on forms different from what is disclosed in the aforementioned patent and patent publication.

As will be more fully described below, lift assembly **18** is configured so that actuators with a shorter stroke and consistent force margin ("applied force less actuator capacity") may be used while still being able to lower the deck to a low height position, such as 11 inches off the floor, and to a full height position, such as in a range of 26 to 34 inches off the floor. In other words, the same energy may be applied by better optimizing the force curve. In this manner, lower maximum loads may be applied to the components, such as the weldments forming the leg assemblies. Additionally, this may reduce costs and allow use of a lighter actuator.

Optionally, the actuator may be mounted to reduce, if not eliminate, any side loading on to the lifting legs by providing sufficient play in the actuator mounting arrangement, but no so much play that will induce lateral loads at its rod mounting location. Further, as noted above, the actuators are not mounted to the frame and, instead, are fully contained and mounted in the leg assemblies, as described below, which reduces forces on the frame so that load cells may be mounted to the frame to measure patient weight, as well as movement and patient biometrics.

Additionally, when lift assembly **18** is moved to its lowermost configuration, such as shown in FIGS. **4** and **8**, the lift assembly **18** may be substantially contained within base **12** without interfering with the central space S under the base, which may be needed, for example, for mounting a drive wheel and controls for the wheel drive system (such as the ZOOM system sold by Stryker). As such, for example, when lowered, patient support apparatus **10** may be configured so that the central space S under the base is clear at least over a length **51** of about **18** inches. In this manner, patient support apparatus **10** can provide a very low height patient support apparatus, which can reduce the chance of a patient fall, but without eliminating the available space under the base.

Referring again to FIG. **2**, lift assembly **18** includes a head end lift assembly **18***a* and a foot end lift assembly **18***b,* which may be substantially mirror images of each other and mounted adjacent the respective head and foot ends of the frame **14**. For ease of description, many of the following details are made in reference to the head end lift assembly **18***a,* with the understanding that the same details apply to the illustrated foot end lift assembly **18***b,* which is shown as a mirror image and numbered with the same numbers as the head end lift assembly. However, it should be understood that the head end and foot end lift assemblies may have different configurations.

As best seen in FIG. **1**A, frame **14** includes a pair of longitudinal frame members **14***a* and a pair of transverse frame members **14***b,* which connect longitudinal frame members **14***a* to form the frame. Referring to FIGS. **2**, **2**A, **3**, **3**A, **4** and **4**A, head end lift assembly **18***a* includes a first lifting leg **20** and a second lifting leg **22**, which are pivotally joined by pivot connections **30** (best seen in FIG. **3**A) to form a folding leg assembly **21**. Pivot connections **30** are formed by pins **30***a* (FIG. **9**F) that pivotally join first lifting leg **20** with second lifting leg **22** via openings **30***b,* **30***c* (see FIG. **12**A and **12**C) formed in the respective legs **20**, **22**.

First lifting leg **20** is pivotally mounted at its upper end to support frame **14** at pivot connections **24** (FIG. **1**A) formed by a pair of pins that are pivotally mounted to frame **14** such as by pivot blocks **14***d,* which are mounted to transverse frame members **14***b* of frame **14** via brackets **14***c*. Optionally, pivot connections **24** may be formed by a single pivot rod **24***a* (shown in phantom in FIG. **2**A) that extends transversely beneath upper transverse frame member **44** (described below) and into the upper ends of leg **20** to extend through pivot blocks **14***d,* which as described below nest in the upper end of legs **20** when the lift assembly is lowered folded. Optionally, rod **26***a* may be supported by intermediate brackets **24***b* (FIG. **2**A) mounted to the underside of frame member **44**.

Lifting leg **20** is pivotally mounted at its lower end to base **12** at sliding pivot connections **26**, such as by the pivot blocks **60** (described more fully below). Second lifting leg **22** is pivotally mounted at its lower end to base **12** at pivot connections **28** and pivotally mounted adjacent its upper end to the medial portion of lifting leg **20** by pivot connections **30**. In this manner, when legs **20** and **22** are unfolded about pivot connections **30** they form an inverted Y shaped frame and when folded are generally arranged in flattened configuration (see FIG. **4**). Further, as will be more fully described below, when folded, the legs **20** and **22** may be arranged in base **12** so that the deck **16** may be lowered to a height H of less than **12** inches off the surface on which the base is supported. Optionally, also more fully described below, when folded, second lifting leg **22** may provide a bearing surface, for example, in the form of a stop **22***a* (see FIG. **1**), for lifting leg **20** so that the load of the frame and deck may be directly transmitted to the base **12** via pivot connections **26** and **28**.

As will be more fully described below, lift assembly **18***a* (as well as lift assembly **18***b*) includes an actuator **36**, in the form of a linear actuator, such as a pneumatic, electric or hydraulic actuator. As will be more fully described below, upper end (fixed base **36***d,* e.g. FIGS. **2**A and **3**) of head end actuator **36** is mounted to the upper end of first lifting leg **20**, for example by a pivot connection **37***a* and bracket **37***b,* and, further, mounted at its opposed end via sliding pivot connection **37***c,* also to first lifting leg **20**. In this manner, when extensible rod **36***a* extends, it is extended along an axis **36***b* that is fixed relative to first lifting leg **20** (further details are provided below). In other words, the actuator does not pivot relative to the first lifting leg **20** and, instead, optionally extends generally parallel to lifting leg **20** (e.g. at least the upper linear portion of leg **20**, see below for further details on the optional construction of first lifting leg **20**).

