



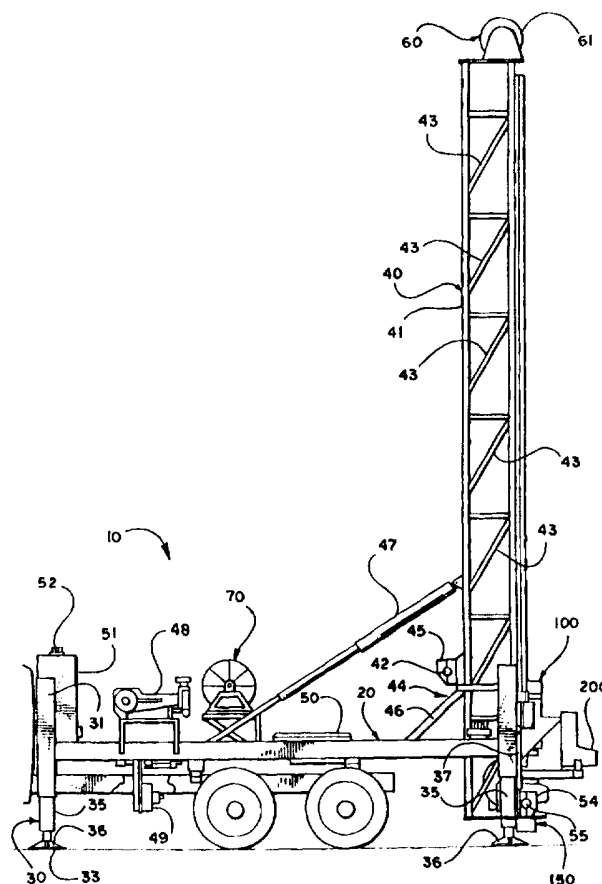
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(54) Title: DRILLING RIG

(57) Abstract

An improved drilling rig (10) having a drillhead assembly (100) positioned onto a mast for vertical movement therewith. The drillhead assembly (100) is hung by cables (250) threaded from a hoist assembly (60) positioned at the top end of the mast (41). One or more cable return assemblies are positioned at the bottom end of the mast (41). The cables (250) are counter-wound on the hoist assembly (60) such that the cables (250) roll off the hoist assembly (60) in the direction towards the drillhead assembly (100) at the same rate the cables (250) are pulled onto the hoist assembly (60) from the direction towards the cable return assemblies. The drillhead assembly has a drive motor assembly (130) rotatably mounted within a frame. A break-out tool assembly (150) is mounted at the lower end of the mast. The break-out tool assembly (150) has means for grasping rotating a length of string so as to separate the lengths of string.



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DRILLING RIG

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Technical Field

The present invention relates generally to a drilling rig, and more particularly relates to a mobile drilling rig with a differential hoist, a swivel drillhead assembly, and a break-out tool assembly.

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Background of the Invention

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Although drilling rigs of various types are well known in the art, drilling rigs have always been considered difficult and time-consuming to operate. Drilling is often dangerous work involving heavy lifting to position the numerous lengths of string and other types of equipment into place. As a result, drilling is often dirty, noisy, labor intensive work. Further, the drilling site is often in a remote, largely inaccessible area.

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As is well known, a drilling rig generally comprises a mast of variable height, drive motor, a drilling head, and a plurality of sections of pipe (also called the string). The rig may be mobile. As the drillhead progresses into the earth, additional lengths of string are added to the drillhead as needed. This procedure generally involves lifting long lengths of string, usually 20 feet or longer, onto the top of the preceding length, joining the two lengths, and then continuing to drill. This process is then reversed when the drillhead and the string are removed from the earth.

Other problems encountered with drilling rigs include limitations on drilling in anything other than the vertical plane. Drilling at any angle off of the vertical plane has often proved to be difficult because of the strain placed on the equipment. This problem is particularly acute with mobile drilling rigs unless sufficient means for anchoring the vehicle can be provided.

Summary of the Invention

The present invention seeks to provide an improved drilling rig that is easy to operate and requires significantly less manpower. The improved drilling rig would provide a drillhead assembly that rotates for easy maneuvering of lengths of the drill string. Such a rig would have a convenient means to hold long lengths of string in place while connecting a following length of string. Further, the drilling rig would be mobile and operate in a quiet and safe fashion. Finally, the drilling rig would permit drilling at angles off of the vertical plane.

In accordance with the invention, these objects are accomplished in an improved drilling rig having a drillhead assembly positioned onto a mast for vertical movement therewith. The drillhead assembly is hung by cables threaded from a hoist assembly positioned at the top end of the mast. One or more cable return assemblies are positioned at the bottom end of the mast. The cables are counter-wound on the hoist assembly such that the cables roll off of the hoist assembly in the direction towards the drillhead assembly at the same rate the cables are pulled onto the hoist assembly from the direction towards the cable return assemblies. The drillhead assembly has a drive motor assembly rotatably mounted within a frame. A break-out tool assembly is mounted at the lower end of the mast. The break-out tool assembly has means for grasping and holding a first length of drilling string and means for rotating a second length of string so as to join or separate the lengths of string.

The drive motor assembly is positioned within a swivel assembly. The swivel assembly is rotatable so as to raise or lower the drive motor assembly and a length of string from the vertical position to the horizontal position or from the horizontal position to the vertical

position. The swivel assembly is rotated by one or more hydraulic cylinders.

5 The drillhead assembly is hung by one or more cables threaded from the hoist assembly to the drillhead assembly and from the drillhead assembly to the cable return assemblies and back to the hoist assembly. The hoist assembly includes a grooved drum powered by two variable speed hydraulic motors. The drillhead assembly is connected to the cables by an upper tensioner assembly. The upper tensioner assembly includes a rocker arm mounted to a piston. The bottom cable return
10 assemblies have a sheave mounted to a bottom tensioner assembly. The bottom tensioner assembly includes a hydraulic cylinder. The upper tensioner assembly and the bottom tensioner assemblies operate in tandem to keep the cables under constant tension.

15 The drilling rig itself may be mounted onto a truck. When the rig arrives at the drilling site, the mast can be raised by a hydraulic cylinder. The mast can pivot about at least two different pivot points so as to permit angled drilling. The drilling rig can be used for mineral or oil exploration. The drilling rig can drill a four inch diameter hole up to a depth of 3000 feet. The rig can also be used with an external rack
20 assembly positioned adjacent to the mast. The rack assembly includes a conveyor and a rack assembly arm to assist in the positioning of the lengths of drilling string.

Other objects, features, and advantages of the present invention will become apparent upon reviewing the following description of the preferred embodiment of the invention, when taken in conjunction with
25 the drawings and the appended claims.

Brief Description of the Drawings

30 Fig. 1 is a side plan view of the rig with the mast assembly completely retracted on top of the truck.

Fig. 2 is a side plan view of the rig with the mast assembly fully extended in the vertical position.

Fig. 3 is a side plan view of the rig with the mast assembly partially raised to permit angled drilling.

35 Fig. 4 is a rear plan view of the rig with the mast assembly and the pad assemblies completely extended.

Fig. 5 is a top plan view of the frame.

Fig. 6 is a side cross-sectional view of a pad assembly.

Fig. 7 is a plan view of the hoist assembly.

Fig. 8 is a plan view of the wire line assembly.

5 Fig. 9 is a side cross-sectional view of a sheave group assembly.

Fig. 10 is a front plan view of the drillhead group assembly.

Fig. 11 is a side plan view of the upper tensioner assembly.

10 Fig. 12 is a side plan view of the drillhead group assembly with a hydraulic cylinder shown in partial phantom lines.

Fig. 13 is a front cross-sectional view of the drive motor assembly.

Fig. 14 is a side cross-sectional view of the break out tool assembly.

15 Fig. 15 is a side plan view of the rack assembly.

Fig. 16 is a front plan view of the rack assembly.

Detailed Description of the Invention

20 Referring now to the drawing, in which like numerals refer to like parts throughout the several views, Figs. 1 through 5 show a mobile drilling rig **10** embodying the present invention. The rig **10** comprises a frame **20**, a plurality of pad assemblies **30**, a mast assembly **40**, a hoist assembly **60**, two sheave groups **80**, a drillhead group **100**, a breakout tool assembly **150**, a control panel **200**, and
25 cables **250**. The rig **10** drills to various depths depending upon the length of the string **300**, or the length of pipe, put into the ground. The rig **10** may operate with the assistance of an external rack assembly **350** (Fig. 15) to position the individual lengths of string **300** into place adjacent to the rig **10**.

30 The rig **10** is mounted on to a truck **15** for transport. The truck **15** is of conventional heavy-duty design, such as a L8000 or L9000 sold by Ford Motor Company. Fig. 1 shows a side plan view of the rig **10** with the mast assembly **40** completely retracted onto the top of the truck **15**. Fig. 2 is a side plan view of the rig **10** showing the mast assembly **40** fully extended in the vertical position for drilling, while
35 Fig. 3 is a side plan view of the rig **10** with the mast assembly **40**

partially raised to permit angled drilling. Fig. 4 is a rear plan view of the rig **10** with the mast assembly **40** and the pad assemblies **30** completely extended. Fig. 5 is a top plan view of the frame **20** showing the drillhead group **100**, aspects of the hoist assembly **60**, and the control panel **200**.

The frame **20** is mounted onto the truck **15** by conventional methods. The frame **20** is preferably made from approximately 8 inch by 6 inch steel tubing with a wall thickness of about 1/4 inch. The length, width, and type of material used for the frame **20** can vary depending upon the size of the truck **15** and the application of the rig **10**.

Four pad assemblies or jacks **30** extend from each of the four corners of the frame **20**. As is shown in Fig. 1 and in the side cross-sectional view of Fig. 6, each pad assembly **30** comprises an extended cylinder **31** mounted to the frame **20** by welding or other conventional means. A pad leg **35** is adapted to be slidably received within the extended cylinder **31**. A ball joint **32** extends from the bottom end of each of the pad leg **35**. Each of the ball joints **32** mate with a swivel pad **33** for rotational movement therewith. The swivel pads **33** are preferably 18 inches in length and width. The swivel pads **33** are preferably made of steel and include reinforcing ribs **36** thereon. The pad legs **35** have sufficient length such the pad legs may extend from the extended cylinders **31** such that the swivel pads **33** reach the ground regardless of whether the mast assembly **40** is fully extended or partially extended.

