United States Patent [19]

Greenlay et al.

[11] **3,868,022**

[45] **Feb. 25, 1975**

[54] **SELF-PROPELLED HEAVY DUTY MOBILE CRANE**

[75] Inventors: **Roy Greenlay,** Greenfield; **George S. Allin, Jr.,** Brookfield, both of Wis.

[73] Assignee: **Harnischfeger Corporation,** Milwaukee, Wis.

[22] Filed: **Nov. 23, 1973**

[21] Appl. No.: **418,679**

[52] **U.S. Cl.** ..... **212/8 R,** 212/48, 280/79.2 C

[51] **Int. Cl.** **B66c 23/36**

[58] **Field of Search** ..... 212/8 R, 8 A, 9, 46, 48, 212/58, 59; 280/91, 9.44, 9.46, 79.2 C

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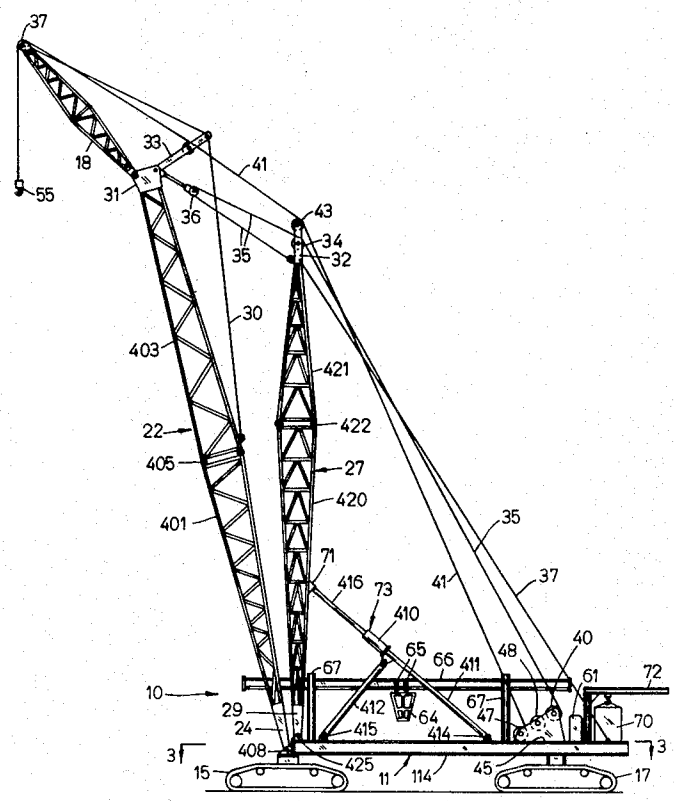
"Sky Horse Counter Balancing Crane," by American Hoist & Derrick Co. Dec. 9, 1971.

Primary Examiner—Robert J. Spar
Assistant Examiner—Lawrence J. Oresky
Attorney, Agent, or Firm—James E. Nilles

[57] **ABSTRACT**

A large self-propelled heavy duty mobile crane comprises a triangular support frame having a pair of spaced apart drivable steerable double bogies at its wide front end and a pair of spaced apart drivable steerable single bogies at its narrow rear end. The pair of front bogies are connected by an adjustable telescopic tie rod which maintains them either parallel or inwardly-toed, depending on the type of crane traverse and steering motion desired. A vertically swingable A-frame boom has its two spaced apart lower ends pivotally connected to the wide front end of the support frame directly above the attachment points of the front bogies to concentrate the load thereat. A vertically swingable inverted U-frame boom support mast has its two spaced apart lower ends pivotally connected to the wide front end of the support frame as close as possible to the boom attachment points.

11 Claims, 29 Drawing Figures



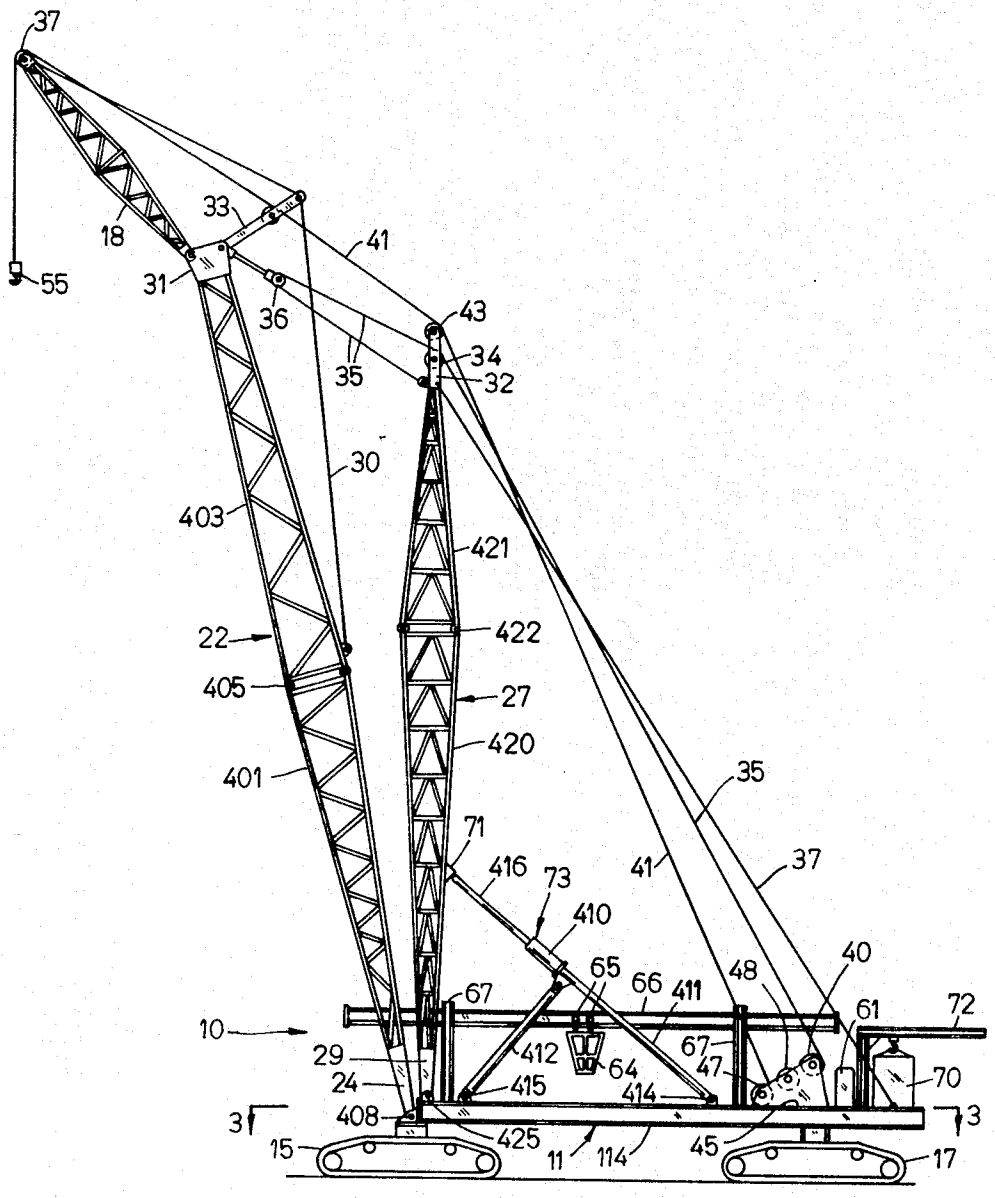

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FIG. 1

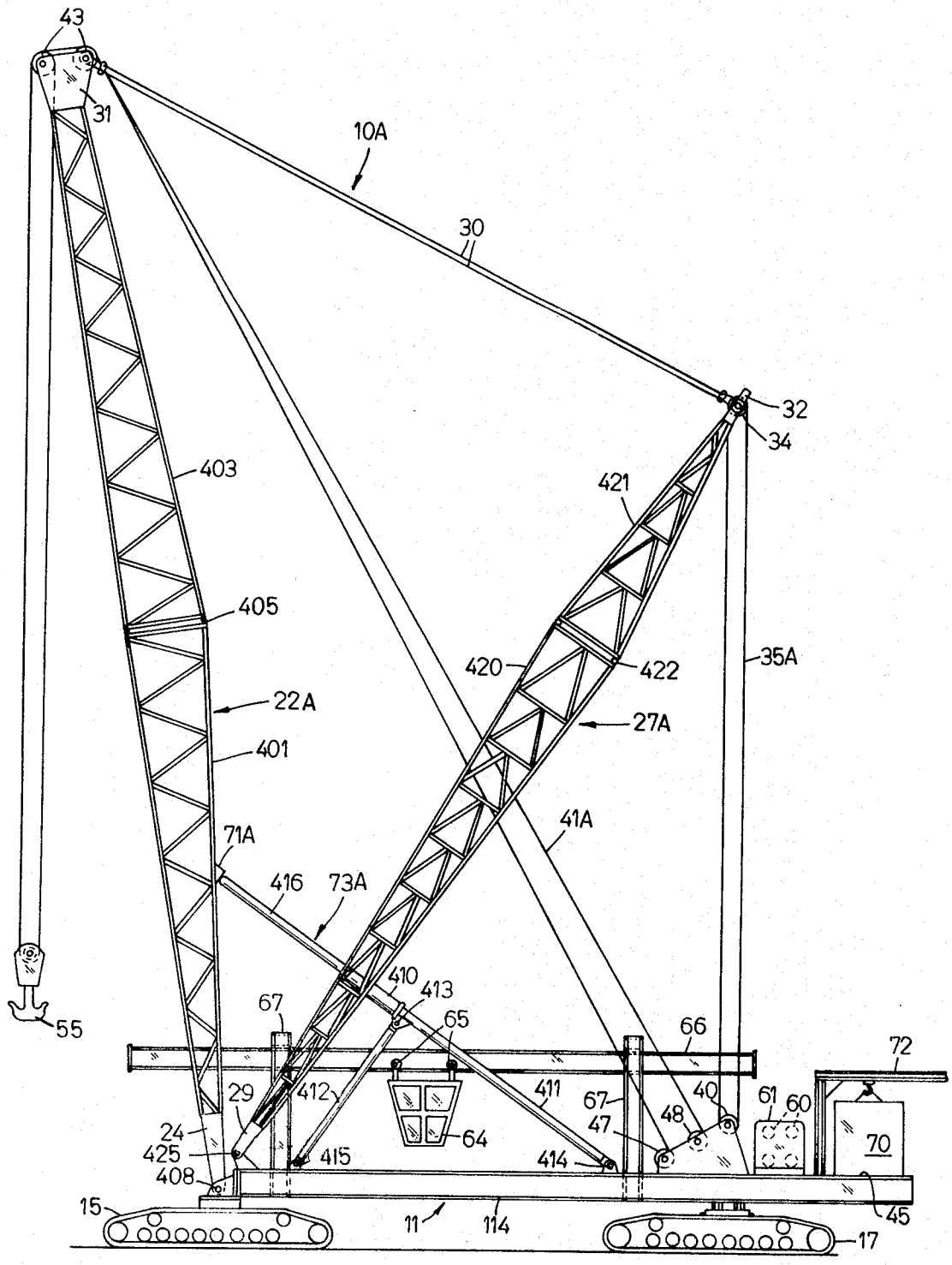

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35A
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FIG. 1A