In order to translate the linear motion of the actuator **36** into pivotal motion of second lifting leg **22** (and hence lifting motion of lift assembly **18***a*), lifting leg **22** is coupled to the actuator via a link and crank arm arrangement. Further, as will be more fully described below, the link and crank arrangement may be configured to tailor the force curve of the lift assembly to closely match the allowable force of the actuator.

For example, in one embodiment, the actuator and link and crank arm arrangements in the lift assembly are configured to produce a maximum force F1 to occur when raising the frame **14** after the lift assembly **18** has been raised from its lowermost configuration. Referring to FIG. **9**H, the maximum force F1 may occur approximately at mid-stroke of the lift assembly. Further, the actuator, link and crank arms are mounted in the leg assembly **21** with a mounting configuration to produce a starting force SF wherein the starting force SF is in a range of 95% to 99% of, 96% to 98% of, or about 97% of the maximum force F1 (see FIG. **9**H). As a result, the actuator may have a shorter stroke size than normally would otherwise be used, and moreover, may have a consistent force margin, with the force margin varying from about 1500 Newtons to about 3000 Newtons (see FIG. **9**H).

Further, in so doing, the speed of the lifting of the deck is more uniform throughout its range of motion, which is more comforting to a patient supported thereon. For example, the speed of the actuator over its full range of motion may be more consistent and may range from about 0.7 to 1.3 dist/time. It should be understood that the speed will vary due to the weight of the patient supported thereon and the capacity of the selected actuator.

In the illustrated embodiment, and referring to FIGS. **9**A-**9**G, second lifting leg **22** is coupled to actuator **36** via a pair of crank arms **32** and via links **38**, **40**. Each crank arm **32** is fixed mounted at its upper end to second lifting arm **22** and pivotally coupled by a pivot connection **32***a* at its lower end to a respective link **40**. In turn, each link **40** is pivotally coupled to link **38** via a pivot connection **40***a*. Additionally, link **38** is pinned at its opposed end to actuator **36** via a transverse pin **36***c* mounted in the distal end of rod **36***a* of actuator **36**. Therefore, the distal end of link **38** is extended along axis **36***b* as rod **36***a* extends or retracts along axis **36***b*. Additionally, pin **36***c* and the distal end of link **38** move in a linear path P**1**, described more fully below. Optionally, the distal end of link **38** may have a slotted opening **38***a* formed therein for receiving pin **36***c* to help offload forces on the actuator at the low height, as more fully described below in reference to stop **22***a*.

As best seen in FIGS. **9**A-9C, link **38** extends rearwardly from pin **36***c* toward the fixed based **36***d* of actuator **36**. Further, link **38** forms an acute angle with respect to rod **36***a* through its full range of motion, described below, while it distal end moves along path P**1**. The opposed, proximal end of link **38** (at pivot connection **40***a*) is guided along a non-linear path P**2** (see FIG. **9**E-9G and **1**A) that at least initially diverges away from the linear path P**1** of pin **36***c*, or in other words away from axis **36***b*. As noted above the rod **36***a* of actuator extends along an axis **36***b* that is fixed and generally parallel to at least the linear portion of lifting leg **20**. As such, when rod **36***a* is extended, link **38** will become a tension driver link that pulls pin **40***a*' of pivot connection **40***a* along path P**2**, which in turn pushes on links **40**. Links **40** in turn push on crank arms **32**, which apply a moment to second lift legs **22** to cause them to rotate counter clockwise (as view in FIG. **9**A, e.g.) about pivot connections **30** and unfold leg assembly **21** until pin **40***a*' of pivot connection **40***a* reaches the end of path P**2**. In reverse, as would be understood, when rod **36***a* is retracted, link **38** will become a compression driver link that pushes pin **40***a*' along path P**2** (toward fixed based **36***d* of actuator **36**), which in turn pulls on links **40**. Links **40** then in turn pull on crank arms **32**, which apply a moment to second lift legs **22** to cause them to rotate clockwise (as view in FIG. **9**E) about pivot connections **30** and fold leg assembly **21** until pin connection **40***a* reaches the other end of path P**2**. As would be understood, the path P**2** may extend beyond the path of the pivot connection **40***a* so that the end of the path of the pivot connection **40***a* is defined by the actuator **36** rather than a hard stop on either end of path P**2**.

To retain the rod **36***a* of actuator **36** along its fixed linear path, first lifting arm **20** includes a track **42** extending therefrom along axis **36***b,* which guides the rod **36***a* of actuator **36** when extending or retracting. In the illustrated embodiment, track **42** is formed form a pair of opposed plates **48**, such as stamped plates, with elongated slots **48***a* for guiding pin **36***c* of rod **36** along its linear path P**1** along axis **36***c*. Optionally, as more fully described below, plates **48** may be configured to provide a bearing surface **48***b* along edges of slots **48***a* for pin **36***c* to reduce slop and play and provide a tighter assembly. For example, bearing surfaces **48***b* may be provided by lips formed in plates **48** along at least the lower edge of slot **48***a,* but which may extend around the full perimeter of the slot to reinforce the plate at the slot location.

