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(54) SENSOR SYSTEM FOR AERIAL LADDER ASSEMBLY

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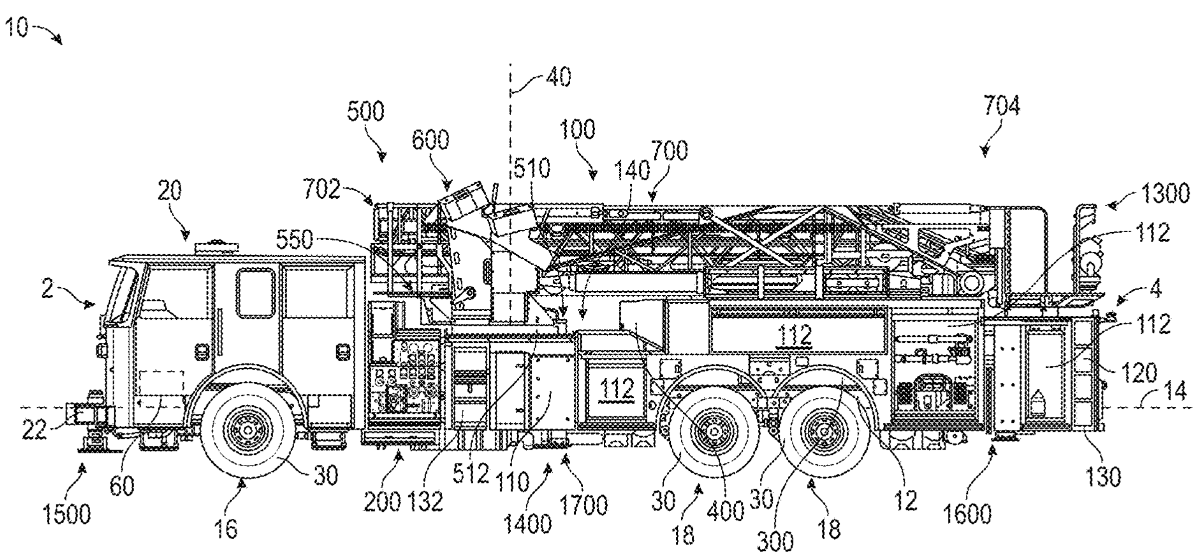
(52) **U.S. Cl.**

CPC ***B66F 17/006*** (2013.01); ***A62C 27/00*** (2013.01); ***B66F 11/044*** (2013.01); *B60R 3/02* (2013.01)

(57) **ABSTRACT**

A vehicle includes, a body assembly, an implement coupled to the body assembly, at least one sensor configured to facilitate monitoring a position of the implement relative to a ground surface or an object, and one or more processing circuits. The one or more processing circuits are configured to determine, based on sensor data acquired by the at least one sensor, the position of the implement relative to the ground surface or the object, permit operation of the implement in a first mode of operation in response to a determination that the position of the implement relative to the ground surface or the object is greater than a threshold distance, and limit operation of the implement in a second mode of operation in response to a determination that the position of the implement relative to the ground surface or the object is less than the threshold distance.



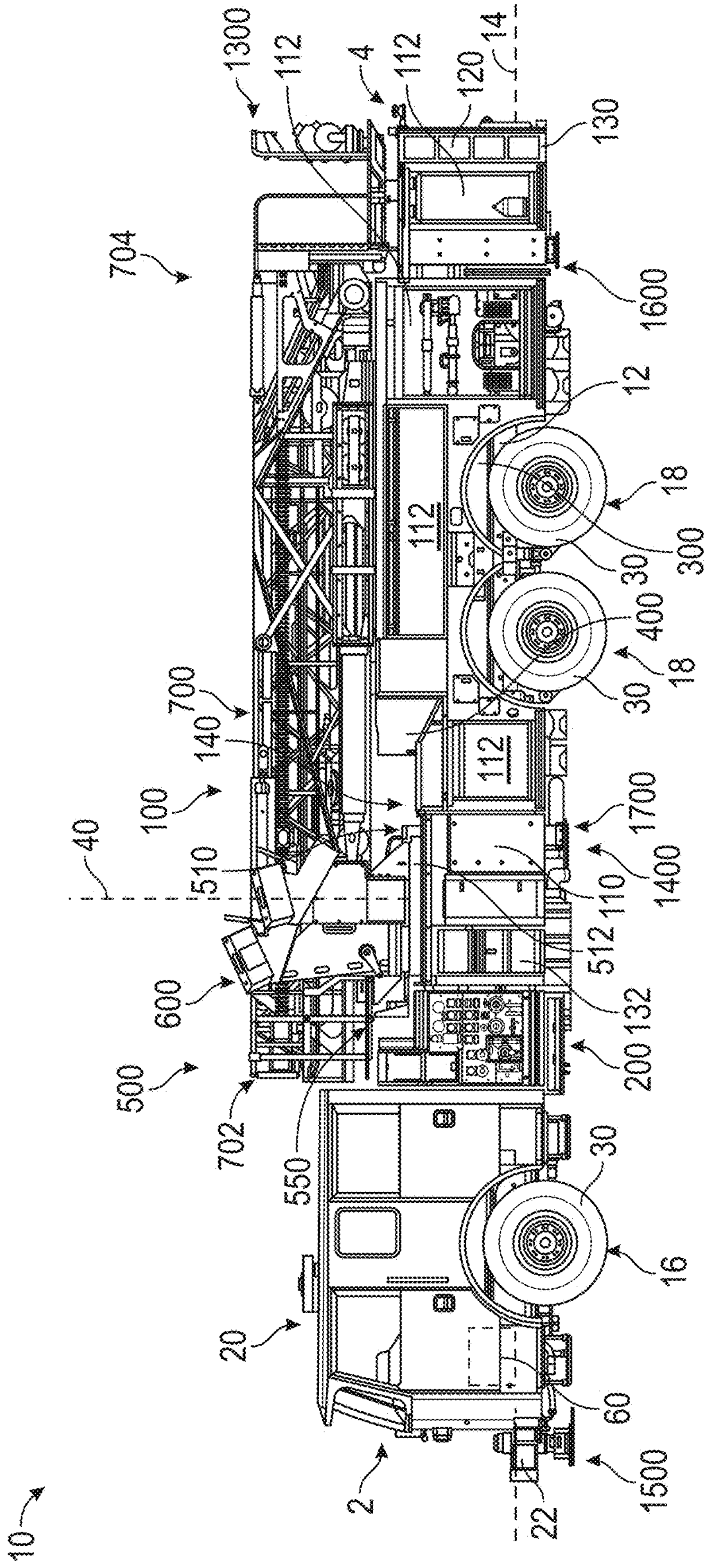

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FIG. 1

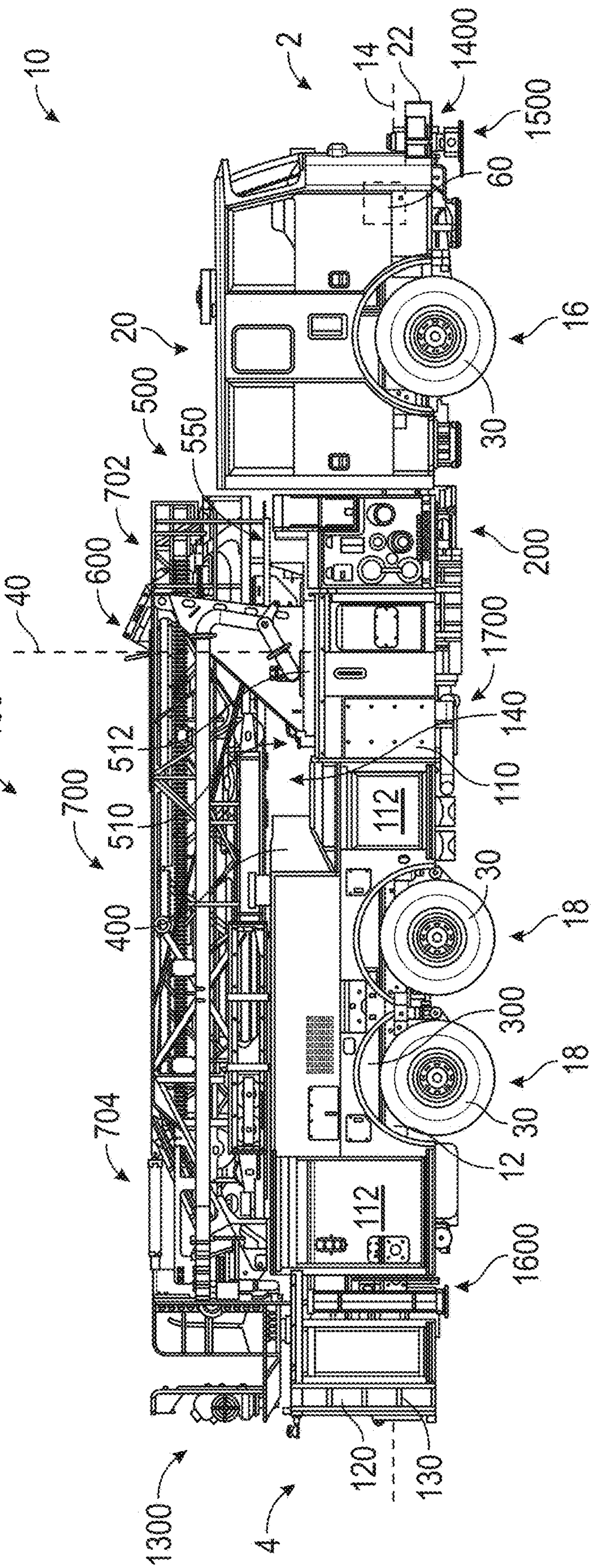
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FIG. 2

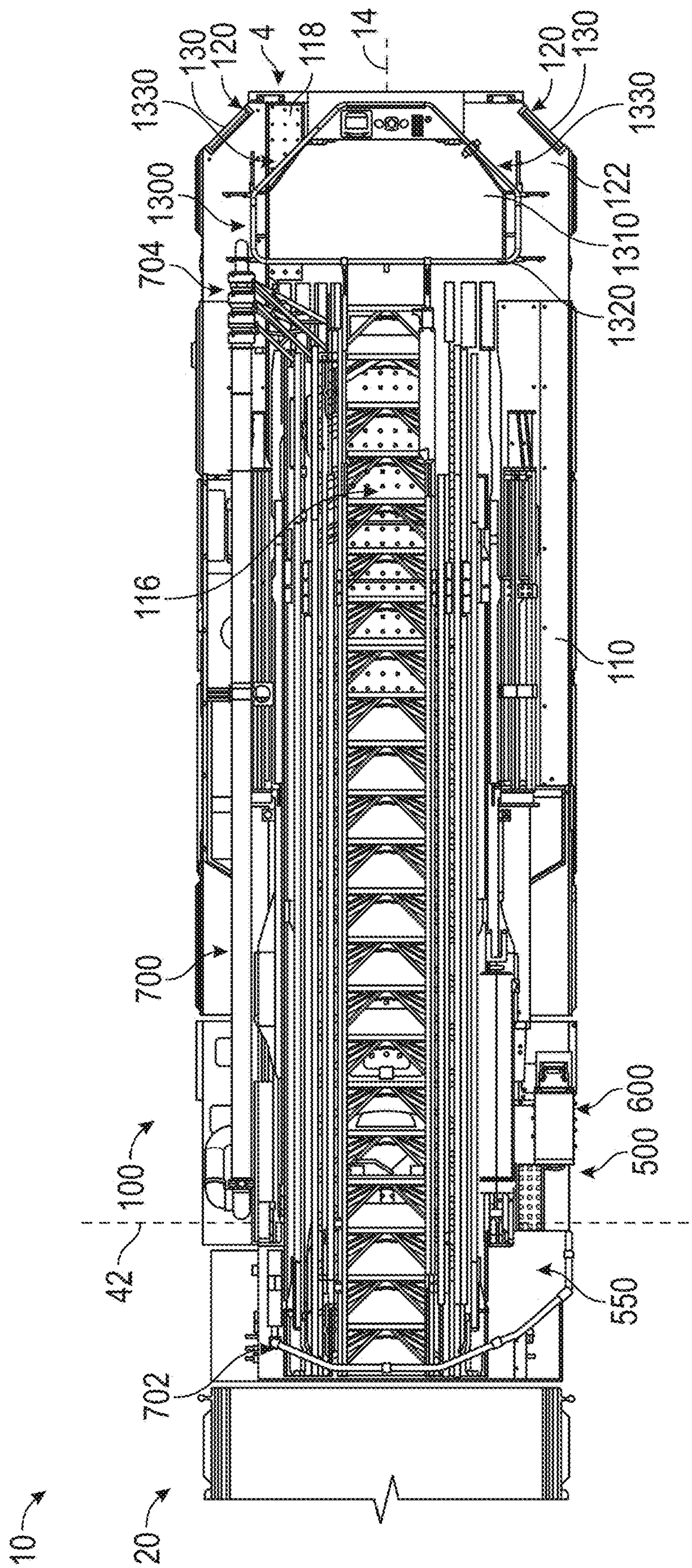

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FIG. 3

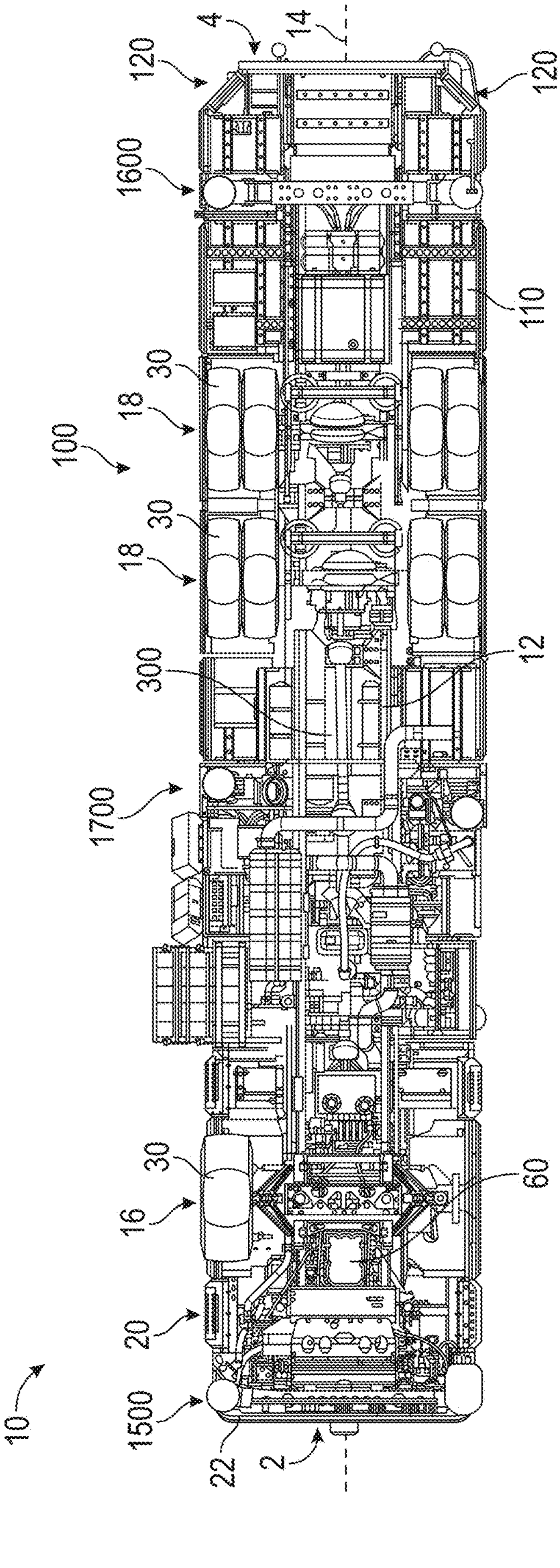
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FIG. 4

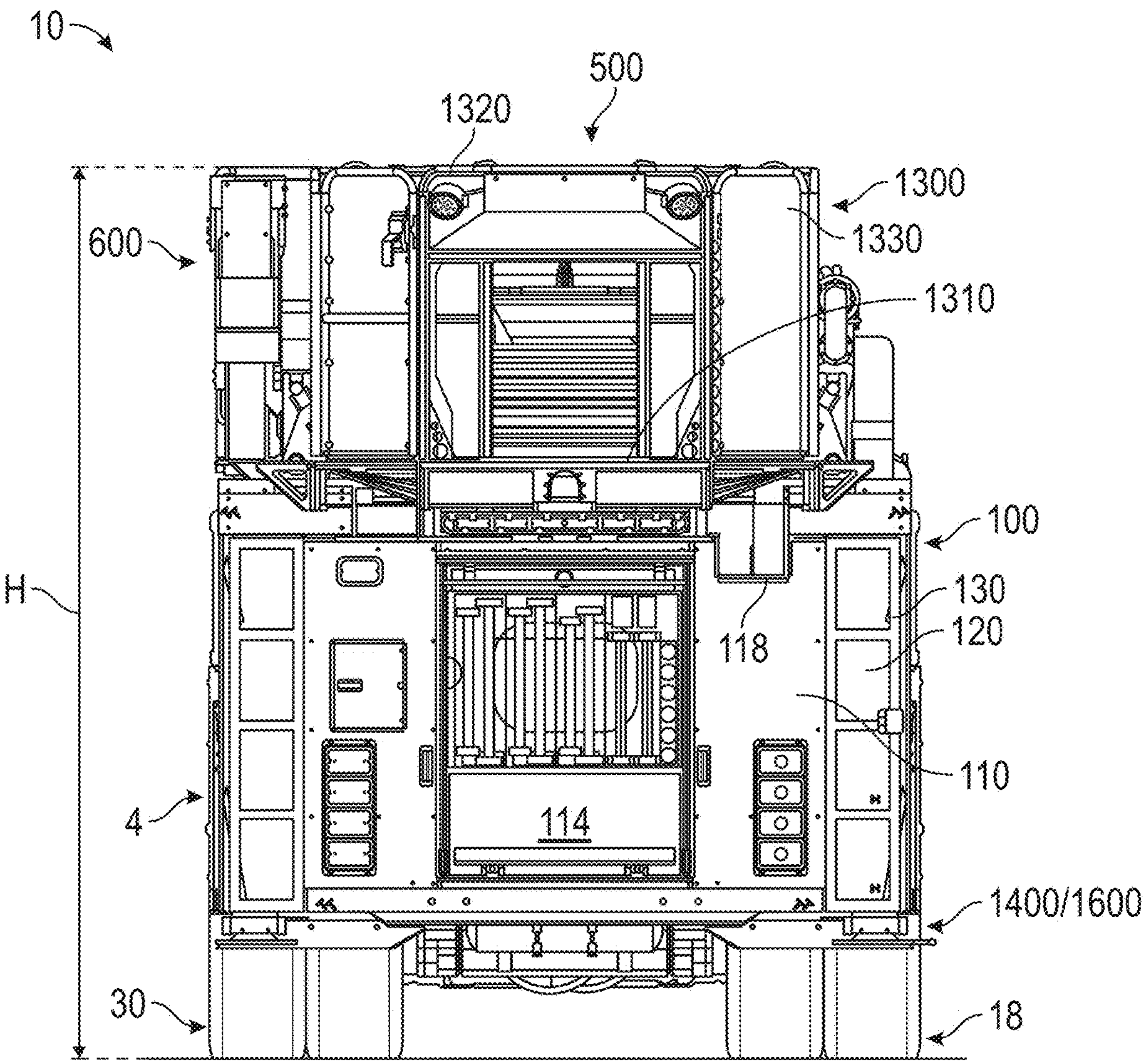
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FIG. 5