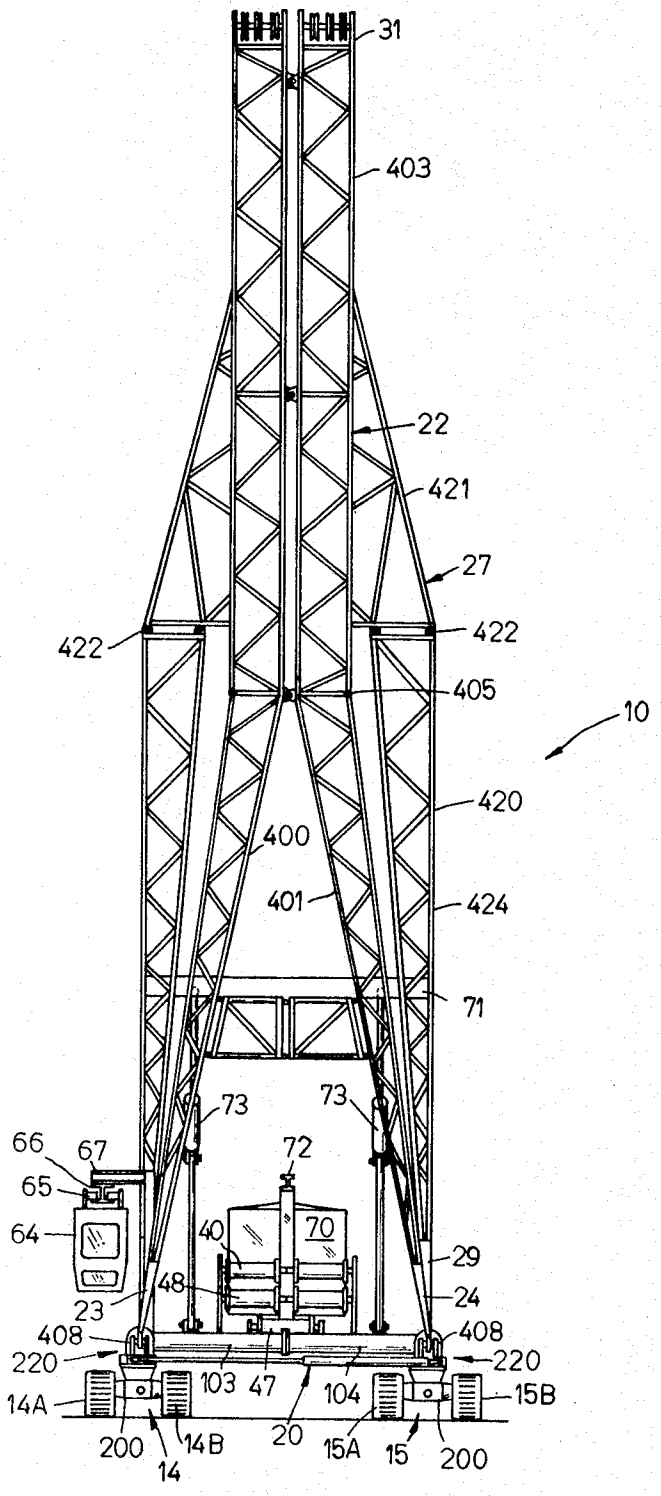

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FIG. 2

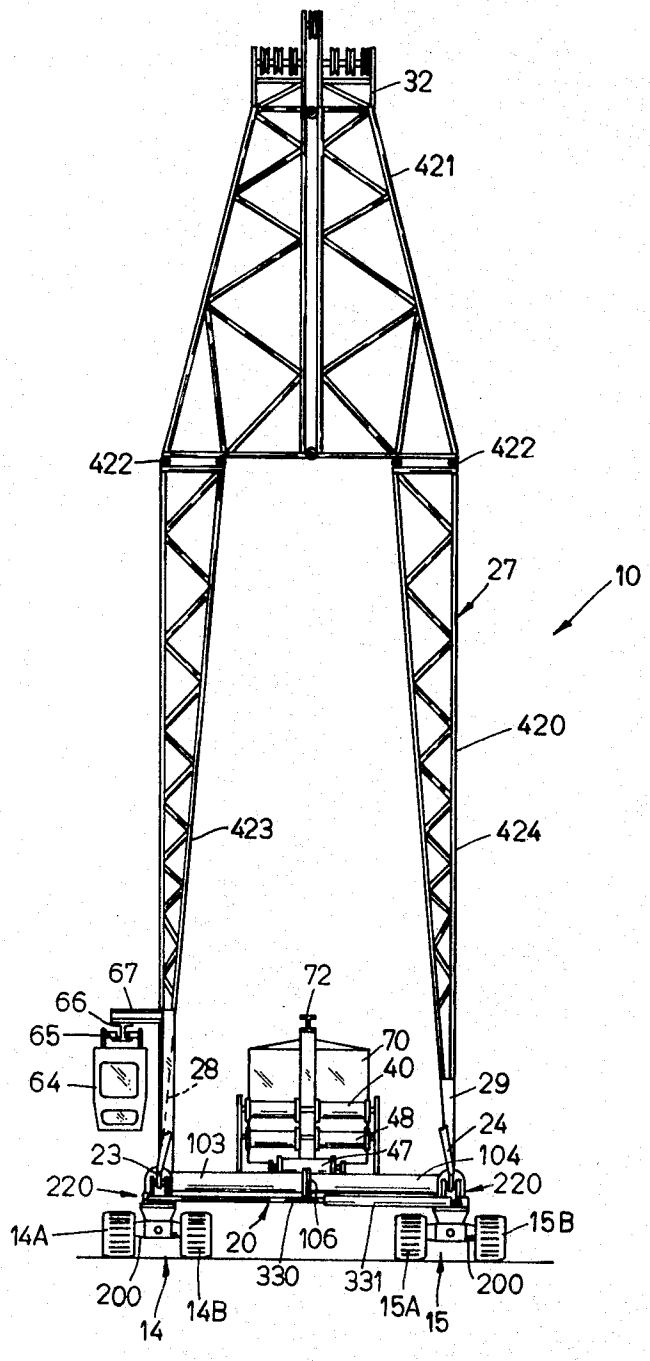

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FIG. 3

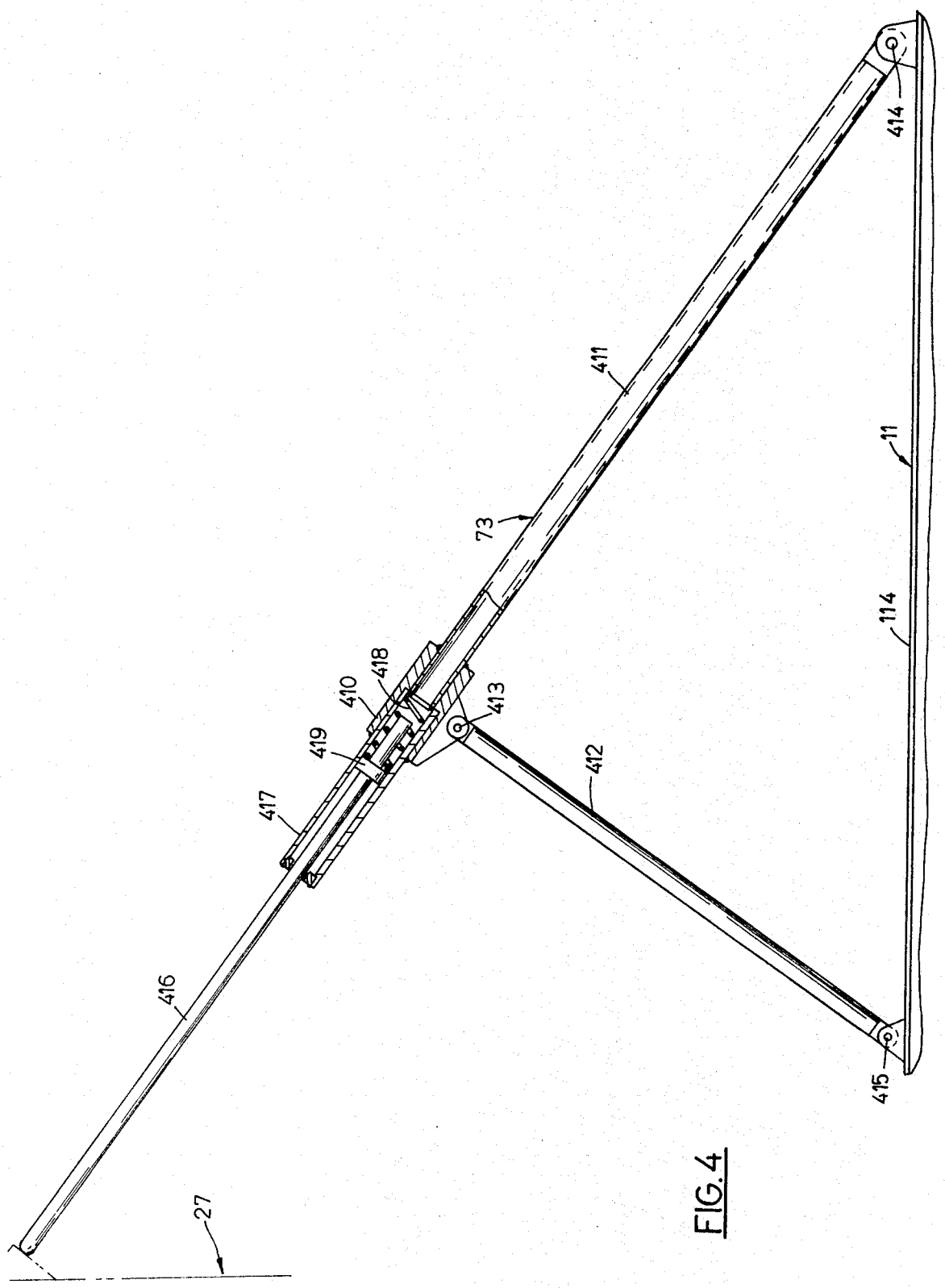


FIG.4

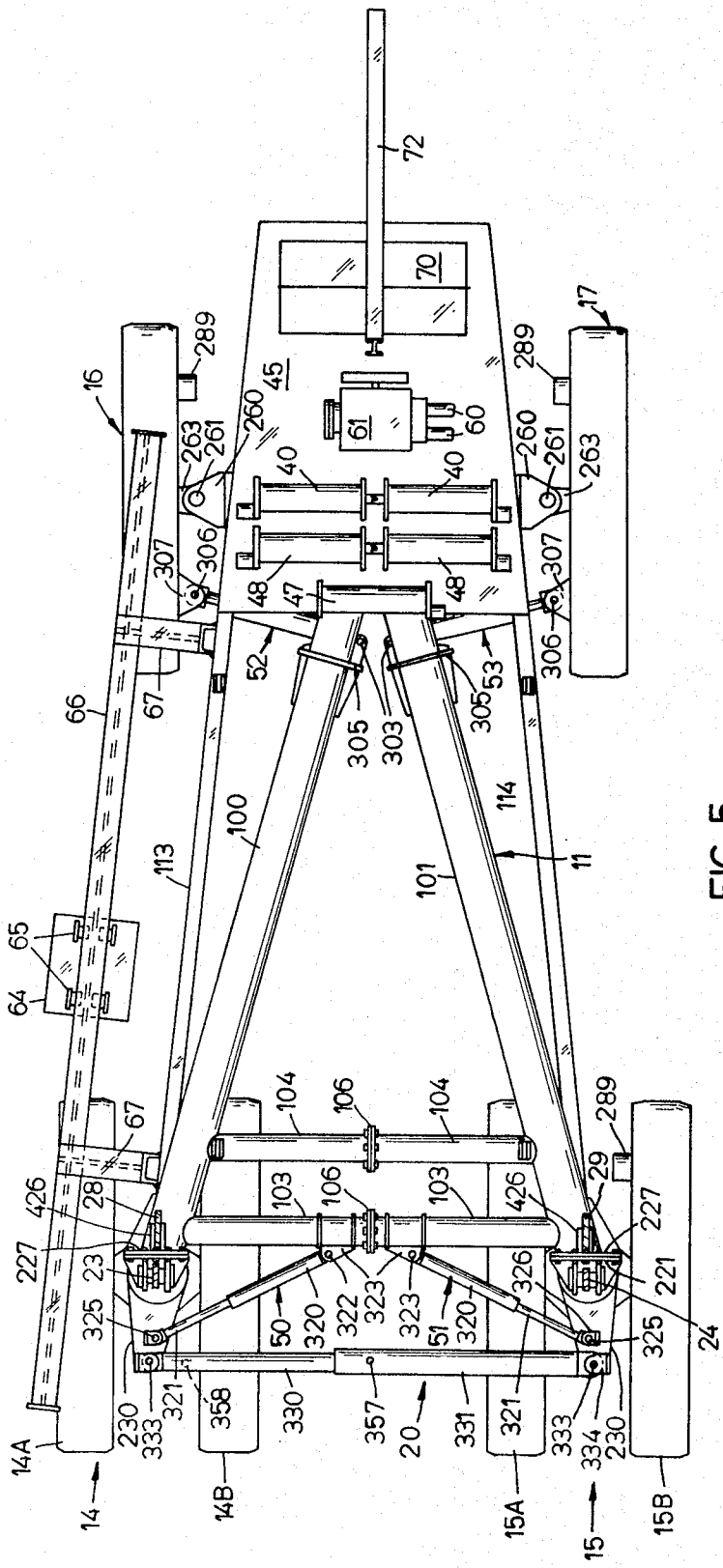

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FIG. 5

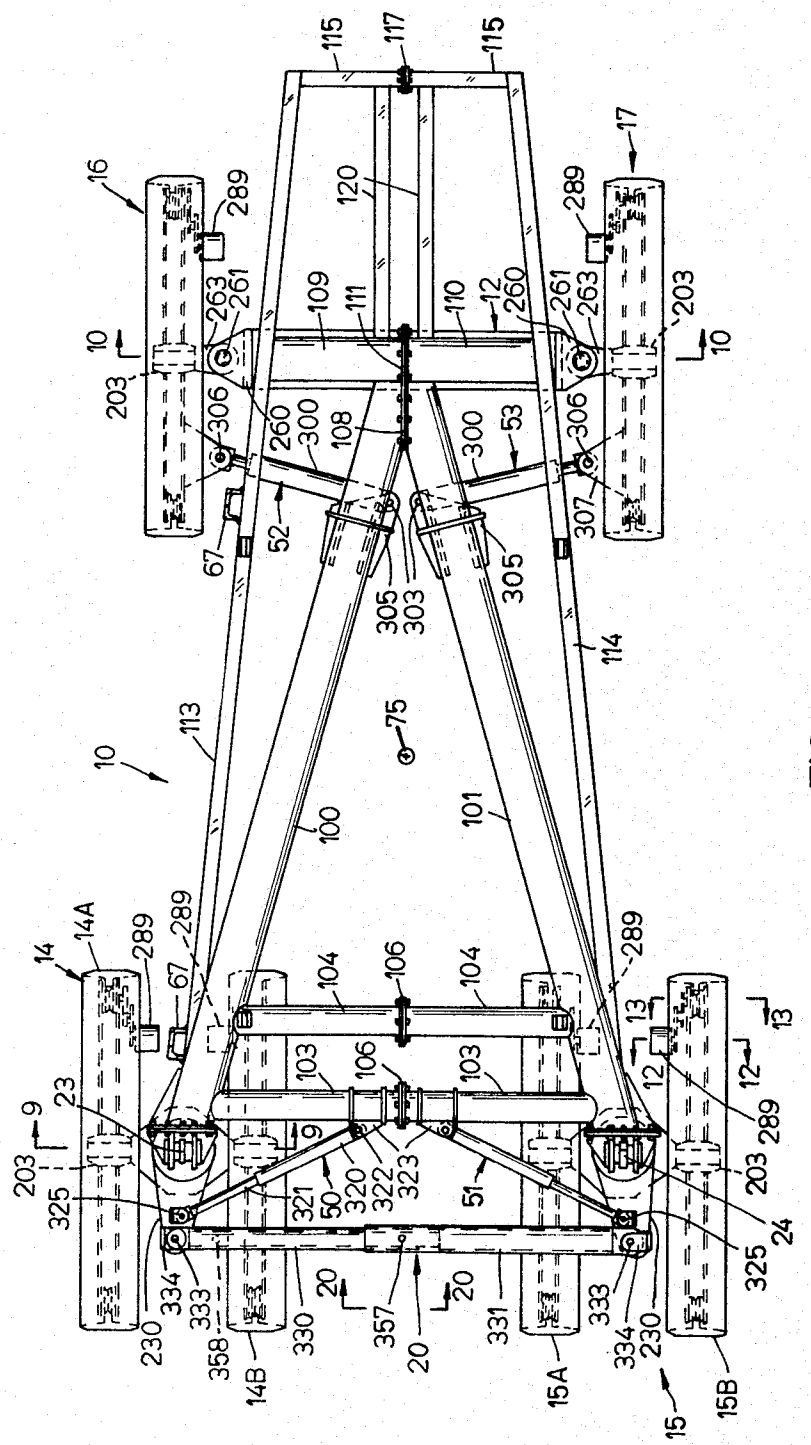


FIG. 6

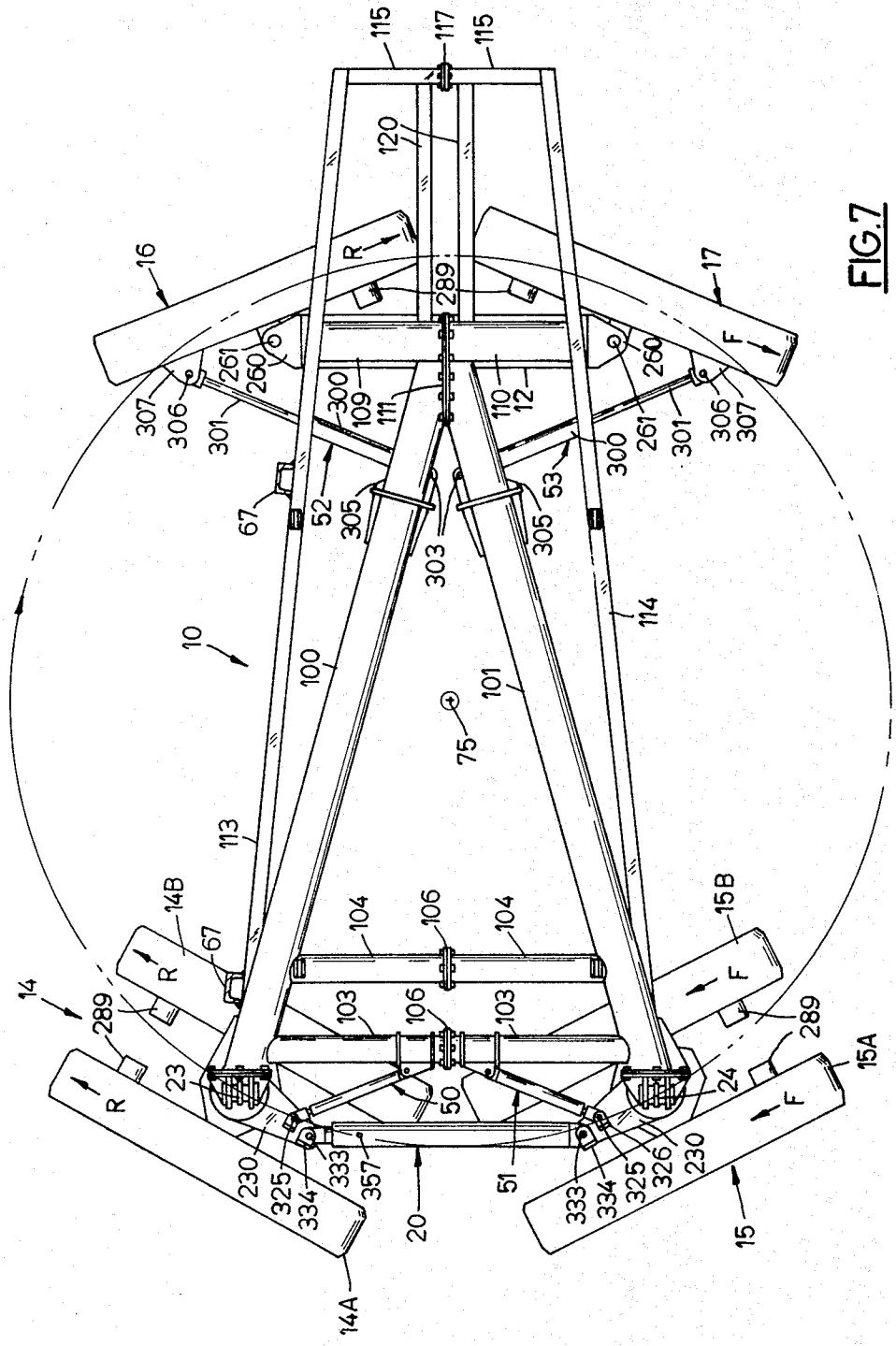

115
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120
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14B
15B
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15A
14A