In the illustrated embodiment, referring to FIG. **9**A, first lifting leg **20** is formed from an inverted U-shape frame with a transverse upper frame member **44** and two depending frame members **46**, which are joined together such by as welding. Actuator **36** is mounted to lifting leg **20** between frame members **46** with its upper end mounted to transverse frame member **44** by a pivot connection **37***a*. Pivot connection **37***a* may be formed by a bracket **37***b*, such a pair of plate brackets attached, such as by welding, to transverse frame member **44**.

Tracks **42** (which as noted guide the extension of rod end **36***a* along axis **36***b*) extend from transverse upper frame member **44** and are supported and rigidly mounted (e.g. by welds) at one end to transverse frame member **44** (see FIGS. **9**A and **2**A). Tracks **42** are also supported and mounted to a second transverse frame member **50**. Transverse frame member **50** is spaced from transverse frame member **44** and rigidly mounted, for example by welding, between frame members **46** and provides rigidity to frame members **46**, in addition to providing support to tracks **42**.

In the illustrated embodiment, second lifting leg **22** may also be formed from an inverted U-shaped frame with an upper transverse member **56** and two depending frame members **58**, which are joined together, for example by welding. Depending frame members **58** straddle frame members **46** of first lifting leg **20** and are each pivotally joined thereto by pivot connections **30**. Transverse frame member **56** supports and provides a mount for crank arms **32**, which are rigidly attached to transverse frame member **56**, for example, by welding, and which straddle tracks **42**.

As best seen in FIGS. **9**A-9G, each plate **48** that forms tracks **42** is supported and mounted to transverse member **44** and to transverse member **50**, for example, by welding. In the illustrated embodiment, transverse member **50** passes through openings **48***c* formed in plates **48** and is welded to the plates **48** about openings **48***c,* which are commensurate in size to the transverse member **50**. Similarly, the upper end of plates **48** have notches **48***d* (FIG. **12**B) formed therein sized to receive transverse member **44** therein so that transverse member **44** can be welded to the respective plates **48** around the respective notches. Optionally, the ends of plates **48** may extend to form bracket **37***b*.

Path P**2** may also be formed by a pair of slots **48***e* to guide pivot connections **40***a*. Slots **48***e* may also be formed in plates **48** and also include bearing surfaces **48***f* for the pin **40***a*' of pivot connections **40***a* to thereby reduce slack and hence increase the tightness of the movement of the lift assembly. Similar to bearing surfaces **48***b,* bearing surfaces **48***f* may be provided by a lip or lips formed in plate **48** along at least the lower edge of slot **48***e,* but which may extend around the full perimeter of the slot **48***e* to reinforce the plate **48** at the slot location.

As best seen in FIG. **9**E, the lips that form bearing surfaces **48***b* and **48***f* may extend in opposed directions from each other—that is bearing surfaces **48***b* are formed on a lip(s) that extend from the inner side of plates **48**, while bearing surfaces **48***f* are formed on a lip(s) that extend from the outer side of plates **48**.

To guide pivot connection **40***a* and link **38**, and hence crank arm **32**, in the desired path, each slot **48***e* may be non-linear. Each slot **48***e* includes a first curved portion that is located approximately at the distal end of the slot **48***e* closest to the end of the rod **36**. The first curved portion forms the portion of the path P**2** that initially diverges away from path P**1** (and hence away from axis **36***b*). The second portion of slot **48***e* may be linear but is angled upwardly toward axis **36***b* and extends from the first curved portion toward to the proximal end of the slot **48***e* (end closest to the fixed body **36***c* of actuator **36**).

In this manner, when rod **36***a* is fully extended and leg assembly **21** is fully raised, and then actuator **36** is retracted, links **38**, now acting as compression links, will push pivot connections **40***a* along the first curved portion of path P**2**, which will pull links **40** and cause links **40** to increase their angle with respective to crank arms **32** while pulling on crank arms **32**. This increase in angle increases as the pivot connections **40***a* move along the curved portion due to the diverging angle of path P**2** from path P**1**, which increases their leverage on crank arms **32**. As the rod **36***a* continues to retract, pivot connections **40***a* will continue to move along path P**2** where links **40** and crank arms **32** increase their angular separation. This increase in angular separation increases the leverage of links **40** to pull on crank arms **32** until the legs are fully folded and in their lower most positions where links **40** can exert their maximum leverage. At the lowermost position, this is normally where the greatest torque is required due to the greatest separation of pivot connections **26**, **28**. However, with the present configuration, at this point, the force needed by the actuator **36** to move second leg **22** is not the maximum and, instead, is less than the maximum force due to the increased leverage of links **40** when in their orientation that corresponds to the lower most position of lift assembly **18***a*. Thus, the shape of the path P**2** is such that the greatest leverage occurs where the greatest force is normally needed to lift the leg assembly, which as noted is typically when leg assembly **21** in its lowest height where the pivot connections **26**, **28** of the first and second legs **20**, **22** are furthest apart. But here due to the increased leverage by links **40** on crank arms **32**, as noted, the force require is not the maximum force. Instead, the maximum force is required when leg assembly **21** is raised about halfway where the pivot connections **26**, **28** of the first and second legs are still significantly separated but links **40** have a reduced leverage on crank arms **32**.