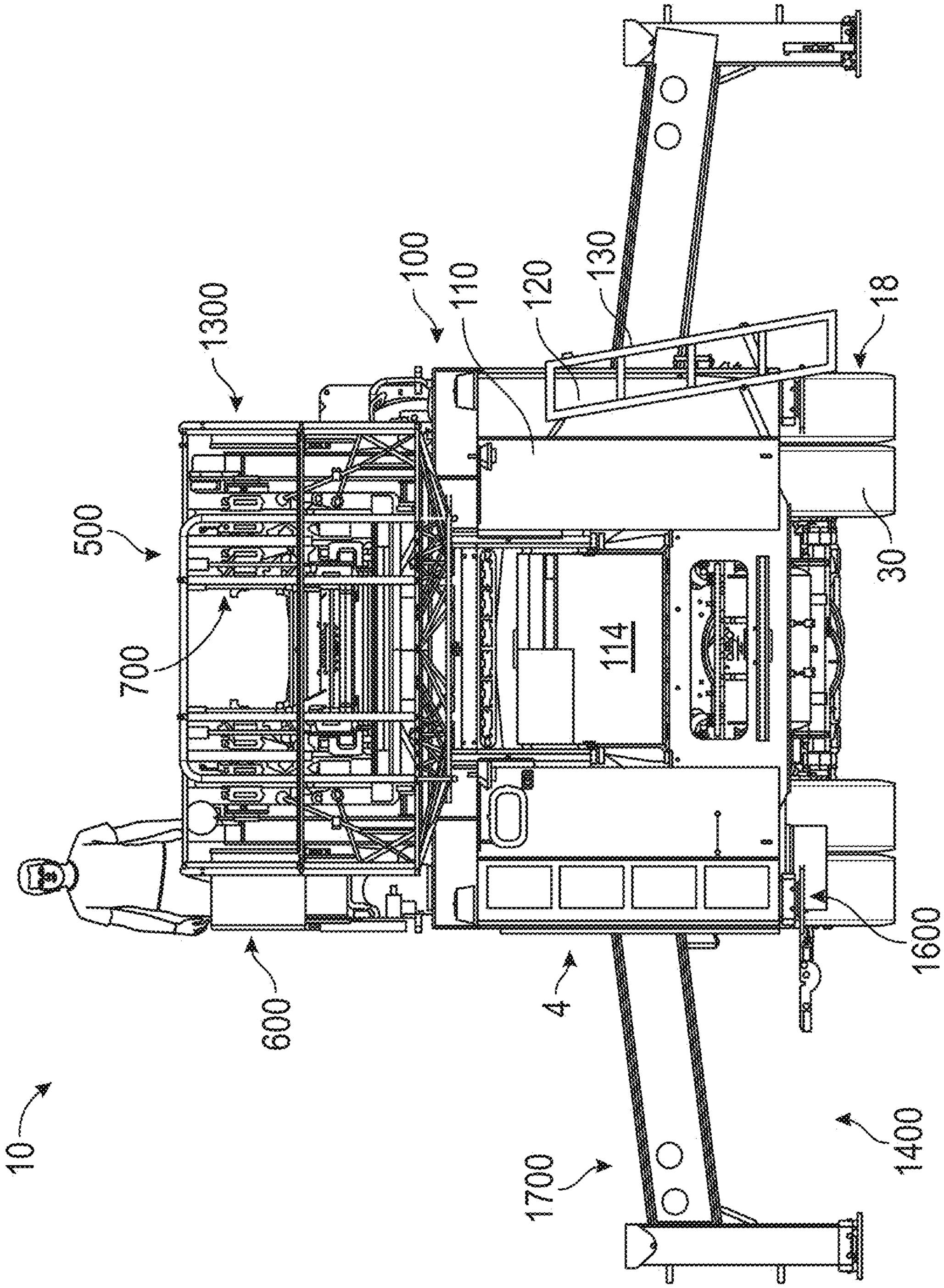

FIG. 6

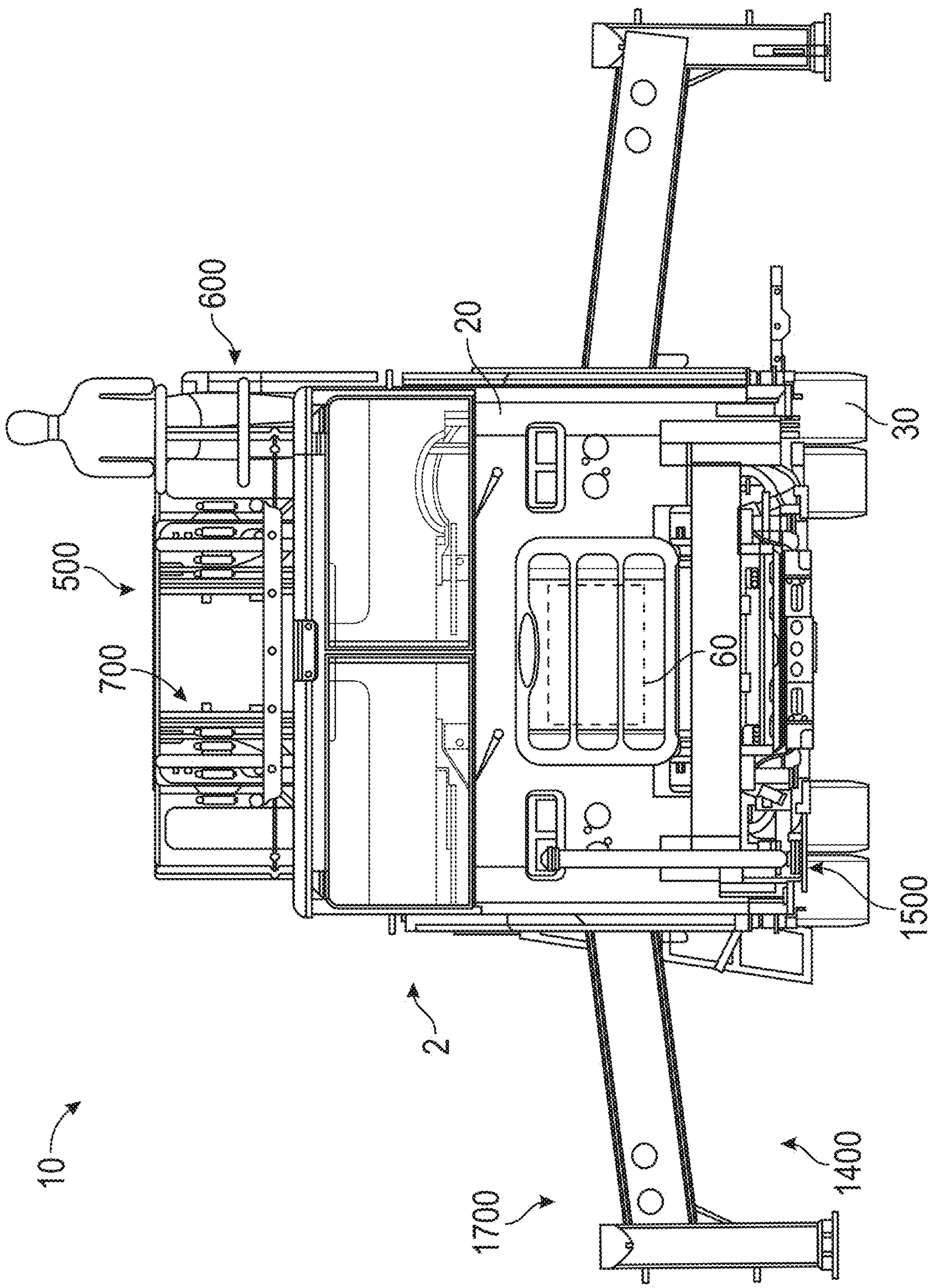

FIG. 7

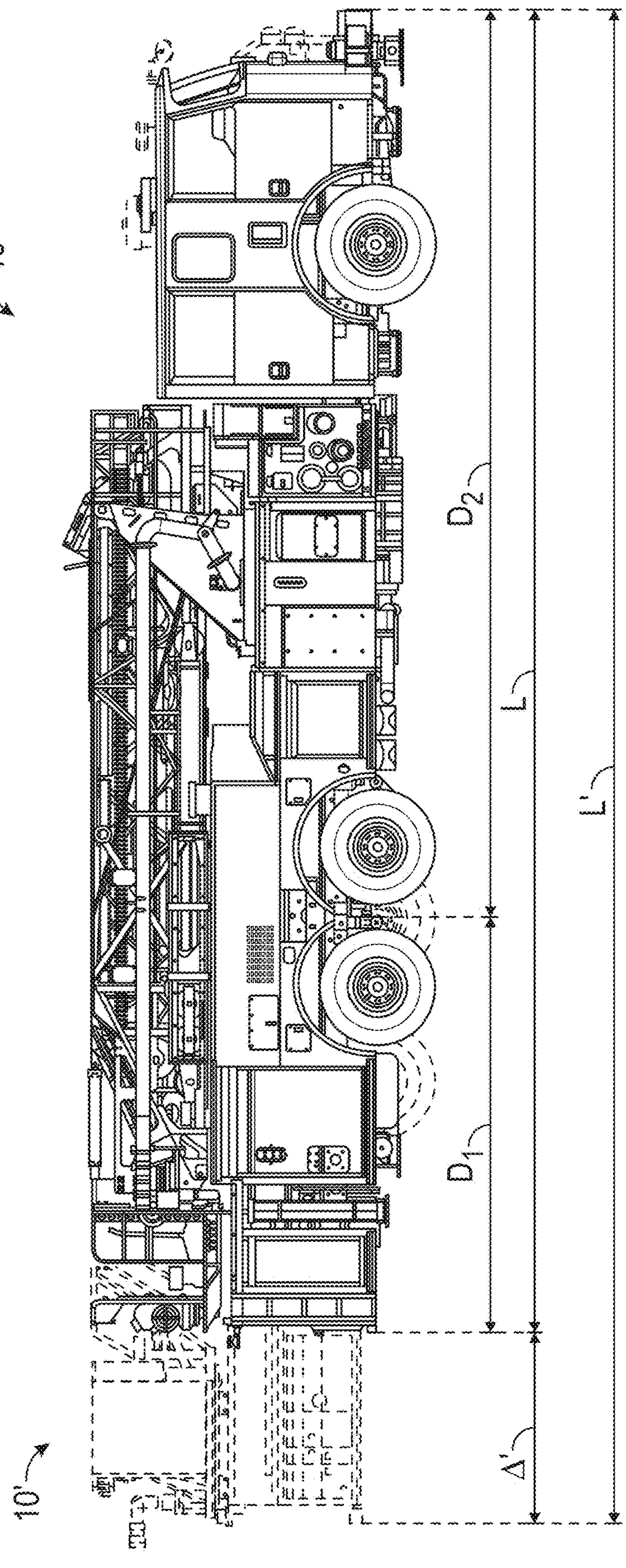

FIG. 8

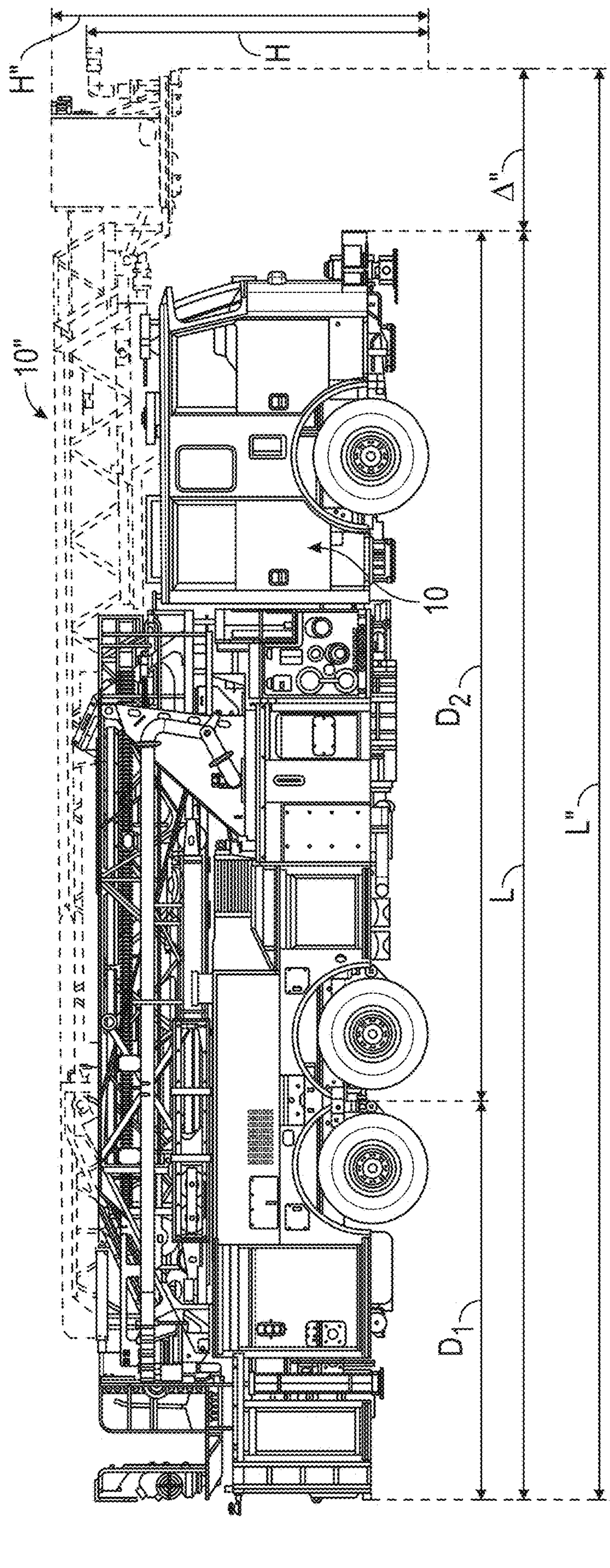

FIG. 9

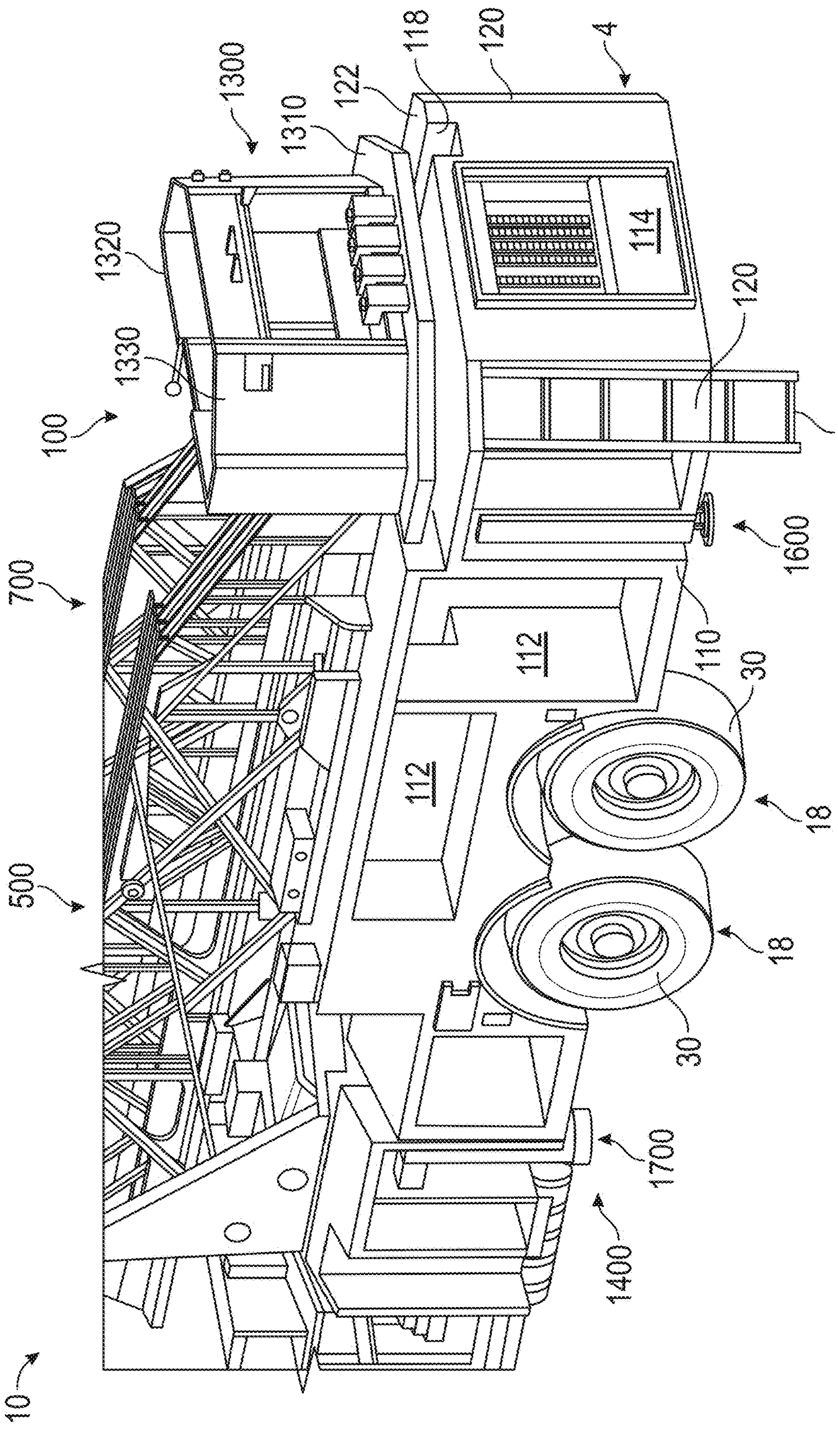

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FIG. 10

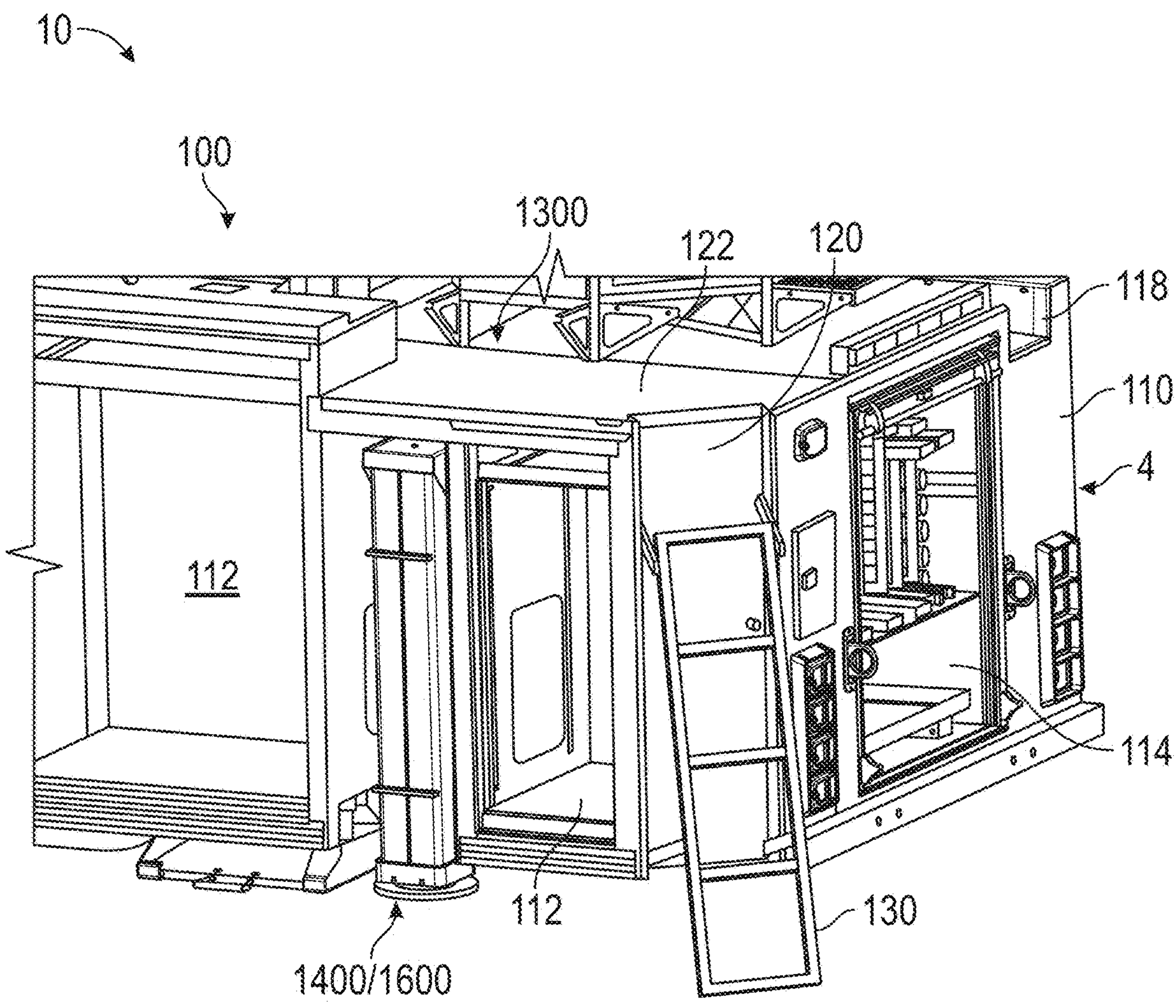

FIG. 11

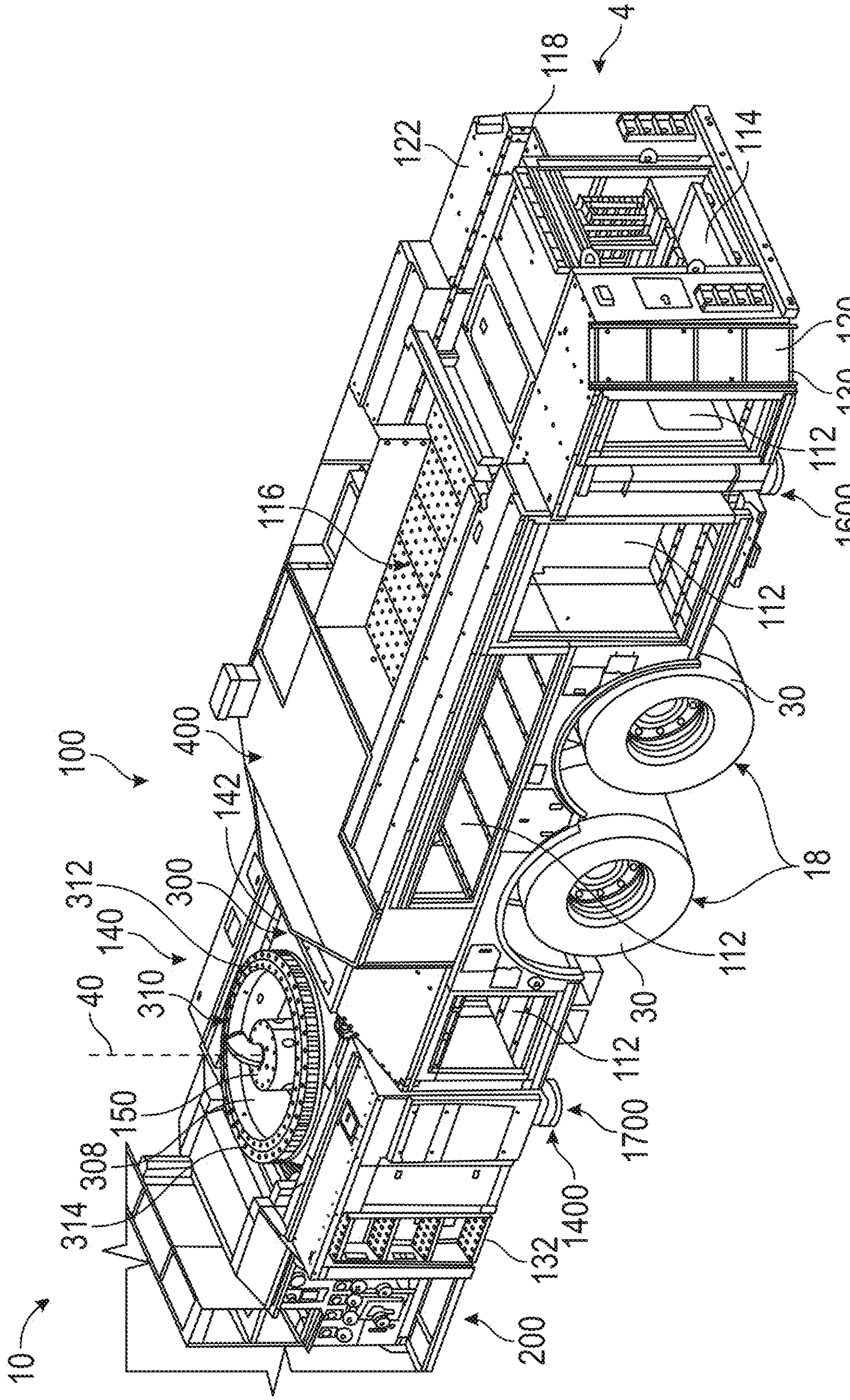
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FIG. 12