The swivel pads **33** may be attached to the pad legs **35** by a quick release pin **34**. The mounting of the swivel pads **33** to the pad legs **35** is such that the swivel pads may pivot to account for any irregularities in ground surface or slope. Hydraulic cylinders **37** are mounted alongside each of the extended cylinders **31** and are associated at a distal end with the respective pad leg **35** or swivel pad **33** such that the cylinders may press the swivel pads in place and stabilize the rig **10**. The hydraulic cylinders **37** may be operated individually, or from the control panel **200**. When extended, the pad assemblies **30** ensure that the rig **10** is stable, even when the rig **10** is on uneven ground.

Also mounted to the frame 20 is the mast assembly 40. As is shown in Fig. 1, the mast assembly 40 comprises a mast 41 with a stabilizing rod 42. The mast 41 has support ribs 43 positioned at 3 to 4 foot intervals for structural strength. The mast 41 preferably comprises ASTM A500 structural steel. The mast 41 is preferably 30 feet in length, although the length of the mast 41 may be varied depending upon the application and size of the rig 10.

As is shown in Figs 1 and 2, the mast assembly 40 is secured both in the retracted or upright position via a mast hinge assembly 44 mounted to the frame 20. As the mast is raised from its retracted position (Fig. 1) to its upright position (Fig. 2), the mast 41 pivots about the stabilizing rod 42 within the hinge assembly 44. The mast hinge assembly 44 comprises a two piece clamp 45 supported by clamp support members 46. The stabilizing rod 42 of the mast 41 is captured by the clamp 45 to keep the mast 41 in proper position while the hydraulic cylinder 47 raises and lowers the mast 41 between its retracted and upright positions.

A second mast hinge assembly 54 is fixed for movement with the two rear pad legs 35 and is located near the ground when the pad legs are in place. A second stabilizing rod 55, located at the bottom of the mast 40, is adapted to engage the second mast hinge assembly 54 when the mast is in the upright position.

As is shown in Fig. 3, the clamp 45 opens to permit the stabilizing rod 42 to escape the hinge assembly 44 and to permit the mast 40 to rotate about the second mast hinge assembly 54. With mast 41 pivoted about second mast hinge assembly 54, the hydraulic cylinder 47 can raise and lower the mast 41 to accommodate angled drilling. The hydraulic cylinder 47 may lower the mast 41 to a point where the stabilizing rod 42 engages the cross-beam 17 on the truck 15. This point is preferably where the mast 40 is at approximately a 45° angle to the ground.

As described, the mast assembly 40 is raised and lowered by the hydraulic cylinder 47 mounted on the frame 20. The hydraulic cylinder 47 is powered by a hydraulic pump 48. The hydraulic pump 48 is in turn powered by a split shaft power take off ("PTO") 49 that is powered by the drive train (not shown) of the truck 15. The hydraulic cylinder

47 may be of conventional manufacture. The hydraulic pump 48 is preferably a pressure compensated pump, manufactured, for example, by Dennison under the model number P16. This same pump 48 may be used to drive the hydraulic cylinders 37 for the pad assemblies 30. A preferred split shaft PTO 49 is sold by Cotta Transmission Company under the model number TR2125-2.

A second hydraulic pump 57 and the split shaft PTO 49 also may use a heat exchanger 50 for cooling, and a hydraulic fluid reservoir 51 for storing the oil used in the hydraulic system. The heat exchanger 50 and the hydraulic fluid reservoir 51 are of conventional design and are mounted on the frame 20 by conventional means. The second pump 57 is used for the cooling oil cycle, as is known in the art. This pump 57 is also attached to the split shaft PTO 49, as is shown in Fig 5. This pump 53 is preferably is a vane pump, such as model number T6D manufactured by Dennison. A mast locking mechanism 52 may be mounted onto or adjacent to the hydraulic fluid reservoir 51 to lock the mast 41 into place when the mast 41 is in the retracted position on the truck 15.

A third pump 56, which is used to run the drillhead assembly 100, as is described in detail below, is also attached to the split shaft PTO 49. This pump 56 is also attached to the split shaft PTO 49, and is preferably is a hydrostatic pump, such as model number P14 manufactured by Dennison and sold under the trademark Gold Cup.

Positioned on top of the mast assembly 40 is the hoist assembly 60. As is shown in Fig. 7, the hoist assembly 60 comprises a two motor hoist 61 mounted to the mast 41 via fasteners 62 or other conventional means. The hoist 61 comprises a drum 63 positioned within a hoist frame 64. Four cables 250 extend around the drum 63 and downward from the drum to the drillhead group 100. The cables 250 are counter-wound on each side of the drum 63, such that, as viewed in Fig. 4, central cables 250a on each side of the drum extend around the drum 63 and downward from the front of the drum, and outer cables 250b extend around the outside of each side of the drum in a direction of rotation opposite of the direction of the central cables 250a and downward from the back side of the drum. Thus, upon rotation of the drum 63 in a first direction, the two central cables 250a

are wound onto the drum and the outer cables **250b** are fed off of the drum. If the direction of rotation of the drum **63** is reversed, the central cables **250a** are let out and the outer cables **250b** are wound onto the drum. The drum **63** is grooved so as to permit the cables **250** to be wound thereon and to ensure that the cables **250** feed off or onto the drum **63** at the same rate.

Each end of the drum **64** includes a separate hydraulic motor **65**. The pump **48** may be used to drive the hydraulic motors **65**. The drum **62** and the hydraulic motors **65** are connected via speed reducer gears **66** and planetary gears **67**. Each motor **65** is also controlled by a fail-safe brake **68**. The hydraulic motors **65** are preferably fixed displacement hydraulic motors, such as those sold by Rexroth under the model number AA24M45. The hydraulic motors **65** preferably have a low speed for drilling operations and a high speed for raising or lowering the drillhead group **100** when the string is being withdrawn or lowered in to the hole. The speed reducer gears **66** and the planetary gears **67** are of conventional design. An example of a preferred fail-safe brake is sold by Mico Company under the model number MC-1414-78-CR.

The hoist assembly **60** further comprises a wire line assembly **70** mounted on to the frame **20** (Fig. 2). As is shown in Fig. 8, the wire line assembly **70** comprises a spool **71** powered by a hydraulic motor **72**. Similar to the positioning of the drum **63**, the spool **71** is connected to the hydraulic motor **72** via a speed reducer gear **73** and a pillow block bearing **74**. The pump **48** may be used to drive the hydraulic motor **72**. The wire line assembly **70** is used to lower and raise the inner tube core assembly (not shown, but known in the art) so as to retrieve a down-hole core sample, as is known in the art.

Mounted on the opposite end of the mast assembly **40** from the hoist **61** are the sheave group assemblies **80** (Fig. 4). One sheave group assembly **80** is mounted on either side of the mast **41**. As is shown in Fig. 9, each sheave group assembly **80** comprises a round, grooved sheave **81** adapted to receive the lower end of the outer cables **250b**, which extend around the sheave and are then connected to the bottom of the drillhead group **100**, as is described in detail below. The sheave **81** is mounted for rotation within a sheave frame **82**. The

sheave **81** rotates within the sheave frame **82** via a spindle **83** with a bearing cone **84** and a bearing cup **85**. Each sheave assembly **81** is mounted onto the mast **41** via a bottom cable tensioner assembly **86**. The bottom cable tensioner assembly **86** comprises a hydraulic cylinder **87** of conventional design. The fluid within the hydraulic cylinders **87** is preferably under approximately 100 psi of pressure. The bottom cable tensioner assemblies **86** keep the cables **250** on either side of the mast **41**, and maintain the outer cables **250** in proper tension during operation.

Anchored by the cables **250** between the hoist **41** and the sheave groups **80** is the drillhead group **100** (Fig. 4). As is shown in Fig. 10, the drillhead group **100** comprises an upper tensioner assembly **110**, a swivel assembly **120**, a drive motor assembly **130**, and a floating sub **145** (Fig. 4). As can best be seen in Figs. 4 and 5, the drillhead group **100** preferably travels along rails **90** located on the outside of the mast **41**. The rails **90** are preferably chrome, and are engaged by traveling heads **92** which preferably utilize Teflon® coated aluminum bearings to avoid wear.

The central cables **250a** are attached to the drillhead group **100** via the upper tensioner assembly **110**. As is shown in Fig. 11, the upper tensioner assembly **110** comprises two bolt eyes **111** positioned on a rocker arm **112**, and a piston **113** positioned within a barrel **114**. The central cables **250a** are secured to the upper end of the drillhead group **100** via the bolt eyes **111**. The rocker arm **112** and the piston **113** keep the cables **250** on either side of the mast **41** in constant, equal tension. The piston **113** is adjustable so as to vary the tension on the cables **250**. The rocker arm **112** and the piston **113** are of conventional design. A load cell **115** may also be used to determine the load supported by the drillhead group **100**. The load cell **115** is preferably positioned adjacent to the piston **113**. The outer cables **250b** extend through the sheave group assemblies **80** and are connected to the lower end of the drillhead group **100**.

As is shown in Figs. 10 and 12, the swivel assembly **120** comprises an extended cylinder **121** positioned on top of the drive motor assembly **130**. The extended cylinder **121**, known as a water swivel in the industry, allows water to be pumped into the core of the

string **300** so that water may reach the drill bit and aid in the drilling process in a manner known in the art.

5 The swivel assembly **120** is configured to rotate the drive motor assembly **130** via a carriage **122**. The carriage **122** is mounted to a drillhead group frame **123** for reciprocal motion via the hydraulic cylinders **124**, each powered by the pump **48**. The hydraulic cylinders **124** are positioned on either side of the drive motor assembly **130** and are of conventional design. The swivel assembly **120** rotates the drive motor assembly **130** approximately 90 degrees from the vertical to the horizontal and back. Swiveling the drive motor assembly **130** allows pipe **300** for the string to be loaded into the drive motor assembly **130** from a horizontal rack while the pipe is in a horizontal orientation. The pipe **300** may then be lifted by raising the drillhead group **100** and, at the same time, allowing the swivel assembly **120** to pivot into a position where the pipe is extending in a direction which is parallel to the hole being drilled. The pipe **300** extending from the drive motor assembly **130** may then be lowered for connection to the string in the hole. During this connection process, the string **300** in the hole is held in place by the breakout tool assembly **150**, as is described in detail below. The swivel assembly **120** also assists in returning pipe **300** to a horizontal rack adjacent the drilling rig when disassembling the string.