FIG.7

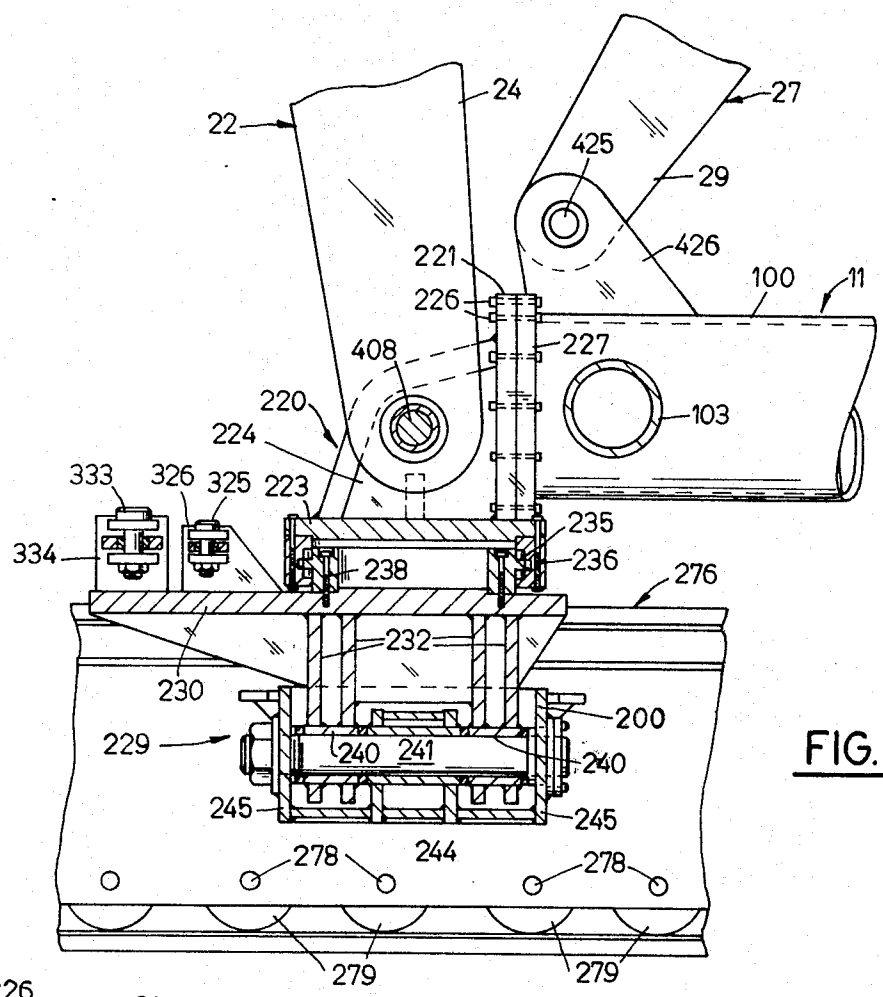

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FIG. 11

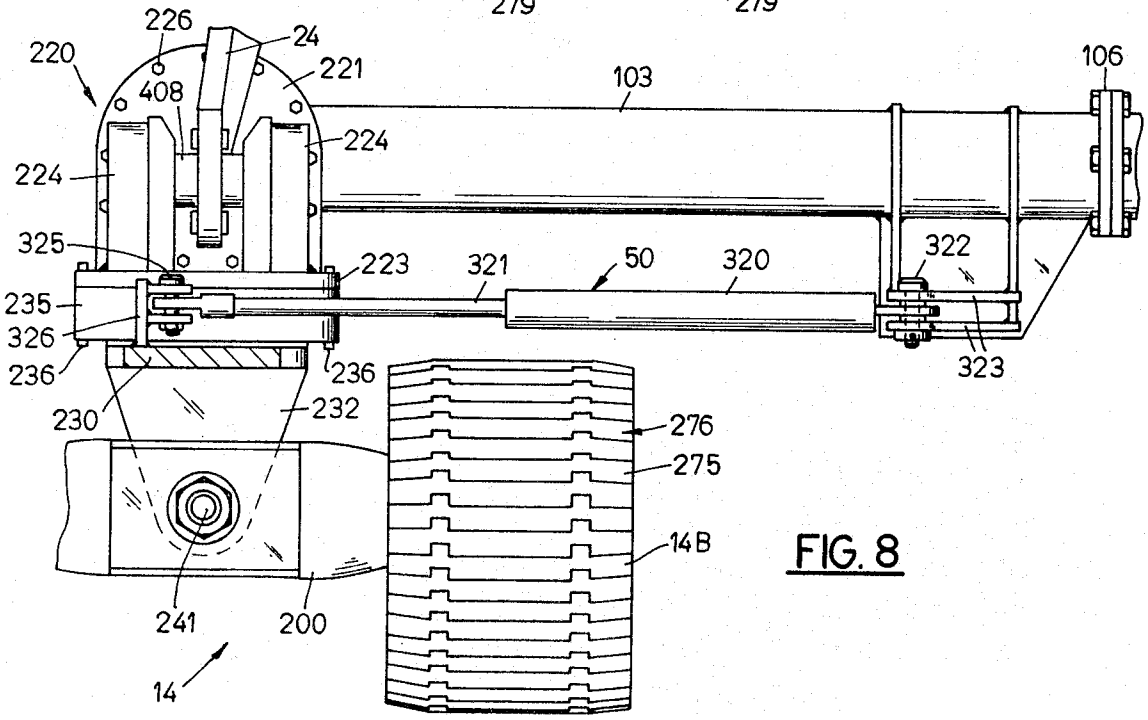

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FIG. 8

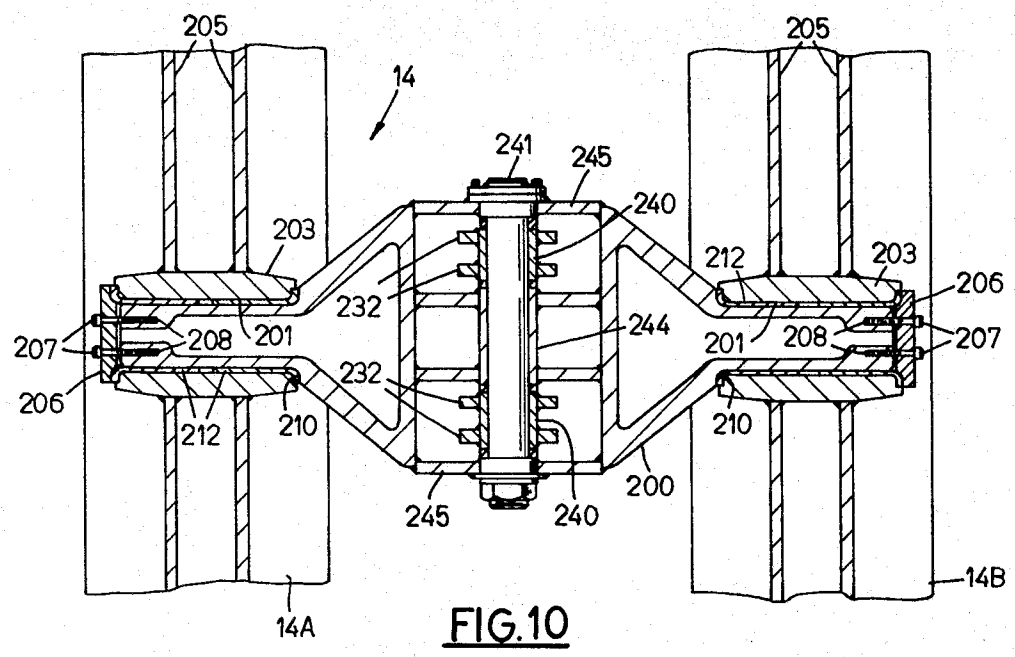

205
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FIG. 10

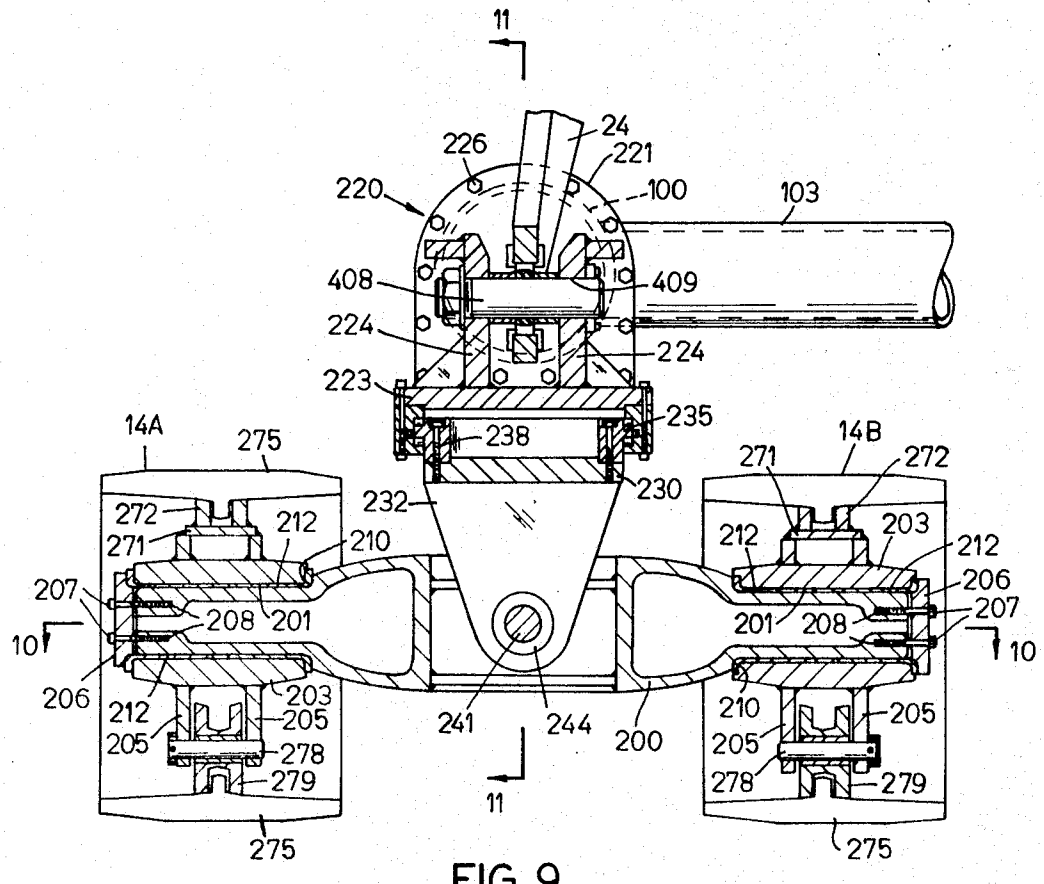

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FIG. 9

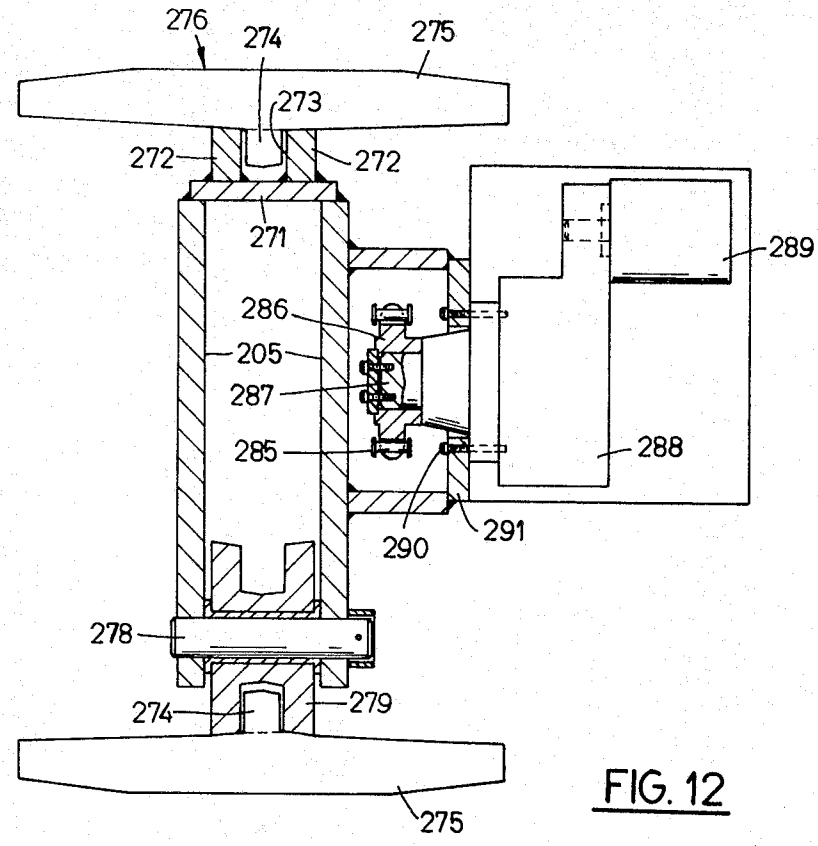

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FIG. 12

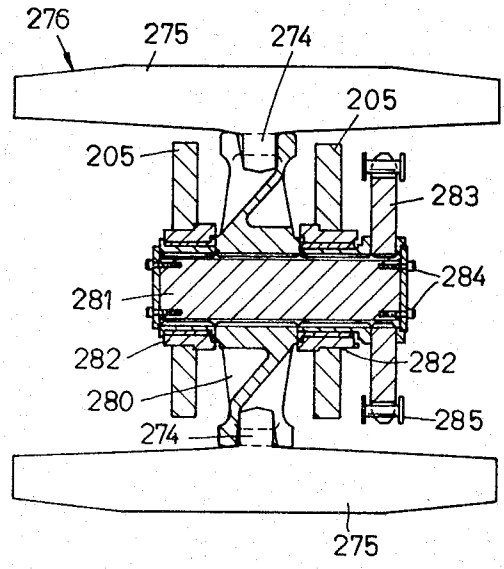