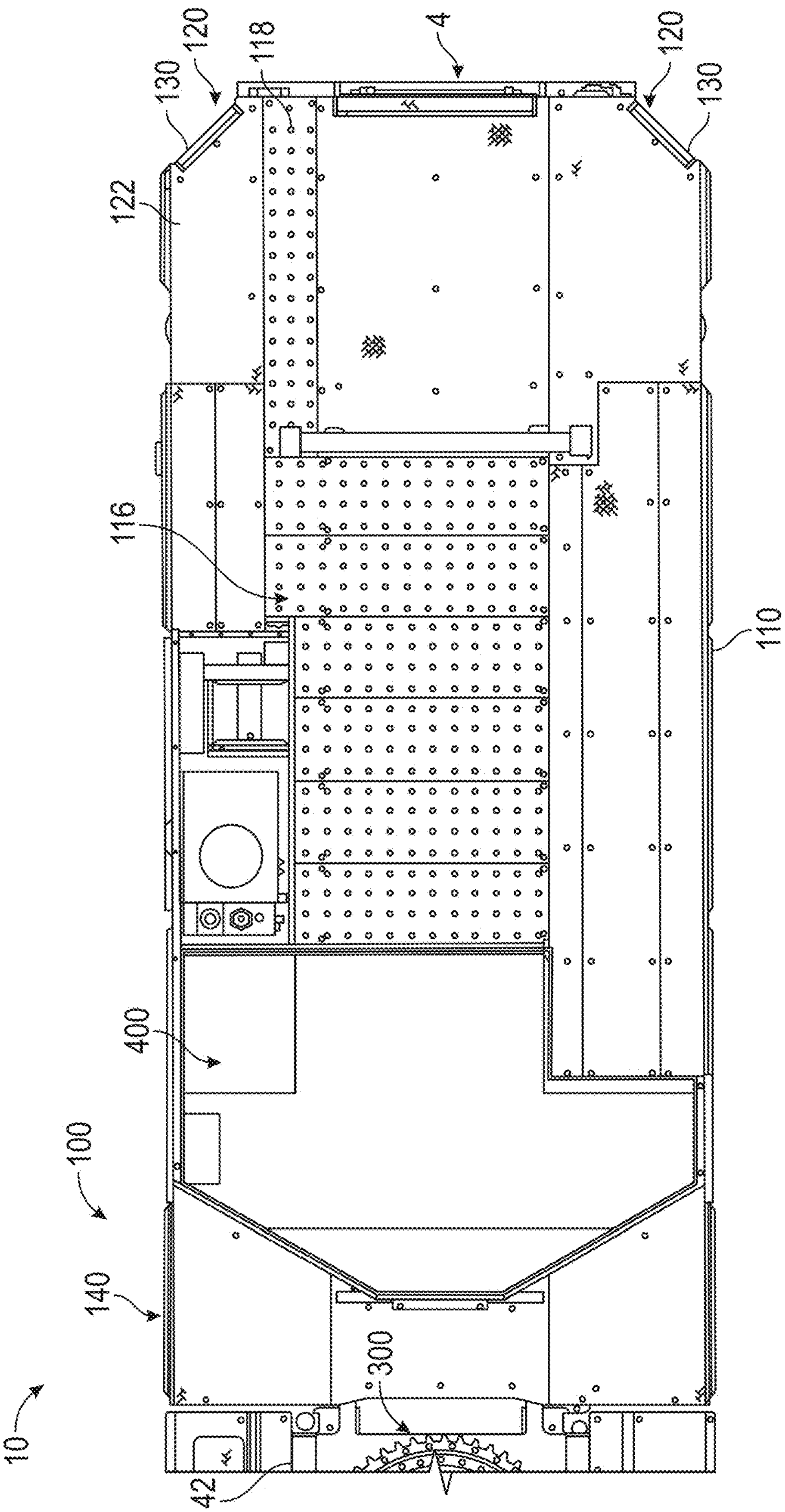

FIG. 13

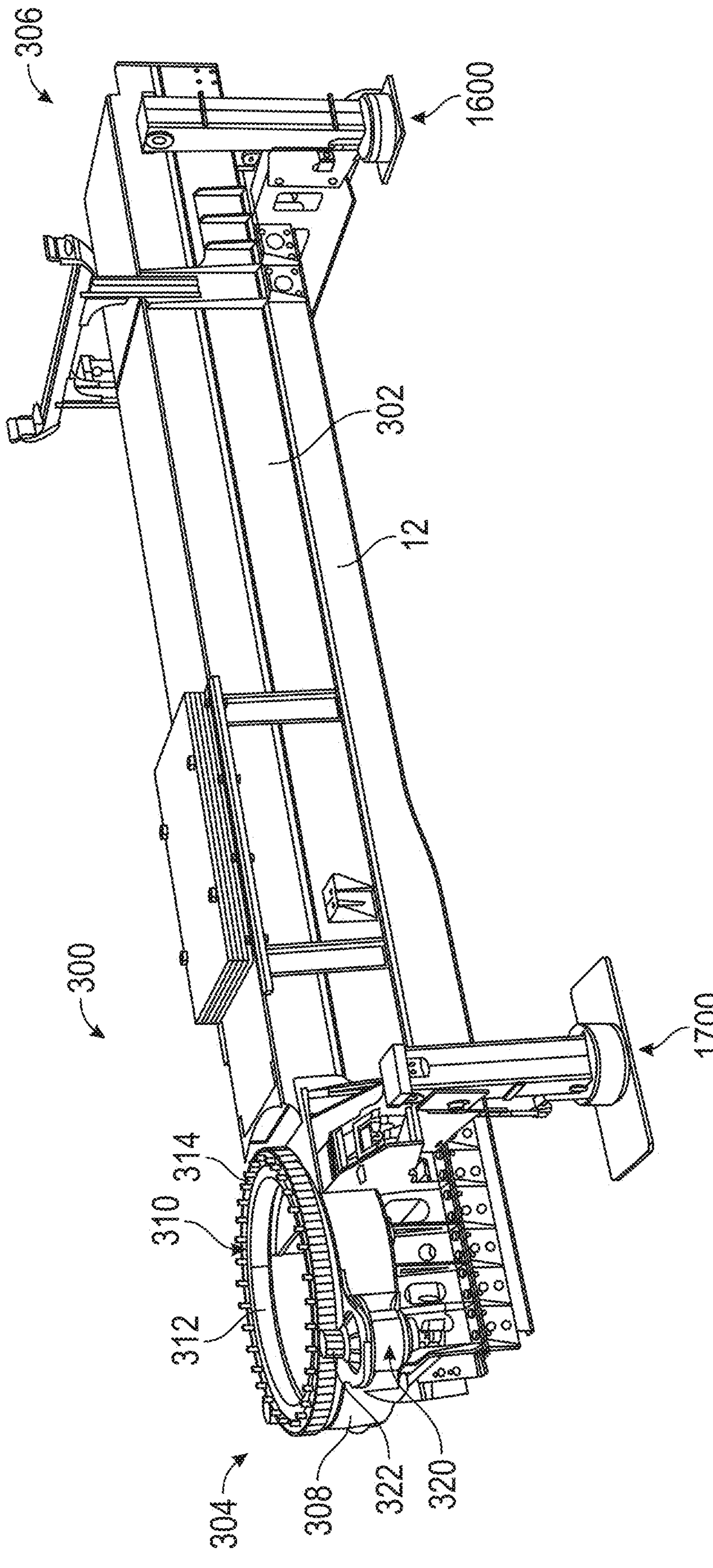

FIG. 14

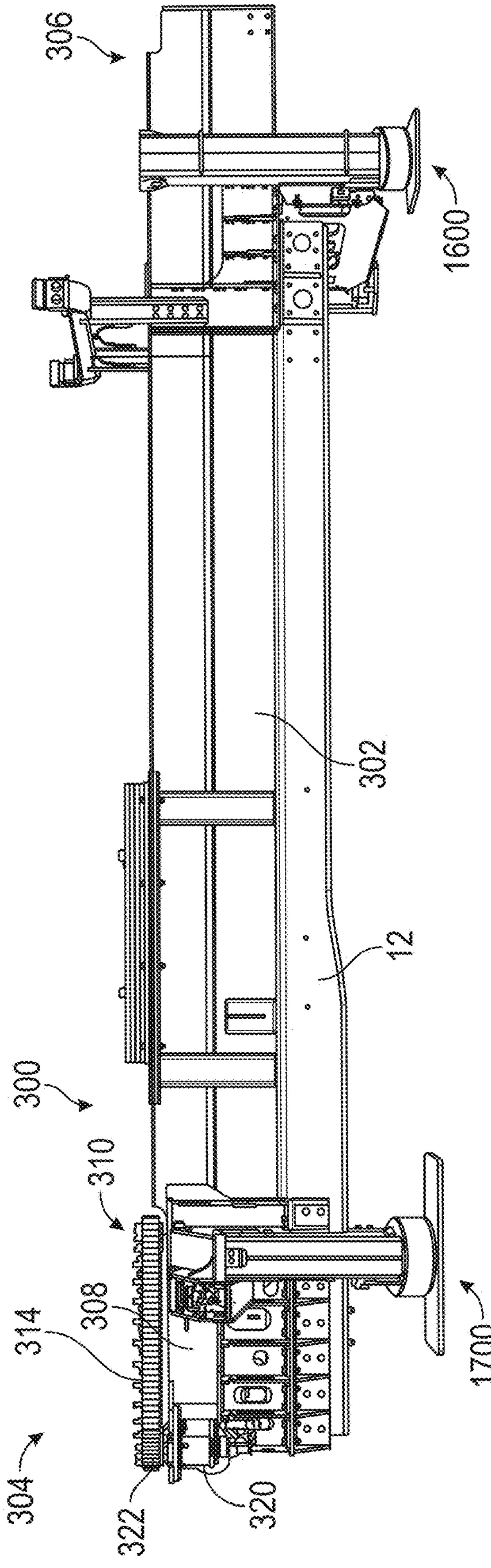

FIG. 15

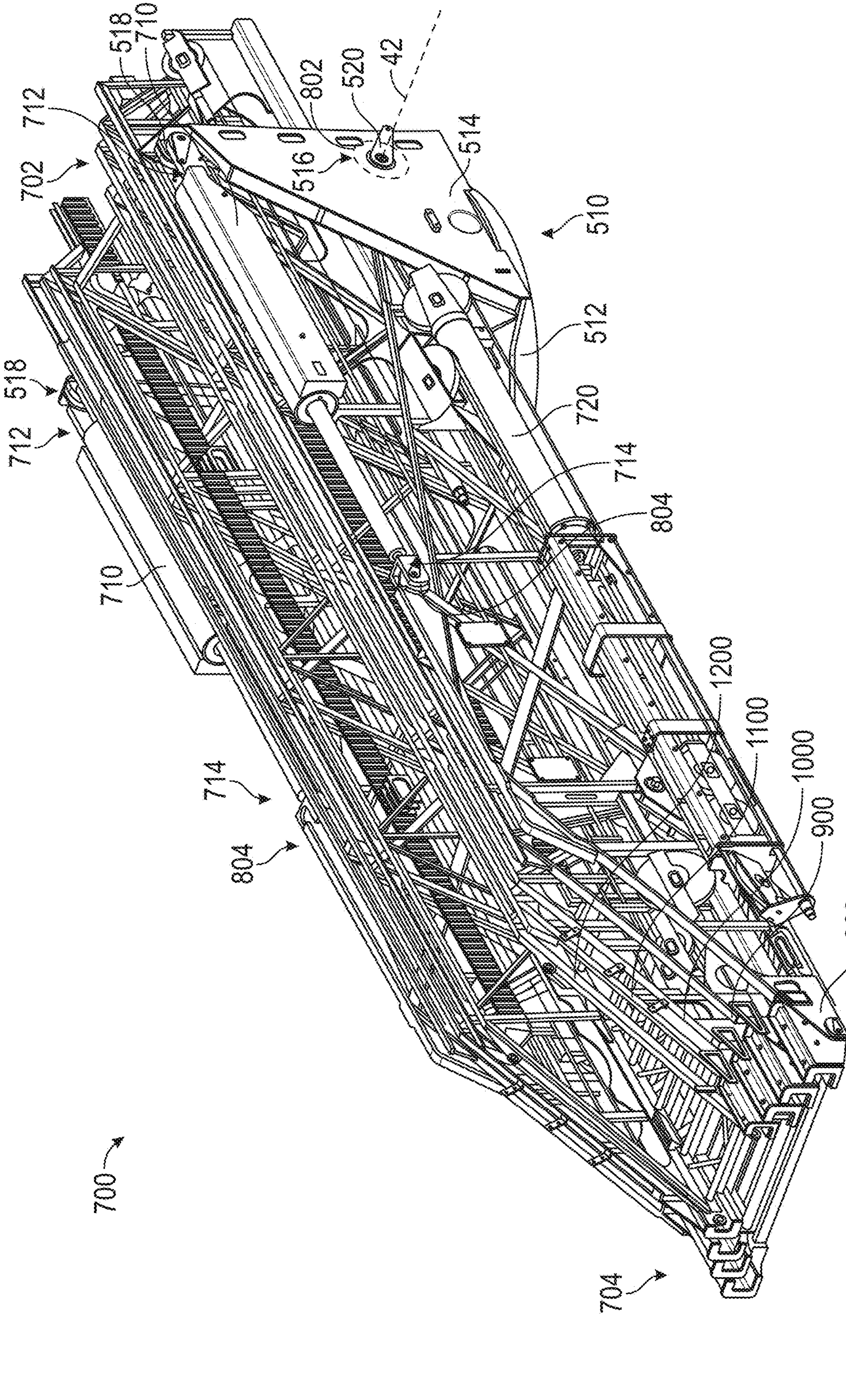
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FIG. 16