Also shown in Fig. 10, the drive motor assembly **130** comprises two hydraulic drive motors **125**. The drive motors **125** each have a drive motor shaft **126** (Fig. 13). The drive motors **125** are preferably variable displacement, two speed hydraulic motors, such as those sold by Dennison under the model number M7H. As is shown in Fig. 13, the drive motor assembly **130** comprises two hydraulic motor adapters **131** and a gear system for driving a motor pinion **138**, which in turn drives a bull gear **139** attached to a central spindle **132**. The drive motor shafts **126** of the drive motors **125** are positioned within and power the hydraulic motor adapters **131**.

Bearings **134** and **135** are positioned within the hydraulic motor adapters **131**. The bearings **134** and **135** permit the motor pinion **138** to rotate with the incoming drive shafts **126** of the hydraulic drive motors **125**. The motor pinions **138** in turn drive the bull gear **139** and the central spindle **132**, which rotates relative to the drive

motor assembly **130** on the bearings **136, 137**. The central spindle **132** provides the drive force to the floating sub **145**. The aperture **133** extends the length of the drive motor assembly **130**, and permits water to flow from the extended cylinder **121** through the floating sub **145** and into the core of the string **300**.

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The break-out tool assembly **150** is positioned at the bottom of the mast **41**. As is shown in Fig. 14, the break-out tool assembly **150** comprises a foot clamp **151** and a gripping housing **152**. The foot clamp **151** is circular in shape and a hollow cylinder **153** at the bottom end thereof. The foot clamp **151** is positioned above the gripping housing **152** and is situated below the drillhead assembly **100**. The foot clamp **151** includes a two couplings **154** positioned on top of the foot clamp **151**. The couplings **154** are pressed diagonally upward or downward via two hydraulic cylinders **155**. The hydraulic cylinders **155** are powered by the pump **48**.

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The two couplings **154** are separated a distance such that the string **300** may be received therebetween, and such that movement of the couplings diagonally downward causes the foot clamp **151** to grasp a length of string **300** and maintain the weight of that string **300**. The coupling **154** can accommodate a number of different sized strings **300**, and includes a two piece slip **160** at the top which matches the outer diameter of the particular string in use. The two piece slip **160** may be removed and replaced via pins **156**. Gear teeth **161** extend downward from the foot clamp **151** and engage a second set of gear teeth **162** in the top of the gripping housing **152**.

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The gripping housing **152** comprises a drive rack **157** operated by a hydraulic cylinder **158**. The drive rack **157** contracts and expands via the hydraulic cylinder **158**, which is powered by the pump **48**. The gripping housing **152** grasps the cylinder **153** by expanding the drive rack **157**. Continued expansion of the cylinder **158** causes the drive rack **157** to rotate and rotates the foot clamp **151**, which is attached for movement with the gripping housing **152** via the gear teeth **161, 162**. Thus, extension of the cylinder **158** causes the gripping housing **152** to grip and rotate the foot clamp **151**, and any string held therein.

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The break-out assembly **150** is used to break the threaded assembly of lengths of string **300** when disassembling the string and

removing it from the hole. Thus, the length of string **300** in the drilling hole is supported by the foot clamp **151**, which in turn is gripped by the gripping housing **152** and rotates the foot clamp and the string to break the threaded seal between a length of string ending above the foot clamp **151** and the rest of the string **300** in the hole. Because the drillhead, and therefore the floating sub **145**, are not rotating when the string **300** is being disassembled, the upper end of the string **300** does not rotate and the threaded engagement is loosened. The upper end of the string **300** above the foot clamp **151** is then rotated by the drillhead group **100** to unscrew the upper length of string **300** from the length of string **300** in the drill hole.

The drill bit is preferably a diamond core bit with a central aperture (not shown, but known in the art). The size of the drill and the central aperture depends upon the application of the rig **10**. The drill bit is attached to the first length of the string **300**, as is known in the art.

As is shown in Figs. 1 through 5, a control panel **200** is mounted on to the mast **41**. The control panel **200** provides controls for the mast assembly **40**, the hoist assembly **60**, the drillhead group **100**, and the break-out tool assembly **150**.

The rig **10** also may be used with an external rack assembly **350**. The rack assembly **350** comprises a roller conveyor **351** of approximately 10 feet in length. The conveyor **351** leads to a rack assembly arm **352** that is operated by a hydraulic cylinder **353**. The hydraulic cylinder **353** is powered by the pump **48**. The roller conveyor **351** is supported by a plurality of support legs **354**. The rack assembly **350** is positioned adjacent to the drillhead group **100**. Lengths of string **300** are positioned upon the conveyor **351** for insertion into the swivel assembly **120**. The conveyor arm **352** assists the swivel assembly **120** in raising the length of string **300** to the upright position. Similarly, the conveyor arm **352** assists in lowering a length of string **300** when removing the string **300** from the ground. The length of string **300** is then lowered onto the roller conveyor **351** for easy removal.

In use, as is shown in Fig. 1, the rig **10** is mounted upon the truck **15** for easy transport to the drilling site. During transport, the mast **41** is secured in place via the mast hinge assembly **44** and the

locking mechanism 52. Once the truck 15 has reached the drilling site, the pad assemblies 30 are deployed to secure the rig 10 in position. The locking mechanism 52 is released.

5 In order to raise the mast 41, the PTO 49 and the hydraulic pump 48 of the mast assembly 40 are engaged to operate the hydraulic cylinder 47. The mast 41 is either partially raised as shown in Fig. 3 or completely raised as shown in Fig. 2. If the mast 41 is completely raised, the clamp 45 maintains the mast stabilizing rod 42 and holds the mast 41 in the vertical position. If the mast 41 is raised to an
10 intermediate position, the clamp 45 of the mast hinge assembly 44 releases the mast stabilizing rod 42 mast rotates about the second stabilizing rod 55. The mast 41 thus has at least two pivot points, the clamp 45 and the second clamp 54, to accommodate drilling at various angles.

15 The floating sub 145 is then attached to the first length of string 300. The swivel assembly 120 of the drillhead group 100 is pivoted to a horizontal position. The first length of string 300 is then threaded onto the floating sub 145 by either rotating the floating sub into the string 300, or by rotating the string relative to the floating sub. The
20 drillhead group 100 is then raised as the swivel assembly 120 is pivoted, until the floating sub 145 and the first length of string 300 are extended in a direction which is parallel to the drilling direction. The drill bit (not shown) is attached to the distal end of the string 300 in a manner known in the art.

25 The hoist assembly 60 then lowers the drill bit and the first length of string 300 through the two piece slip 160 and cylinder 153 of the break-out tool assembly 150 to the ground. The drive motor assembly 130 rotates the floating sub 145 and the first length of string 300 in order to penetrate the earth. As the drive motor assembly 130
30 rotates the floating sub 145 and the first length of string 300, the hoist assembly 60 lowers the drillhead group 100 in the slow speed setting. Once the drillhead group 100 has advanced the first string as far as possible, the foot clamp 151 grabs the first length of string 300 and the gripping housing 152 rotates the foot clamp and the first length of
35 string and to release the string from the threaded engagement with the floating sub 145. The drillhead group 100 is then reversed so that the

floating sub **145** may unthreaded from the string **300**. The length of string **300** in the hole is held in place by the foot clamp **151**. A second string **300** is then attached to the floating sub **145** in the same manner as the first was attached.

5 The hoist **61** then raises the drillhead group **100**, along with the second string **300**, toward the top of the mast **41** until the second string is aligned with the top end of the first length of string **300**. The hoist **61** lifts the drillhead group **100** into this position via the high speed setting of the hydraulic motors **72**.

10 The drive motor assembly **130** of the drillhead group **100** then rotates the second string **300** into the upper end of the first length of string **300** positioned within the foot clamp **151**. As the second string **300** fully engages the upper end of the first length of string **300**, break-out tool assembly **150** releases the first string **300**. The drive
15 motor assembly **130** then rotates the floating sub **145** and the first and second lengths of string **300** to further penetrate the earth.

 After the respective lengths of string **300** are joined, the drillhead group **100** is again transported to the top end of the second length of string **300** and the drilling procedure is repeated. Further
20 lengths of string **300** may then be added in this same manner until the desired drilling depth is achieved. This overall procedure can be repeated for a plurality of string **300** lengths. In the preferred embodiment, the rig **10** can drill a four inch diameter hole up to depths of 3,000 feet or more. Such a depth requires approximately 150 or
25 more sections of string **300**.

 Because the grooved drum **63** of the hoist assembly **60** is counter-wound, the cables **250** connected to the upper tensioner assembly **110** of the drillhead group **100** roll off the drum **63** at the same rate the cables **250** passing through the bottom tensioner
30 assemblies **86** are pulled onto the drum **63**. The upper tensioner assembly **110** and the bottom tensioner assemblies **86** maintain the cables **250** and the drillhead group **100** under tension at all times such that the cables **250** push and pull the drillhead group **100** with equal force.

35 This drilling procedure is essentially repeated in reverse when removing the string **300**. The hydraulic motors **65** of the hoist

assembly 60 operate at the full speed setting to lift the entire length of string 300. The top length of string 300 is extended toward the top of the mast 41 until the next string is fully inserted into the break-out tool assembly 150. The foot clamp 151 of the break-out tool assembly 150 then grabs and the gripping housing 152 rotates the following length of string 300 to break the threaded connection to the upper string. The drillhead motor 130 of the drillhead group 100 then reverses and unthreads the upper string 300 from the string held by the break-out tool assembly 150. Once the string 300 is released, the swivel assembly 120 then rotates the length of string 300 as the hoist assembly 60 lowers the length of string until the string reaches the horizontal position where it can be removed from the rig 10. After the string 300 is removed, the floating sub 145 is lowered to a position where it may engage the top of the following string. The drillhead motor 130 then rotates the floating sub 145 into the following string 300. The break-out assembly 150 then releases the string 300, and the drillhead assembly 100 is lifted until yet another string 300 reaches the break-out tool assembly 150. This third string 300 is grasped and rotated by the break-out tool assembly 150 and the top string is detached and removed. This procedure is repeated until the entire string 300 is removed from the ground. The mast 41 is then lowered back onto the truck 15 and secured. The pad assemblies 30 are raised. The rig 10 is then ready to move to the next drilling site.