Stated another way, when leg assembly **21** is fully lowered (see FIGS. **9**G and **8**A), and pivot connections **40***a* are at the proximal end of path P**2**, links **40** are substantially perpendicular to crank arms **32** and, therefore, as noted have the greatest leverage. In addition, as noted, due to the increased leverage, the amount of force is less than the maximum force needed during raising or lowering leg assembly **21**. As rod **36** is extended, however, the force needed by the actuator increases as the leg assembly is moved from its lower most position to its medial position where pivot connection **40***a* reaches its furthest distance from path P**1** (or axis **36***b*), which corresponds to where link **40** forms an acute angle and therefore is angled closer to crank arm **32**. In this orientation, link **40** has less leverage than when in the lower most position. As the rod continues to extend, however, the pivot connections **26**, **28** of the first and second legs are moved closer together to reduce the amount of torque needed for continued unfolding of the first and second legs **20**, **22** so that the reduced leverage of link **40** as it approaches the distal end of path P**2** coincides with a reduce amount of torque needed to move second leg **22** closer to the fully raised height of leg assembly **21**. As a result, and referring to FIG. **9**H, the force margins of the actuator are reduced.

Although described as sliding pivot connections, pivot connections **40***a* may be formed from a single pin or rod **40***a*' that extends between links **40** and plates **48**.

Optionally, to provide additional support to tracks **42**, crank arms **32** may be pivotally coupled to tracks **42** by a pin or rod **58***a* that passes through apertured flanges **48***g* (FIG. **9**B and **12**A) extending upwardly from plates **48**.

In the illustrated embodiment, in order to increase the rigidity and torsional resistance of lifting legs **20**, **22**, each frame member that forms the respective lifting leg may be formed from one or more closed cross-section members, such as formed from a metal, such as steel. Alternately, each lifting leg **20**, **22** may be formed from a solid member, such as steel bar or plate. Similarly, transverse frame members **50** and **56** may also be formed from tubular members and extended into one or more transverse openings formed in the respective legs **20**, **22** and welded thereto around one or both openings to thereby form a rigid frame.

For example, depending members **46** and **58** may be formed from closed tubular members or solid plates. The closed tubular members may be formed from structural channel members or two stamped plates that are joined together, such as by welding. For example, each plate may be stamped into a channel shaped cross-section, which are then joined together in a facing relationship (open sides facing each other, like a clam shell arrangement). Optionally, the two plates may be slightly nested to allow the flanges of one channel shaped member to be inserted into the open face of the other channel-shaped plate and then welded in place with spot welds or continuous welds along their length. Alternately, the plates may be sized so their flanges abut each other and are also welded together, for example, by spot welding or continuous welds along their lengths.

In addition to increasing the strength and torsional resistance of the lifting legs, their construction allows the shape of the legs to be tailored. For example, rather than having to have longer pins **26***b* on pivot connections **26** to span the space between leg **20** and base (**12**), as seen in FIG. **9**A, the lower portions of leg **20** (e.g. depending members **46**) may be formed so that they are offset or angled outwardly. For example, starting below pivot connections **30**, the lower portions of leg **20** (e.g. depending members **46**) may be formed so that they are offset or angled outwardly so that the mounts **26***a* for pivot connections **26** on leg **20** are offset outwardly and can be aligned in the same plane as the mounts **28***a* for pivot connections **28**. In this manner, pivot connections **26** and **28** may be mounted in the same channel (channel **12***c* of frame members **12***a*). Consequently, a single tube weldment may be used to form base **12**.

Transverse member **44**, on the other hand, may be formed from an open sectioned member, such as a channel shaped member, including a channel formed from a stamped plate or a structural channel member.

Track **42**, as noted, may be formed from plates, which may be reinforced with braces **48***h* (FIG. **9**A). Similarly, links **38**, **40** and crank arms **32** may also be formed from plates and when needed provided with embossments or bosses around their mounting openings to increase their strength. For example referring to FIG. **12**E, each link **40** may be formed from an elongated rectangular plate with an embossment **40***b* to reinforce the plate. Similar, crank arms **32** (FIG. **12**C) may be formed from a generally triangular shaped pate and include embossments **32***b*, which reinforce the crank arms.

Referring to FIG. **12**B, links **38** may be formed from two plates **38***b* joined at their (e.g. lower) edges by a transverse plate **38***c*, which may be welded to or formed with plates **38***b* to form an U-shaped link assembly. Openings **38***a* to may be reinforced by bosses or lips **38***a*' that encircle openings **38***a* and which also form bearing surfaces for pin **36***c* of actuator **36**. As noted above, openings **38***a* may also be elongated to allow off-loading from the actuator **36**, for example, when lift assembly **18***a* is fully lowered.

Further, as shown in the illustrated embodiment, the cross-section for the components of the lift assembly may vary along their length to provide increased strength where needed, but reduced in cross-section where the loads on the lift assembly are reduced to thereby provide a more compact and reduced weight light assembly. Further, by varying the cross-sections, the components of the lift assembly may provide a better nesting arrangement when folded. In the illustrated embodiment, frame members **46** are formed with three different cross-sections at three different elevations, which allow the lifting leg **20** to avoid interference with other components of the bed, including leg **22**, as it swings though its full range of motion.

For example, referring to FIG. **9**A, the upper end of leg **20**, for example, depending frame members **46** may have the largest cross-section given that the forces to raise or lower the frame **14** are greatest at the upper end of leg **20**. Further, with the increased cross-section, a portion of the frame members **46** may have an open section at their upper ends to provide for cable routing through lift assembly and, further, to provide better nesting. As best understood from FIG. **1**A, when lift assembly is fully folded and frame **14** is lowered, the mounting brackets **14***c* and mounting blocks **14***d* may extend into and nest in the open sections of the upper portion of frame members **46**, which again assists in reducing the overall height of the deck when the lift assembly is in its lower most configuration.