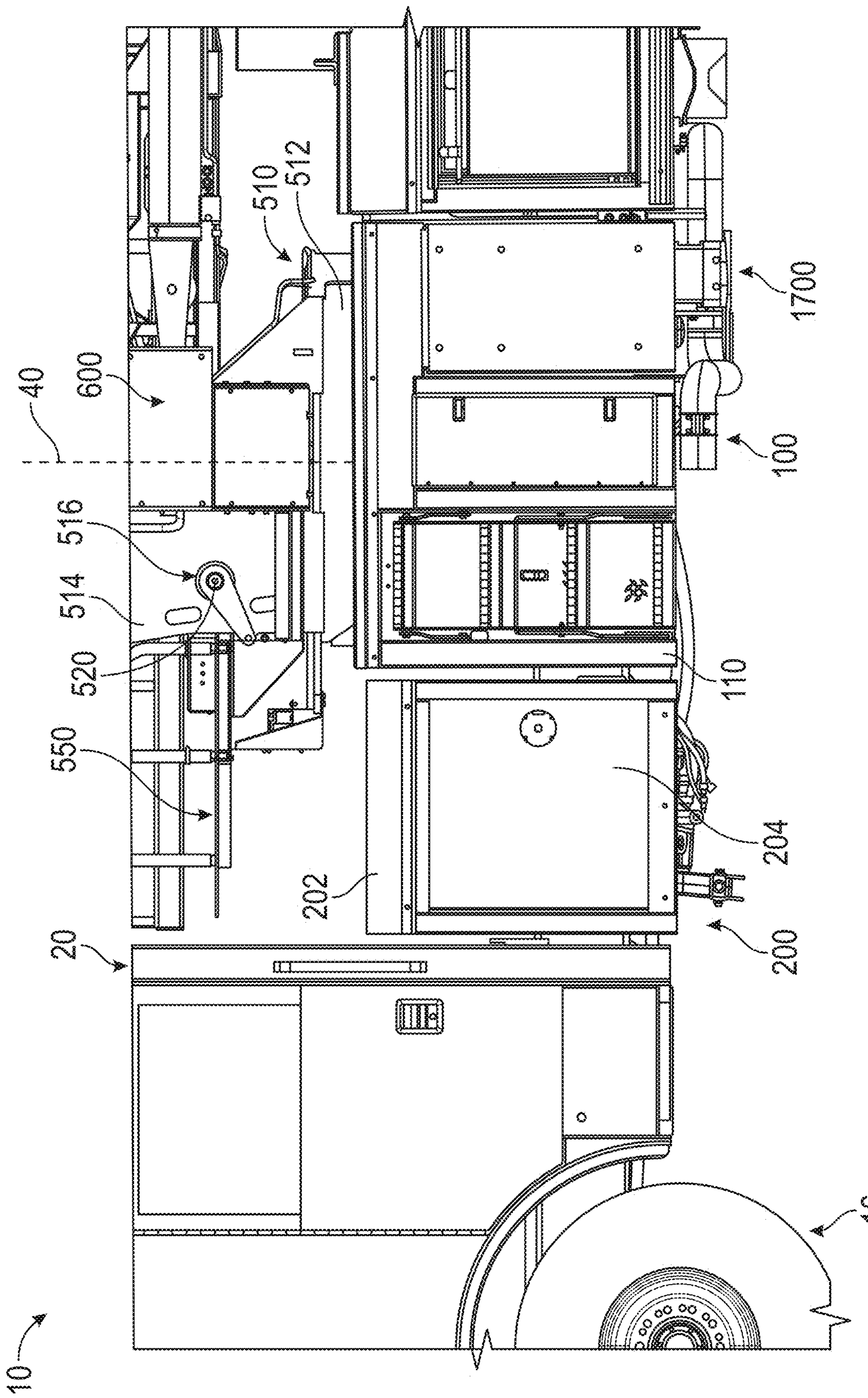


FIG. 17

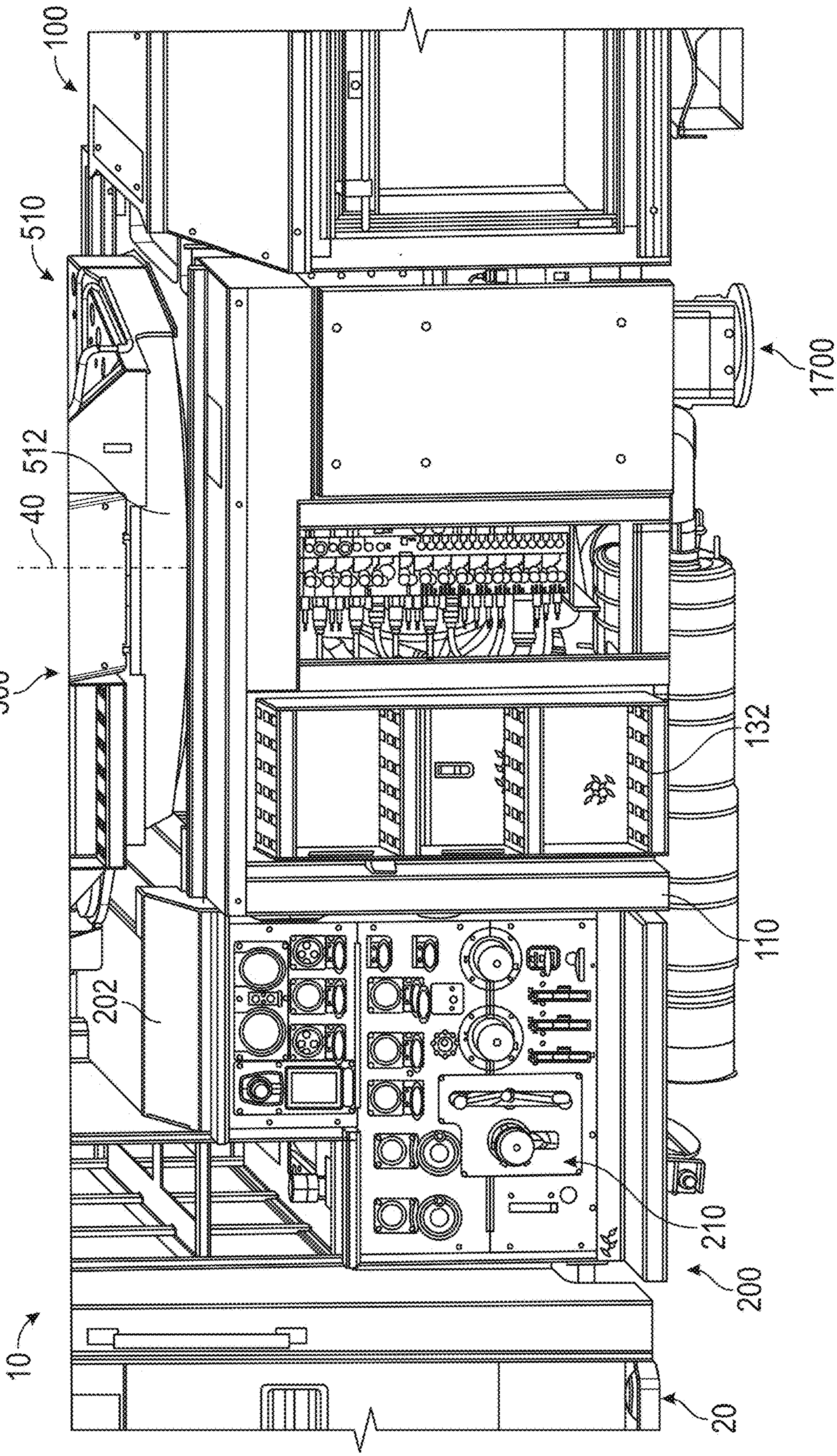


FIG. 18

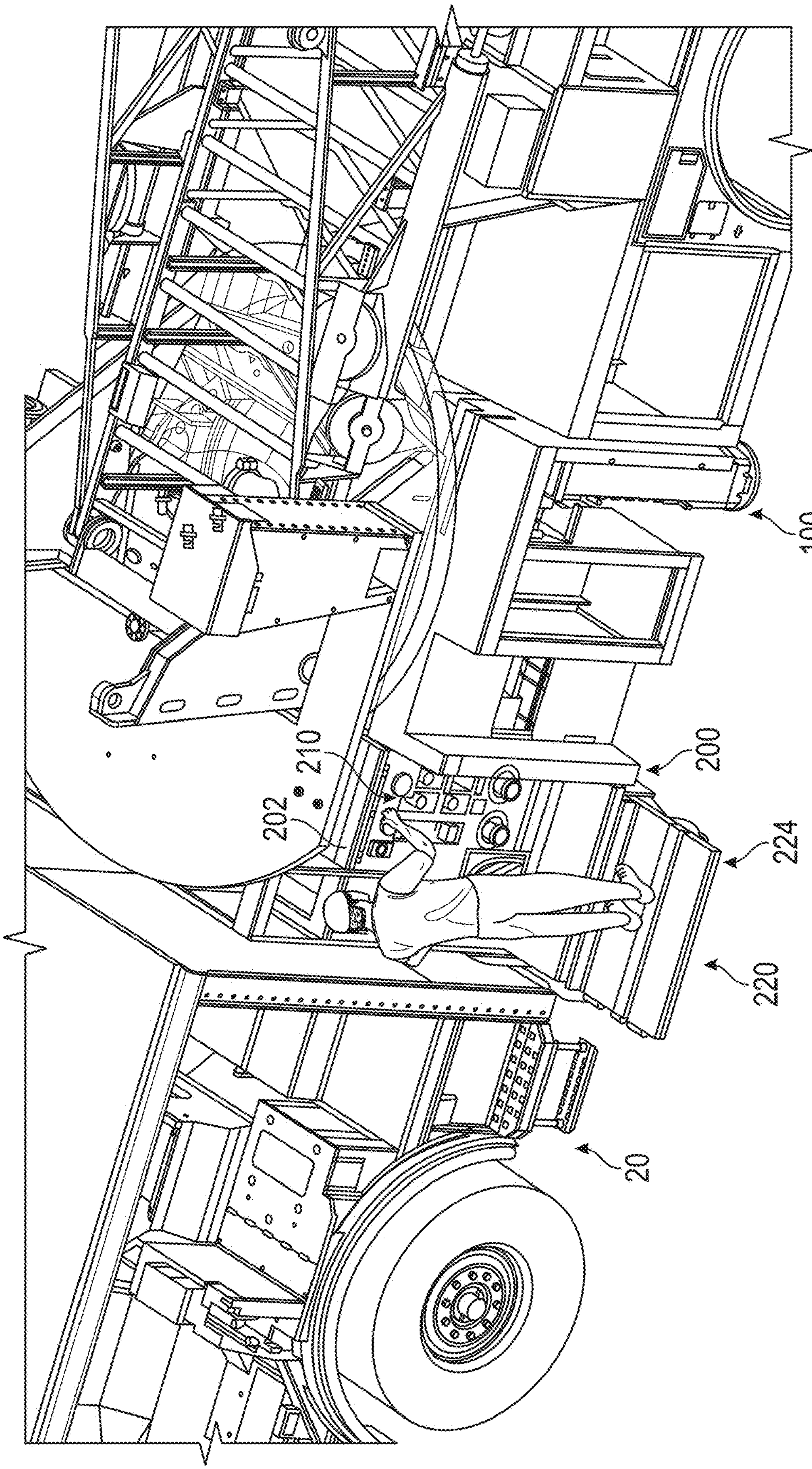


FIG. 19

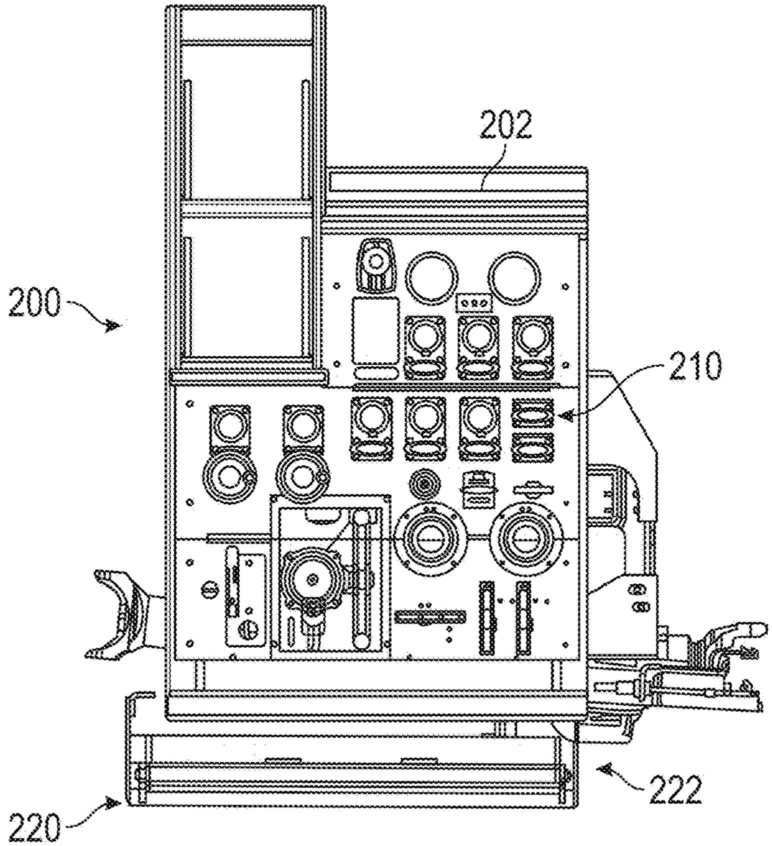


FIG. 20

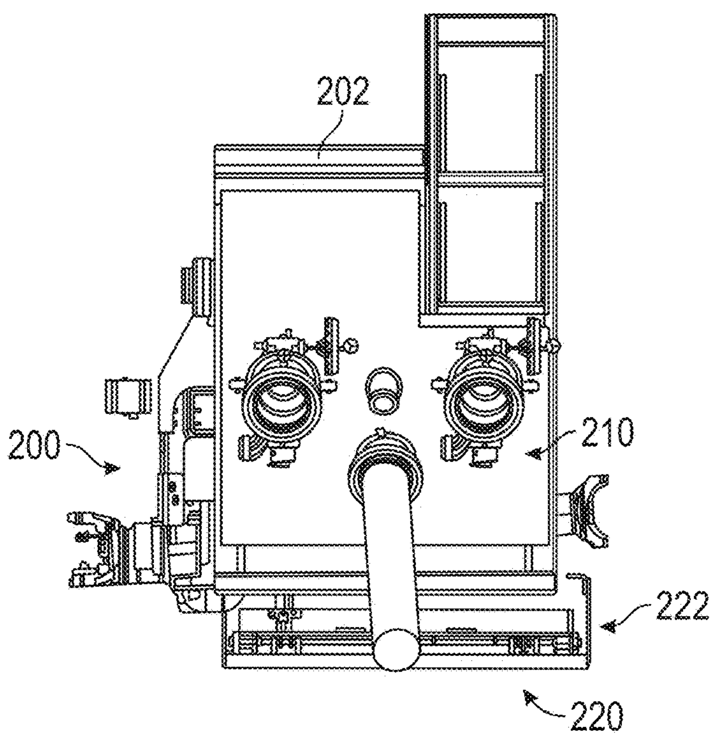


FIG. 21

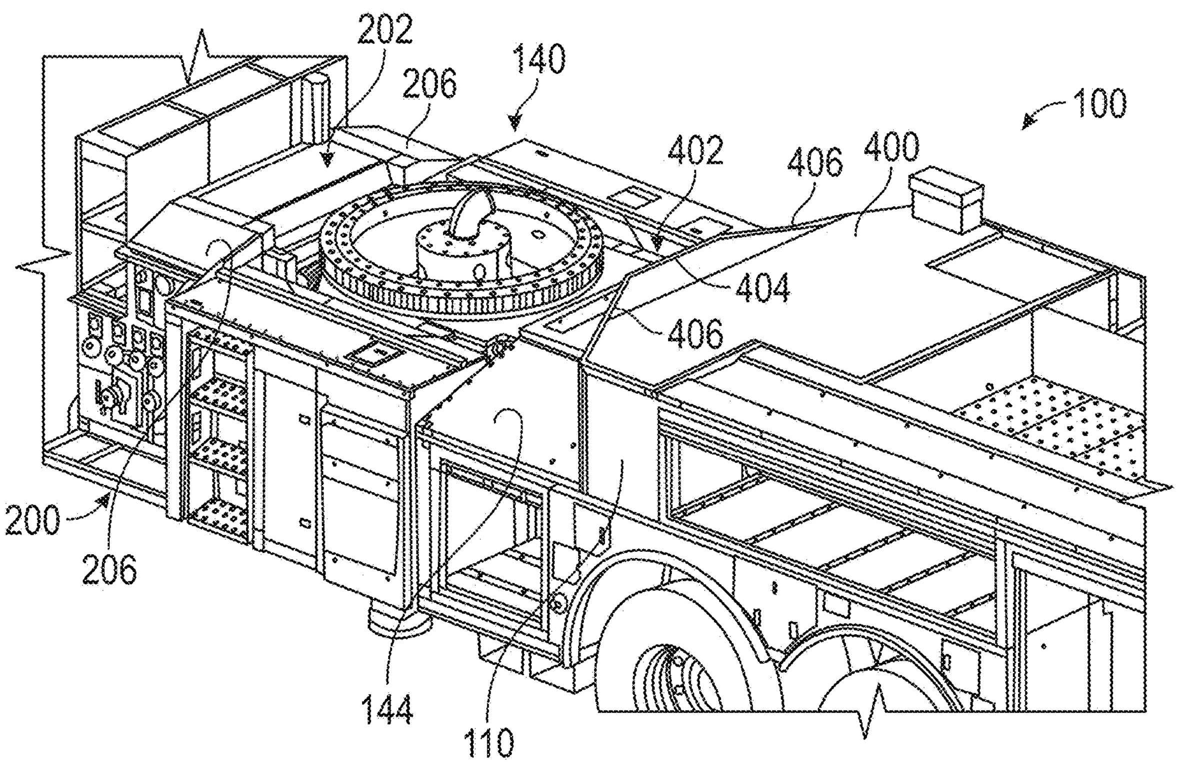


FIG. 22

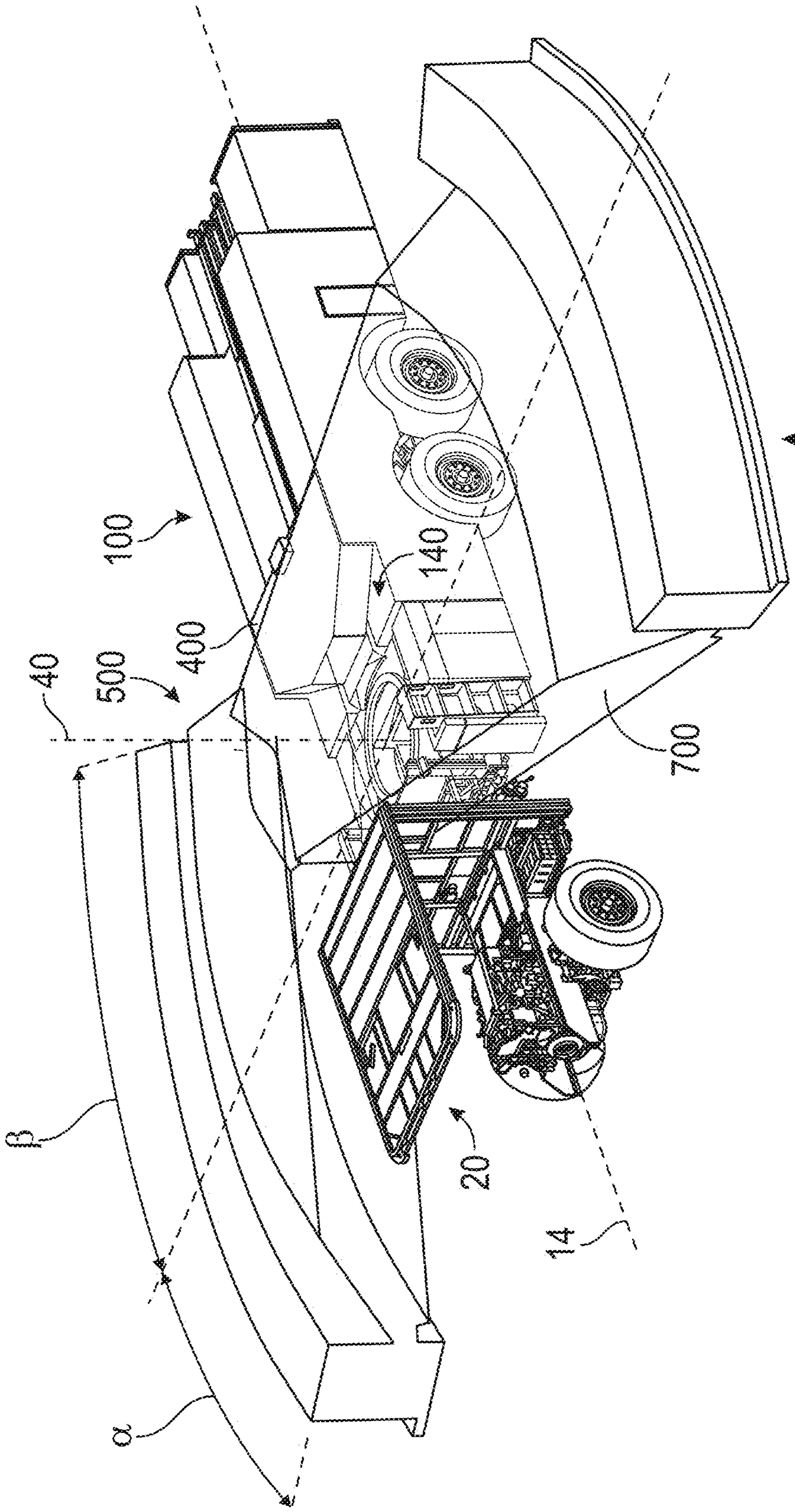


FIG. 23

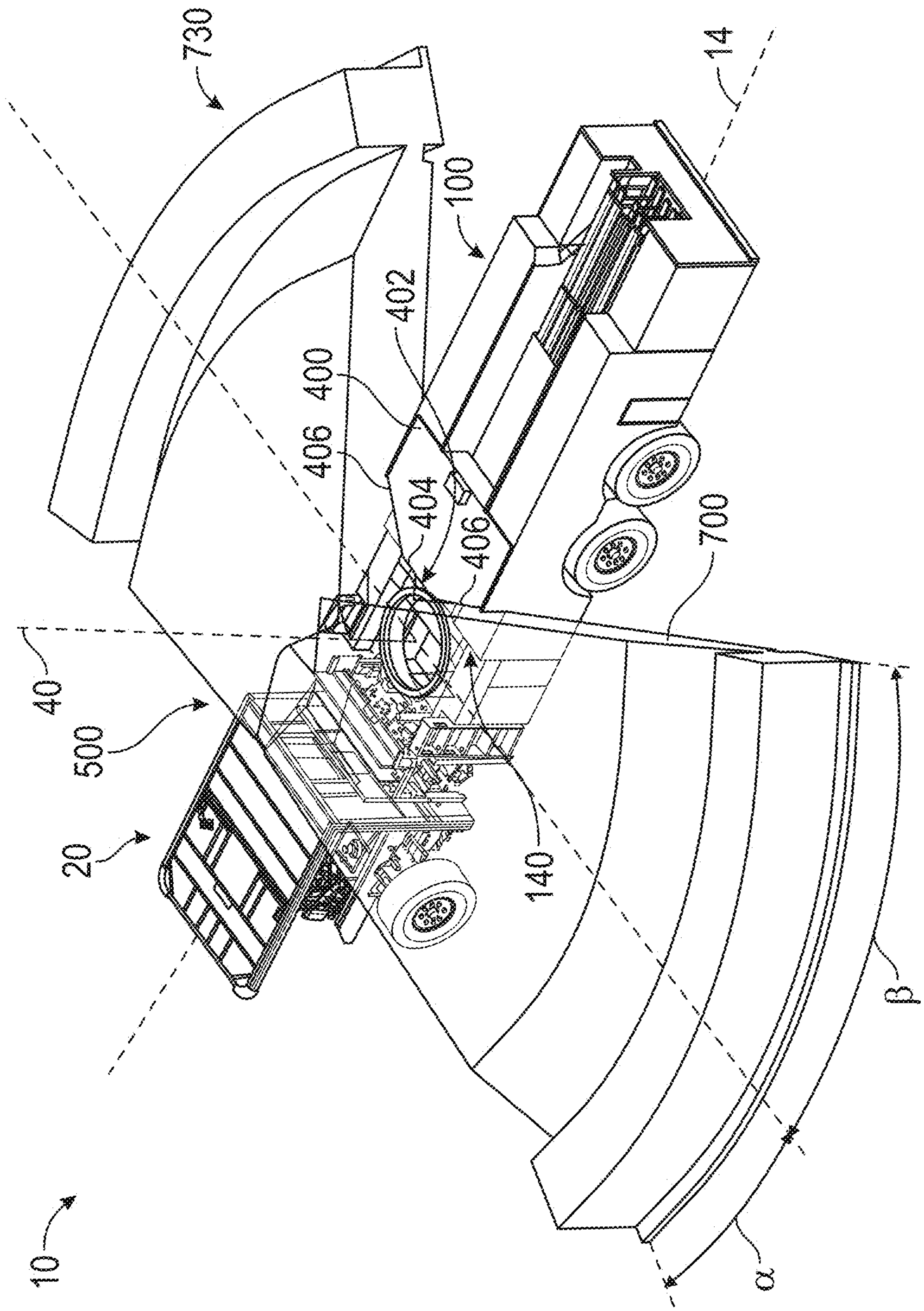


FIG. 24

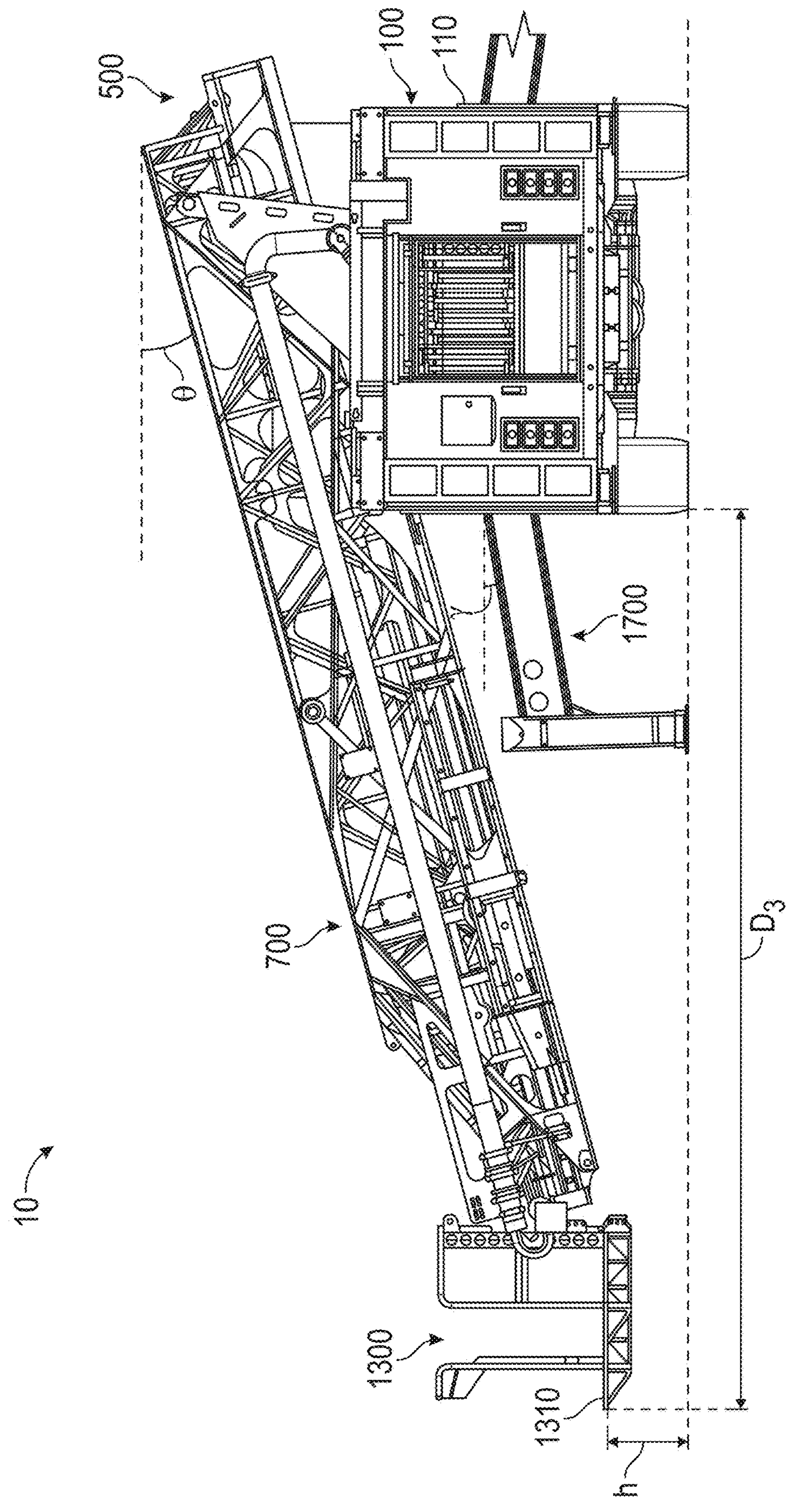


FIG. 25

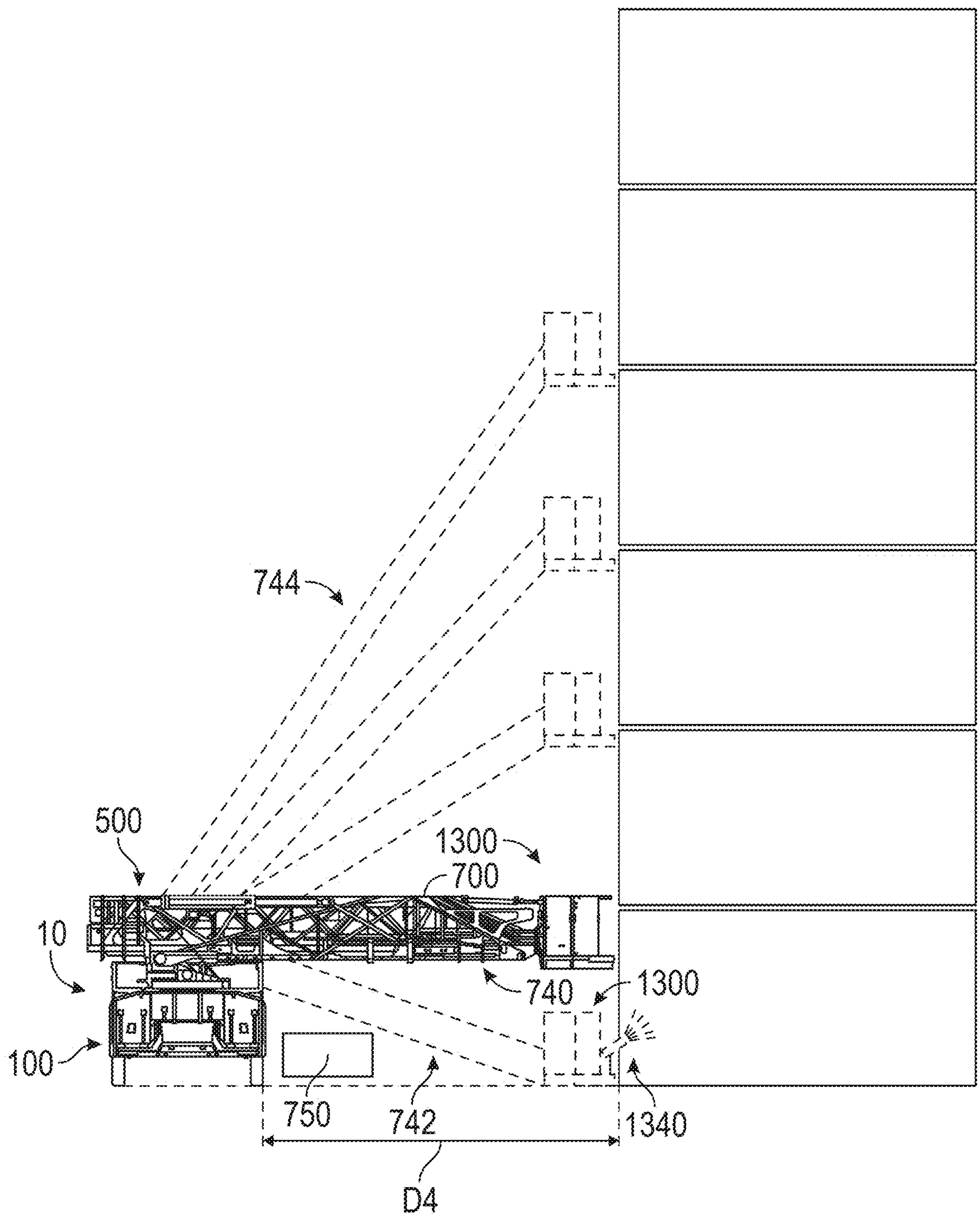
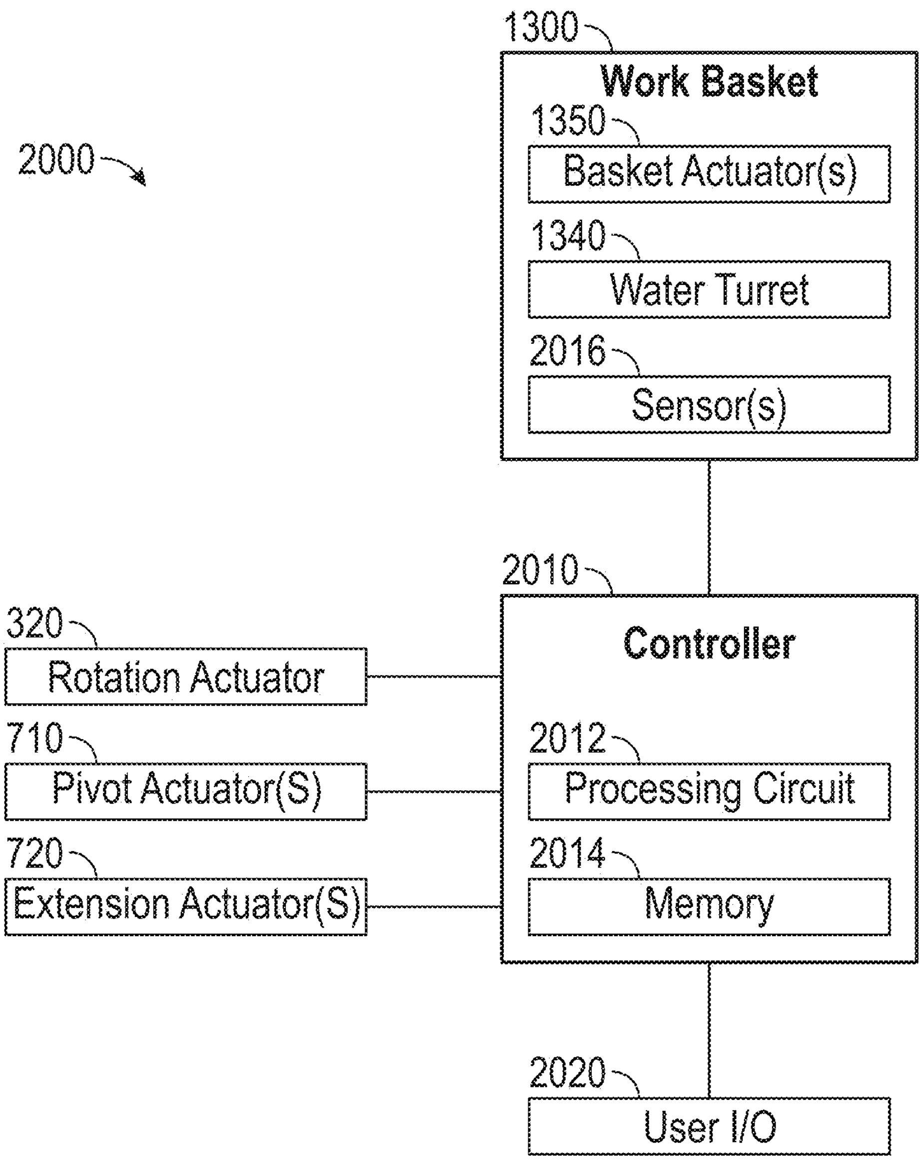