As described above, the rig 10 may be used with a rack assembly 350. Lengths of string 300 are placed upon the roller conveyor 351 of the rack assembly 350 and are rolled toward the rack assembly arm 352 and into the swivel assembly 120 of the drillhead group 100. As the swivel assembly 120 rotates the length of string 300 to the vertical position, the swivel assembly 120 is assisted by the rack assembly arm 352. Likewise, when removing a length of string 300, the rack assembly arm 352 assists the swivel assembly 120 in lowering the length of string 300 from the vertical position to the horizontal position. The length of string 300 is then rolled off of the roller conveyor 351 and stored.

It should be understood that the foregoing relates only to preferred embodiments of the present invention, and that numerous

changes may be made therein without departing from the spirit and scope of the invention as defined by the following claims.

CLAIMS

1. An improved drilling rig, characterized by:
a mast having an upper end and a lower end;
5 a drillhead assembly mounted onto said mast for vertical movement therewith;
said drillhead assembly comprising a drive motor assembly and a floating sub; and
a break-out tool assembly mounted at said lower end of
10 said mast;
said break-out tool assembly comprising means for grasping and rotating a length of drilling string relative to said floating sub whereby the threaded engagement of the string to said floating sub is loosened.
- 15 2. The improved drilling rig of Claim 1, wherein said drive motor assembly is rotatable so as to raise or lower a length of string from a vertical position to a horizontal position or from the horizontal position to the vertical position.
- 20 3. The improved drilling rig of Claim 1, wherein said break-out tool assembly comprises a foot clamp for maintaining the weight of the string.
- 25 4. The improved drilling rig of Claim 3, wherein said break-out tool assembly comprises a gripping housing for grasping and rotating said foot clamp.
- 30 5. The improved drilling rig of Claim 1, wherein said break-out tool assembly comprises a gripping assembly for grasping and rotating said string.
- 35 6. The improved drilling rig of Claim 1, further comprising a rack assembly positioned adjacent to said mast, said rack assembly comprising a conveyor and a rack assembly arm.

7. An improved drilling rig, characterized by:
a mast having an upper end and a lower end;
a hoist assembly positioned at said top end of said mast;
one or more cable return assemblies positioned at said
5 bottom end of said mast; and
a drillhead assembly;
said drillhead assembly being hung by one or more
cables threaded from said hoist assembly to said drillhead assembly and
from said drillhead assembly to said one or more cable return assemblies
10 and back to said hoist assembly;
said cables being counter-wound on said hoist assembly
such that said cables roll off of said hoist assembly in the direction
towards said drillhead assembly at the same rate said cables are pulled
onto said hoist assembly from the direction towards said one or more
15 cable return assemblies.

8. The improved drilling rig of Claim 7, wherein said hoist
assembly comprises a grooved drum.

20 9. The improved drilling rig of Claim 7, wherein said
drillhead assembly is connected to said cables by an upper tensioner
assembly, said upper tensioner assembly comprising a rocker arm
mounted to a piston.

25 10. The improved drilling rig of Claim 7, wherein said one
or more bottom cable return assemblies comprise a sheave mounted to a
bottom tensioner assembly, said bottom tensioner assembly comprising
a hydraulic cylinder.

30 11. The improved drilling rig of Claim 10, wherein said
upper tensioner assembly and said bottom tensioner assemblies operate
in tandem to keep said cables under constant tension.

35 12. The improved drilling rig of Claim 7, wherein said
drillhead assembly comprises a swivel assembly, said swivel assembly
being operated by two hydraulic cylinders.

13. The improved drilling rig of Claim 12, wherein said swivel assembly is rotatable so as to raise or lower said swivel assembly and a length of string from the vertical to the horizontal position or from the horizontal position to the vertical position.

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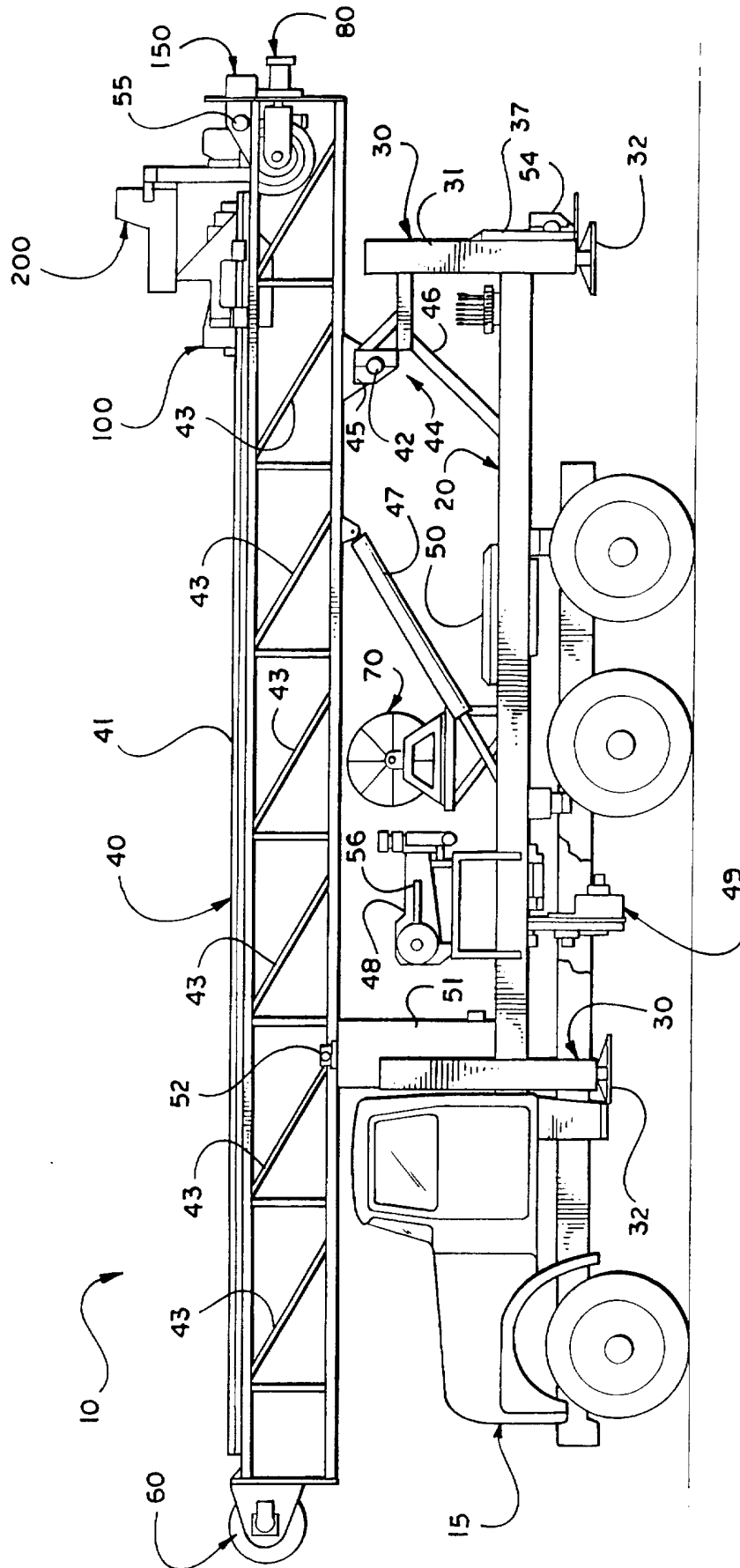
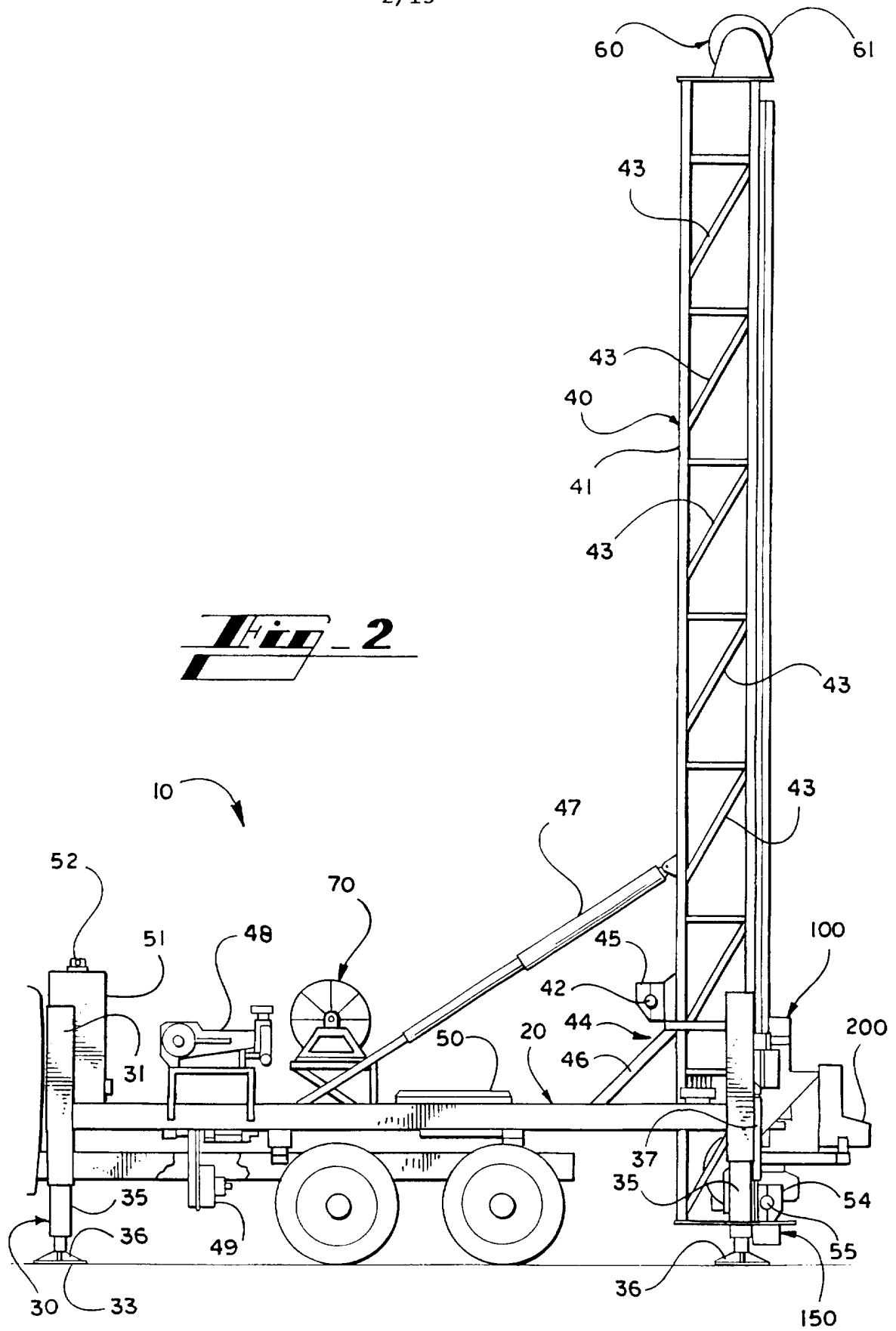