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FIG. 13

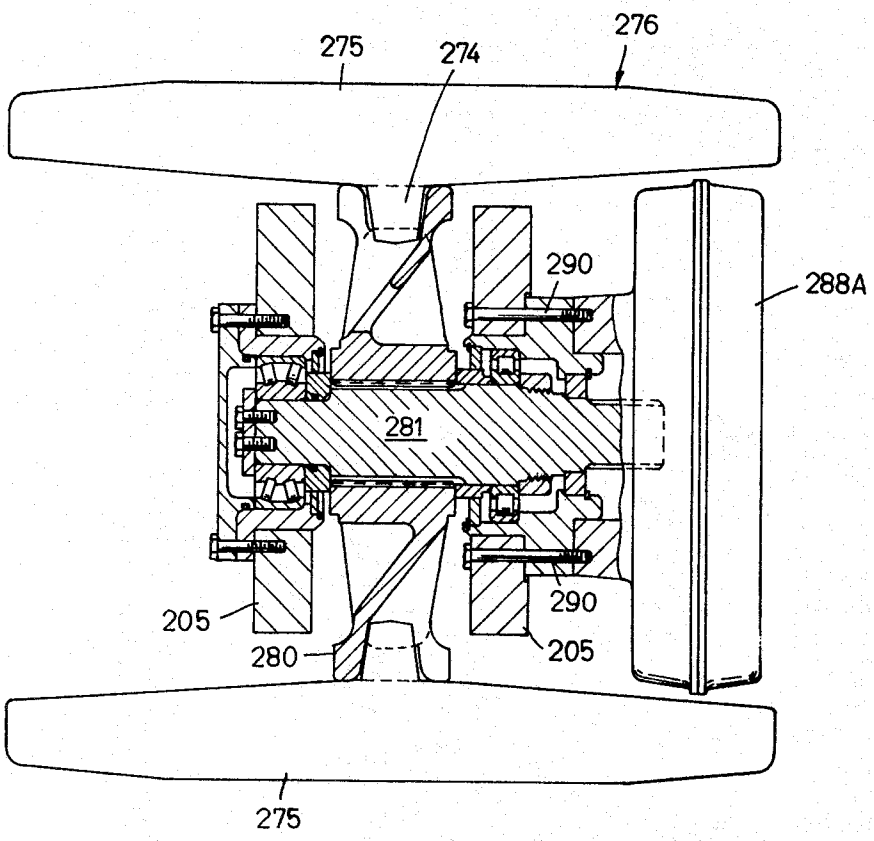


FIG. 14

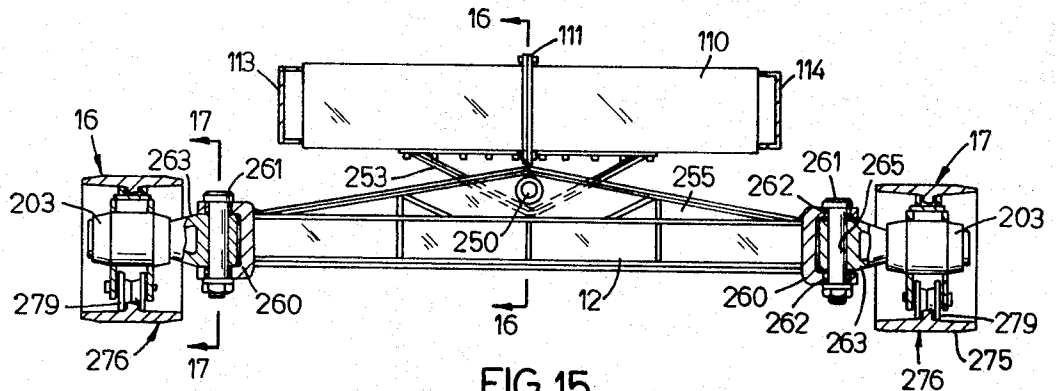


FIG. 15

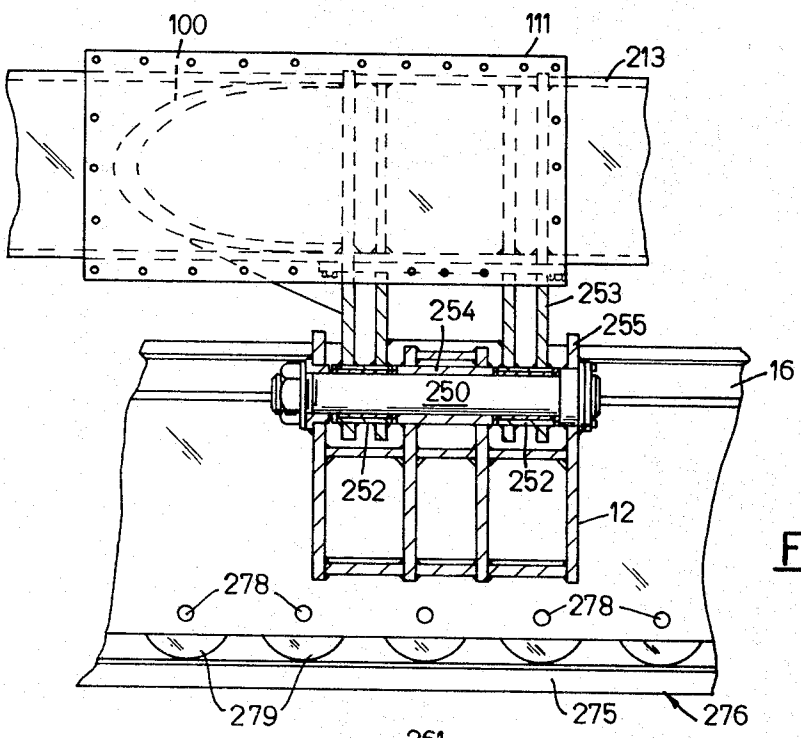


FIG. 16

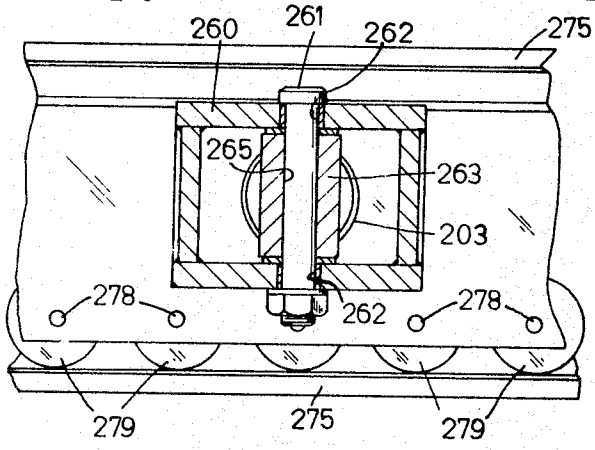


FIG. 17

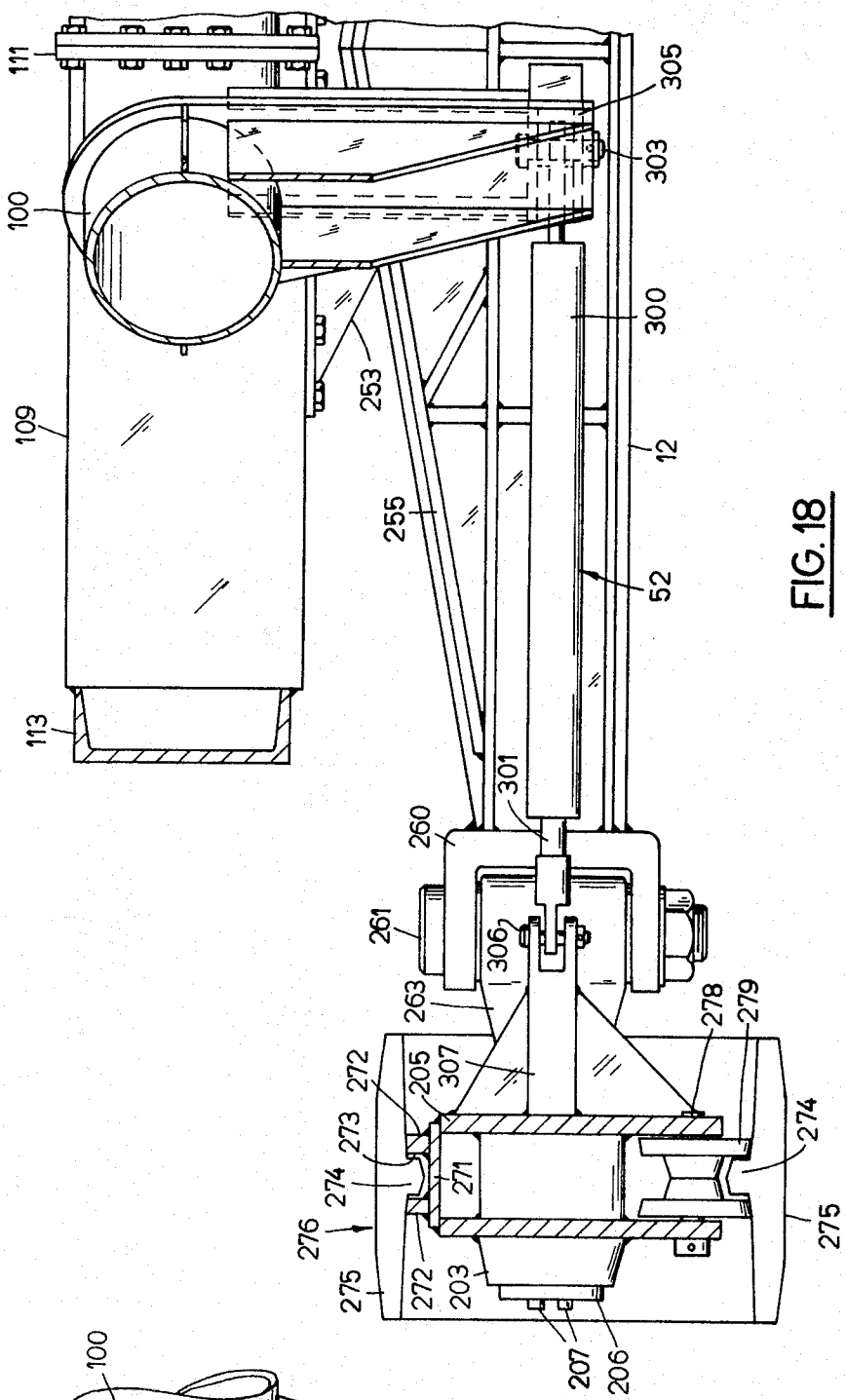

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FIG. 18

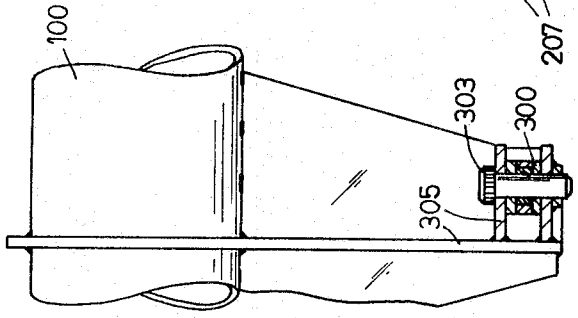

100
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300
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FIG. 19