FIG. 26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Work Basket
1350
Basket Actuator(s)
1340
Water Turret
2016
Sensor(s)
2010
Controller
2012
Processing Circuit
2014
Memory
320
Rotation Actuator
710
Pivot Actuator(S)
720
Extension Actuator(S)
2020
User I/O

FIG. 27

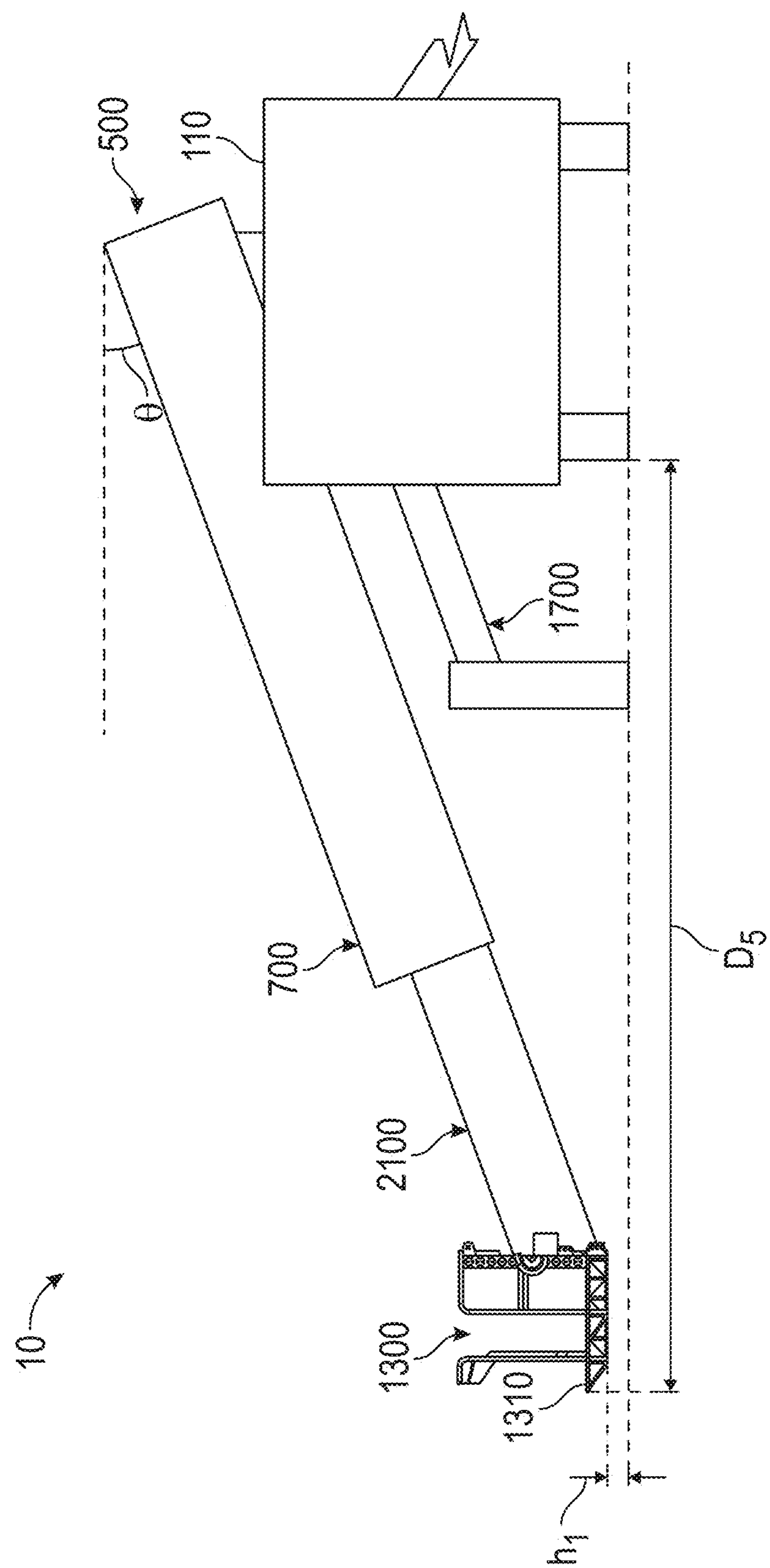

FIG. 28

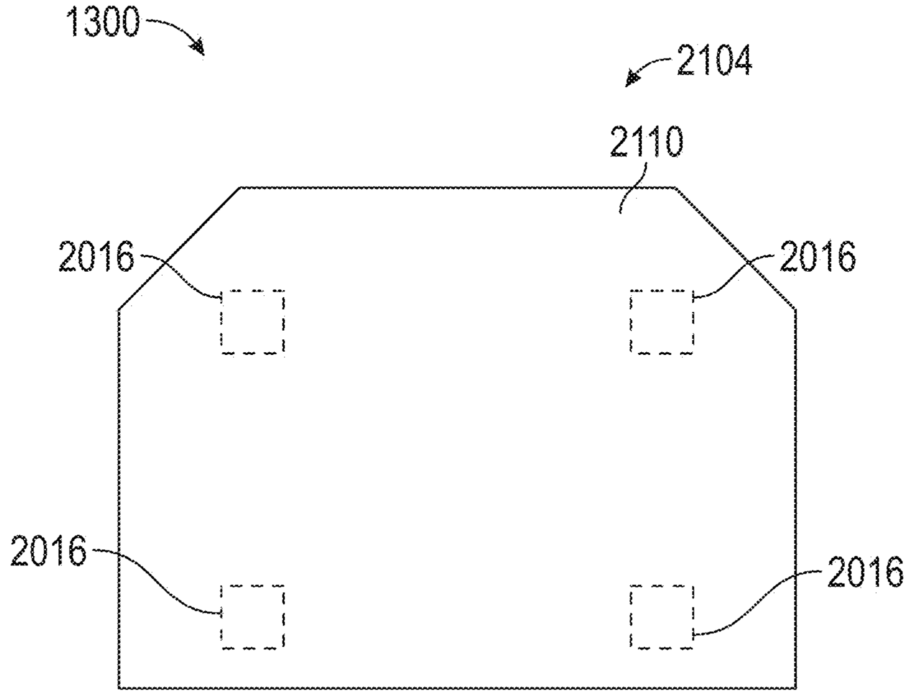

FIG. 29

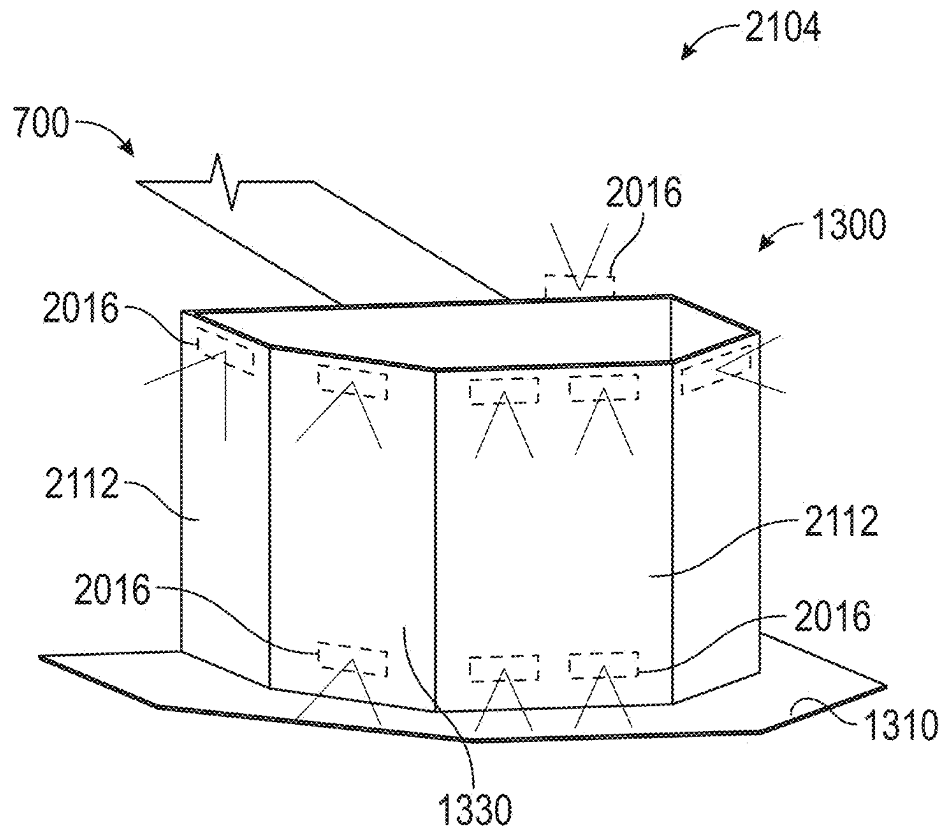

FIG. 30

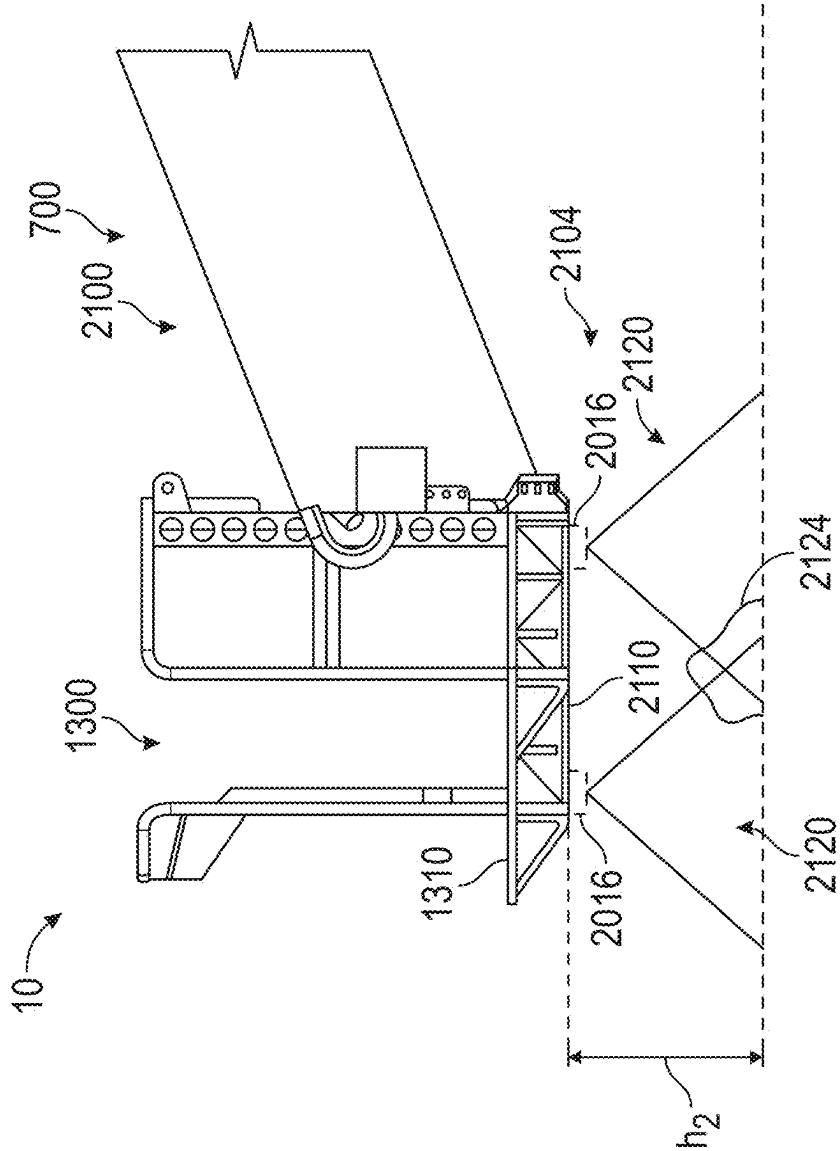

FIG. 31

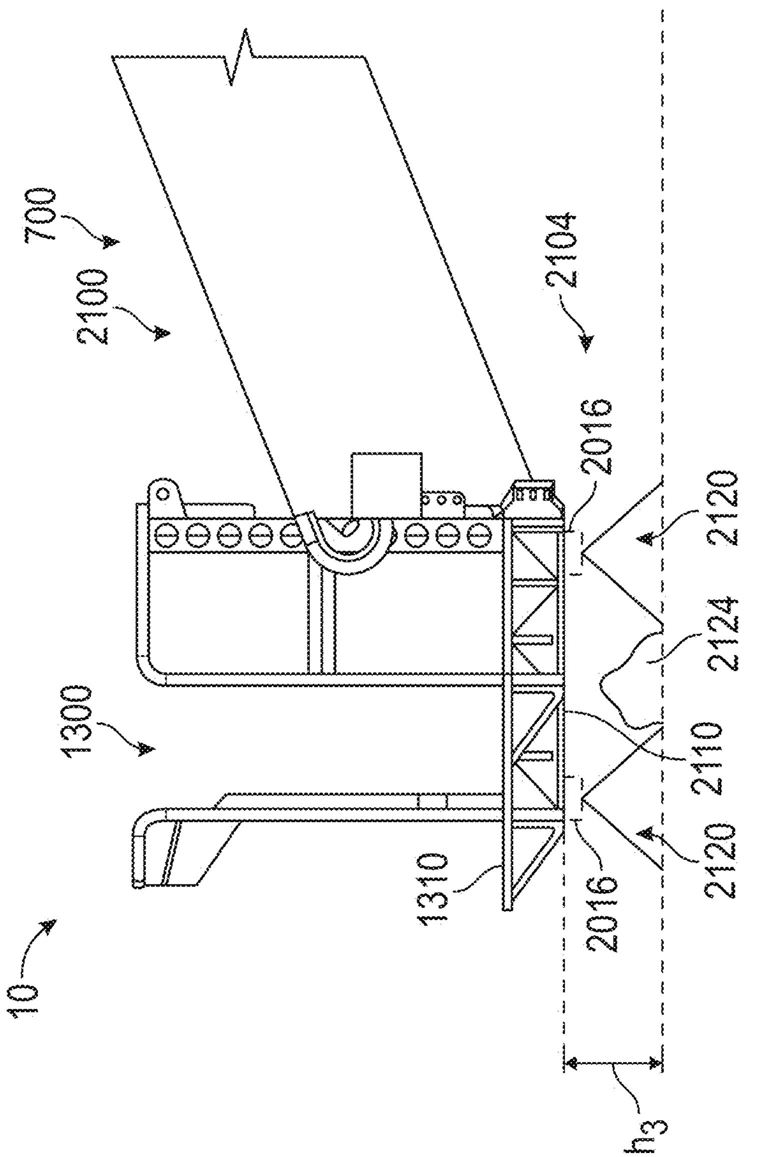

FIG. 32

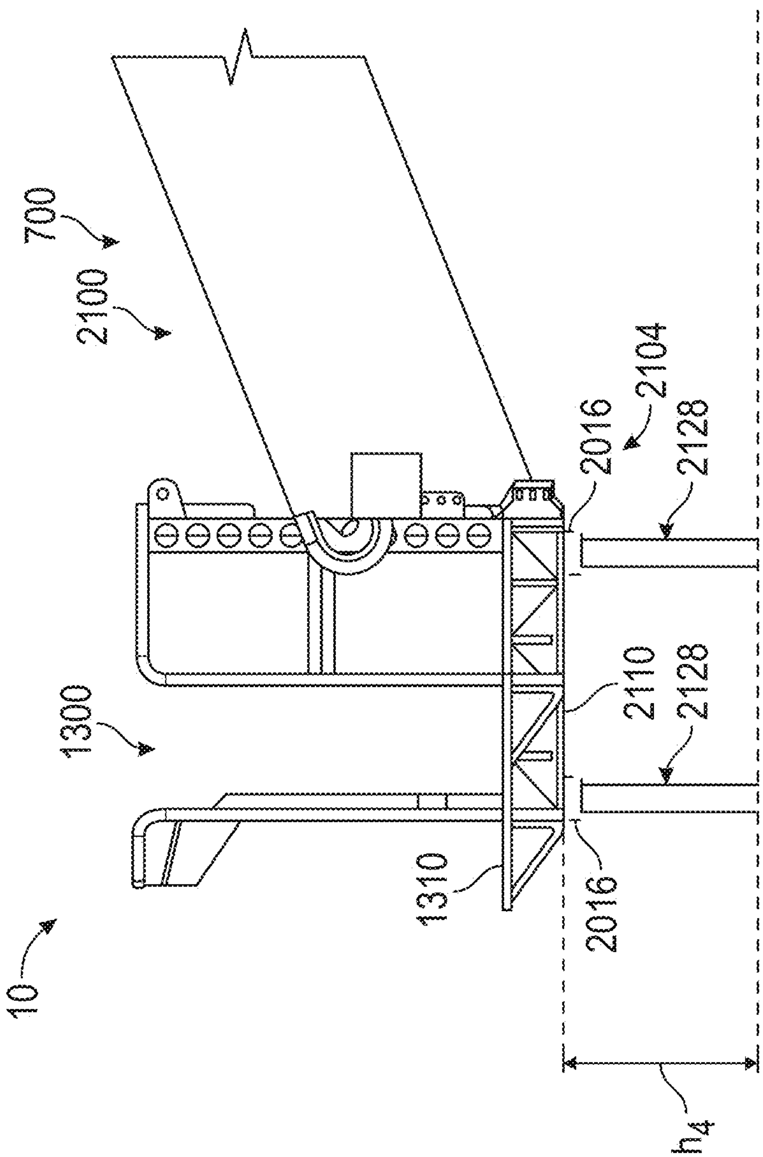

FIG. 33

SENSOR SYSTEM FOR AERIAL LADDER ASSEMBLY

CROSS-REFERENCE TO RELATED PATENT APPLICATION

[0001] This application claims the benefit of and priority to U.S. Provisional Patent Application No. 63/551,218, filed Feb. 8, 2024, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Fire apparatuses may be configured as rear-mount aerial fire apparatuses or mid-mount aerial fire apparatuses. During operation of the aerial ladder a work basket thereof or another component thereof may unintentionally run aground or inadvertently contact an object in the environment surrounding the aerial ladder. This may damage the aerial ladder.

SUMMARY

[0003] One embodiment relates to a vehicle. The vehicle includes a chassis, a body assembly coupled to the chassis, an implement coupled to the body assembly, at least one sensor configured to facilitate monitoring a position of the implement relative to a ground surface or an object, and one or more processing circuits. The one or more processing circuits are configured to determine, based on sensor data acquired by the at least one sensor, the position of the implement relative to the ground surface or the object, permit operation of the implement in a first mode of operation in response to a determination that the position of the implement relative to the ground surface or the object is greater than a threshold distance, and limit operation of the implement in a second mode of operation in response to a determination that the position of the implement relative to the ground surface or the object is less than the threshold distance

[0004] Another embodiment relates to a vehicle system. The vehicle system includes one or more processing circuits configured to acquire sensor data of an area including at least one of a ground surface or an object, monitor a position of a portion of a ladder assembly of a fire apparatus relative to the ground surface or the object based on the sensor data, permit operation of the ladder assembly in a first mode of operation in response to a determination that the position of the portion of the ladder assembly relative to the ground surface or the object is greater than a threshold distance, and limit operation of the ladder assembly in a second mode of operation in response to a determination that the position of the portion of the ladder assembly relative to the ground surface or the object is less than the threshold distance.

[0005] Still Another embodiment relates to a fire apparatus. The fire apparatus includes a chassis, a body assembly coupled to the chassis, a ladder assembly coupled to the body assembly and including at least one extensible ladder section and a work basket coupled to a distal end of the ladder assembly, at least one sensor coupled to the ladder assembly and configured to acquire sensor data of an area surrounding the ladder assembly, and one or more processing circuits. The one or more processing circuits are configured to determine a position of a portion of the ladder assembly relative to an object in the area based on the sensor data, permit operation of the ladder assembly in a first mode of operation in response to a determination that the position of the portion of the ladder assembly relative to the object is greater than a first threshold distance, limit operation of the ladder assembly in a second mode of operation in response to a determination that the position of the portion of the ladder assembly relative to the object is less than the first threshold distance, limit operation of the ladder assembly in a third mode of operation in response to a determination that the position of the portion of the ladder assembly relative to the object is at or less than a second threshold distance, and control operation of the ladder assembly in the first mode of operation, the second mode of operation, or the third mode of operation based on point cloud data of the object included in the sensor data when at least a portion of the object is not sensed by the at least one sensor. The second threshold distance is less than the first threshold distance. The third mode of operation is more restrictive than the second mode of operation.

[0006] This summary is illustrative only and is not intended to be in any way limiting. Other aspects, inventive features, and advantages of the devices or processes described herein will become apparent in the detailed description set forth herein, taken in conjunction with the accompanying figures, wherein like reference numerals refer to like elements.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a left side view of a mid-mount fire apparatus, according to an exemplary embodiment.

[0008] FIG. **2** is a right side view of the mid-mount fire apparatus of FIG. **1**, according to an exemplary embodiment.

[0009] FIG. **3** is a top view of the mid-mount fire apparatus of FIG. **1**, according to an exemplary embodiment.