As noted above, the lower ends of lifting legs **20**, **22** are mounted to base **12** by pivot connections **26**, **28**. As seen in FIG. **9**, pivot connections **26** may be formed by a sliding block **60** rotationally mounted to each of the lower ends of the lifting legs **20** by pins **26***b*. Blocks **60** are guided in channels **12***c* formed in base frame members **12***a* (FIGS. **2** and **4**) between upper and lower flanges **12***b*. Similarly pivot connections **28** may be formed by blocks **64** rotationally mounted to each of the lower ends of the lifting legs **20** by pins **28***b*. Blocks **64** are located and fixed in channels **12***c* by fasteners **65**, which extend through openings in upper flange **12***c* of frame members **12***a*.

To make the lift assembly more compact, blocks **60** and **64** may be mounted to pins **26***b*, **28***b* without the use fasteners or spring clips and, instead, retained on pins **26***b* and **28***b* using a tab and slot arrangement with blocks **60** and **64**, respectively, described below in reference to FIGS. **10**, **10**A, **10**B, and **10**C. Further, in order to avoid blocks **60**, **64** being rotated off pins **26***b*, **28***b*, each block has a tabbed connection for mounting the pins **26***b*, **28***b* to the block. Each pin **26***b*, **28***b* has one or more tabs that have to align with corresponding notches provided in the block mounting opening **60***b*, **64***b* in order to mount the blocks or remove the blocks from the pins. Additionally, referring to FIGS. **3** and **10**, each of the mounting blocks are square or rectangular in shape so that they can be retained between the upper and lower flanges **12***b* of frame members **12***a* and do not rotate, though pins **26***b* and **28***b* are free to rotate in the blocks. The tabs on the pins (and corresponding notches) are arranged so that they do not align during normal movement of the lift mechanism and, therefore, retain the respective blocks on the pins (**26***b* **28***b*) during normal operation.

As best seen in FIGS. **10**A and **10**B, blocks **60** have rectangular body **60***a* with a central transverse opening **60***b*, which includes one or more notches **60***c*. In the illustrated embodiment, opening **60***b* includes a pair of opposed notches. Similarly, pin **26***b* has one or more tabs **26***c* for aligning with the notch or notches. When so aligned, pins **26***b* may be inserted into the opening **60***b* in the block **60** and, thereafter, the block **60** rotated about the pin to thereby retain the pin on the block. The block is then inserted into the frame member **12***a* (via cutouts or notches **12***e* described below) and captured between the upper and lower flanges. Optionally, upper and low flanges may include downwardly and upwardly extending lips **12***b*' (FIGS. **10** and **10**A), respectively, to further help retain blocks **60** and **64** in channels **12***c*.

As best seen in FIG. **10**C, blocks **64** similarly have a rectangular body **64***a* with a central transverse opening **64***b*, which includes one or more notches **64***c*. In the illustrated embodiment, opening **64***b* includes a pair of opposed notches **64***c*. Similarly, pin **28***b* has one or more tabs **28***c* for aligning with the notch or notches. When so aligned, pins **28***b* may be inserted into the opening **64***b* in the block **64** and, thereafter, the block **64** rotated about the pin to thereby retain the pin on the block. The block is then inserted into the frame member **12***a* (via cutouts or notches **12***e* described below) and captured between the upper and lower flanges **12***b*. To secure block **64** in a fixed location, block **64** includes transverse openings through body **64***a* and offset portions **64***d* that are curved and align with the transverse openings for receiving fasteners **65** through body **64***a* and thereby fix the location of the pivot connection **28** along frame members **12***a* of base **12**.

Referring to FIGS. **3** and **10**, blocks **60** and **64** are inserted in channels **12***c* of frame members **12** via notches **12***e* formed in the upper flanges **12***b* of frame members **12**. Notches **12***e* are located offset from pivot connections **28**, which when installed are fixed along the longitudinal axis of frame members **12***a* via fasteners **65**, and out of the normal travel of the sliding pivot connections **26**. Once inserted therein, blocks **60**, **64** are moved to their in use locations and then retained therein by the upper and lower flanges **12***b* and optional lips **12***b*' of frame members **12***a*. Thus, base **12** has install locations for the pivot connections offset from their use locations.

In addition to the overall construction, this installation arrangement and mounting configuration allows for lift assembly **18***a* (and **18***b*) to be installed as a unit (with the actuator and lines (e.g. power and/or hydraulic lines and/or pneumatic lines) already assembled in the unit), simply requiring the lift assembly to be inserted into the base and connected at their upper ends to mounting blocks **14***d* without the need for additional brackets and fasteners for installation.

Further, referring again to FIGS. **1**C and **4**, when frame **14** is in its lowermost position, frame members **14***a* of frame **14** may rest on base **12**, namely on between base members **12***a*. Additionally, lifting legs **20**, **22** and crank arms **32** are arranged so that they fold into the space defined between base members **12***a*, with the majority, if not all of, legs **20** and actuator **36** lying at or below the upper flange of base members **12***a* (FIG. **8**). Further, as noted, pivot connections **26** and **28** are aligned along the respective base frame members **12***a* and lie in the same plane, with pivot connections **30** aligned at or just below the upper flange of the respective frame members **12***a*.