Fig. 1

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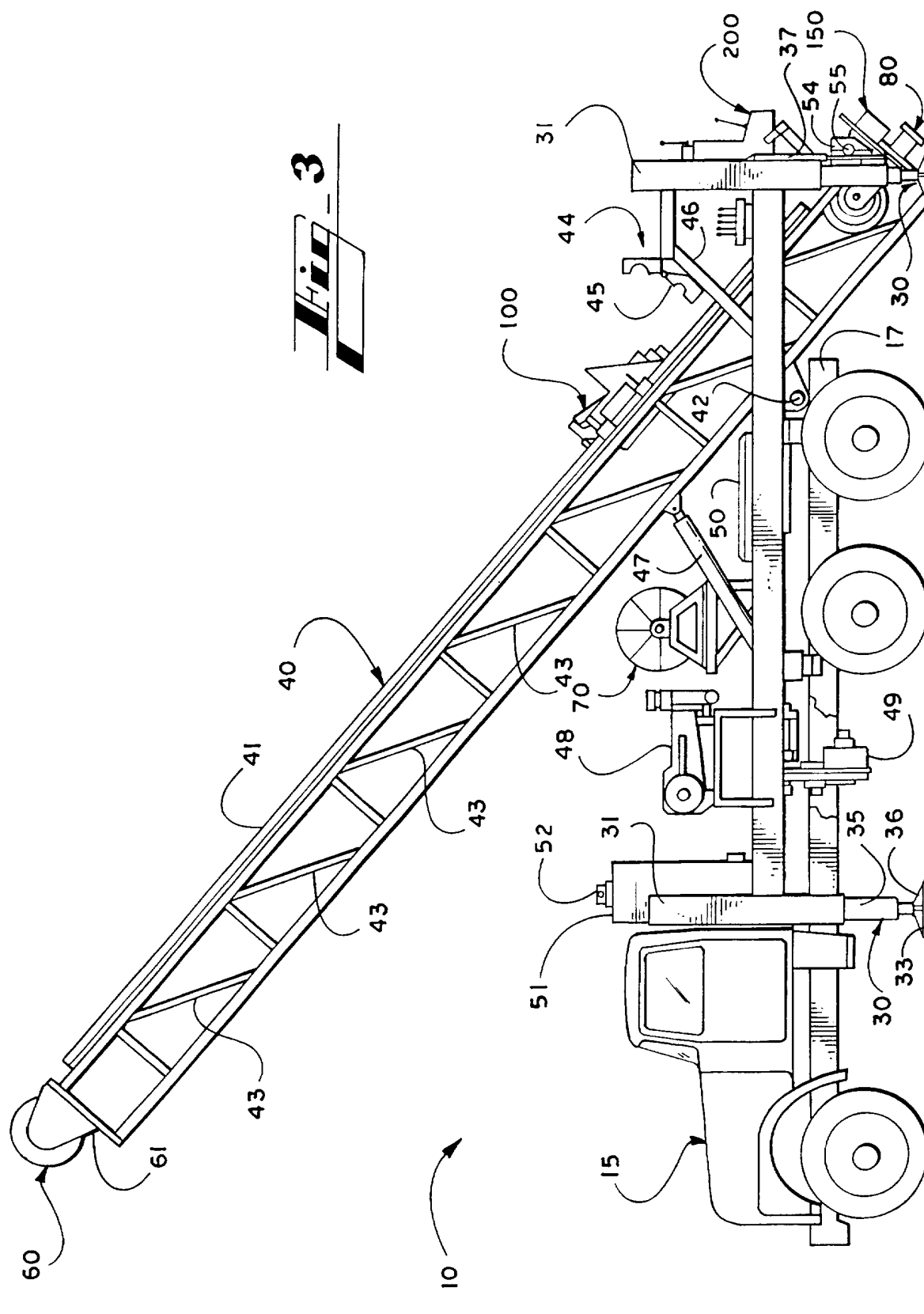
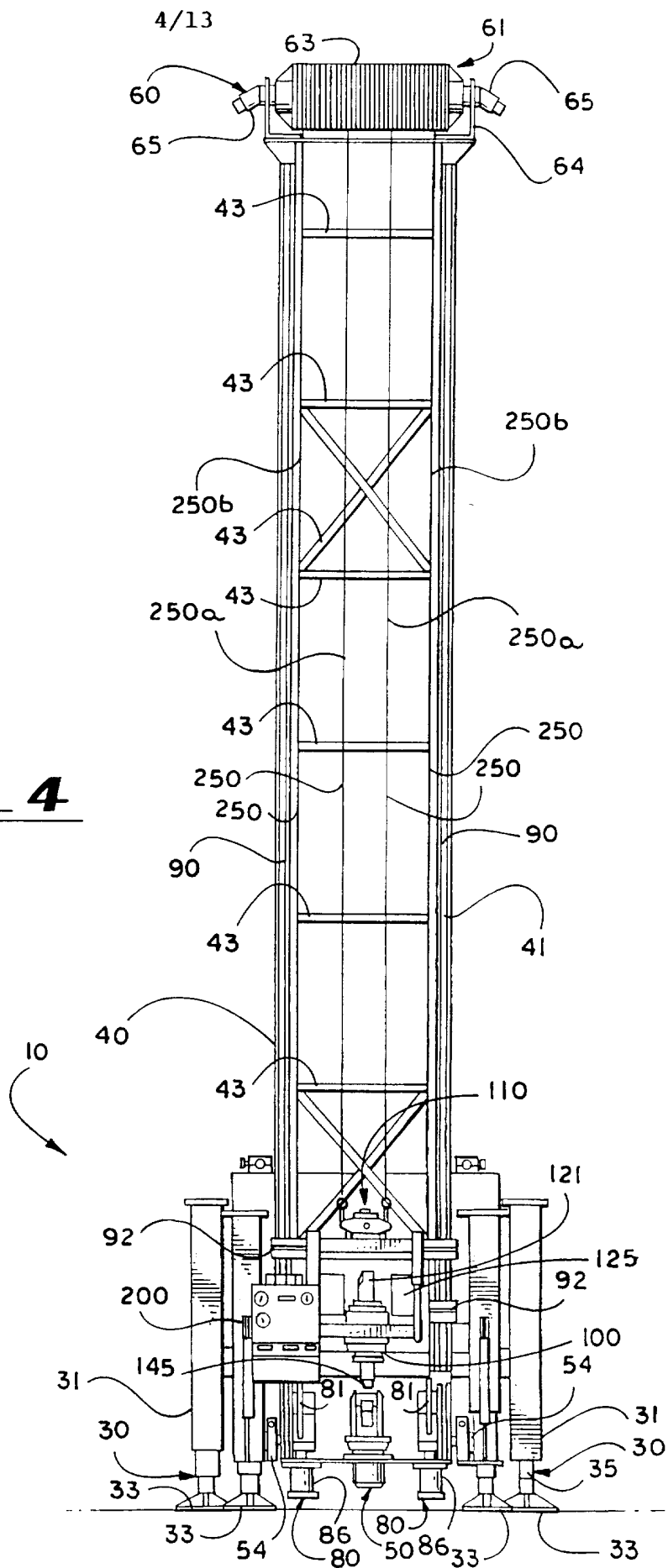