[0010] FIG. **4** is a bottom view of the mid-mount fire apparatus of FIG. **1**, according to an exemplary embodiment.

[0011] FIG. **5** is a rear view of the mid-mount fire apparatus of FIG. **1**, according to an exemplary embodiment.

[0012] FIG. **6** is a rear view of the mid-mount fire apparatus of FIG. **1** having outriggers in an extended configuration, according to an exemplary embodiment.

[0013] FIG. **7** is a front view of the mid-mount fire apparatus of FIG. **1** having outriggers in an extended configuration, according to an exemplary embodiment.

[0014] FIG. **8** is a side view of the mid-mount fire apparatus of FIG. **1** relative to a traditional mid-mount fire apparatus, according to an exemplary embodiment.

[0015] FIG. **9** is a side view of the mid-mount fire apparatus of FIG. **1** relative to a traditional rear-mount fire apparatus, according to an exemplary embodiment.

[0016] FIG. **10** is a rear perspective view of a rear assembly of the mid-mount fire apparatus of FIG. **1**, according to an exemplary embodiment.

[0017] FIG. **11** is detailed rear perspective view of the rear assembly of FIGS. **10**, according to an exemplary embodiment.

[0018] FIG. **12** is another rear perspective view of the rear assembly of FIG. **10** without a ladder assembly, according to an exemplary embodiment.

[0019] FIG. **13** is a top view of the rear assembly of FIG. **12**, according to an exemplary embodiment.

[0020] FIG. **14** is a perspective view of a torque box of the mid-mount fire apparatus of FIG. **1**, according to an exemplary embodiment.

[0021] FIG. **15** is a side view of the torque box of FIG. **14**, according to an exemplary embodiment.

[0022] FIG. **16** is a perspective view of an aerial ladder assembly and turntable of the mid-mount fire apparatus of FIG. **1**, according to an exemplary embodiment.

[0023] FIG. **17** is a side view of a pump housing of the mid-mount fire apparatus of FIG. **1** in a first configuration, according to an exemplary embodiment.

[0024] FIG. **18** is a side perspective view of a pump system within the pump housing of FIG. **17** in a second configuration, according to an exemplary embodiment.

[0025] FIG. **19** is a side perspective view of the pump system of FIG. **18** with a platform in a deployed configuration, according to an exemplary embodiment.

[0026] FIGS. **20** and **21** are opposing side views of the pump system of FIG. **18**, according to an exemplary embodiment.

[0027] FIG. **22** is a detailed perspective view of an aerial assembly recess of the mid-mount fire apparatus of FIG. **1**, according to an exemplary embodiment.

[0028] FIGS. **23** and **24** are various perspective views of a scrub area of an aerial assembly of the mid-mount fire apparatus of FIG. **1**, according to an exemplary embodiment.

[0029] FIG. **25** is a rear view of the mid-mount fire apparatus of FIG. **1** having an aerial assembly with a work basket at a negative depression angle, according to an exemplary embodiment.

[0030] FIG. **26** is a front view of an aerial assembly of the mid-mount fire apparatus of FIG. **1** in a plurality of configurations, according to an exemplary embodiment.

[0031] FIG. **27** is a block diagram of a control system of the mid-mount fire apparatus of FIG. **1**, according to an exemplary embodiment.

[0032] FIG. **28** is a rear view of the mid-mount fire apparatus of FIG. **25** with the aerial assembly at the negative depression angle and at least partially extended, according to an exemplary embodiment.

[0033] FIG. **29** is a bottom view of the work basket of the aerial assembly of FIGS. **25** and **28** including one or more sensors, according to an exemplary embodiment.

[0034] FIG. **30** is a perspective view of the work basket FIG. **29**, according to an exemplary embodiment.

[0035] FIGS. **31-33** are various detailed side views of the aerial assembly and the work basket of FIGS. **25** and **28** in various positions, according to an exemplary embodiment.

DETAILED DESCRIPTION

[0036] Before turning to the figures, which illustrate certain exemplary embodiments in detail, it should be understood that the present disclosure is not limited to the details or methodology set forth in the description or illustrated in the figures. It should also be understood that the terminology used herein is for the purpose of description only and should not be regarded as limiting.

[0037] According to an exemplary embodiment, a vehicle includes various components that improve performance relative to traditional systems. In one embodiment, the vehicle is a mid-mount quint configuration fire apparatus that includes a water tank, an aerial ladder, hose storage, ground ladder storage, and a water pump. The aerial ladder is coupled to the chassis between a front axle assembly and a rear axle assembly of the fire apparatus and pivotable about a lateral pivot axis and about a vertical pivot axis. The aerial ladder includes a base ladder section, at least one extensible ladder section, and/or a basket coupled to an end of the aerial ladder. The aerial ladder may be operable in a scrub area below grade in a negative depression angle range (e.g., zero degrees to at least more than negative eight degrees, up to negative fifteen degrees, up to negative twenty degrees, etc.) and through a sweep angle range (e.g., more than fifteen degrees, at least 30 degrees, at least 50 degrees, etc.). The basket includes one or more sensors positioned to detect a surrounding environment to facilitate providing user-warning and/or user-assist functionality to prevent the basket from running into objects or the ground.

Overall Vehicle

[0038] According to the exemplary embodiment shown in FIGS. **1-21**, a vehicle, shown as fire apparatus **10**, is configured as a mid-mount quint fire truck having a tandem rear axle. A "quint" fire truck as used herein may refer to a fire truck that includes a water tank, an aerial ladder, hose storage, ground ladder storage, and a water pump. In other embodiments, the fire apparatus **10** is configured as a mid-mount quint fire truck having a single rear axle. A tandem rear axle may include two solid axle configurations or may include two pairs of axles (e.g., two pairs of half shafts, etc.) each having a set of constant velocity joints and coupling two differentials to two pairs of hub assemblies. A single rear axle chassis may include one solid axle configuration or may include one pair of axles each having a set of constant velocity joints and coupling a differential to a pair of hub assemblies, according to various alternative embodiments. In still other embodiments, the fire apparatus **10** is configured as a non-quint mid-mount fire truck having a single rear axle or a tandem rear axle. In yet other embodiments, the fire apparatus **10** is configured as a rear-mount, quint or non-quint, single rear axle or tandem rear axle, fire truck.

[0039] As shown in FIGS. **1-7**, **10-13**, **17**, and **18**, the fire apparatus **10** includes a chassis, shown as frame **12**, having longitudinal frame rails that define an axis, shown as longitudinal axis **14**, that extends between a first end, shown as front end **2**, and an opposing second end, shown as rear end **4**, of the fire apparatus **10**; a first axle, shown as front axle **16**, coupled to the frame **12**; one or more second axles, shown as rear axles **18**, coupled to the frame **12**; a first assembly, shown as front cabin **20**, coupled to and supported by the frame **12** and having a bumper, shown as front bumper **22**; a prime mover, shown as engine **60**, coupled to and supported by the frame **12**; and a second assembly, shown as rear assembly **100**, coupled to and supported by the frame **12**.

[0040] As shown in FIGS. **1-7**, **10**, and **12**, the front axle **16** and the rear axles **18** include tractive assemblies, shown as wheel and tire assemblies **30**. As shown in FIGS. **1-4**, the front cabin **20** is positioned forward of the rear assembly **100** (e.g., with respect to a forward direction of travel for the fire apparatus **10** along the longitudinal axis **14**, etc.). According to an alternative embodiment, the cab assembly may be positioned behind the rear assembly **100** (e.g., with respect to a forward direction of travel for the fire apparatus **10** along the longitudinal axis **14**, etc.). The cab assembly may be positioned behind the rear assembly **100** on, by way of example, a rear tiller fire apparatus. In some embodiments, the fire apparatus **10** is a ladder truck with a front portion that includes the front cabin **20** pivotally coupled to a rear portion that includes the rear assembly **100**.

[0041] According to an exemplary embodiment, the engine **60** receives fuel (e.g., gasoline, diesel, etc.) from a fuel tank and combusts the fuel to generate mechanical energy. A transmission receives the mechanical energy and provides an output to a drive shaft. The rotating drive shaft is received by a differential, which conveys the rotational energy of the drive shaft to a final drive (e.g., the front axle **16**, the rear axles **18**, the wheel and tire assemblies **30**, etc.). The final drive then propels or moves the fire apparatus **10**. According to an exemplary embodiment, the engine **60** is a compression-ignition internal combustion engine that utilizes diesel fuel. In alternative embodiments, the engine **60** is another type of prime mover (e.g., a spark-ignition engine, a fuel cell, an electric motor, etc.) that is otherwise powered (e.g., with gasoline, compressed natural gas, propane, hydrogen, electricity, etc.).

[0042] As shown in FIGS. **1-7**, **10-13**, and **17-19**, the rear assembly **100** includes a body assembly, shown as body **110**, coupled to and supported by the frame **12**; a fluid driver, shown as pump system **200**, coupled to and supported by the frame **12**; a chassis support member, shown as torque box **300**, coupled to and supported by the frame **12**; a fluid reservoir, shown as water tank **400**, coupled to the body **110** and supported by the torque box **300** and/or the frame **12**; and an aerial assembly, shown as aerial assembly **500**, pivotally coupled to the torque box **300** and supported by the torque box **300** and/or the frame **12**. In some embodiments, the rear assembly **100** does not include the water tank **400**. In some embodiments, the rear assembly **100** additionally or alternatively includes an agent or foam tank (e.g., that receives and stores a fire suppressing agent, foam, etc.).

[0043] As shown in FIGS. **1**, **2**, and **10-12**, the sides of the body **110** define a plurality of compartments, shown as storage compartments **112**. The storage compartments **112** may receive and store miscellaneous items and gear used by emergency response personnel (e.g., helmets, axes, oxygen tanks, hoses, medical kits, etc.). As shown in FIGS. **5**, **6**, and **10-12**, the rear end **4** of the body **110** defines a longitudinal storage compartment that extends along the longitudinal axis **14**, shown as ground ladder compartment **114**. The ground ladder compartment **114** may receive and store one or more ground ladders. As shown in FIGS. **3**, **5**, and **10-13**, a top surface, shown as top platform **122**, of the body **110** defines a cavity, shown as hose storage platform **116**, and a channel, shown as hose chute **118**, extending from the hose storage platform **116** to the rear end **4** of the body **110**. The hose storage platform **116** may receive and store one or more hoses (e.g., up to 1000 feet of 5 inch diameter hose, etc.), which may be pulled from the hose storage platform **116** though the hose chute **118**.

[0044] As shown in FIGS. **1-6** and **10-13**, the rear end **4** of the body **110** has notched or clipped corners, shown as chamfered corners **120**. In other embodiments, the rear end **4** of the body **110** does not have notched or clipped corners (e.g., the rear end **4** of the body **110** may have square corners, etc.). According to an exemplary embodiment, the chamfered corners **120** provide for increased turning clearance relative to fire apparatuses that have non-notched or non-clipped (e.g., square, etc.) corners. As shown in FIGS. **1-3**, **5**, **6**, and **10-13**, the rear assembly **100** includes a first selectively deployable ladder, shown as rear ladder **130**, coupled to each of the chamfered corners **120** of the body **110**. According to an exemplary embodiment, the rear ladders **130** are hingedly coupled to the chamfered corners **120** and repositionable between a stowed position (see, e.g., FIGS. **1-3**, **5**, **12**, **13**, etc.) and a deployed position (see, e.g., FIGS. **6**, **10**, **11**, etc.). The rear ladders **130** may be selectively deployed such that a user may climb the rear ladder **130** to access the top platform **122** of the body **110** and/or one or more components of the aerial assembly **500** (e.g., a work basket, an implement, an aerial ladder assembly, the hose storage platform **116**, etc.). In other embodiments, the body **110** has stairs in addition to or in place of the rear ladders **130**.

[0045] As shown in FIGS. **1**, **12**, **17**, and **18**, the rear assembly **100** includes a second selectively deployable ladder, shown as side ladder **132**, coupled to a side (e.g., a left side, a right side, a driver's side, a passenger's side, etc.) of the body **110**. In some embodiments, the rear assembly **100** includes two side ladders **132**, one coupled to each side of the body **110**. According to an exemplary embodiment, the side ladder **132** is hingedly coupled to the body **110** and repositionable between a stowed position (see, e.g., FIGS. **1**, **2**, **17**, **18**, etc.) and a deployed position. The side ladder **132** may be selectively deployed such that a user may climb the side ladder **132** to access one or more components of the aerial assembly **500** (e.g., a work platform, an aerial ladder assembly, a control console, etc.).

[0046] As shown in FIGS. **1**, **2**, **12** and **13**, the body **110** defines a recessed portion, shown as aerial assembly recess **140**, positioned (i) rearward of the front cabin **20** and (ii) forward of the water tank **400** and/or the rear axles **18**. The aerial assembly recess **140** defines an aperture, shown as pedestal opening **142**, rearward of the pump system **200**.

[0047] According to an exemplary embodiment the water tank **400** is coupled to the frame **12** with a superstructure (e.g., disposed along a top surface of the torque box **300**, etc.). As shown in FIGS. **1**, **2**, **12**, and **13**, the water tank **400** is positioned below the aerial ladder assembly **700** and forward of the hose storage platform **116**. As shown in FIGS. **1**, **2**, **12** and **13**, the water tank **400** is positioned such that the water tank **400** defines a rear wall of the aerial assembly recess **140**. In one embodiment, the water tank **400** stores up to 300 gallons of water. In another embodiment, the water tank **400** stores more than or less than 300 gallons of water (e.g., **100**, **200**, **250**, **350**, **400**, **500**, etc. gallons). In other embodiments, fire apparatus **10** additionally or alternatively includes a second reservoir that stores another firefighting agent (e.g., foam, etc.). In still other embodiments, the fire apparatus **10** does not include the water tank **400** (e.g., in a non-quint configuration, etc.).

[0048] As shown in FIGS. **1-3**, **5-7**, **10**, **17**, and **18**, the aerial assembly **500** includes a turntable assembly, shown as turntable **510**, pivotally coupled to the torque box **300**; a platform, shown work platform **550**, coupled to the turntable **510**; a console, shown as control console **600**, coupled to the turntable **510**; a ladder assembly, shown as aerial ladder assembly **700**, having a first end (e.g., a base end, a proximal end, a pivot end, etc.), shown as proximal end **702**, pivotally coupled to the turntable **510**, and an opposing second end (e.g., a free end, a distal end, a platform end, an implement end, etc.), shown as distal end **704**; and an implement, shown as work basket **1300**, coupled to the distal end **704**.

[0049] As shown in FIGS. **1**, **2**, **4**, **14**, and **15**, the torque box **300** is coupled to the frame **12**. In one embodiment, the torque box **300** extends laterally the full width between the lateral outsides of the frame rails of the frame **12**. As shown in FIGS. **14** and **15**, the torque box **300** includes a body portion, shown as body **302**, having a first end, shown as front end **304**, and an opposing second end, shown as rear end **306**. As shown in FIGS. **12**, **14**, and **15**, the torque box **300** includes a support, shown as pedestal **308**, coupled (e.g., attached, fixed, bolted, welded, etc.) to the front end **304** of the torque box **300**. As shown in FIG. **12**, the pedestal **308** extends through the pedestal opening **142** into the aerial assembly recess **140** such that the pedestal **308** is positioned (i) forward of the water tank **400** and the rear axles **18** and (ii) rearward of pump system **200**, the front axle **16**, and the front cabin **20**.

[0050] According to the exemplary embodiment shown in FIGS. **1**, **2**, and **12**, the aerial assembly **500** (e.g., the turntable **510**, the work platform **550**, the control console **600**, the aerial ladder assembly **700**, the work basket **1300**, etc.) is rotatably coupled to the pedestal **308** such that the aerial assembly **500** is selectively repositionable into a plurality of operating orientations about a vertical axis, shown as vertical pivot axis **40**. As shown in FIGS. **12**, **14**, and **15**, the torque box **300** includes a pivotal connector, shown as slewing bearing **310**, coupled to the pedestal **308**. The slewing bearing **310** is a rotational rolling-element bearing with an inner element, shown as bearing element **312**, and an outer element, shown as driven gear **314**. The bearing element **312** may be coupled to the pedestal **308** with a plurality of fasteners (e.g., bolts, etc.).

[0051] As shown in FIGS. **14** and **15**, a drive actuator, shown as rotation actuator **320**, is coupled to the pedestal **308** (e.g., by an intermediate bracket, etc.). The rotation actuator **320** is positioned to drive (e.g., rotate, turn, etc.) the driven gear **314** of the slewing bearing **310**. In one embodiment, the rotation actuator **320** is an electric motor (e.g., an alternating current (AC) motor, a direct current motor (DC), etc.) configured to convert electrical energy into mechanical energy. In other embodiments, the rotation actuator **320** is powered by air (e.g., pneumatic, etc.), a fluid (e.g., a hydraulic cylinder, etc.), mechanically (e.g., a flywheel, etc.), or still another power source.

[0052] As shown in FIGS. **14** and **15**, the rotation actuator **320** includes a driver, shown as drive pinion **322**. The drive pinion **322** is mechanically coupled with the driven gear **314** of the slewing bearing **310**. In one embodiment, a plurality of teeth of the drive pinion **322** engage a plurality of teeth on the driven gear **314**. By way of example, when the rotation actuator **320** is engaged (e.g., powered, turned on, etc.), the rotation actuator **320** may provide rotational energy (e.g., mechanical energy, etc.) to an output shaft. The drive pinion **322** may be coupled to the output shaft such that the rotational energy of the output shaft drives (e.g., rotates, etc.) the drive pinion **322**. The rotational energy of the drive pinion **322** may be transferred to the driven gear **314** in response to the engaging teeth of both the drive pinion **322** and the driven gear **314**. The driven gear **314** thereby rotates about the vertical pivot axis **40**, while the bearing element **312** remains in a fixed position relative to the driven gear **314**.

[0053] As shown in FIGS. **1**, **2**, and **16-18**, the turntable **510** includes a first portion, shown as rotation base **512**, and a second portion, shown as side supports **514**, that extend vertically upward from opposing lateral sides of the rotation base **512**. According to an exemplary embodiment, (i) the work platform **550** is coupled to the side supports **514**, (ii) the aerial ladder assembly **700** is pivotally coupled to the side supports **514**, (iii) the control console **600** is coupled to the rotation base **512**, and (iv) the rotation base **512** is disposed within the aerial assembly recess **140** and interfaces with and is coupled to the driven gear **314** of slewing bearing **310** such that (i) the aerial assembly **500** is selectively pivotable about the vertical pivot axis **40** using the rotation actuator **320**, (ii) at least a portion of the work platform **550** and the aerial ladder assembly **700** is positioned below the roof of the front cabin **20**, and (iii) the turntable **510** is coupled rearward of the front cabin **20** and between the front axle **16** and the tandem rear axles **18** (e.g., the turntable **510** is coupled to the frame **12** such that the vertical pivot axis **40** is positioned rearward of a centerline of the front axle **16**, forward of a centerline of the tandem rear axle **18**, rearward of a rear edge of a tire of the front axle **16**, forward of a front edge of a wheel of the front axle of the tandem rear axles **18**, rearward of a front edge of a tire of the front axle **16**, forward of a rear edge of a wheel of the rear axle of the tandem rear axles **18**, etc.). Accordingly, loading from the work basket **1300**, the aerial ladder assembly **700**, and/or the work platform **550** may transfer through the turntable **510** into the torque box **300** and the frame **12**.

[0054] As shown in FIG. **12**, the rear assembly **100** includes a rotation swivel, shown as rotation swivel **316**, that includes a conduit. According to an exemplary embodiment, the conduit of the rotation swivel **316** extends upward from the pedestal **308** and into the turntable **510**. The rotation swivel **316** may couple (e.g., electrically, hydraulically, fluidly, etc.) the aerial assembly **500** with other components of the fire apparatus **10**. By way of example, the conduit may define a passageway for water to flow into the aerial ladder assembly **700**. Various lines may provide electricity, hydraulic fluid, and/or water to the aerial ladder assembly **700**, actuators, and/or the control console **600**.

[0055] According to an exemplary embodiment, the work platform **550** provides a surface upon which operators (e.g., fire fighters, rescue workers, etc.) may stand while operating the aerial assembly **500** (e.g., with the control console **600**, etc.). The control console **600** may be communicably coupled to various components of the fire apparatus **10** (e.g., actuators of the aerial ladder assembly **700**, rotation actuator **320**, water turret, etc.) such that information or signals (e.g., command signals, fluid controls, etc.) may be exchanged from the control console **600**. The information or signals may relate to one or more components of the fire apparatus **10**. According to an exemplary embodiment, the control console **600** enables an operator (e.g., a fire fighter, etc.) of the fire apparatus **10** to communicate with one or more components of the fire apparatus **10**. By way of example, the control console **600** may include at least one of an interactive display, a touchscreen device, one or more buttons (e.g., a stop button configured to cease water flow through a water nozzle, etc.), joysticks, switches, and voice command receivers. An operator may use a joystick associated with the control console **600** to trigger the actuation of the turntable **510** and/or the aerial ladder assembly **700** to a desired angular position (e.g., to the front, back, or side of fire apparatus **10**, etc.). By way of another example, an operator may engage a lever associated with the control console **600** to trigger the extension or retraction of the aerial ladder assembly **700**.

[0056] As shown in FIG. **16**, the aerial ladder assembly **700** has a plurality of nesting ladder sections that telescope with respect to one another including a first section, shown as base section **800**; a second section, shown as lower middle section **900**; a third ladder section, shown as middle section **1000**; a fourth section, shown as upper middle section **1100**; and a fifth section, shown as fly section **1200**. As shown in FIGS. **16** and **17**, the side supports **514** of the turntable **510** define a first interface, shown as ladder interface **516**, and a second interface, shown as actuator interface **518**. As shown in FIG. **16**, the base section **800** of the aerial ladder assembly **700** defines first interfaces, shown as pivot interfaces **802**, and second interfaces, shown as actuator interfaces **804**. As shown in FIGS. **16** and **17**, the ladder interfaces **516** of the side supports **514** of the turntable **510** and the pivot interfaces **802** of the base section **800** are positioned to align and cooperatively receive a pin, shown as heel pin **520**, to pivotally couple the proximal end **702** of the aerial ladder assembly **700** to the turntable **510**. As shown in FIG. **17**, the aerial ladder assembly **700** includes first ladder actuators (e.g., hydraulic cylinders, etc.), shown as pivot actuators **710**. Each of the pivot actuators **710** has a first end, shown as end **712**, coupled to a respective actuator interface **518** of the side supports **514** of the turntable **510** and an opposing second end, shown as end **714**, coupled to a respective actuator interface **804** of the base section **800**. According to an exemplary embodiment, the pivot actuators **710** are kept in tension such that retraction thereof lifts and rotates the distal end **704** of the aerial ladder assembly **700** about a lateral axis, shown as lateral pivot axis **42**, defined by the heel pin **520**. In other embodiments, the pivot actuators **710** are kept in compression such that extension thereof lifts and rotates the distal end **704** of the aerial ladder assembly **700** about the lateral pivot axis **42**. In an alternative embodiment, the aerial ladder assembly **700** only includes one pivot actuator **710**.