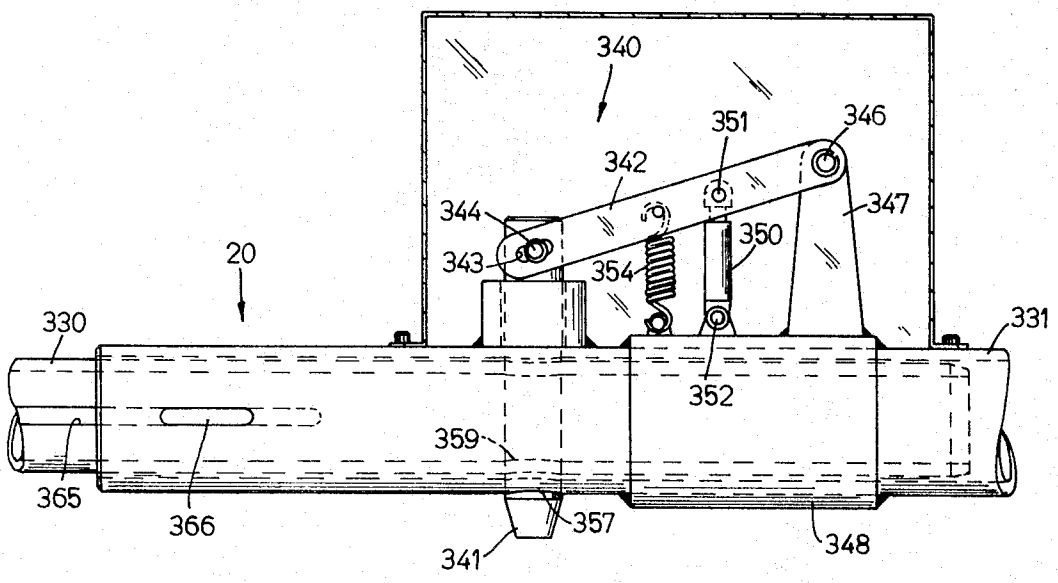

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FIG. 20

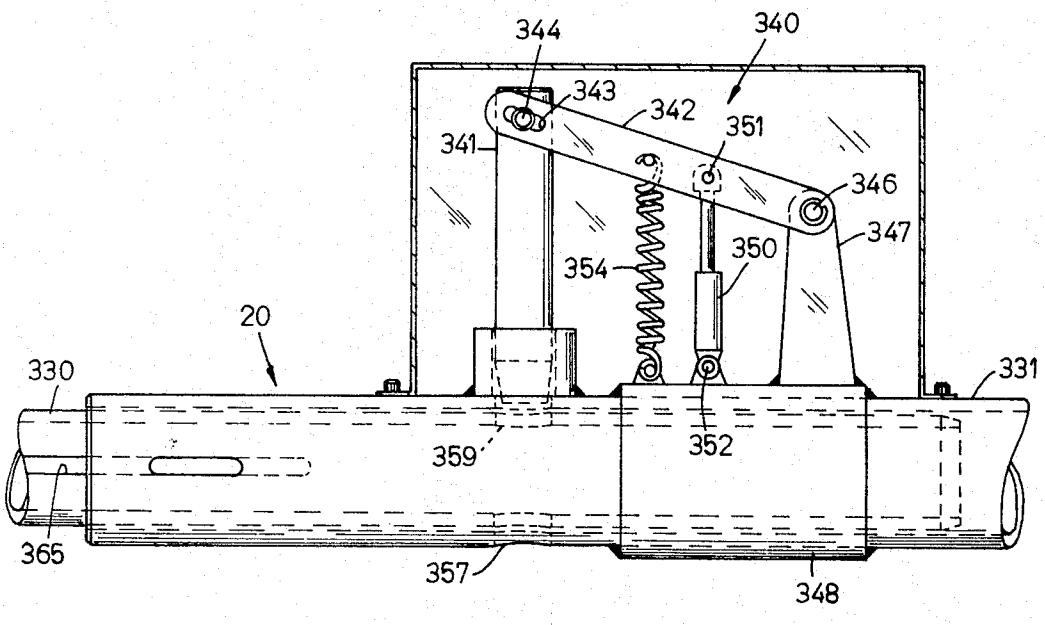

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FIG. 21

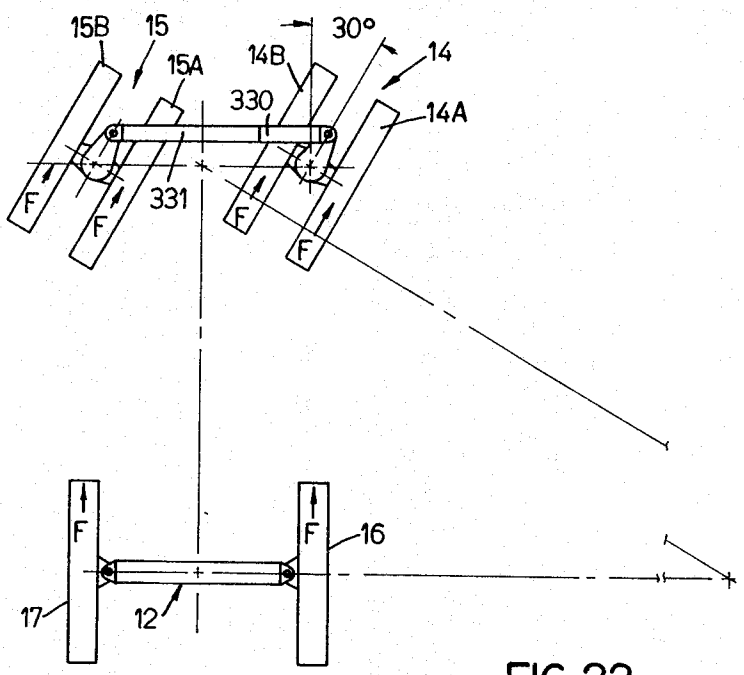

15B
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15A
30°
14B
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14A
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331
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12

FIG. 22

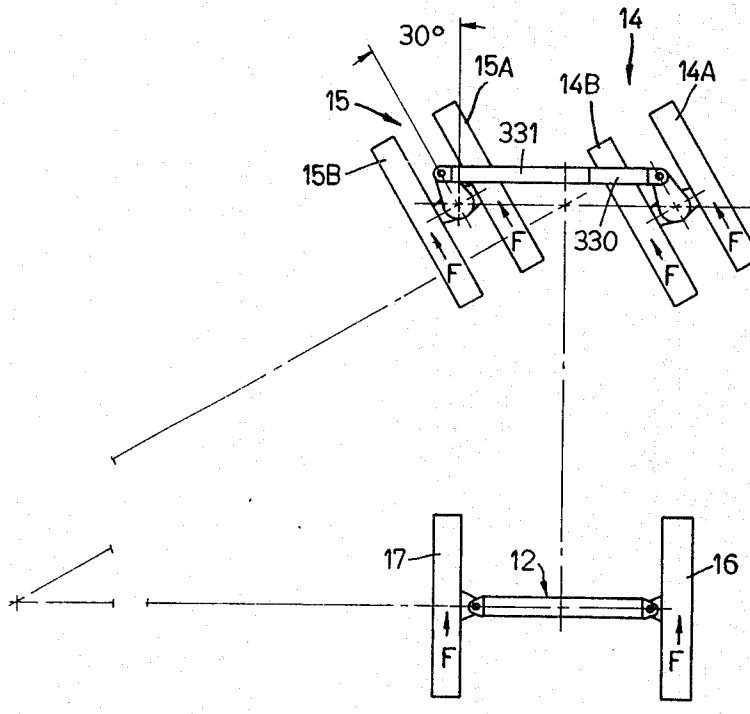

30°
14
15A
14B
14A
15
331
15B
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330
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12
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FIG. 23

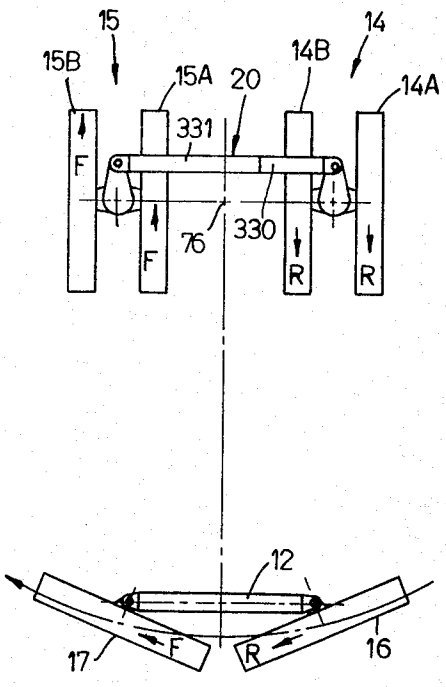

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15B
15A
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14B
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14A
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F
76
330
R
R
12
17
F
R
16

FIG.24

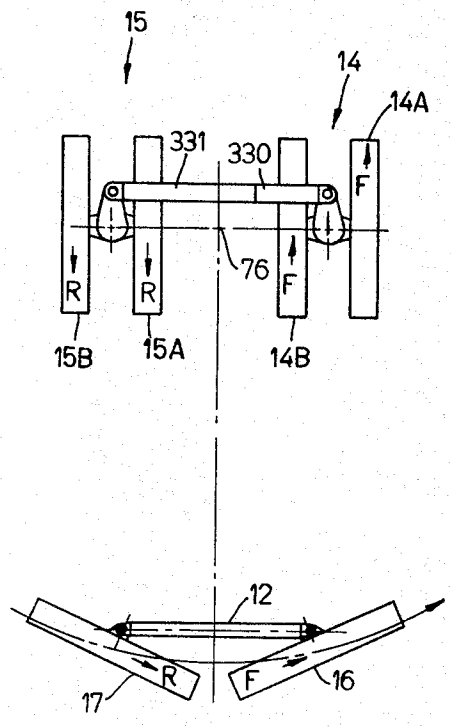

15
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14A
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330
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R
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76
15B
15A
14B
12
17
R
F
16

FIG.25

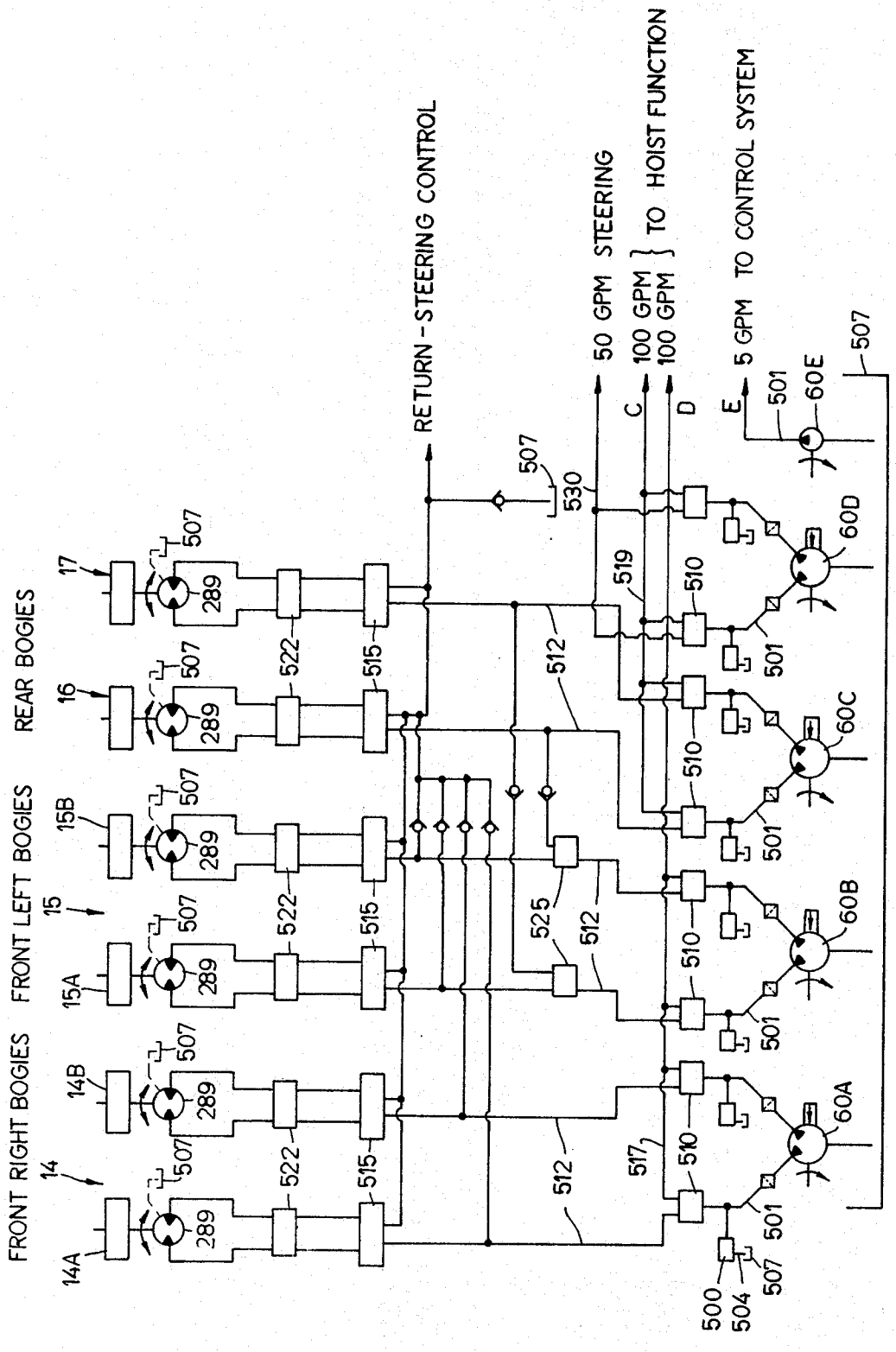

FRONT RIGHT BOGIES
FRONT LEFT BOGIES
REAR BOGIES
RETURN - STEERING CONTROL
50 GPM STEERING
100 GPM } TO HOIST FUNCTION
100 GPM
5 GPM TO CONTROL SYSTEM
14
14A
14B
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15A
15B
16
17
289
507
522
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512
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504
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60E
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D
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FIG.26

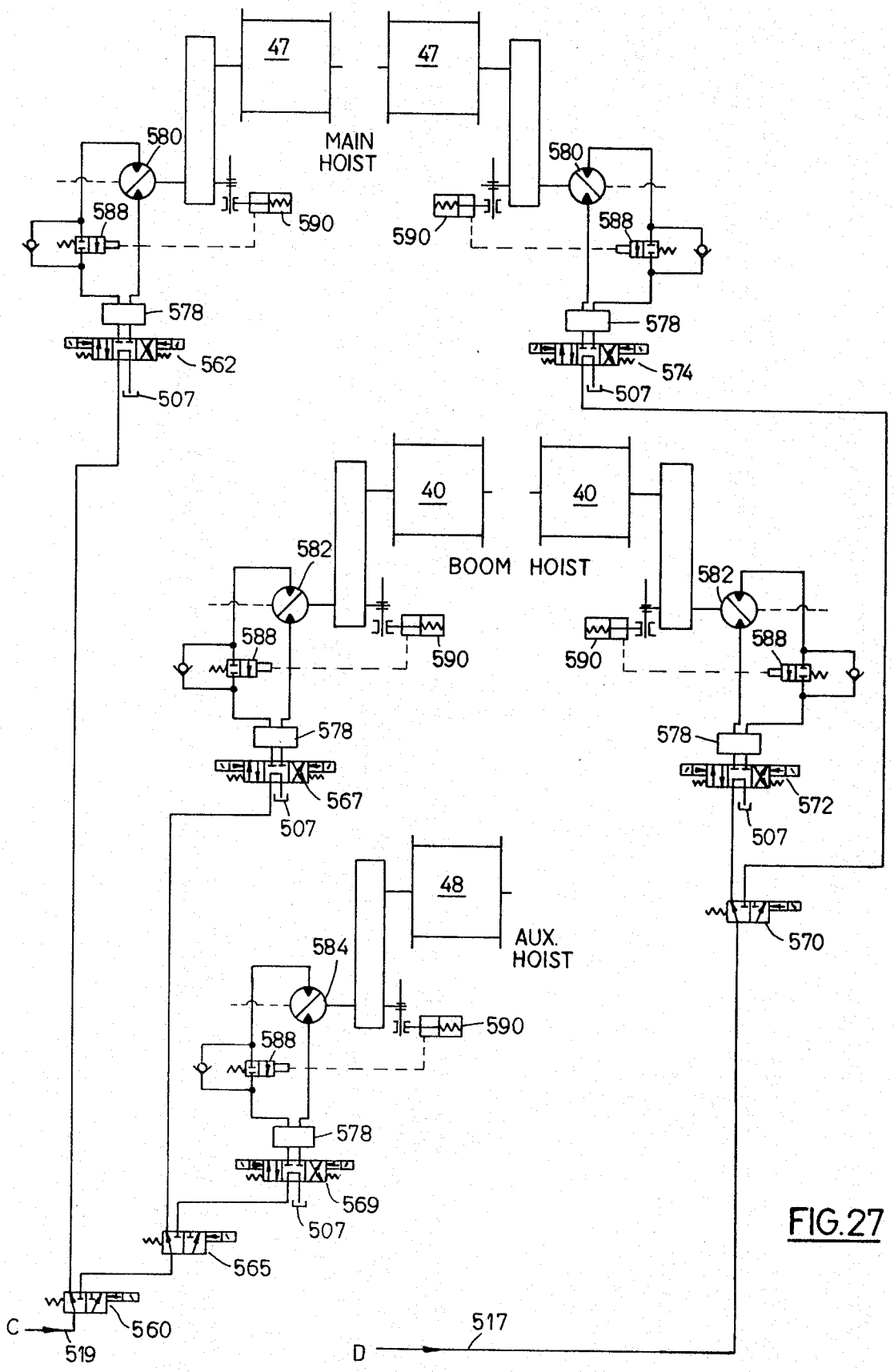

47
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MAIN HOIST
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562
574
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507
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40
BOOM HOIST
582
582
588
588
590
590
578
578
567
572
507
507
48
AUX. HOIST
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578
569
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565
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560
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C
517
D