Fig. 3

Fig. 4



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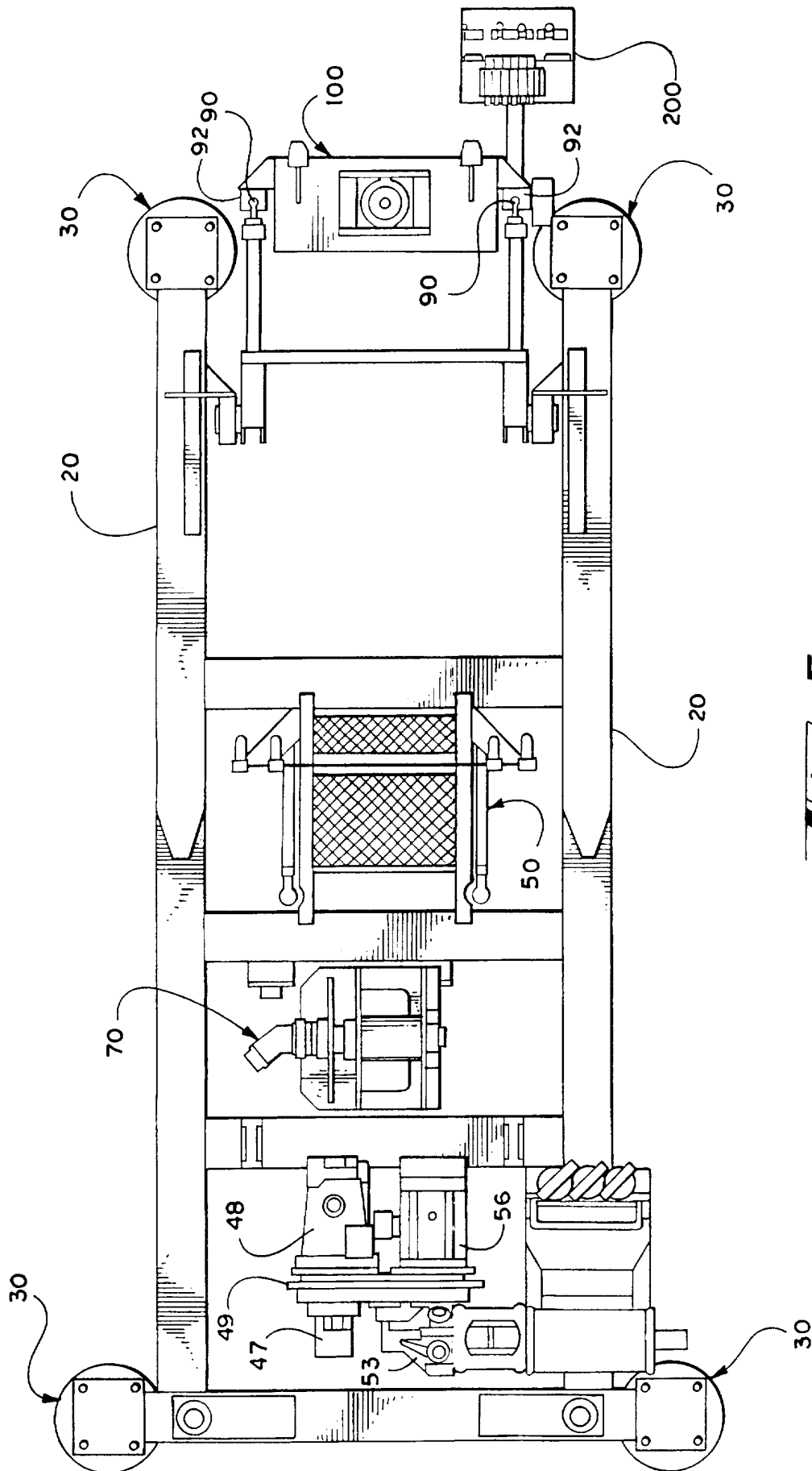


Fig. 5

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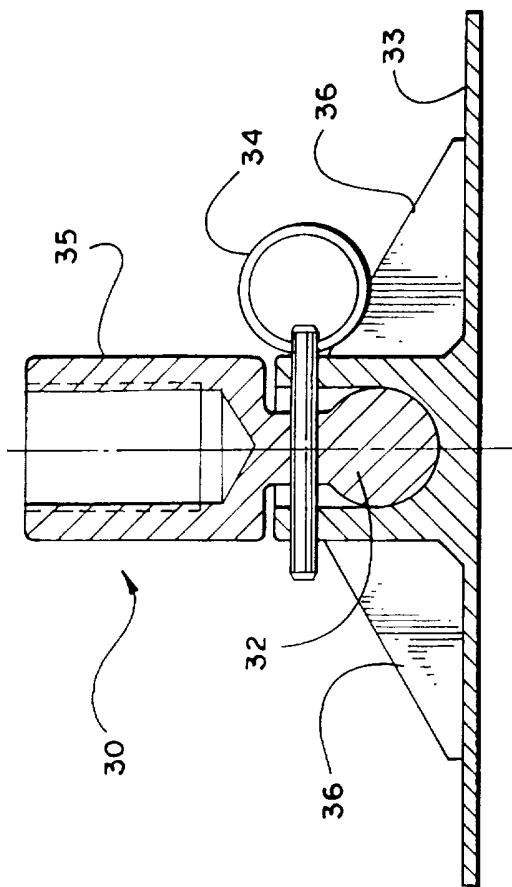


Fig. 6

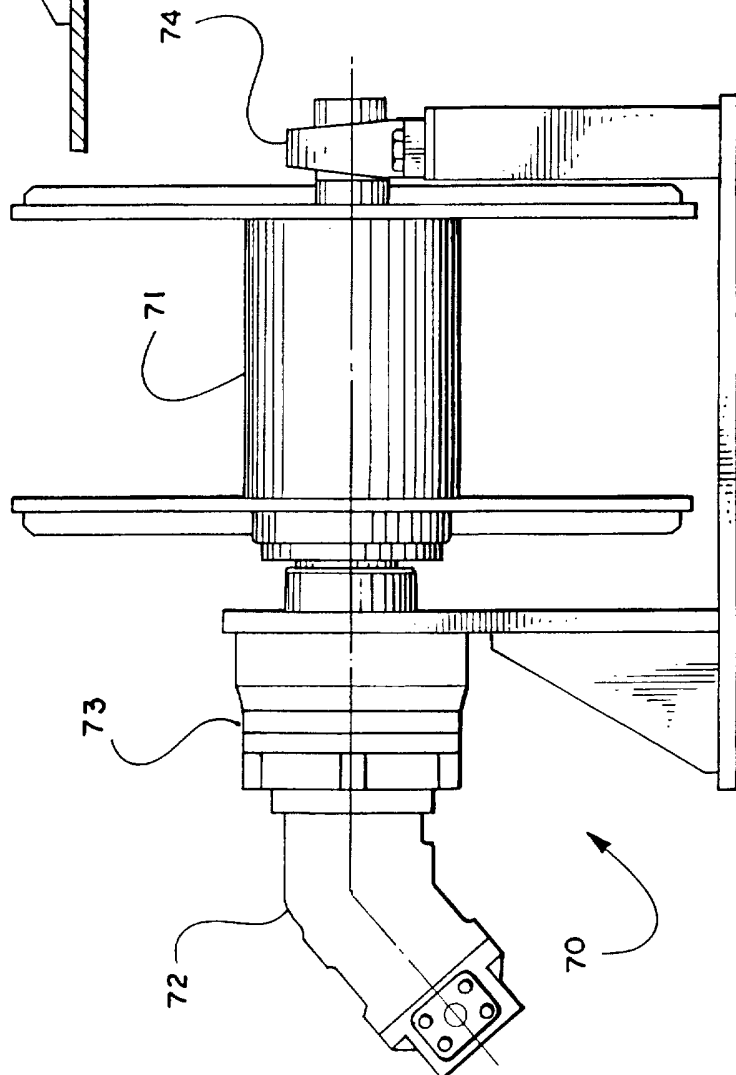


Fig. 8

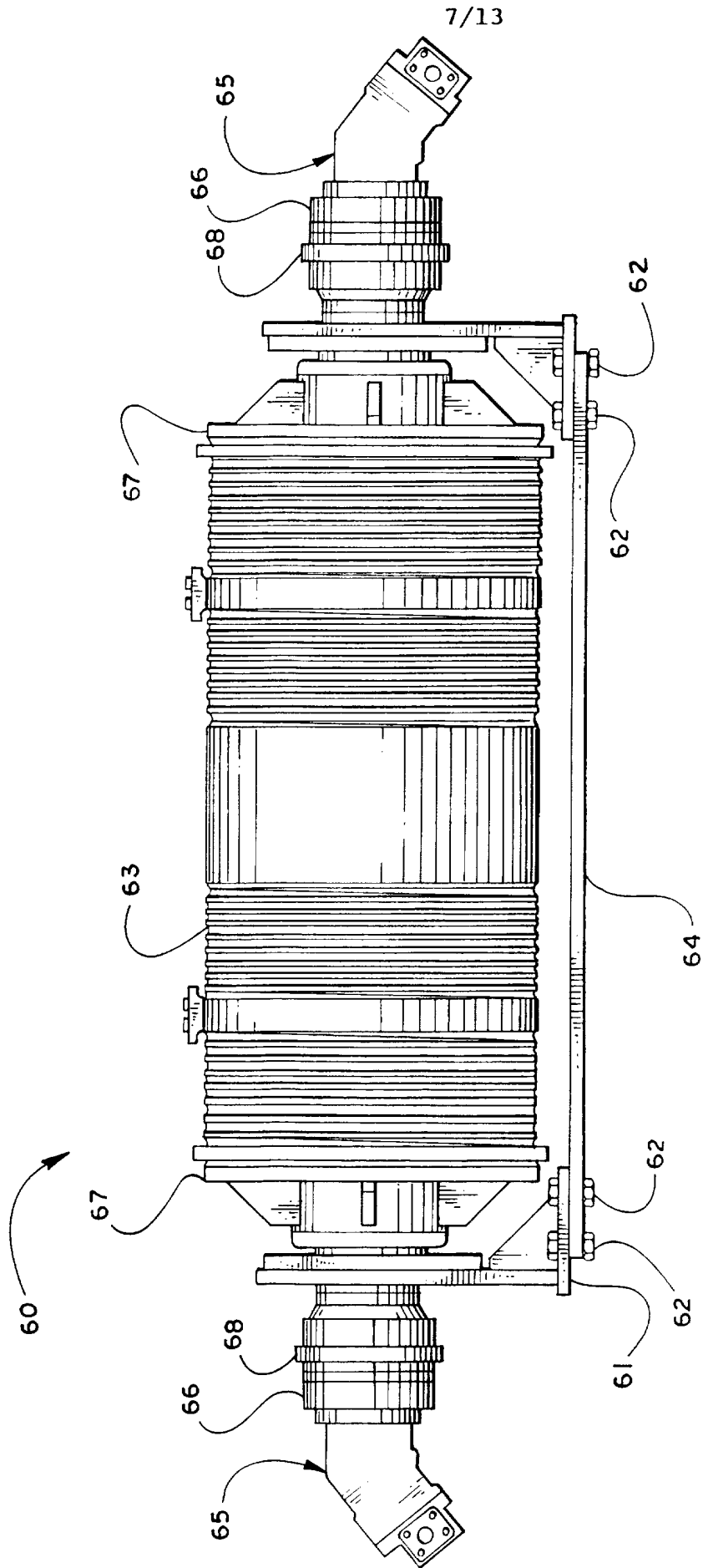
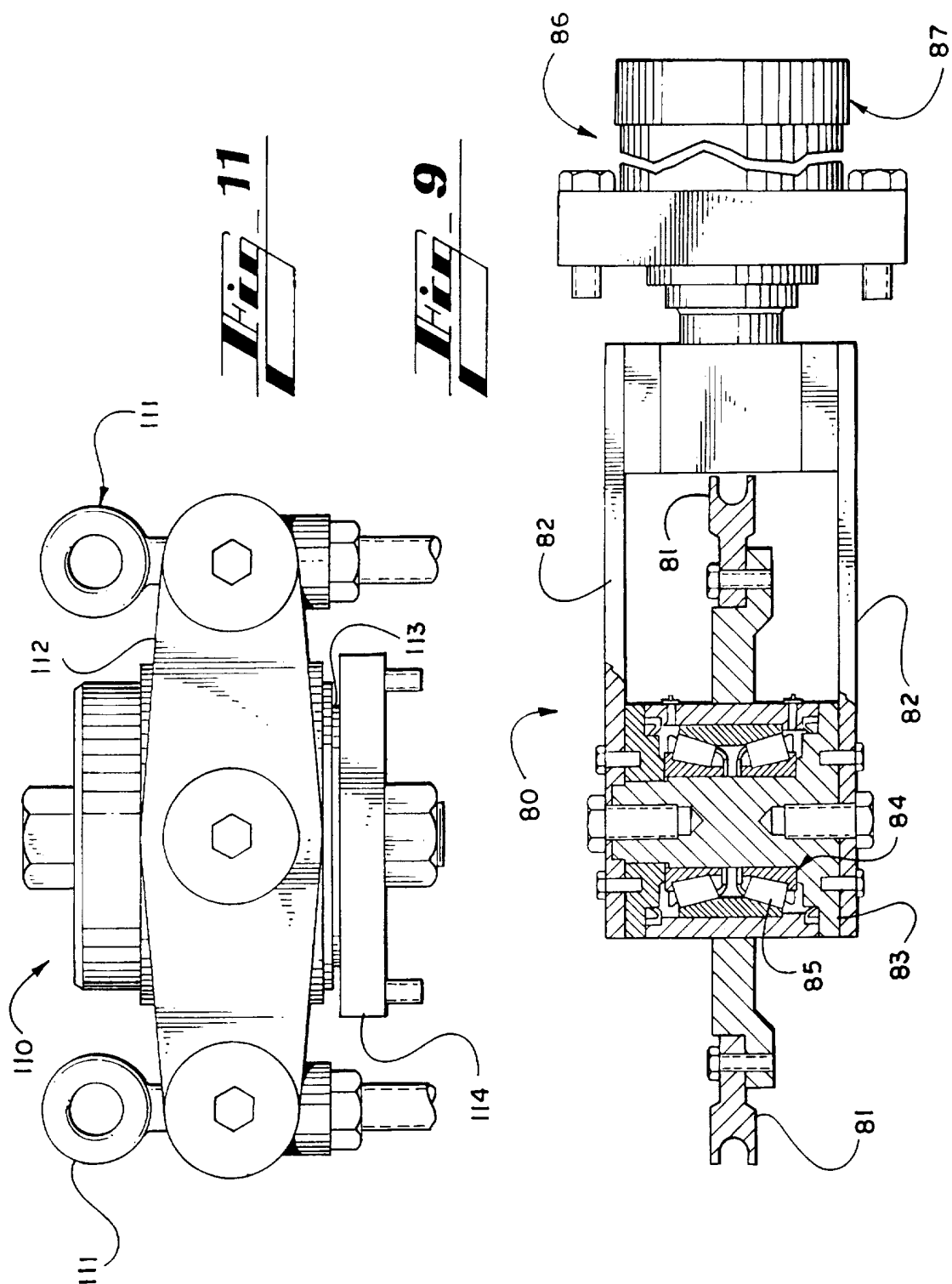