[0057] As shown in FIG. **16**, the aerial ladder assembly **700** includes one or more second ladders actuators, shown as extension actuators. According to an exemplary embodiment, the extension actuators **720** are positioned to facilitate selectively reconfiguring the aerial ladder assembly **700** between an extended configuration and a retracted/stowed configuration (see, e.g., FIGS. **1-3**, **16**, etc.). In the extended configuration (e.g., deployed position, use position, etc.), the aerial ladder assembly **700** is lengthened, and the distal end **704** is extended away from the proximal end **702**. In the retracted configuration (e.g., storage position, transport position, etc.), the aerial ladder assembly **700** is shortened, and the distal end **704** is withdrawn towards the proximal end **702**.

[0058] According to the exemplary embodiment shown in FIGS. **1-3** and **16**, the aerial ladder assembly **700** has over-retracted ladder sections such that the proximal ends of the lower middle section **900**, the middle section **1000**, the upper middle section **1100**, and the fly section **1200** extend forward of (i) the heel pin **520** and (ii) the proximal end of the base section **800** along the longitudinal axis **14** of the fire apparatus **10** when the aerial ladder assembly **700** is retracted and stowed. According to an exemplary embodiment, the distal end **704** of the aerial ladder assembly **700** (e.g., the distal end of the fly section **1200**, etc.) is extensible to the horizontal reach of at least 88 feet (e.g., 93 feet, etc.) and/or or a vertical reach of at least 95 feet (e.g., 100 feet, etc.). According to an exemplary embodiment, the aerial ladder assembly **700** is operable below grade (e.g., at a negative depression angle relative to a horizontal, etc.) within an aerial work envelope or scrub area. In one embodiment, the aerial ladder assembly **700** is operable in the scrub area such that it may pivot about the vertical pivot axis **40** up to 50 degrees (e.g., 20 degrees forward and 30 degrees rearward from a position perpendicular to the longitudinal axis **14**, etc.) on each side of the body **110** while at a negative depression angle (e.g., up to negative 15 degrees, more than negative 15 degrees, up to negative 20 degrees, etc. below level, below a horizontal defined by the top platform **122** of the body **110**, etc.).

[0059] According to an exemplary embodiment, the work basket **1300** is configured to hold at least one of fire fighters and persons being aided by the fire fighters. As shown in FIGS. **3**, **5**, and **10**, the work basket **1300** includes a platform, shown as basket platform **1310**; a support, shown as railing **1320**, extending around the periphery of the basket platform **1310**; and angled doors, shown as basket doors **1330**, coupled to the corners of the railing **1320** proximate the rear end **4** of the fire apparatus **10**. According to an exemplary embodiment, the basket doors **1330** are angled to correspond with the chamfered corners **120** of the body **110**.

[0060] In other embodiments, the aerial assembly **500** does not include the work basket **1300**. In some embodiments, the work basket **1300** is replaced with or additionally includes a nozzle (e.g., a deluge gun, a water cannon, a water turret, etc.) or other tool. By way of example, the nozzle may be connected to a water source (e.g., the water tank **400**, an external source, etc.) with a conduit extending along the aerial ladder assembly **700** (e.g., along the side of the aerial ladder assembly **700**, beneath the aerial ladder assembly **700**, in a channel provided in the aerial ladder assembly **700**, etc.). By pivoting the aerial ladder assembly **700** into a raised position, the nozzle may be elevated to expel water from a higher elevation to facilitate suppressing a fire.

[0061] According to an exemplary embodiment, the pump system **200** (e.g., a pump house, etc.) is a mid-ship pump assembly. As shown in FIGS. **1**, **2**, **12**, **17**, and **18**, the pump system **200** is positioned along the rear assembly **100** behind the front cabin **20** and forward of the vertical pivot axis **40** (e.g., forward of the turntable **510**, the torque box **300**, the pedestal **308**, the slewing bearing **310**, the heel pin **520**, a front end of the body **110**, etc.) such that the work platform **550** and the over-retracted portions of the aerial ladder assembly **700** overhang above the pump system **200** when the aerial ladder assembly **700** is retracted and stowed. According to an exemplary embodiment, the position of the pump system **200** forward of the vertical pivot axis **40** facilitates ease of install and serviceability. In other embodiments, the pump system **200** is positioned rearward of the vertical pivot axis **40**.

[0062] As shown in FIGS. **17-21**, the pump system **200** includes a housing, shown as pump house **202**. As shown in FIG. **17**, the pump house **202** includes a selectively openable door, shown as pump door **204**. As shown in FIGS. **18-21**, the pump system **200** includes a pumping device, shown as pump assembly **210**, disposed within the pump house **202**. By way of example, the pump assembly **210** may include a pump panel having an inlet for the entrance of water from an external source (e.g., a fire hydrant, etc.), a pump, an outlet configured to engage a hose, various gauges, etc. The pump of the pump assembly **210** may pump fluid (e.g., water, agent, etc.) through a hose to extinguish a fire (e.g., water received at an inlet of the pump house **202**, water stored in the water tank **400**, etc.). As shown in FIGS. **19-21**, the pump system **200** includes a selectively deployable (e.g., foldable, pivotable, collapsible, etc.) platform, shown as pump platform **220**, pivotally coupled to the pump house **202**. As shown in FIGS. **20** and **21**, the pump platform **220** is in a first configuration, shown as stowed configuration **222**, and as shown in FIG. **19**, the pump platform **220** is in a second configuration, shown as deployed configuration **224**.

[0063] As shown in FIGS. **1**, **2**, **4**, **6**, **7**, **10-12**, **14**, and **15**, the fire apparatus **10** includes a stability system, shown as stability assembly **1400**. As shown in FIGS. **1**, **2**, **4**, and **7**, the stability assembly **1400** includes first stabilizers, shown as front downriggers **1500**, coupled to each lateral side of the front bumper **22** at the front end **2** of the front cabin **20**. In other embodiments, the front downriggers **1500** are otherwise coupled to the fire apparatus **10** (e.g., to the front end **2** of the frame **12**, etc.). According to an exemplary embodiment, the front downriggers **1500** are selectively deployable (e.g., extendable, etc.) downward to engage a ground surface. As shown in FIGS. **1**, **2**, **4-6**, **10-12**, **14**, and **15**, the stability assembly **1400** includes second stabilizers, shown as rear downriggers **1600**, coupled to each lateral side of the rear end **4** of the frame **12** and/or the rear end **306** of the torque box **300**. According to an exemplary embodiment, the rear downriggers **1600** are selectively deployable (e.g., extendable, etc.) downward to engage a ground surface. As shown in FIGS. **1**, **2**, **4**, **6**, **7**, **10**, **12**, **14**, **15**, **17**, and **18**, the stability assembly **1400** includes third stabilizers, shown outriggers **1700**, coupled to the front end **304** of the torque box **300** between the pedestal **308** and the body **302**. As shown in FIGS. **6** and **7**, the outriggers **1700** are selectively deployable (e.g., extendable, etc.) outward from each of the lateral sides of the body **110** and/or downward to engage a ground surface. According to an exemplary embodiment, the outriggers **1700** are extendable up to a distance of eighteen feet (e.g., measured between the center of a pad of a first outrigger and the center of a pad of a second outrigger, etc.). In other embodiments, the outriggers **1700** are extendable up to a distance of less than or greater than eighteen feet.

[0064] According to an exemplary embodiment, the front downriggers **1500**, the rear downriggers **1600**, and the outriggers **1700** are positioned to transfer the loading from the aerial ladder assembly **700** to the ground. For example, a load applied to the aerial ladder assembly **700** (e.g., a fire fighter at the distal end **704**, a wind load, etc.) may be conveyed into to the turntable **510**, through the pedestal **308** and the torque box **300**, to the frame **12**, and into the ground through the front downriggers **1500**, the rear downriggers **1600**, and/or the outriggers **1700**. When the front downriggers **1500**, the rear downriggers **1600**, and/or the outriggers **1700** engage with a ground surface, portions of the fire apparatus **10** (e.g., the front end **2**, the rear end **4**, etc.) may be elevated relative to the ground surface. One or more of the wheel and tire assemblies **30** may remain in contact with the ground surface, but may not provide any load bearing support. While the fire apparatus **10** is being driven or not in use, the front downriggers **1500**, the rear downriggers **1600**, and the outriggers **1700** may be retracted into a stored position.

[0065] According to an exemplary embodiment, with (i) the front downriggers **1500**, the rear downriggers **1600**, and/or the outriggers **1700** extended and (ii) the aerial ladder assembly **700** fully extended (e.g., at a horizontal reach of 88 feet, at a vertical reach of 95 feet, etc.), the fire apparatus **10** withstands a rated tip load (e.g., rated meaning that the fire apparatus **10** can, from a design-engineering perspective, withstand a greater tip load, with an associated factor of safety of at least two, meets National Fire Protection Association ("NFPA") requirements, etc.) of at least 1,000 pounds applied to the work basket **1300**, in addition to the weight of the work basket **1300** itself (e.g., approximately 700 pounds, etc.). In embodiments where the aerial assembly **500** does not include the work basket **1300**, the fire apparatus **10** may have a rated tip load of more than 1,000 pounds (e.g., 1,250 pounds, etc.) when the aerial ladder assembly **700** is fully extended.

[0066] According to an exemplary embodiment, the tandem rear axles **18** have a gross axle weight rating of up to 48,000 pounds and the fire apparatus **10** does not exceed the 48,000 pound tandem-rear axle rating. The front axle **16** may have a 24,000 pound axle rating. Traditionally, mid-mount fire trucks have greater than a 48,000 pound loading on the tandem rear-axles thereof. However, some state regulations prevent vehicles having such a high axle loading, and, therefore, the vehicles are unable to be sold and operated in such states. Advantageously, the fire apparatus **10** of the present disclosure has a gross axle weight loading of at most 48,000 pounds on the tandem rear axles **18**, and, therefore, the fire apparatus **10** may be sold and operated in any state of the United States.

[0067] As shown in FIGS. **5** and **9**, the fire apparatus **10** has a height H. According to an exemplary embodiment, the height H of the fire apparatus **10** is at most 128 inches (i.e., 10 feet, 8 inches). In other embodiments, the fire apparatus **10** has a height greater than 128 inches. As shown in FIGS. **8** and **9**, the fire apparatus **10** has a longitudinal length L. According to an exemplary embodiment, the longitudinal length L of the fire apparatus **10** is at most 502 inches (i.e., 41 feet, 10 inches). In other embodiments, the fire apparatus **10** has a length L greater than 502 inches. As shown in FIGS. **8** and **9**, the fire apparatus **10** has a distance D_1 between the rear end **4** of the body **110** and the middle of the tandem rear axles **18** (e.g., a body rear overhang portion, etc.). According to an exemplary embodiment, the distance D_1 of the fire apparatus **10** is at most 160 inches (i.e., 13 feet, 4 inches). In other embodiments, the fire apparatus **10** has a distance D_1 greater than 160 inches. As shown in FIGS. **8** and **9**, the fire apparatus **10** has a distance D_2 between the front end **2** of the front cabin **20** (excluding the front bumper **22**) and the middle of the tandem rear axles **18**. According to an exemplary embodiment, the distance D_2 of the fire apparatus **10** is approximately twice or at least twice that of the distance D_1 (e.g., approximately 321 inches, approximately 323 inches, at least 320 inches, etc.).

[0068] As shown in FIG. **8**, the longitudinal length L of the fire apparatus **10** is compared to the longitudinal length L' of a traditional mid-mount fire apparatus **10'**. As shown in FIG. **8**, when the front axles of the fire apparatus **10** and the fire apparatus **10'** are aligned, the fire apparatus **10'** extends beyond the longitudinal length L of the fire apparatus **10** a distance Δ'. The distance Δ' may be approximately the same as the amount of the body **110** rearward of the tandem rear axles **18** of the fire apparatus **10** such that the amount of body rearward of the tandem rear axle of the fire apparatus **10'** is approximately double that of the fire apparatus **10**. Decreasing the amount of the body **110** rearward of the tandem rear axles **18** improves drivability and maneuverability, and substantially reduces the amount of damage that fire departments may inflict on public and/or private property throughout a year of operating their fire trucks.

[0069] One solution to reducing the overall length of a fire truck is to configure the fire truck as a rear-mount fire truck with the ladder assembly overhanging the front cabin (e.g., in order to provide a ladder assembly with comparable extension capabilities, etc.). As shown in FIG. **9**, the longitudinal length L of the fire apparatus **10** is compared to the longitudinal length L' of a traditional rear-mount fire apparatus **10"**. As shown in FIG. **9**, when the front axles of the fire apparatus **10** and the fire apparatus **10"** are aligned, the ladder assembly of the fire apparatus **10"** extends beyond the longitudinal length L of the fire apparatus **10** a distance Δ" such that the ladder assembly overhangs past the front cabin. Overhanging the ladder assembly reduces driver visibility, as well as rear-mount fire trucks do not provide as much freedom when arriving at a scene on where and how to position the truck, which typically requires the truck to be reversed into position to provide the desired amount of reach (e.g., which wastes valuable time, etc.). Further, the height H" of the fire apparatus **10"** is required to be higher than the height H of the fire apparatus **10** (e.g., by approximately one foot, etc.) so that the ladder assembly of the fire apparatus **10"** can clear the front cabin thereof.

Aerial Configuration

[0070] As shown in FIGS. **1-3**, the over-retracted portions of the aerial ladder assembly **700** (e.g., the proximal ends of the lower middle section **900**, the middle section **1000**, the upper middle section **1100**, the fly section **1200**, etc.) extend forward of (i.e., past) (i) the lateral pivot axis **42** defined by the heel pin **520** and (ii) the proximal end of the base section **800** (i.e., the portion of the base section **800** that is coupled to the heel pin **520**) along the longitudinal axis **14** of the fire apparatus **10** when the aerial ladder assembly **700** is retracted and stowed (e.g., such that at least one of the lower middle section **900**, the middle section **1000**, the upper middle section **1100**, the fly section **1200**, etc. spans across the lateral pivot axis **42** when the aerial ladder assembly **700** is retracted and stowed). Such over-retraction disposes the over-retracted portions of the aerial ladder assembly **700** to extend over the pump house **202** adjacent (i.e., rearward of) a rearmost wall of the front cabin **20**. In other embodiments, at least a portion of the over-retracted portions of the aerial ladder assembly **700** extend past and forward of the rearmost wall of the front cabin **20** (e.g., in an embodiment where the rearmost cab wall is angled, notched, etc.). As shown in FIGS. **1** and **2**, at least a portion of the plurality of nesting ladders sections (e.g., at least a base rail of the base section **800**, the lower middle section **900**, the middle section **1000**, the upper middle section **1100**, the fly section **1200**, etc.) of the aerial ladder assembly **700** is positioned below the top (i.e., roof) of the front cabin **20** (e.g., when the aerial ladder assembly **700** is not pivoted/raised about the lateral pivot axis **42**, etc.).

[0071] As shown in FIGS. **22-25**, (i) the body **110** of the rear assembly **100** within the aerial assembly recess **140** is shaped, (ii) the pump house **202** adjacent the aerial assembly recess **140** is shaped, (iii) the water tank **400** adjacent the aerial assembly recess **140** is shaped, and/or (iv) the outriggers **1700** extend at negative depression angle γ from the body **110** to facilitate a substantial aerial work envelope of the aerial ladder assembly **700**, shown as scrub area **730**. Such component configurations facilitate operation of the aerial ladder assembly **700** at a negative depression angle below grade (e.g., below horizontal, etc.) of up to an angle θ. According to an exemplary embodiment, the angle θ is approximately negative fifteen degrees. In other embodiments, the angle θ is greater than fifteen degrees (e.g., eighteen, twenty, etc. degrees) or less than fifteen degrees (e.g., ten, twelve, fourteen, etc. degrees). In some embodiments, the angle θ is at least greater than eight degrees.

[0072] As shown in FIG. **22**, the body **110** of the rear assembly **100** includes first angled portions, shown as angled body panels **144**, extending at a negative, downward angle within the aerial assembly recess **140**. The pump house **202** of the pump system **200** includes second angled portions, shown as angled pump house panels **206**, extending at a negative, downward angle within the aerial assembly recess **140**. As shown in FIGS. **22** and **24**, the water tank **400** has a wall, shown as frontmost wall **402**, adjacent the aerial assembly recess **140**. The frontmost wall **402** includes a pair of third angled portions, shown as angled wall portions **406**, extending from a wall portion perpendicular to the longitudinal axis **14**, shown as perpendicular wall portion **404**, at a rearward angle (e.g., towards the rear end **4** of the fire apparatus **10**, etc.). According to an exemplary embodiment, the angle γ of the outriggers **1700** is approximately in the range of negative eight to negative twelve degrees relative to a horizontal axis. In other embodiments, the angle γ is greater than twelve degrees (e.g., fifteen degrees, etc.) or less than eight degrees (e.g., five degrees, zero degrees, etc.).

[0073] According to an exemplary embodiment, the angled body panels **144** of the body **110**, the angled pump house panels **206** of the pump house **202**, the angled wall portions **406** of the water tank **400**, and/or the angle γ of the outriggers **1700** facilitate operating the aerial ladder assembly within the scrub area **730** up to the angle θ. As shown in FIGS. **23** and **24**, the aerial ladder assembly **700** is operable within the scrub area **730** below grade (e.g., at any angle below zero degrees up to angle θ, etc.) about the vertical pivot axis **40** up to (i) an angle α forward of the aerial ladder assembly **700** being perpendicular to the longitudinal axis **14** and (ii) an angle β rearward of the aerial ladder assembly **700** being perpendicular to the longitudinal axis **14**. According to an exemplary embodiment, the angle α is approximately twenty degrees. In other embodiments, the angle α is greater than twenty degrees (e.g., twenty-two, twenty-five, thirty, etc. degrees) or less than twenty degrees (e.g., ten, fifteen, eighteen, etc. degrees). According to an exemplary embodiment, the angle β is approximately thirty degrees. In other embodiments, the angle β is greater than thirty degrees (e.g., thirty-two, thirty-five, etc. degrees) or less than thirty degrees (e.g., fifteen, twenty, twenty-five, etc. degrees). The scrub area **730** may therefore have a total sweep angle (e.g., the aggregate of the angle α and the angle (, etc.) of approximately fifty degrees. In other embodiments, the sweep angle of the scrub area **730** is at least more than fifteen degrees. In still other embodiments, the sweep angle of the scrub area **730** is at least more than thirty degrees.

[0074] As shown in FIG. **25**, the aerial ladder assembly **700** is oriented to extend perpendicularly from the body **110** of the rear assembly **100** (e.g., the aerial ladder assembly

700 is perpendicular relative to the longitudinal axis 14, etc.) and is positioned below grade at the angle θ (e.g., negative fifteen degrees, etc.). When configured in such a position, the aerial ladder assembly 700 extends from the side of the body 110 a distance D_3, and the basket platform 1310 of the work basket 1300 is positioned at a height h above a ground surface while none of the plurality of nesting ladder sections (e.g., the lower middle section 900, the middle section 1000, the upper middle section 1100, the fly section 1200, etc.) are extended (e.g., the lower middle section 900, the middle section 1000, the upper middle section 1100, and the fly section 1200 are over-retracted relative to the base section 800 and the heel pin 520, etc.). According to an exemplary embodiment, being able to operate at the angle θ and the over-retracting configuration of the plurality of nesting ladder sections of the aerial ladder assembly 700 facilitate accessing the work basket 1300 from the ground surface without requiring the extension of the aerial ladder assembly 700. The height h of the basket platform 1310 is at most 20.3 inches, according to an exemplary embodiment (e.g., meeting the maximum step height limit as set by NFPA regulations, without requiring extension of the aerial ladder assembly 700, etc.). In some embodiments, the height h is less than 20.3 inches (e.g., in embodiments where the stability assembly 1400 of the fire apparatus 10 has a leaning capability, etc.). According to an exemplary embodiment, the distance D_3 is approximately 19.5 feet. In other embodiments, the distance D_3 is greater than 19.5 feet (e.g., 20 feet, 22 feet, in embodiments with a longer aerial ladder assembly 700, etc.) or less than 19.5 feet (e.g., 19 feet, 18.5 feet, etc.).

[0075] As shown in FIG. 26, the aerial ladder assembly 700 is pivotable about the lateral pivot axis 42 to reposition the aerial ladder assembly 700 at a plurality of different positions including a horizontal position, shown as horizontal set-back configuration 740, a below grade position, shown as blitz configuration 742, and a plurality of above grade positions, shown as raised configurations 744. As shown in FIG. 26, when the aerial ladder assembly 700 is arranged in the horizontal set-back configuration 740 and the longitudinal axis 14 of the fire apparatus 10 is positioned parallel or substantially parallel with a fire scene (e.g., a house, a building, an apartment, etc.), the aerial ladder assembly 700 extends from the side of the body 110 a set-back distance D_4. According to an exemplary embodiment, the set-back distance D_4 is approximately twenty feet. In other embodiments, the set-back distance D_4 is greater than twenty feet (e.g., twenty-seven feet, in an embodiment where the aerial ladder assembly 700 includes a side-mounted e-trac versus a rung-mounted e-trac, etc.) or less than twenty feet (e.g., in embodiments where the fire apparatus 10 includes a shorter aerial ladder assembly 700, in embodiments where the aerial ladder assembly 700 does not include the work basket 1300, etc.; fifteen, sixteen, seventeen, eighteen, nineteen, etc. feet).

[0076] As shown in FIG. 26, when the aerial ladder assembly 700 is arranged in the blitz configuration 742, the aerial ladder assembly 700 is oriented at a negative depression angle (e.g., up to the angle θ, etc.) such that the work basket 1300 is positioned substantially close to the ground surface and adjacent the fire scene (e.g., the first level of a building, a store front, etc.). In the blitz configuration 742, the work basket 1300 may be extended from the rear assembly 100 by pivoting the aerial ladder assembly 700 about the vertical pivot axis 40 toward the fire scene and then pivoting aerial ladder assembly 700 about the lateral pivot axis 42 such that the work basket 1300 clears any obstacles 750 (e.g., cars, etc.) positioned in front of the fire scene. A turret, shown as water turret 1340, that is coupled to the work basket 1300 may be manipulated (e.g., using a user input device of the fire apparatus 10, the control console 600, etc.) to expel water or another fire surprising agent from the water tank 400 or other source (e.g., a fire hydrant, an agent tank, etc.) into the first level of the fire scene upward at the ceiling thereof to expel a fire therein (e.g., to prevent a fire from spreading to the upper levels of the building, etc.). In other embodiments, the water turret 1340 is otherwise positioned (e.g., coupled to the distal end of the fly section 1200, in embodiments where the aerial ladder assembly 700 does not include the work basket 1300, etc.).

[0077] As shown in FIG. 26, when the aerial ladder assembly 700 is arranged in the raised configurations 744, the aerial ladder assembly 700 is oriented at a positive angle such that the work basket 1300 is positioned above the fire apparatus 10. To extend further in the vertical direction, the plurality of nesting sections of the aerial ladder assembly 700 may begin to be extended. In order to un-bed the aerial ladder assembly 700 (e.g., pivot the aerial ladder assembly 700 upward, etc.), the over-retracted portions of the aerial ladder assembly 700 may need to be extended past the heel pin 520. Such may require that the fire apparatus 10 be set back a distance slightly further than the set-back distance D_4 (e.g., twenty-four feet, etc.).