In this manner, when lift assembly **18** is in its lowermost configuration, many of the components of the lift assembly (lifting legs, crank arms) are lowered into the space defined between or slightly below base frame members **12***a*, but leave there between space S, as described above. Additionally, when lift assembly **18** is in its lowermost configuration, the distance from the top of the deck to the floor may be less than 14", less than 13", and optionally less than 12". Further, the space below base members **12***a* is sufficient to allow a base of an overbed table or lift assembly to extend under base. For example, the distance from the underside of the base members **12***a* to the floor is at least 4", at least 5" or between about 5"-6".

As noted about, second lifting legs **22** have one or more stops **22***a* to provide a stop for the upper portion of leg **20** when leg assembly **21** is fully folded. Stops **22***a* are mounted and arranged to extend inwardly of legs **22** so that they provide bearing surfaces for depending frame members **46** of first lifting leg **20** when it is fully folded.

In the illustrated embodiment, stops **22***a* are formed by L-shaped brackets **22***b* mounted, such as by welding, to the inner side **22***c* of lifting legs **22**. Brackets **22***b* extend inwardly from inwardly facing side **22***d* of leg **22** to contact downwardly facing side of leg **20** when leg **20** is folded. Brackets **22***b* may have a rubber bumper or rubber bumpers **22***c* (FIG. **11**) mounted thereto to reduce noise and absorb some vibration. Because the stop is located adjacent pivot connection **28**, when folded, the weight of the deck and frame pass essentially directly through legs **22** to base **12**.

Referring to FIG. **9**A, as described above, actuator **36** may be mounted to reduce side loading on the lift assembly components. For example, pin **36***c* of actuator **36** may be mounted in slot **48***a* of plate **48** between links **38** and between a pair of bushings **37***e* (FIG. **9**D). Optionally, gaps or spaces are provided between bushings **37***e,* for example plastic bushings, and rod **36***a* (or between the bushings and links **48**) to provide sufficient play to avoid binding but also play that is sufficiently small to avoid inducing side loading (e.g. to avoid actuator from angling relative to path P**1**) on lift assembly, and more specifically on track **42**. For example, the gaps on each side may fall in a range of ½ to 1/1000th inch. Further, to help retaining pin in slots **48***a,* each opposed end of the pin **36***c* may be guided by a rectangular bushing **37***f* that is taller than the height of the slots **48***a* so that they ride on the outside of plates **48**. Optionally, springs may be provided in lieu of, or in addition to bushings **37***e,* to help maintain the alignment of the rod **36***a* along path P**1**.

Referring to FIGS. **1**A and **3**, optionally one or more of the lift assembly components may include protective and/or aesthetic covers, formed, for example, from plastic. For example, covers C**1** and C**2** may be provided to cover and optionally protect the head end and foot ends of the base **12**. Similarly, at least the rods of the actuators and track may be covered by a cover C**3**. Covers C**4** may also be provided to extend over legs **22**. However, it should be understood with the closed construction of many of the lift assembly components, covers need not be provided for the leg assemblies of the lift assembly.

Although not specifically described in each instance, it should be understood that the structural load bearing members of the lift assembly may all be formed from metal, including steel, and further may be stamped, molded, cast or forged members, and assembled by welding. Other members, such as the mounting blocks or covers, may be formed from plastic or other low friction materials, which may be molded.

Optionally, at least some, if not all, of the pivot connections may incorporate a retainer **70** (FIG. **12**F) that renders the pivot connection tamper resistant, and optionally non-serviceable. It also makes the lift assembly connections easy to inspect. Although detailed in reference to pivot connection **40***a* of link **40**, it should be understood that the same or similar details apply to the other pivot connections.

As best seen in FIG. **12**F, the end of the pin **40***a*' of the pivot connection (**40***a*) projects though the opening provided in link **40**. Optionally, the opening may be reinforced by a raised boss **40***c*. Mounted on pin **40***a*' about opening is retainer **70**. Retainer **70** is mounted to the distal end of pin **40***a*' via a standard pop rivet **72**, which extends though retainer **70** and though a transverse opening provided in the distal end of pin **40***a'.*

In the illustrated embodiment, retainer **70** includes a cylindrical body **70***a* with a closed end **70***b,* which rests against the distal end of pin **40***a*'. The cylindrical wall **70***c* of body **70***a* is bifurcated to ease installation on the end of pin **40***a*' so that it can be manually mounted on the distal end of pin **40***a*', though a tool can be used as well. Optionally, body **70***a* includes a flanged end **70***d* that forms an annular bearing surface **70***e,* which can provide some thrust load when for example, when pin **40***a*' pulls inwardly as view in FIG. **12**F and engages washer W. Thus, retainer **70** provides an easy to inspect connection, which is tamper resistant and, further, may be non-serviceable, to ensure the correct assembly at the original manufacturing facility.

As would be understood, because the head end and foot end lifting assemblies are independent, they can be independently moved to raise or lower the head or foot ends of the support frame to move the deck in a Trendelenburg or reverse Trendelenburg position (see FIGS. **1**A, and **5**). Additionally, the speeds of each actuator can be independently controlled. For example, suitable actuators include Linak actuators, such as model number LA **40**, or Ilcon actuators. For example, the actuators may include sensors or magnets to measure the speed of the actuator so that, as noted, the actuation and speed of each actuator may be independently controlled.