Fig. 7



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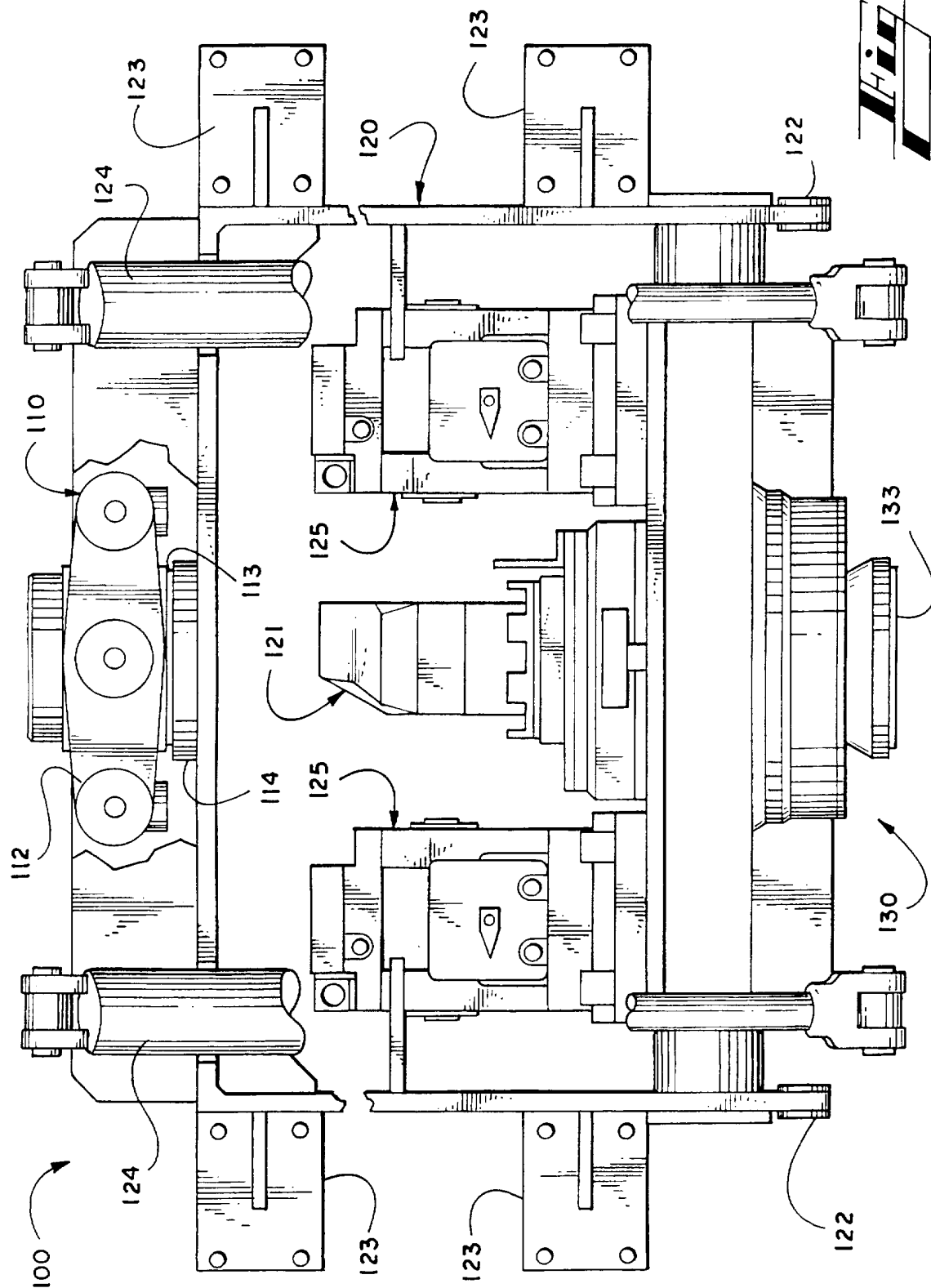


Fig. 10

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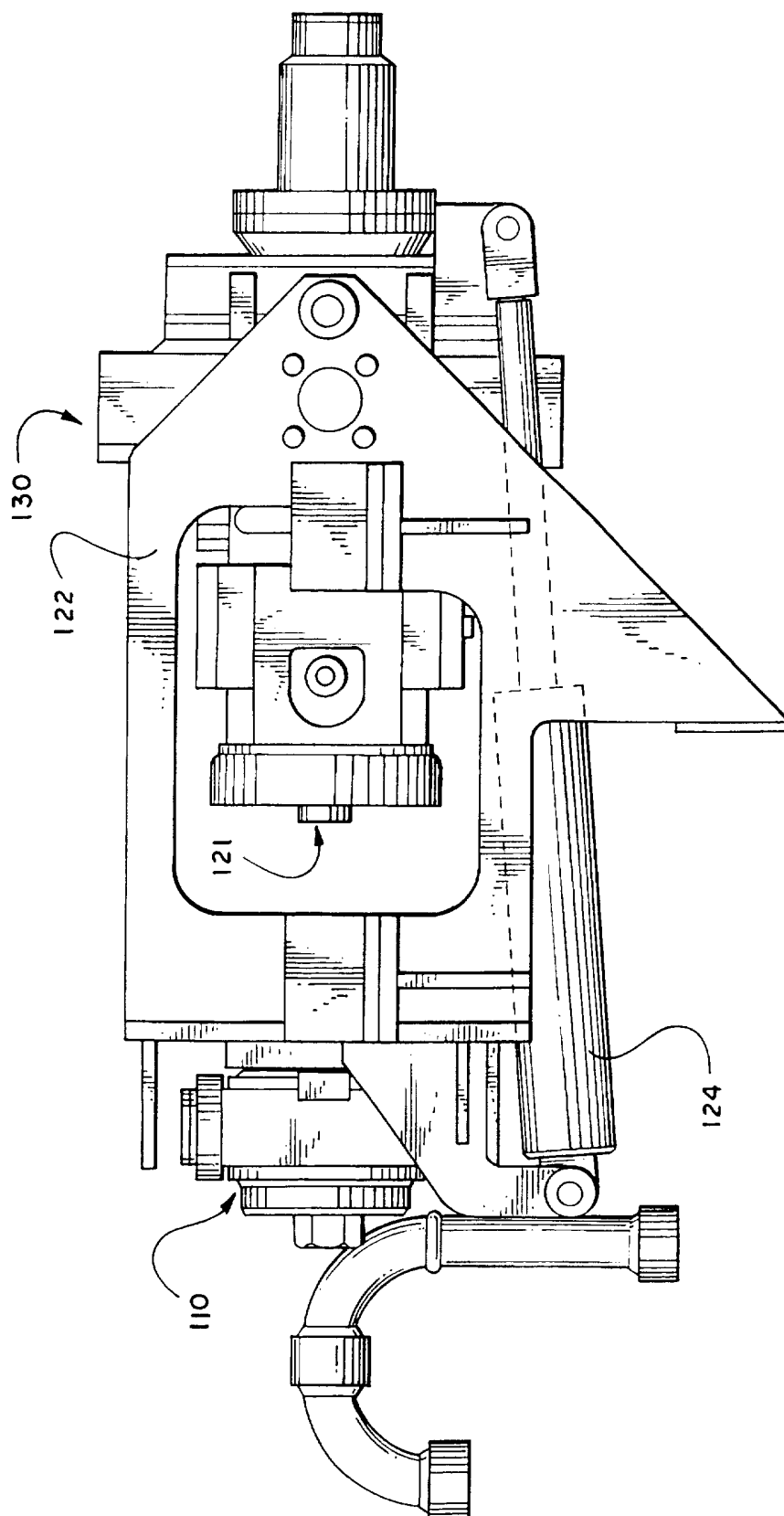