FIG.27

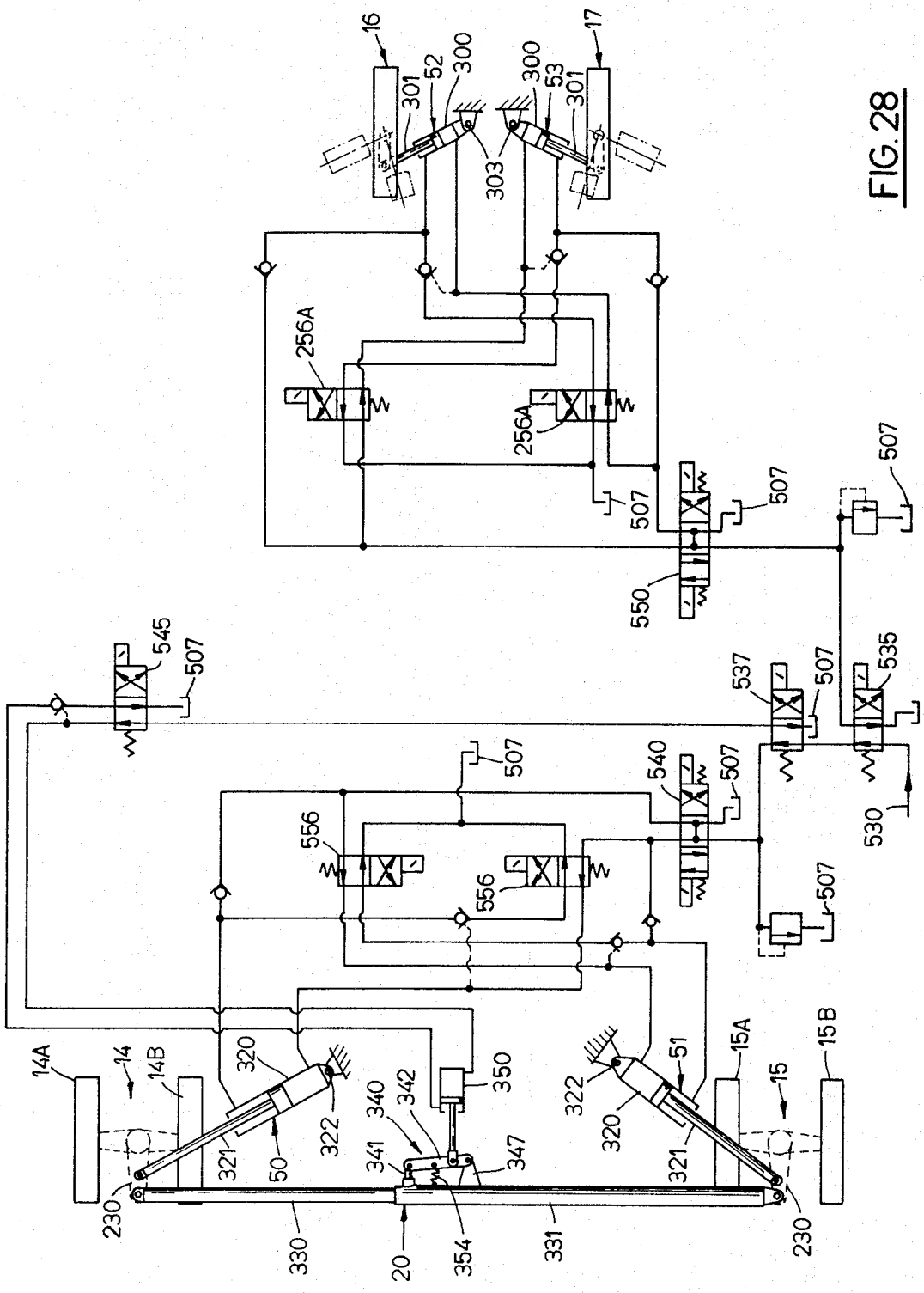

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FIG. 28

SELF-PROPELLED HEAVY DUTY MOBILE CRANE

BACKGROUND OF THE INVENTION

1. Field of Use

This invention relates generally to self-propelled heavy duty mobile cranes.

2. Description of the Prior Art

Some self-propelled mobile cranes such as tower cranes or the like, comprise a mobile lower section on which a horizontally rotatable upper section is mounted and a vertically and horizontally swingable boom is mounted on the upper section. Wheels or crawlers on the lower unit, some or all of which are power driven or steerable, support the crane and enable it to move about a job site. In some instances the nature of the terrain or the character of the soil at the job site is such that large cranes of this type can become bogged down, unmaneuverable, unbalanced or unstable due to their own weight or the size of their loads. Therefore, in some cases it is necessary to use cranes which comprise a large circular slew ring or track which is temporarily installed at the job site and upon which a crane upper is rotatably mounted. In such an arrangement, horizontal swing of the crane boom mounted on the crane upper is effected by propelling the upper about the slew ring. Such cranes have the advantage of great stability and load-carrying capacity, but it is difficult, timeconsuming and costly to set up the slew ring and to mount the other crane components thereon. Furthermore, such a crane is not mobile on the terrain and has a limited working range. Another approach, then, is to employ a large traveling crane having a mobile lower section with large widely spaced multi-wheeled or multi-track bogies and a conventional horizontally rotatable upper mounted on the mobile lower section. A crane of the latter character is disclosed in U.S. Pat. No. 3,638,805 for "Mobile Chassis For Carrying A Tower Crane" issued Feb. 1, 1972 to Garnier, and comprises a conventionally driven and steerable chassis, auxiliary outriggers on the chassis to enhance crane stability and a large, heavy duty complex mounting arrangement to enable the horizontally swingable upper to rotate on the mobile chassis or lower unit.

SUMMARY OF THE PRESENT INVENTION

A self-propelled traveling crane in accordance with the invention comprises a generally triangular tubular support frame having a relatively wide front end, a narrow rear end and a transverse beam attached at the narrow rear end. A pair of drivable and steerable double crawler type front bogies are articulately connected to the frame at spaced apart connection points near the corners of the front end of the frame. A pair of drivable and steerable single crawler type rear bogies are articulately connected at opposite ends of the transverse beam. An adjustably extendable and retractable telescopic tie rod is connected to and between the pair of double front bogies to maintain them in specific relationship with each other, depending on the steering mode desired. A vertically swingable A-frame boom, having an optionally usable jib, has its two spaced apart lower ends pivotally connected to the front end of the support frame at boom attachment points directly above the connection points of the front double bogies to concentrate a load thereat. An inverted U-frame boom support mast has its two spaced apart lower ends

pivotally connected to the front end of the support frame close to the boom attachment poits also for load concentration. In one embodiment, pennant cables are connected between the boom and mast, and boom hoist cables between the mast and a boom hoist winch on the frame enable both the boom and mast to swing vertically for lifting operations. In another embodiment, pennant cables are connected between the mast and support frame, and boom hoist cables between the boom and the boom hoist winch enable only the boom to swing vertically for lifting operations. In both embodiments, however, the mast can be pivoted vertically to facilitate crane assembly and disassembly. One or more load lines are reeved over pulleys on the boom and mast and are connected to load hoist winches on the support frame. Suitable means are provided to supply power to drive the bogies, to operate the steering means therefor and to drive the winches and such means preferably comprise engine-driven hydraulic pumps for supplying hydraulic cylinders and motors. An operator's cab containing suitable controls is mounted for fore and aft movement on a runway supported on the support frame along an edge thereof, but could be fixed to the boom or main frame.

The crane is capable of self-propelled movement or traverse over the terrain in forward and reverse directions, can be steered conventionally during such movement, and is capable of self-rotation on the terrain around the vertical centerline of the crane or around a vertical centerline between the front bogies. During normal forward and reverse movement and during normal steering, wherein both front bogies are turned together in the appropriate direction, the telescopic tie rod is in extended position. During self-rotation around the vertical centerline of the crane, the front bogies are maintained in inwardly-toed position by telescoping the tie rod to retracted position and the rear bogies are outwardly-toed with respect to each other. During self-rotation around the vertical centerline between the front bogies, the telescopic tie rod is in extended position and the rear bogies are outwardly-toed with respect to each other. The direction in which the individual bogies are steered and driven to effect various rotative movements is hereafter described in detail.

In further accordance with the invention and to facilitate the transport of the extremely large crane to and from the job site, the boom, the mast and the bogies are designed to be readily dismountable and detachable from the support frame and the support frame itself is fabricated of dismountable or detachable modular sections. The bogies, which are disclosed as hydraulically driven by individual hydraulic motors, could be electrically driven and could take the form of wheel type units instead of the crawler tractor type disclosed. The bogies are fully articulated at their connection points to the support frame to ensure uniform ground bearing pressures on eneven terrain. The disposition of the attachment points of the boom and boom support mast substantially above the front bogie connection points ensures that the weight of the superstructure, and any load being handled by the boom, is distributed directly to the front bogies and through them to the ground.

A crane in accordance with the present invention has several advantages over prior art cranes. For example, the overall design of the frame, the location of the connection points for the front bogies and location of the attachment points for the boom and mast, enable con-

struction of an extremely large crane on the order of about 80 feet long and capable of handling loads up to 1000 tons. Furthermore, the disposition of the bogies and the manner in which they are steered and driven, enables such a large crane to be able to turn even with a full load through 360° in either direction. In addition, such a crane can travel while carrying its maximum lifted load and has a favorable lifted load weight to crane weight ratio on the order of 1.69 or 1.7. Because horizontal swing of the boom is accomplished by appropriate rotation of the entire crane on the terrain, the enormous structural and mechanical elements requried to horizontally swing the boom through 360° with respect to the mobile lower unit of the crane is eliminated. The location of the boom and mast attachment points on the frame directly above the connection points of the forward bogies eliminates heavy frame bending loads which would otherwise occur if the attachment points of the boom were remote from the connection points of the front bogies. The movable operator's cab enables the operator to be positioned side by side with a lifted load and enables the operator to work at either end of the crane and at other positions thereon. Other objects and advantages of the invention will hereinafter appear.

DRAWINGS

FIG. **1** is an elevational view of the left side of a crane in accordance with the invention;

FIG. **1A** is an elevational view of the left side of another embodiment of a crane in accordance with the invention;

FIG. **2** is an elevational view of the front end of the crane shown in FIG. **1**;

FIG. **3** is a view similar to FIG. **2**, but with the boom removed to show mast details;

FIG. **4** is an enlarged side elevation view of the mast stop shown in FIG. **1**;

FIG. **5** is a top plan view of the lower portion of the crane shown in FIGS. **1**, **2** and **3**;

FIG. **6** is a view similar to FIG. **5**, but with the platform removed to show frame details;

FIG. **7** is a view similar to FIG. **6**, but showing the bogies arranged and driven in a manner to effect self-rotation of the crane about its central vertical axis;

FIG. **8** is an enlarged front view of one of the double front bogies;

FIG. **9** is an enlarged cross-section view of one of the double front bogies of the crane;

FIG. **10** is a cross-section view of a double front bogie taken on line **10—10** of FIG. **9**;

FIG. **11** is a cross-section view of a double front bogie taken on line **11—11** of FIG. **10**;

FIG. **12** is a cross section view of one part of a bogie drive unit taken on line **12—12** of FIG. **6**;

FIG. **13** is a cross section view of another part of a bogie drive unit taken on line **13—13** of FIG. **6**;

FIG. **14** is a cross-section view of an alternative type of bogie drive unit;

FIG. **15** is a cross section view of the rear bogies mounted on the lower portion of the rear of the crane taken in line **15—15** of FIG. **6**;

FIG. **16** is an enlarged cross-section view taken on line **16—16** of FIG. **15**;

FIG. **17** is a view partly in cross-section taken on line **17—17** of FIG. **15**;

FIG. **18** is an enlarged front elevation view of the mounting means for one rear bogie;

FIG. **19** is a side elevation view taken on line **19—19** of FIG. **18**;

FIG. **20** is an enlarged elevation view of the locking means for the telescopic tie rod taken on line **20—20** of FIG. **6** and shows the locking means in locked position;

FIG. **21** is a view similar to FIG. **20**, but shows the locking means is unlocked position;

FIG. **22** is a schematic view of the manner of steering and driving the bogies to effect conventional steering to the right;

FIG. **23** is similar to FIG. **22**, but shows conventional steering to the left;

FIG. **24** is similar to FIGS. **22** and **23**, but shows steering to the right around a vertical centerline between the front bogies;

FIG. **25** is similar to FIG. **24**, but shows steering to the left around a vertical centerline between the front bogies; and

FIGS. **26**, **27** and **28** are schematic diagrams of a control system for the crane.

DESCRIPTION OF A PREFERRED EMBODIMENT

General Arrangement

Referring to FIGS. **1** through **6** of the drawings, a self-propelled mobile crane **10** in accordance with the invention comprises a generally triangular tubular support frame **11** having a relatively wide front end, a narrow rear end and a transverse tubular beam **12** rigidly attached at the narrow rear end. A pair of drivable and steerable double crawler type front bogies **14** and **15** are articulately connected to frame **11** at spaced apart connection points near the corners of the front end of the frame. A pair of drivable and steerable single crawler type rear bogies **16** and **17** are articulately connected at opposite ends of transverse beam **12**. An adjustably extendable and retractable telescopic tie rod **20** is connected to and between the pair of double front bogies **14** and **15** to maintain them in specific relationship with each other, depending on the steering mode desired.

A vertically swingable A-frame boom **22**, having a jib **18** mounted at the upper end thereof, has its two spaced apart lower ends **23** and **24** pivotally connected to the front end of support frame **11** at boom attachment points directly above the connection points of the front double bogies **14** and **15** to concentrate a load thereat. A vertically swingable inverted U-frame boom support mast **27** has its lower ends **28** and **29** pivotally connected at the front end of the support frame directly behind but as close as possible to the boom attachment points, also for load concentration. Alternatively, the mast ends **28** and **29** could be pivotally mounted on the same pins as the lower boom ends **23** and **24**. A suitable pennant cable **30** is connected between the top end of jib **18** at the top end **31** of boom **22** and a point near the middle of boom **22**, passing over a jib mast **33** connected to top end **31** of boom **22**. Boom hoist cables **35** are connected to the top end **32** of mast **27** and around pulleys **36** and **34** at the top ends **32** and and **31** of mast **27** and boom **22**, respectively, and take up on a boom hoist winch **40** on a platform **45** on the support frame **11**. A load line **41** is reeved over pulley means **43** on the top end **32** of mast **27** and pulley means **37** on jib **18** on the top end **31** of boom **22**

and is connected to a main load hoist winch **47** on platform **45.** An auxiliary load hoist winch **48** is provided on platform **45** for use if needed. The load line **41** is provided with a load hook **55.** Pennant cables **37** are connected at their lower end to a point on support frame **11** and at their upper end to a point on the top end **32** of mast **27** to prevent forward pivotal movement of mast **27** during raising and lowering operations of boom **22.** However, the pennant cables **37** are detachable to enable mast **27** to be lowered for crane dismantling.

FIG. 1A of the drawing discloses an embodiment of a crane **10A** in accordance with the invention which is similar in all respects to crane **10** except that it is not provided with a jib **18** (although it could be) and has a different arrangement of pennants, boom hoist cables **35A** and load hoist cables or lines **41A.** Crane **10A** further differs from crane **10** in that boom stops **73A** are provided for cooperation with the boom **22A,** as shown in FIG. **1A,** instead of with the mast.