Referring to FIG. **9**H, in one embodiment of a standard hospital bed, the force of the actuators may range from about 5300-5400 N when in the lowermost position, up to about 5700-5800 N when about midway between the lowermost position, and then back down to about 3200-3300 N when in the uppermost position. As would be understood normally the greatest force is needed when the lift assembly is in its most compact, lowermost position; however, with the current arrangement of links and crank arms, which maximizes the moment arm when the leg assembly is in its lowest most position, the initial starting force (SF), as noted above, is less than the maximum force F1. As the lifting legs raise up relative to the base, the leverage provided by the crank arms decreases until the lift assembly has reached the midway region, approximately 19-24 inches off the floor, thus increasing the required force. As the lift assembly continues to rise , the leverage provided by the crank arms furthers reduces but at a reducing rate, as shown in FIG. **9**H, until the lift assembly is in its uppermost configuration.

With the above configuration, when lift assembly **18** is in its lowermost position, the distance from the top of the litter deck (shown in phantom in FIG. **30**) to the floor may be less than 14", less than 13", and optionally less than 12", and the space beneath base frame members **12***a* is unobstructed to allow a base of an overbed table or lift assembly to extend under base. For example, the distance from the underside of the base frame members **12***a* to the floor is at least 4", at least 5" or between about 5"-6" and provides a minimum clearance of about 2 to 3 inches or about 2.4 inches below the lowermost member of the patient support. Further, when lift assembly is in its raised position, the lifting legs move outwardly toward the ends of the frame to thereby leave a space sufficient to allow a fluoroscope device to extend between the frame and the base.

Though not described in each instance, it should be understood that the structural components of the frame, the deck, and the lift assembly may be formed from metal structural members, such as steel, that are either welded (as noted in some cases) or fastened together, e.g. by bolts, rivets, pins, or screws or the like, or simply mechanically interlocked (as noted above in reference to some of the brackets). Further, features on one embodiment may be combined with features of another embodiment or embodiments. Additionally, it should be understood that the actuators may be controlled to extend or contract independently, for example, so that they can raise or lower one end of the patient support apparatus to orient the patient support apparatus deck in a Trendelenburg or reverse Trendelenburg position.

Directional terms, such as "vertical," "horizontal," "top," "bottom," "upper," "lower," "inner," "inwardly," "outer" and "outwardly," are used to assist in describing the disclosure based on the orientation of the embodiments shown in the illustrations. The use of directional terms should not be interpreted to limit the disclosure to packages of any specific orientation(s).

Various alterations and changes can be made to the above-described embodiments without departing from the spirit and broader aspects of the disclosure as defined in the appended claims, which are to be interpreted in accordance with the principles of patent law including the doctrine of equivalents. This disclosure is presented for illustrative purposes and should not be interpreted as an exhaustive description of all embodiments of the disclosure or to limit the scope of the claims to the specific elements illustrated or described in connection with these embodiments. For example, and without limitation, any individual element(s) of the described disclosure may be replaced by alternative elements that provide substantially similar functionality or otherwise provide adequate operation. This includes, for example, presently known alternative elements, such as those that might be currently known to one skilled in the art, and alternative elements that may be developed in the future, such as those that one skilled in the art might, upon development, recognize as an alternative. Further, the disclosed embodiments include a plurality of features that are described in concert and that might cooperatively provide a collection of benefits. The present disclosure is not limited to only those embodiments that include all of these features or that provide all of the stated benefits, except to the extent otherwise expressly set forth in the issued claims. Any reference to claim elements in the singular, for example, using the articles "a," "an," "the" or "said," is not to be construed as limiting the element to the singular.

We claim:

1. A patient support apparatus comprising:

a base;

a frame supported relative to said base, said frame configured to support a deck for supporting a patient thereon;

a lift assembly for raising or lowering said frame relative to said base and being pivotally coupled to said frame at an upper end thereof and pivotally coupled to said base at a lower end thereof;

said lift assembly including a first leg and a second leg, said second leg being pivotally mounted to said first leg at a medial portion thereof to form an inverted Y-shaped leg assembly when unfolded; said lift assembly being configured to be raised from a lowermost configuration according to a starting force SF that is less than a maximum force F**1** when raising said frame relative to said base after said lift assembly is raised from said lowermost configuration; and

an actuator mounted in said lift assembly with a mounting configuration to produce said maximum force F**1** when raising said frame occurring after said lift assembly is raised from said lowermost configuration, a minimum force F**2** when lowering said frame or raising said frame after said lift assembly is raised from said lowermost configuration, and said starting force SF at the lowermost configuration that is less than said maximum force F**1**, and wherein said minimum force F**2** is in a range of 50% to 70% of said maximum force F**1**.

2. The patient support apparatus according to claim **1**, wherein said maximum force F**1** occurs prior to reaching a mid-stroke of said lift assembly.

3. The patient support apparatus according to claim **2**, wherein said actuator is mounted in said lift assembly with a mounting configuration to produce said starting force SF when said lift assembly in said lowermost configuration and wherein said starting force SF is in a range of 95% to 99% of said maximum force F**1**.

4. The patient support apparatus according to claim **2**, wherein said actuator is mounted in said lift assembly with a mounting configuration to produce said starting force SF when said lift assembly in said lowermost configuration wherein said starting force SF is about 97% of said maximum force F**1**.