Fig. 12

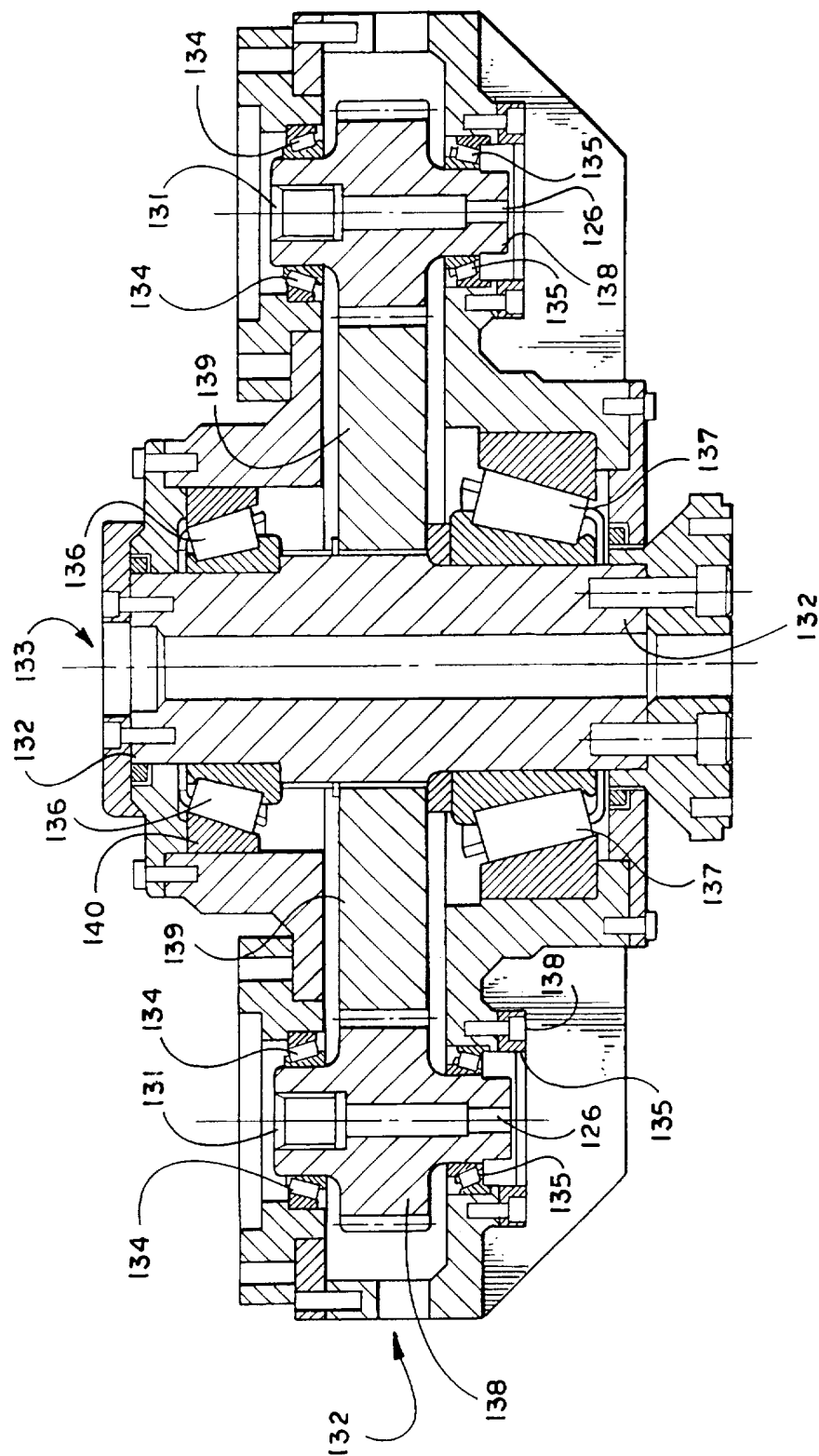
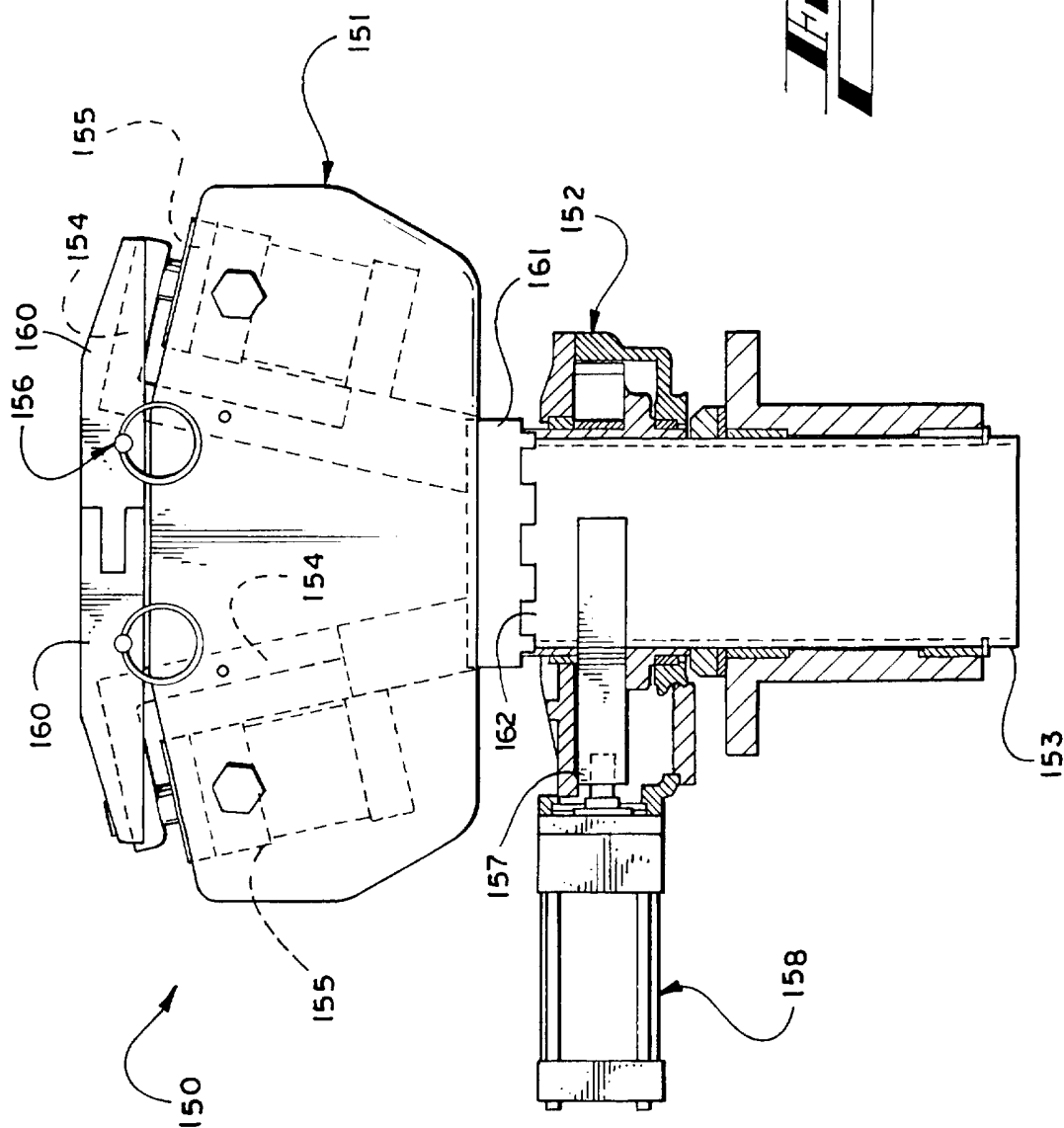


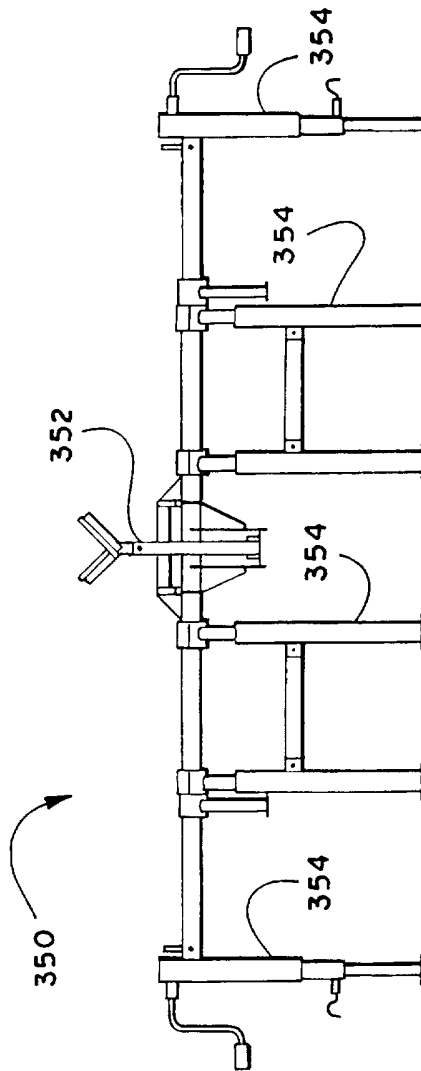
Fig. 13

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Fig. 14



***Fig* - 16**



***Fig* - 15**