Suitable means are provided to supply power to drive the bogies **14, 15, 16** and **17,** to operate the steering means therefor and to drive the winches **40, 47** and **48.** Such power supply means preferably comprise hydraulic pumps **60,** driven by an internal combustion engine **61** mounted on platform **45** on frame **11** for supplying hydraulic cylinders and hydraulic motors, hereinafter described in detail. An operator's cab **64** containing suitable controls is mounted, as by suspension from driven rollers **65,** for fore and aft movement on an I-beam runway **66** supported on, at the side of, and above frame **11** by support members **67** connected to the frame. A removable counterweight **70** is provided at the rear of frame **11,** being suspended from a rearwardly projecting I-beam **72** to enable it to be slide rearwardly and clear of the frame to facilitate removal. A mast stop **73,** shown in FIG. **4,** for limiting rearward travel of mast **27** or boom **22** is mounted on frame **11.**

Crane **10** is capable of self-propelled movement or traverse over the terrain in forward and reverse directions, can be steered conventionally during such movement, and is capable of self-rotation on the terrain around the vertical centerline **75** (shown in FIG. **7**) of the crane or around the vertical centerline **76** (shown in FIGS. **24** and **25**) between the front bogies **14** and **15.**

During normal forward and reverse straight movement of crane **10,** the bogies **14, 15, 16** and **17** are positioned as shown in FIG. **5** and all are driven simultaneously in forward or reverse directions. The tie rod **20** is disposed in extended position during such movement. During normal forward and reverse movement of crane **10,** normal steering is effected by turning both front bogies together in the appropriate direction as shown in FIGS. **22** and **23.** Tie rod **20** is disposed in extended position during such turning. However, steering could also be effected by turning both rear bogies together in the appropriate direction to the limited degree possible.

During self-rotation around the vertical centerline **75** of crane **10,** as FIG. **7** shows, the front bogies **14** and **15** are turned inwardly by the cylinders **50** and **51,** respectively, and are maintained in inwardly-toed position by telescoping tie rod **20** to retracted position and the rear bogies **16** and **17** are outwardly-toed with respect to each other by the steering cylinders **52** and **53,** respectively.

During self-rotation of crane **10** around the vertical centerline **76** the front bogies **14** and **15** are disposed as shown in FIGS. **24** and **25,** with the telescopic tie rod **20** in extended position, and the rear bogies **16** and **17** are outwardly-toed with respect to each other.

The direction in which the individual bogies are driven to effect various aforedescribed movements is indicated in the appropriate figures by an arrow on the top of the bogie track and an associated letter F or R, indicating forward or reverse motion, respectively, of the bogie.

The Frame

Referring to FIG. **6,** frame **11** comprises two rearwardly converging rigid tubular side brace members **100** and **101** which are jointed together at or near the front end of crane **10** by rigid tubular cross braces or members **103** and **104.** The converging rear ends of the side members **100** and **101** are flanged and bolted together as at **108.** The cross members **103** and **104** are welded at their ends to the side members **100** and **101** and each takes the form of separable or disconnectable flanged members bolted together as at **106.**

A pair of rigid tubular rear cross braces **109** and **110** extend laterally outwardly from the rear ends of the side members **100** and **101** and are welded thereto, as well as being flanged and bolted together as at **111.** The rear cross braces **109** and **110** are welded to and afford support for the rear ends of rigid side girders **113** and **114,** respectively, which have their forward ends welded to the outer sides of the tubular side members **100** and **101,** respectively. The rigid side girders **113** and **114,** which are joined together at their rear ends by a cross girder **115** having a separable flanged bolted joint **117,** defines a supporting means for the platform of base **45** on which various crane elements are supported. A pair or rigid girders **120** are welded between girder **115** and the rear cross braces **109** and **110** on opposite sides of flanged connection **111.** The generally triangular configuration of frame **11** and the use of large tubular members therein results in an exceedingly strong frame capable of handling very heavy loads. The detachable bolted connections at **106, 108, 111** and **117,** which are disposed along the fore and aft longitudinal centerline of crane **10,** enable the frame to be broken down into two more easily transportable symmetrical sections for transport to and from a job site, as by a large truck or railroad car.

The Bogies

Referring to FIGS. **1** through **19,** crane **10** comprises a pair of spaced apart crawler type double front bogies **14** and **15** near its front end and a pair of spaced apart crawler type single rear bogies **16** and **17** near its rear end. The bogies support crane **10** and enable it to traverse and rotate on the terrain at the job site. The bogies, which are shown as of the crawler type but could be multi-wheeled untis, are sufficiently large to distribute a load over a large area of the terrain and thereby resist a tendency to sink into soft or wet terrain. The double front bogies **14** and **15** are similar to each other and each comprises two single bogie units. The units in bogie **14** are designated **14A** and **14B** and those in bogie **15** are designated **15A** and **15B,** where appropriate. Each bogie unit **14A, 14B, 15A** and **15B** is generally similar to a single bogie **16** or **17** at the rear of crane **10,** as regards its general construction and pro-

pulsion means. Therefore, a description of bogie unit 14A will suffice for all the others.

As FIGS. 6, 8, 9, 10, 11, 12 and 13 show, double bogie 14, for example, comprises a centrally located double-ended axle-like member 200 which is rigidly interconnected to and between the bogie units 14A and 14B so that those units can be steered together as a unit.

Each end of axle 200 extends into and is rigidly (and non-rotatably) secured within a hole 201 in a sleeve 203 which is rigidly secured (as by welding) to and extends through a pair of spaced apart elongated side frame or support frames 205 which form the basic supporting framework of each bogie unit. Each end of axle 200 is secured in sleeve 203 by bolts 207 which extend through a plate 206 and take up into threaded holes 208 in the axle 200. Plate 206 bears against the outer end of sleeve 203 as bolts 207 are tightened and forces the inner end end of sleeve 203 against a flange or shoulder 210 on axle 200. To facilitate attachment or detachment of the bogie units 14A and 14B from the axle 200 when the crane is being set up or broken down, a pair of smooth bearings sleeves or liners 212 are provided in hold 201.

Each front double bogie 14 and 15 is articulately and steerably connected at a connection point directly below a front corner of frame 11 by connection means which enable the double bogie to pivot horizontally to a limited degree (about 30° in each direction) about its vertical centerline for steering purposes. The connection means also enable each double bogie to pivot vertically to a limited degree about its horizontal longitudinal centerline. Such articulation enables crane 10 to adapt to uneven terrain.

Thus, the front end of tubular side member 100 of frame 11 is provided with a connector 220 which comprises a rigid vertical back plate 221, a rigid horizontal forwardly extending bottom plate 223 welded to the back plate, and a pair of spaced apart rigid vertical forwardly extending boom pin support plates 224, each of which is welded to and between back plate 221 and bottom plate 223. The boom pin support plates 224 afford support for boom 22, as hereinafter described. Back plate 221 is secured by removable bolts 226 to a flange 227 on the front end of side member 100 of frame 11 to enable ready attachment or detachment of the connector 220 for front bogie 14 from frame 11 during crane assembly or disassembly.

Connector 220 further comprises a pivot assembly 229 including a rigid horizontal forwardly extending top plate 230 and a plurality of rigid vertical downwardly extending pin support plates 232 which are welded to the underside of plate 230. Pivot assembly 229 is rotatably connected to bottom plate 223 by means of a horizontally disposed ring-type roller bearing assembly 235 which has its outer race connected by bolts 236 to plate 223 and its inner race connected by bolts 238 to plate 230. Each double bogie 14 and 15 is steerable about a vertical centerline through the center of bearing assembly 235. The pin support plates 232 are rigidly connected to and support two sleeves 240 which accommodate a horizontally disposed cylindrical pivot pin 241. Pivot pin 214 is also disposed in and through holes through a sleeve 244 and the end plates 245 of axle 200. Thus, each double bogie 14 and 15 is articulately pivotable about its fore and aft horizontal axis.

As FIGS. 6 and 15 through 19 show, each rear single bogie 16 and 17 is connected at one end of the transverse beam 12 and the latter is connected below frame 11 near the rear end thereof by means of a horizontally disposed cylindrical pivot pin 250. Pivot pin 250 extends fore and aft of frame 11 through holes in sleeves 252 supported on vertically depending brackets 253 bolted or pinned to the underside of the rear end of the tubular side members 100 and 101 of frame 11. Pivot pin 250 also extends in and through holes through a sleeve 254 supported by the plates 255 near the upper side of beam 12. Thus, beam 12 and the bogies 16 and 17 thereon can pivot as a unit to a limited degree about a horizontal fore and aft axis of frame 11 for articulation purposes to adapt to uneven terrain.

Each rear bogie 16 and 17 is steerably connected to an end of beam 12 by means of a thrust bearing assembly comprising a U-shaped support bracket 260 rigidly connected to the beam 12 as by welding. The bracket 260 supports a vertically disposed pivot pin 261 which extends through holes 262 therein and which also extends through a hole 265 in a laterally outwardly extending stub axle 263 which connects to a single bogie 14 and 15 in the same manner as one end of an axle 200 connects to its associated bogie, as hereinbefore described.

Each bogie unit 14A, 14B, 15A and 15B of the double bogies 14 and 15, and each single bogie 16 and 17, is independently powered and its track 276 can be driven in the forward or reverse direction, as required, by means of its own hydraulic motor 289, as FIGS. 7, 12, 13 and 14 show. The track 276 of each bogie is conventional and comprises articulately connected track shoes 275 forming an endless flexible track. Each bogie unit 14A, 14B, 15A, 15B, 16 and 17, as part of its basic structure, comprises two spaced apart flat elongated support plates 205 which are joined together along their top edges by a cap plate 271 which is welded thereto. Cap plate 271 supports a pair of spaced apart members 272 which are welded thereto and define a recessed track shoe guide slot 273 for guiding a projection 274 which is provided on the inside surface of each track shoe 275.

The support plates 205 of each bogie support a plurality of horizontal pins 278 along their lower edge on which conventional crawler rollers 279 are mounted. A driven roller 280 rigidly mounted on a splined shat 281 is located near the rear end of the support plates 205, as FIG. 13 shows, by means of bearings 282 on the support plates 205. Shaft 281 and its roller 280 are rotatably drivable in forward or reverse directions by a chain sprocket 283 affixed to shaft 281 by bolts 284 and driven by an endless flexible roller chain 285 which engages sprocket 283 and a drive pinion 286, as FIGS. 12 and 13 show. Pinion 286 is affixed to an output or drive shat 287 of a conventional three-stage planetary spur gear reducer 288, driven by a conventional reversible variable speed variable torque hydraulic motor 289. Motor 289 and reducer 288 are detachably supported on a side of plate 205 by means of removable bolts 290 which connect to a suitable support 291. A protective housing 292 is provided for the motor 289 and reducer 288. If preferred, however, roller 280 may be driven directly by a hydraulic motor 288A, as shown in FIG. 14, which attaches directly to the end of splined shaft 281.

The Steering Mechanism

As FIGS. 6, 7, 18, 24 and 25 show, the rear bogies 16 and 17 are independently steerable about their respective pivot points by means of the conventional hydraulic rear steering cylinders 52 and 53, respectively. Each cylinder 52 and 53 comprises a cylinder section 300 and a cylinder rod 301 tetescopable therewithin. The base end of each cylinder section 300 is pivotally connected by a pin 303 to a support plate 305 which is rigidly connected to a member 100 and 101 of frame 11 and extends downwardly therefrom. The remote end of each cylinder rod 301 is pivotally connected by a pin 306 to a bracket 307 rigidly connected as by welding to the inner plate 205 of its respective rear bogie. Extension and retraction of each cylinder 52 and 53 effects steering of its associated bogie, as comparison of FIGS. 6 and 7 shows. The rear bogies 16 and 17 are parallel to each other when both cylinders 52 and 53 are retracted (as FIG. 6 shows) and assume an outwardly-toed position (as FIG. 7 shows) when both cylinders are fully extended. Each cylinder 52 and 53 can retract further to a limited degree from the position shown in FIG. 6 to enable conventional steering use of the rear bogies as shown schematically in FIG. 28. If preferred, the base end of each cylinder section 300 could be pinned or anchored to beam 12 instead of to support frame 11.

As FIGS. 6, 7, 8, 11, 22 and 23 show, the front bogies 14 and 15 are steered by the front steering hydraulic cylinders 50 and 51, respectively. Each cylinder 50 and 51 comprises a cylinder section 320 and a piston rod 321. The base end of each cylinder section 320 is pivotally connected by a pin 322 to a bracket 323 which is rigidly secured as by welding in cross member 103. The remote end of each piston rod 321 is pivotally connected by a pin 325 to a bracket 326 on plate 230 of its associated steering assembly 229.

Extension and retraction of each cylinder 50 and 51 effects steering of its associated bogie, as comparison of FIGS. 6 and 7 show. The front bogies 14 and 15 are parallel when the cylinders 50 and 51 are fully extended (as shown in FIG. 6) and assume an inwardly-toed position (as shown in FIG. 7) when both cylinders are fully retracted.

The front bogies 14 and 15 are maintained in either parallel or inwardly-toed relationship, despite the tremendous load forces inposed on the bogies as crane 10 moves in any of its possible directions by means of tie rod 20. As FIGS. 6, 7, 11, 20 and 21 show, tie rod 20 comprises a first tubular section 330 which fits telescopically within a second tubular section 331. The remote end of each section 330 and 331 is pivotally connected, as FIG. 11 makes clear, by a pin 333 to a steering anchor bracket 334 which is rigidly secured to plate 230 of the associated steering assembly 229. As FIGS. 20 and 21 best show, tie rod locking means 340 are provided to releasably lock the tie rod in either fully extended position (shown in FIG. 6). The locking means 340 comprises a cylindrical locking pin 341 which is vertically movable between a lowered locking position (shown in FIG. 20) and a raised unlocking position (shown in FIG. 21) by means of a movable lever arm 342 pivotally connected thereto at one end by a slot 343 and pin 344 arranged as shown. The other end of lever arm 342 is pivotally connected by a pin 346 to a fulcrum or support bracket 347 rigidly connected as by welding to a sleeve 348 which, in turn, is welded to tubular section 331. Lever arm 342 is movable upwardly by a hydraulic actuator 350 pivotally connected by pins 351 and 352 to and between lever arm 342 and sleeve 348. A biasing spring 354 is provided between arm 342 and sleeve 348 to ensure that pin 341 always returns to locked position.

Pin 341 is movable to locking position through a pair of holes 357 in tubular section 331 of tie rod 20 and either through a pair of holes 358 near the inner end of tubular section 330 (to maintain the forward bogies 14 and 15 parallel) or through another pair of holes 359 near the outer end of tubular section 330 (to maintain the forward bogies 14 and 15 inwardly-toed). FIGS. 20 and 21 depict holes 357 and 359 only.

In operation, the locking means 340 are unlocked, the bogies 14 and 15 are then simultaneously steered or turned inwardly or outwardly, by use of their hydraulic steering cylinders, as the case may be, and then the locking means 340 are again locked to hold the tie rod in its retracted or extended position. To prevent window-locking of sections 330 and 331, the former is provided with a slot 365 into which a projection 366 on section 331 extends.