5. The patient support apparatus according to claim **1**, wherein said minimum force F**2** is in a range of 55% to 65% of said maximum force F**1**.

6. The patient support apparatus according to claim **5**, wherein said actuator is mounted with a configuration to produce said minimum force F**2** when raising or lowering said frame wherein said minimum force F**2** is about 60% of said maximum force F**1**.

7. The patient support apparatus according to claim **1**, wherein said minimum force F**2** occurs at a maximum height of said lift assembly.

8. The patient support apparatus according to claim **7**, wherein said actuator is mounted in said lift assembly with a mounting configuration to produce said starting force SF wherein said minimum force F**2** is in a range of 55% to 65% of said starting force SF.

9. A patient support apparatus comprising:

a base;

a frame supported relative to said base;

a deck supported relative to said frame for supporting a patient thereon, said deck having articulatable deck sections;

a lift assembly for raising or lowering said frame relative to said base between raised and lowered positions wherein said deck sections are raised or lowered together, and lift assembly being pivotally coupled relative to said frame at an upper end thereof and pivotally coupled to said base at a lower end thereof;

an actuator;

said lift assembly including a first leg and a second leg, said second leg being pivotally mounted to said first leg at a medial portion of said first leg about a folding pivot axis to form a Y-shaped leg assembly, said Y-shaped leg assembly including a slot fixed relative to and movable with said first leg;

said actuator mounted in said lift assembly, said actuator having a base mounted at a first pivotal connection with said first leg, and said actuator having an extendible rod coupled to a second sliding pivot connection with said first leg, said second sliding pivot connection being guided by said slot of said Y-shaped leg assembly, said second sliding pivot connection being located between said frame and said base when said frame is in a raised position; and

said second sliding pivot connection linked to said second leg wherein when said actuator extends or contracts, said first leg and said second leg are unfolded or folded with respect to each other to raise or lower said deck.

10. The patient support apparatus according to claim **9**, further comprising a link slidingly coupled to said first leg at said second sliding pivot connection and eccentrically coupled to said second leg by a crank arm.

11. The patient support apparatus according to claim 10, wherein said second sliding pivot connection between said link and said first leg comprises a non-linear sliding pivot connection.

12. The patient support apparatus according to claim 11, wherein said first leg includes lower pivot connections to said base, and wherein said second sliding pivot connection between said link and said first leg extends below said lower pivot connections of said first leg when said lift assembly is in said lowermost position.

13. A patient support apparatus comprising:

a base;

a frame supported relative to said base, said frame configured to support a deck for supporting a patient thereon;

a lift assembly for raising or lowering said frame relative to said base and being pivotally coupled to said frame at an upper end thereof and pivotally coupled to said base at a lower end thereof;

an actuator having a base and an extendable rod;

said lift assembly including a first leg and a second leg, said second leg being pivotally mounted to said first leg at a medial portion of said second leg to form an inverted Y-shaped leg assembly, said medial portion between first and second ends of said second leg that are spaced apart from said medial portion of said second leg;

said second leg having a crank arm;

a first link having first and second ends, said first end of said first link coupled to said crank arm; and

a second link having first and second ends, said first end of said second link pivotally coupled to said extendable rod of said actuator, and said second end of said second link coupled to said second end of said first link, said second link configured to apply force to said crank arm via said first link, and said first link configured to move in a nonlinear path to thereby push or pull on said crank arm from a range of angles and thereby unfold or fold said first leg and said second leg with respect to each other to contract or extend said lift assembly.

14. The patient support apparatus according to claim 13, wherein said first leg includes an upper pivot connection to said frame, a lower pivot connection to said base, and said first link slidingly coupled to said first leg by a sliding pivot connection and pivotally coupled to said crank arm.

15. The patient support apparatus according to claim 14, wherein said sliding pivot connection comprises a non-linear sliding pivot connection.

16. A patient support apparatus comprising:

a base;

a frame supported relative to said base, said frame configured to support a deck for supporting a patient thereon;

a head end actuator;

a foot end actuator; and

a lift assembly for raising or lowering said frame relative to said base, said lift assembly including a head end leg assembly and a foot end leg assembly, each of said leg assemblies having a pair of legs, each pair of legs including a first leg and a second leg forming an inverted Y-shaped configuration when raising said frame and being folded when lowering said frame, said inverted Y-shaped configuration including a slot fixed relative to and moveable with the first leg, said first legs pivotally mounted at upper ends to said frame and pivotally mounted at lower ends to said base, each pair of legs having a folding pivot axis, and each of said head end and foot end actuators having a pivot connection to a respective first leg and having a sliding lower pivot connection linked to said respective second leg, each of said sliding lower pivot connections having a path that is guided by said slot and that includes a linear portion and a curved portion, each of said sliding lower pivot connections being above said base when said frame is raised and extending below said base when said frame is fully lowered, and wherein said first and second legs of each leg assembly are linked such that extension and contraction of the respective actuators will unfold or fold said leg assemblies to raise or lower said frame.

17. The patient support apparatus according to claim 16, wherein each of said first legs is linked to said respective second leg by a link, and said links eccentrically mounted to respective second legs.

18. The patient support apparatus according to claim 17, wherein one end of each of said links is coupled to said respective first leg by a respective sliding pivot connection of said sliding pivot connections.

19. The patient support apparatus according to claim 18, wherein said sliding pivot connections of said actuators to said first legs having linear paths.

* * * * *