The Boom and Mast

As FIGS. 1 and 2 show, boom 22 is an A-frame lattice type boom having two upwardly converging lower sections 400 and 401 which are rigidly secured together at their upper ends and are adapted to accommodate a detachable upper section 403 of a suitable length which is connectable and disconnectable as at 405 and which has jib 18 secured thereto. The lower ends 23 and 24 of the lower boom sections 400 and 401 are each pivotally connected to frame 11 by a removable boom attachment pin 408 which is mounted and supported in holes 409 in the boom support plates 224 on the connector 220 hereinbefore described. Thus, the lower ends 23 and 24 are connected directly above and on the vertical centerlines of the front bogies 14 and 15, respectively, to ensure direct transmission of lifting loads to the front bogies.

The boom 22 is vertically swingable or pivotable about $\pi°$ between its extreme upright position shown in FIG. 1 to its extreme lowered position (not shown) wherein its upper end 31 rests on the ground for dismantling. Upward boom travel (and upward mast travel) is limited by a pair of boom stops 73, one of which is shown in detail in FIG. 4, each of which comprises a shock absorbing assembly 410 on the upper end of a forwardly and upwardly sloped boom stop rod 411 which is detachably connected to frame 11 by a pin 414 at its lower end. Rod 411 is supported at its upper end by a detachable brace 412 which is connected by a pin 413 to rod 411 and which is also connected to frame 11 by a pin 425. Shock absorbing assembly 410 comprises a mast engaging rod 416 extending outwardly from a cylinder 417 and a cushioning spring 418 is disposed in cylinder 417 between a flange 419 on rod 416 and the inner end wall of cylinder 417.

As FIGS. 1, 2 and 3 show, mast 27 is an inverted U-shaped lattice-type structure comprising a lower section 420 having spaced apart legs 423 and 424 and also having an upper section 421 detachably connected thereto in a conventional manner, as at 422. The lower ends 28 and 29 of mast 27 are each pivotally connected by a horizontally disposed mast pivot pin 425 to a pair

of spaced mast support plates **426** rigidly secured as by welding to the cross member **103** of frame **11.** The pins **425** are located directly behind the boom base ends **23** and **24** and as close as physically practical to the boom pins **408** so as to transmit load forces at the lower ends of the mast directly to the front bogies **14** and **15.** The frame **11** and mast **27** are joined by pennant cables **37,** as hereinbefore described and the boom is connected by the boom hoist cables **35** to boom hoist winch **40.** Therefore, the boom **22** and mast **27** of crane **10,** shown in FIG. **1,** do not pivot concurrently as boom **22** is raised and lowered, whereas the boom **22A** and mast **27A** do pivot concurrently as the boom **22A** is raised and lowered.

The Control System

FIGS. **26, 27** and **28** show a control system for crane **10** in accordance with the invention. FIG. **26** principally shows the engine driven pumps **60,** the control valves therefor and the drive motors **289** for the bogies. FIG. **27** principally shows the front and rear steering cylinders and the control valves therefor. FIG. **28** principally shows the hydraulic motors for the main hoist, boom hoist and auxiliary hoist and the control valves therefor. It is to be understood that the pumps for supplying the hydraulic cylinders and hydraulic motors shown in FIGS. **27** and **28** are shown in FIG. **26** and the same reference numerals are used in those figures to show the interconnection of the fluid lines between them.

Referring to FIG. **26,** the engine **61** is connected to drive four hydraulic pumps generally designated by the numeral **60** in FIGS. **1** and **5** but more specifically designated as **60A, 60B, 60C** and **60D** in FIG. **26.** These pumps supply the drive motors and hydrauic cylinders as hereinafter described. Engine **61** also drives a small auxiliary hydraulic pump **60E** to supply hydraulic fluid to energize the various control valves in the system. The four pumps **60A** through **60D** are identical and each may, for example, be a conventional hydraulic pump capable of operating at 1800 rpm to discharge 25 gallons per minute of fluid from each of its two pressure ports. The pump **60A** supplies fluid for the bogie units **14A** and **14B** of right front bogie **14.** The pump **60B** supplies fluid for operating the bogie units **15A** and **15B** of the left front bogie **15.** The pump **60C** supplies fluid for operating the rear bogies **16** and **17** and also supplies fluid for effecting hoisting functions of the crane, as hereinafter explained. Pump **60D** also supplies fluid for performing hoisting functions as hereinafter explained.

As FIG. **26** shows, each pump **60A** through **60D** is provided with a conventional pressure relief valve **500** in the pressure line **501** which leads from the pump pressure port **501.** Each relief valve **500** is connected by a fluid return line **504** to a fluid reservoir generally designated throughout FIGS. **26, 27** and **28** by the numeral **507.** Reservoir **507** is quite large and is understood to have a capacity for handling, for example, fluid flow of up to **350** gallons per minute of circulating fluid. Each pressure line **501** is also provided with a conventional two-position selector valve **510** which enables the operator, except in the case of pump **60D,** the divert fluid flow either to the appropriate drive motors for the bogies or to the hydraulic motors for performing hoisting functions. The selector valve **510** for the pump **60D** enables the operator to divert fluid either to the steering system or to perform hoisting functions. The selector valve **510** for the motors **60A** through **60C** each have one port which is connected, as by the fluid lines **512,** to a conventional directional control valve **515** which determines fluid flow direction to the bogie drive motors **289** and thereby determines whether a particular bogie unit operates in the forward or reverse direction. The other ports of the selector valve **510** for the pumps **60A** and **60B** are connected to a supply line **517** which is able to provide a fluid flow of, for example, **100** gallons per minute to perform hoisting functions. The other ports of the selector valves **510** for the pumps **60C** and **60D** provide fluid to a fluid supply line **519** which also is available for hoisting functions. As FIGS. **26** and **27** show, the supply lines **517** and **519** are connected to supply the conventional hydraulic motors for the various hoists. Each directional control valve **515** is connected through a conventional dual relief valve **522** to its respective drive motor **289.** The pressure lines **512** for the pump **60B** are each provided with a work-travel conventional selector valve **525** which is used by the operator to direct fluid flow either to the bogie units **15A** and **15B** of left front bogie **15** or to supplement the fluid flow from pump **60C** to the rear bogies **16** and **17,** depending on the type of operations being performed by the crane **10.**

From the arrangement shown in FIG. **26** it is apparent that each bogie unit **14A, 14B** and **15A** and **15B** and each bogie **16** and **17** can be independently operated in either forward or reverse direction by the crane operator. The units in the front bogies **14** and **15** are capable of being driven at a speed of 0.5 mph. Each rear bogie **16** and **17** is capable of being driven at a speed of 1.0 mph. This differential in speed is provided because during self-rotation of crane **10** about the center of rotation between the front bogies, the ground travel of the rear bogies **16** and **17** is substantially greater than is required by the front bogie units. Of course, during normal forward and reverse movement of crane **10** all bogies would be driven in the same direction and at the same speed, except in cases where it might be desirable to increase the ground speed of either or both of the rear bogies **16** and **17** during a conventional steering operation.

Referring now to FIG. **28,** it is seen that the fluid supply line **530** from pump **60D** shown in FIG. **26** is connected to a conventional two-position front-rear selector valve **535** which determines whether the front steering cylinders **50** and **51** or the rear steering cylinders **52** and **53** are to be supplied with operating fluid. If selector valve **535** is operated to select the front steering position, valve **535** then supplies a bogie positioning selector valve **537** which, in the position shown in FIG. **28,** supplies a conventional three-position valve **540** which is operable to supply the front steering cylinders **50** and **51** through two-position valves **556** to cause the front bogies **14** and **15** to move either toward or away from each other or to be steered simultaneously to the right or left. The bogie position valve **537** in its other position connects the fluid source to a conventional two-position valve **545** which is connected to the piston **350** on the locking means and is operable to move pin **341** to locked or unlocked position. The front-rear selector valve **535** is operable in its rear selector position to supply a conventional three-position valve **550** which is operable to supply the rear steering cylinders **52** and **53** through two-position valves **556** to cause the

rear bogies to move either toward or away from each other or to be steered simultaneously to the right or left. Operation of valve **550** enables the bogies **16** and **17** to be steered outwardly and inwardly with respect to each other.

As FIG. **27** shows, a selector valve **560** is provided to connect fluid supply line **519** either to a conventional three-position valve **562** which controls one side of the main hoist drum **47** or a conventional two-position valve **565** which is operable to connect supply line **519** for operating either boom hoist **40** or auxiliary hoist **48.** The two-position selector valve **565** is connected to a conventional three-position control valve **567** for operating one section of boom hoist **40** and is also connected to a conventional three-position control valve **569** for controlling auxiliary hoist **48.** The supply line **517** is connected through a conventional two-position selector valve **570** to supply a conventional three-position control valve **572** for the other side of boom hoist **40** or a conventional three-position control valve **574** for the other side of main hoist **47.** Each three-position control valve is provided with a conventional dual relief valve **578.** The hydraulic motors **580** for main hoist **47,** motors **582** for boom hoist **40,** and motor **584** for auxiliary hoist **48** are each connected in circuit with a conventional two-position electrically operated solenoid valve **588** which is operatively connected to operate a brake mechanism **590** which comes into play to stop the rotation of its respective hoist drum whenever the hoist motor is de-energized. As FIG. **27** shows, each hoist motor is connected through a suitable conventional transmission mechanism **592** to its respective hoist drum **594.**

We claim:

1. A self-propelled mobile crane comprising: a substantially triangular support frame having one end wider than an opposite end; spaced apart drivable and steerable first bogie means connected at spaced apart bogie connection points near said one end of said support frame; second drivable and steerable second bogie means connected near an opposite end of said support frame; driving means and steering means for said first and second bogie means; a vertically swingable room having a pair of spaced apart lower ends mounted for vertical swinging movement on said support frame, each boom end being pivotally attached to said support frame at a boom attachment point adjacent one of said bogie connection points; and a boom support mast having a pair of spaced apart lower ends mounted for vertical swinging movement on said support frame, each mast end being attached to said support frame at a mast attachment point adjacent one of said bogie connection points, said boom and mast attachment points being located substantially directly above said connection points of said frist bogies.

2. A self-propelled mobile crane comprising: a triangular support frame having a wide front end and a narrow rear end and a transverse beam attached at said narrow end; a pair of drivable and steerable front bogies connected to said frame at spaced apart connection points near the corners of said wide front end of said frame; a pair of drivable and steerable rear bogies mounted at opposite ends of said transverse beam; driving means and steering means for said front and rear bogies; and adjustable telescopic tie rod connected to and between said pair of front bogies to maintain them in specific relationship with each other for steering purposes; means for locking said tie rod in extended or retracted positions; a vertically swingable boom having two spaced apart lower ends pivotally connected to said front end of said support frame at boom attachment points above said connection points of said front bogies to concentrate a load thereat; and a boom support mast having its lower end connected to said front end of said support frame adjacent a line between said boom attachment points.

3. A crane according to claim **2** wherein said boom support mast comprises two spaced apart lower ends pivotally attached to said frame at mast attachment points adjacent said boom attachment points.

4. A self-propelled mobile crane comprising: a support frame having a center of rotation; a first pair of drivable and steerable bogies connected at spaced apart connection points near one end of said frame; each bogie in said first pair having a center of rotation; a second pair of drivable and steerable bogies connected at spaced apart connection points near another end of said frame; driving means for said first and second pairs of bogies; and adjustable telescopic tie rod connected to and between said first pair of bogies to maintain them in specific relationship with respect to each other for steering purposes; means for locking said tie rod in extended or retracted positions; a vertically swingable boom having two spaced apart lower ends pivotally attached to said frame at boom attachment points substantially directly above said connection points of said first pair of bogies; a boom support mast having its lower end attached to said frame adjacent a line between said boom attachment points, and steering means for said first and second pairs of bogies to enable said crane to be steered for rotation either about the center of rotation of said crane or about a center of rotation between said bogies in said first pair.

5. A self-propelled mobile crane comprising: a triangular support frame having a center of rotation and having a wide front end and a narrow rear end and a transverse beam attached at said narrow end; a pair of drivable and steerable front bogies connected to said frame at spaced apart points near the corners of said wide front end of said frame; each front bogies being a double bogie and comprising two independently drivable bogie untis; a center of rotation between said front double bogies; a pair of drivable and steerable rear bogies mounted at opposite ends of said transverse beam, each rear bogie being a single bogie and comprising one independently drivable bogie unit; and adjustable telescopic tie rod connected to and between said pair of front bogies to maintain them in specific relationship with each other; means for locking said tie rod in extended or retracted position; a vertically swingable boom having two spaced apart lower ends pivotally connected to said front end of said support frame at boom attachment points above said connection points of said front bogies to concentrate a load thereat; a boom support mast having its lower end connected to said front end of said support frame adjacent a line between said boom attachment points; and steering means and drive means for said front and rear bogies to enable said crane to be steered conventionally or for rotation either about the center of rotation of said crane or about said center of rotation between said front double bogies.

6. A crane according to claim **5** wherein said boom support mast comprises two spaced apart lower ends

pivotally attached to said frame at mast attachment points adjacent said boom attachment points.

7. A self-propelled mobile crane comprising: a support frame having a center of rotation on a longitudinal center line of said crane; a first pair of drivable and steerable bogies connected at spaced apart connection points near one end of said frame; a center of rotation between said first pair of bogies; a second pair of drivable and steerable bogies connected at spaced apart connection points near another end of said frame; and adjustable telescopic tie rod connected to and between said first pair of bogies to maintain them in specific relationship with respect to each other for steering purposes, said tie rod being movable between extended and retracted positions in response to outward and inward steering of said first bogies; remotely operable means for releasably locking said tie rod in either position; a vertically swingable boom having two spaced apart lower ends pivotally attached to said frame at boom attachment points adjacent said connection points of said first pair of bogies; a boom support mast having its lower end attached to said frame adjacent a line between said boom attachment points; steering means for said first and second pairs of bogies; and propulsion means for said first and second pairs of bogies; said crane being steerable conventionally by operation of said steering means to steer both of said bogies in said first pair simultaneously in the same direction and to maintain both said bogies in said second pair parallel to each other and parallel to said longitudinal axis of said crane while all said bogies are driven in the same direction by said propulsion means; said crane being steerable about its center of rotation by operation of said steering means to steer said bogies in said first pair inwardly with respect to each other and to steer said bogies in said second pair outwardly with respect to each other and by operation of said propulsion means to drive said bogies in said first pair in opposite directions with respect to each other and to drive said bogies in said second pair in opposite directions with respect to each other; and said crane being steerable about said center of rotation between said bogies in said first pair by operation of said steering means to maintain both bogies in said first pair parallel to each other and parallel to said longitudinal axis of said crane and to steer said bogies in said second pair outwardly with respect to each other and by operation of said propulsion means to drive said bogies in said first pair in opposite directions with respect to each other and to drive said bogies in said second pair in opposite directions with respect to each other.

8. A crane according to claim **7** wherein said steering means comprises an individual hydraulic steering motor for each bogie and hydraulic means for operating said hydraulic steering motors and an individual propulsion motor for each bogie and means for operating said propulsion motor.

9. A crane according to claim **8** wherein said remotely operable means is hydraulically operated.

10. A crane according to claim **7** wherein each first bogie is a double bogie comprising two independently drivable bogie units and wherein each rear bogie is a single bogie comprising one independently drivable bogie unit.

11. A crane according to claim **1** including an adjustable telescopic tie rod connected to and between said first spaced apart bogie means to maintain them in specific relationship with respect to each other for steering purposes and means for locking said tie rod in extended or retracted positions.

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