[0078] According to the exemplary embodiment shown in FIG. 27, a control system, shown as fire apparatus control system 2000, for the fire apparatus 10 includes a controller 2010. In one embodiment, the controller 2010 is configured to selectively engage, selectively disengage, control, and/or otherwise communicate with components of the fire apparatus 10. As shown in FIG. 27, the controller 2010 is coupled to the rotation actuator 320, the pivot actuator(s) 710, the extension actuator(s) 720, the water turret 1340, basket actuator(s) 1350 positioned to manipulate the work basket 1300 (e.g., a rotation actuator, a pivot actuator, a lift actuator, an extension actuator, etc.) relative to the distal end of the fly section 1200 of the aerial ladder assembly 700, one or more basket sensors, shown as sensors 2016, and a user input/output ("I/O") device 2020. In other embodiments, the controller 2010 is coupled to more or fewer components (e.g., the stability assembly 1400, etc.). By way of example, the controller 2010 may send and/or receive signals with the rotation actuator 320, the pivot actuator(s) 710, the extension actuator(s) 720, the water turret 1340, the basket actuator(s) 1350, the sensors 2016, and/or the user I/O device 2020.

[0079] The controller 2010 may be implemented as a general-purpose processor, an application specific integrated circuit (ASIC), one or more field programmable gate arrays (FPGAs), a digital-signal-processor (DSP), circuits containing one or more processing components, circuitry for supporting a microprocessor, a group of processing components, or other suitable electronic processing components. According to the exemplary embodiment shown in FIG. 27, the controller 2010 includes a processing circuit 2012 and a memory 2014. The processing circuit 2012 may include an ASIC, one or more FPGAs, a DSP, circuits containing one or more processing components, circuitry for supporting a microprocessor, a group of processing components, or other suitable electronic processing components. In some embodiments, the processing circuit **2012** is configured to execute computer code stored in the memory **2014** to facilitate the activities described herein. The memory **2014** may be any volatile or non-volatile computer-readable storage medium capable of storing data or computer code relating to the activities described herein. According to an exemplary embodiment, the memory **2014** includes computer code modules (e.g., executable code, object code, source code, script code, machine code, etc.) configured for execution by the processing circuit **2012**. In some embodiments, controller **2010** represents a collection of processing devices (e.g., servers, data centers, etc.). In such cases, the processing circuit **2012** represents the collective processors of the devices, and the memory **2014** represents the collective storage devices of the devices.

[0080] According to an exemplary embodiment, the sensors **2016** include one or more sensors positioned about the aerial ladder assembly **700**, the work basket **1300**, and/or any other component of the fire apparatus **10** to acquire information of data relating to the operation of the fire apparatus **10** and the one or more components thereof. The sensors **2016** may include any type of distance, proximity, image, and/or object sensors, such as one or more ultrasonic sensors, laser sensors, visible light cameras, full-spectrum cameras, LIDAR cameras/sensors, radar sensors, infrared cameras, image sensors (e.g., charged-coupled device (CCD), complementary metal oxide semiconductor (CMOS) sensors, etc.), or any other type of suitable distance sensor, proximity sensor, or imaging device. Data captured by or acquired using the sensors **2016** may include, for example, data used to determine a distance that the aerial lift assembly **700**, the work basket **1300**, and/or any other component of the fire apparatus **10** are from a ground surface, object, etc. In some embodiments, the data captured by the sensors **2016** is used to detect objects near or around the aerial lift assembly **700**, the work basket **1300**, and/or any other component of the fire apparatus **10**. In some embodiments, the data captured by the sensors **2016** is used to determine a state in which the aerial lift assembly **700** and/or any other component of the fire apparatus **10** are operating. By way of example, the sensors **2016** may be configured to acquire data to facilitate monitoring operation of the extension actuators **720**, and such data may be used to determine whether the aerial lift assembly **700** is in an extended position, a retracted position, any other position therebetween, and/or whether the aerial lift assembly **700** is in the process of extending or retracting. By way of another example, the sensors **2016** may be configured to acquire data to facilitate monitoring an orientation of the aerial lift assembly **700** including a decline or depression angle, a rotation angle, and/or incline angle of the aerial lift assembly **700**.

[0081] The sensors **2016** may transmit a sensor signal to the controller **2010** indicative of the data captured by the sensors **2016**. The controller **102** may be configured to make determinations (e.g., determine a height that the work basket **1300** is from the ground surface, determine a state in which the fire apparatus **10** is operating, determine a position of a detected object relative to the work basket **1300**, etc.) and control operation (e.g., generate control signals) of one or more components of the fire apparatus **10** (e.g., rotation actuator **320**, the pivot actuator(s) **710**, the extension actuator(s) **720**, the water turret **1340**, the basket actuator(s) **1350**, the user I/O device **2020**, etc.) based on the sensor signal transmitted by the sensors **2016** and indicative of the data captured by the sensors **2016**.

[0082] In one embodiment, the user I/O device **2020** includes a display and an operator input. The display may be configured to display a graphical user interface, an image, an icon, and/or still other information. In one embodiment, the display includes a graphical user interface configured to provide general information about the fire apparatus **10** (e.g., vehicle speed, fuel level, warning lights, battery level, etc.). The graphical user interface may also be configured to display a current position of the aerial ladder assembly **700** (e.g., a distance from the body **110**), a current position of the work basket **1300** (e.g., a height from a ground surface), a current position of the turntable **510**, an orientation of the fire apparatus **10** (e.g., an angle relative to a ground surface, etc.), and/or still other information relating to the fire apparatus **10** and/or the aerial assembly **500** based on the sensor signal transmitted by the sensors **2016** and indicative of the data captured by the sensors **2016**. The user I/O device **2020** may be or include the control console **600**, a user interface within the front cabin **20**, a user interface in the work basket **1300**, a user interface on the side of the body **110**, and/or a portable device wirelessly connected to the controller **2010** (e.g., a mobile device, a smartphone, a tablet, etc.).

[0083] The operator input may be used by an operator to provide commands to at least one of the rotation actuator **320**, the pivot actuator(s) **710**, the extension actuator(s) **720**, the water turret **1340**, and the basket actuator(s) **1350**. The operator input may include one or more buttons, knobs, touchscreens, switches, levers, joysticks, pedals, a steering wheel, or handles. The operator input may facilitate manual control of some or all aspects of the operation of the fire apparatus **10**. It should be understood that any type of display or input controls may be implemented with the systems and methods described herein.

[0084] According to an exemplary embodiment, the controller **2010** is configured to limit or prevent activation of the pivot actuators **710** while the proximal ends of the plurality of nesting ladder sections of the aerial ladder assembly **700** are over-retracted beyond the heel pin **520**. By way of example, the controller **2010** may be configured to automatically extend the plurality of nesting ladder sections forward until the proximal ends of each extends along the base section **800** beyond the heel pin **520** (e.g., in response to a lift command while the ladder sections are over-retracted), and then begin pivoting the aerial ladder assembly about the lateral pivot axis **42** and/or continue extending the plurality of nesting ladder sections (e.g., if an extension command is being provided by an operator using the user I/O device **2020**, to limit or prevent the over-retracted portions from pivoting into the work platform **550**, etc.).

[0085] As shown in FIG. **28**, the aerial ladder assembly **700** is oriented to extend laterally (e.g., perpendicularly, to the side at an angle, etc.) from the body **110** of the rear assembly **100** (e.g., the aerial ladder assembly **700** is perpendicular relative to the longitudinal axis **14**, etc.) and is positioned below grade at the angle θ (e.g., negative fifteen degrees, etc.). As shown in FIG. **28**, the aerial ladder assembly **700** is positioned in an extended position, such that one or more of the plurality of nesting ladder sections (e.g., the lower middle section **900**, the middle section **1000**, the upper middle section **1100**, the fly section **1200**, etc.), collectively shown as section **2100**, are at least partially extended (e.g., relative to a stowed position). Stated another way, the aerial ladder assembly **700** is in a lengthened or extended configuration such that the distal end **704** is extended further away from the proximal end **702** relative to when in the retracted configuration. Stated yet another way, at least a portion of at least one of the lower middle section **900**, the middle section **1000**, the upper middle section **1100**, or the fly section **1200** is extended from the over-retracted nesting positions shown in FIG. **16**.

[0086] As shown in FIG. **28**, the aerial ladder assembly **700** is arranged in the extended position or configuration, and extends from the side of the body **110** a distance D_5. The basket platform **1310** of the work basket **1300** is positioned at a height h_1 above a ground surface when the aerial ladder assembly **700** is arranged in the extended configuration. In such a configuration, the height h_1 is less than the height h, and the distance D_5 is greater than the distance D_3. In other words, when the aerial ladder assembly **700** is (i) positioned below grade at the angle θ and (ii) in the extended position or configuration (e.g., shown in FIG. **28**), the basket platform **1310** of the work basket **1300** is closer to the ground surface when compared to the position of the basket platform **1310** of the work basket **1300** relative to the ground surface when the aerial ladder assembly **700** is (i) positioned below grade at the angle θ and (ii) in the retracted position or configuration (e.g., shown in FIG. **25**). Similarly, when the aerial ladder assembly **700** is (i) positioned below grade at the angle θ and (ii) in the extended position or configuration (e.g., shown in FIG. **28**), the aerial ladder assembly **700** and the work basket **1300** are positioned farther away (e.g., in a lateral direction) from the body **110** when compared to the position of the aerial ladder assembly **700** and the work basket **1300** relative to the body **110** when the aerial ladder assembly **700** is (i) positioned below grade at the angle θ and (ii) in the retracted position or configuration (e.g., shown in FIG. **25**).

[0087] During operations of the aerial assembly **500**, such as (i) extension and retraction of the aerial ladder assembly **700** by way of the extension actuator **720**, (ii) manipulation of the work basket **1300** by way of the basket actuator **1350**, (iii) rotation of the aerial ladder assembly **700** by way of the pivot actuator **710**, and/or (iv) rotation of the aerial assembly **500** about the vertical pivot axis **40** by way of the rotation actuator **320**, the sensors **2016** are configured to acquire data to facilitate monitoring (i) a position of the aerial ladder assembly **700** and the work basket **1300** and/or (ii) the area surrounding the fire apparatus **10**. The sensor data gathered by the sensors **2016** may be used by the controller **2010** to control one or more components of the aerial assembly **700** (e.g., the section **2100**) and the work basket **1300** such that such components do not unintentionally contact the ground surface or one or more objects (e.g., a tree, a portion of a building, a telephone pole, a person, construction equipment, a rock, a parking block, etc.) in the surrounding area to prevent damaging the fire apparatus **10**, the aerial ladder assembly **700**, and/or the objects in the surrounding area.

[0088] As shown in FIGS. **29** and **30**, a system (e.g., a sensor system, a grounding mitigation system, a collision avoidance system, a basket sensor system, an aerial assembly sensor system), shown as monitoring system **2104**, includes one or more of the sensors **2016** variously positioned about the work basket **1300** and the controller **2010**. As shown in FIG. **29**, the sensors **2016** are variously positioned along a bottom surface **2110** of the work basket **1300** (e.g., a bottom surface of the basket platform **1310**). As shown in FIG. **30**, the sensors **2016** are additionally or alternatively positioned along a sidewall **2112** of the work basket **1300** (e.g., an outer surface of the sidewall **2112**, an inner surface of the sidewall **2112**) and/or the basket doors **1320**. In some embodiments, the sensors **2016** are additionally or alternatively positioned along the basket platform **1310** (e.g., an outer facing edge thereof), the railing **1320**, and/or any other component of the work basket **1300** to facilitate monitoring an operation and a position thereof relative to the surrounding environment. Additionally or alternatively, one or more of the sensors **2016** are variously positioned about the aerial ladder assembly **700** (e.g., the base section **800**, the lower middle section **900**, the middle section **1000**, the upper middle section **1100**, the fly section **1200**, etc.) to facilitate monitoring an operation and a position thereof relative to the surrounding environment. Additionally or alternatively, one or more of the sensors **2016** are positioned along the front cabin **20** and/or the rear assembly **100** to facilitate monitoring an operation and a position of the aerial ladder assembly **700** relative to the surrounding environment. Generally, the monitoring system **2104** is configured to (i) monitor a position of the work basket **1300** and/or the section **2100** relative to the ground surface and/or one or more objects detected around the work basket **1300** and (ii) control operation of one or more components of the fire apparatus **10** to prevent the work basket **1300** and/or the section **2100** from inadvertently contacting the ground surface and/or the one or more detected objects.

[0089] The sensors **2016** may be arranged in an array (e.g., a pattern, rows, etc.) along the bottom surface **2110** of the work basket **1300** to acquire sensor data indicative of the position of the work basket **1300** relative to the ground surface and/or one or more objects. By way of example, one of the sensors **2016** may be positioned along the bottom surface **2110** at each of the four corners of the work basket **1300**. In some embodiments, more or fewer than four sensors **2016** are positioned along the bottom surface **2110** (e.g., two sensors **2016**, six sensors **2016**, at the corners and at the center, etc.). The sensors **2016** may be arranged along the bottom surface **2110** of the work basket **1300** such that the sensors **2016** facilitate monitoring a substantial entirety of an area under the work basket **1300** when the work basket **1300** is positioned at or above a certain vertical height (e.g., 6 feet, 4 feet, 3 feet, 10 feet, etc.) from the ground surface. As used herein, the phrase "array of sensors **2016**" refers to a combination of one or more of the sensors **2016** configured to facilitate monitoring the aerial ladder assembly **700** and the one or more components included therein and the area surrounding the aerial ladder assembly **700**. In some embodiments, the sensors **2016** are arranged along the bottom surface **2110** of the work basket **1300** such that substantially the entire area under the work basket **1300** is within a field of view of the array of sensors **2016** when the work basket **1300** is at least 6 feet above the ground surface below the work basket **1300**. In some embodiments, the sensors **2016** are arranged along the bottom surface **2110** of the work basket **1300** such that substantially the entire area under the work basket **1300** is within a field of view of the array of sensors **2016** when the work basket **1300** is at least 3 feet above the ground surface below the work basket **1300**.

[0090] As shown in FIG. **31**, when the work basket **1300** is positioned at or above a height h_2 from the ground surface, substantially the entire area under the work basket **1300** is within a field of view ("FOV") (e.g., a sensing window), shown as FOV **2120**, of the array of sensors **2016**. In some embodiments, the height h_2 at or above which the substantial entirety of the area under the work basket **1300** is within the FOV **2120** of the sensors **2016** is 6 feet. In other embodiments, the height h_2 at or above which the substantial entirety of the area under the work basket **1300** is within the FOV **2120** of the sensors **2016** is greater or less than 6 feet (e.g., 3 feet, 4 feet, 10 feet, etc.). As shown in FIGS. **31** and **32**, an object (e.g., a tree, a telephone pole, a person, construction equipment, a rock, a roof of a building, etc.), shown as object **2124**, is disposed on the ground surface below the work basket **1300**. In some embodiments, the object **2124** is otherwise positioned relative to the aerial ladder assembly **700** and the work basket **1300**. According to an exemplary embodiment, if the object **2124** (or a surface such as the ground surface) is within the FOV **2120** of the sensors **2016**, then the sensors **2016** can sense the object **2124**. By way of example, when the work basket **1300** is positioned at or above the height h_2 from the object **2124** (e.g., from a top surface, a highest point, etc.) of the object **2124** located below the work basket **1300**, substantially the entire area of the object **2124** under the work basket **1300** may be within the FOV **2120** of the array of sensors **2016** (e.g., sensible, detectable, etc., by the array of sensors **2016**). In some embodiments, the area of the object **2124** under the work basket **1300** extends beyond (e.g., outside of) the area under the work basket **1300**. In such an embodiment, the work basket **1300** may need to be raised above the height h_2 or otherwise repositioned such that the substantial entirety of the object **2124** is within the FOV **2120**.

[0091] As shown in FIGS. **31** and **32**, the FOV **2120** of the sensors **2016** is conically shaped such that the sensors **2016** are positioned at an apex of the conical shape of the FOV **2120** and the FOV **2120** extends outward in all directions from the sensor **2016** within an angle defined by the conical shape. The angle defined by the conical shape of the FOV **2120** and the height of the work basket **1300** may determine the width of the FOV **2120**. By way of example, a first respective sensor **2016** having an FOV **2120** with a first angle can monitor a larger area compared to a second respective sensor **2016** having an FOV **2120** with a second angle narrower than the first angle. In some embodiments, when the work basket **1300** is positioned at or above a height h_2 from the ground surface, the FOV **2120** of the sensors **2016** extends beyond the area below the work basket **1300** such that the sensors **2016** can monitor the area surrounding the work basket **1300** (e.g., an area of the ground surface that is larger than the area of the ground surface directly below the work basket **1300**). In some embodiments, the FOV **2120** of the sensors **2016** is otherwise suitably shaped (e.g., cuboidally, pyramidally, cylindrically, etc.) to monitor the area surrounding the work basket **1300**.

[0092] As shown in FIG. **32**, the work basket **1300** is positioned at a height h_3 from the ground surface. According to an exemplary embodiment, the height h_3 is less than the height h_2 (e.g., less than 6 feet, less than 10 feet, less than 4 feet, less than 3 feet, etc.). In other words, the work basket **1300** is positioned closer to the ground surface and/or a top surface of the object **2124** at height h_3 when compared to the position of the work basket **1300** at height h_2. In such a configuration (e.g., when the work basket **1300** is positioned below the height h_2, when the work basket **1300** is positioned at height h_3), at least a portion of the area below the work basket **1300** may fall outside of the FOV **2120** of the sensors **2016** positioned along the bottom surface **2110** of the work basket **1300**. In other words, as the work basket **1300** is positioned closer to the ground surface and/or a top surface of the object **2124** (e.g., below the height h_2), the area sensed and monitored by the sensors **2016** may decrease.

[0093] The data captured by the sensors **2016** may include, for example, data that may be used to detect (i) the presence or absence of the object **2124** and/or (ii) a location or position of the object **2124** relative to the fire apparatus **10** and the components thereof (e.g., the work basket **1300**, the section **2100**, etc.). By way of example, the controller **2010** may receive and process data from the sensors **2016** to detect (i) the presence or absence of the object **2124** and/or (ii) a location or position of the object **2124** relative to the fire apparatus **10** and the components thereof (e.g., the work basket **1300**, the section **2100**, etc.). In response to a detection of the object **2124** under the work basket **1300**, based on the sensor data acquired by the sensors **2016**, and/or another object **2124**, such as a tree, within the surrounding environment of the fire apparatus **10**, the object **2124** may be represented as a point cloud indicative of the position and orientation of the object **2124** relative to the sensors **2016** and the work basket **1300** and/or section **2100**. By way of example, the sensors **2016** may emit one or more signals (e.g., radio waves, laser beams, etc.) and sense the intensity of the reflections from the points where the signals reflected off surfaces of the object **2124**.

[0094] Based on this data (e.g., point cloud data), the position and orientation of the object **2124** relative to the sensors **2016** and the work basket **1300** may be determined. The point cloud data may be stored in the memory **2014** and used to determine the position and orientation of the object **2124** relative to the sensors **2016** and the work basket **1300** and/or section **2100** when the work basket **1300** and/or the second **2100** are repositioned (e.g., when the work basket **1300** is positioned at a height that is different from the height at which the point cloud data was acquired, when the aerial ladder assembly **700** is positioned at an angle (e.g., angle θ) that is different from an angle at which the point cloud data was acquired, etc.). In some embodiments, the point cloud data is used to generate a graphical representation (e.g., a two-dimensional representation, a three-dimensional representation) of the object **2124** to be displayed by the user I/O device **2020**. In some embodiments, the raw point cloud data (e.g., coordinates, distances, angles, etc.) of the object is displayed by the I/O device **2020**. In some embodiments, the sensors **2016** are configured to capture the point cloud data at a predetermined frequency (e.g., every second, every 500 milliseconds, etc.) such that the graphical representation and the raw point cloud data of the object **2124** are indicative of the current (e.g., real-time) position and orientation of the object **2124** relative to the work basket **1300**.

[0095] As shown in FIG. **32**, the work basket **1300** is positioned at a height below the height h_2 (e.g., at the height h_3) such that at least a portion of the area below the work basket **1300** is outside of the FOV **2120** of the sensors **2016**, and therefore is not being sensed (e.g., actively sensed) by the sensors **2016**. As shown in FIG. **32**, at least a portion of the object **2124** is positioned within the area below the work basket **1300** that is outside of the FOV **2120** of the sensors **2016**, and therefore is not being sensed (e.g., actively sensed) by the sensors **2016**. The controller **2010** may retrieve the last stored point cloud data (e.g., from the memory **2014**) associated with the position and orientation of the portion of the object **2124** that is positioned within the area below the work basket **1300** that is outside of the FOV **2120** of the sensors **2016** to determine the position and orientation of the object **2124** relative to the work basket **1300**. As discussed in greater detail below, the controller **2010** may control operation of one or more components of the fire apparatus **10** based on the retrieved point cloud data of the object **2124** to prevent inadvertent contact between the object **2124** and the fire apparatus **10**.

[0096] As shown in FIG. **33**, one or more sensors **2016** are positioned along the bottom surface **2110** of the work basket **1300**. The work basket **1300** is positioned at a height h_4 from the ground surface. As shown in FIG. **33**, the sensors **2016** have a sensing window, shown as FOV **2128**, configured to extend in a direction substantially perpendicular to the surface (e.g., the bottom surface **2110**) to which the sensors **2016** are coupled. In some embodiments, the FOV **2128** of the sensors **2016** is cylindrical. In such embodiments, the sensors **2016** may be configured to acquire distance data that may be used to determine the height h_4 of the work basket **1300** relative to the ground surface. In some embodiments, the field of view of the sensors **2016** is adjustable between the FOV **2120**, the FOV **2128**, and any other field of view therebetween. In such embodiments, the field of view of the sensors **2016** may be set to the FOV **2120** during object detection operations and set to the FOV **2128** during distance sensing operations. In other embodiments, the field of view of the sensors **2016** is not adjustable. In such embodiments, a first subset of the sensors **2016** may have a conical field of view (e.g., FOV **2120**) and a second subset of sensors **2016** may have a cylindrical field of view (e.g., FOV **2128**). In yet other embodiments, the field of view of the sensors **2016** is not adjustable such that each sensor **2016** of the array of sensors **2016** has the FOV **2120** and is configured to collect data used for both object detection and distance sensing.

[0097] According to an exemplary embodiment, the data (e.g., the point cloud data, the distance data) captured by the sensors **2016** includes, for example, data used to determine a distance (e.g., the height h_2, the height h_3, the height h_4, a horizontal distance, etc.) that the aerial lift assembly **700**, the work basket **1300**, and/or any other component of the fire apparatus **10** are from the ground surface and/or the object **2124**. By way of example, the controller **2010** may receive and process data from the sensors **2016** to determine a distance that the aerial lift assembly **700**, the work basket **1300**, and/or any other component of the fire apparatus **10** are from the ground surface and/or the object **2124**. In some embodiments, the data is displayed by the user I/O device **2020**. In some embodiments, the data captured by the sensors **2016** is used to determine a slope of the ground surface. In such an embodiment, the data captured by the sensors **2016** may be used to calculate a grade of the slope (e.g., an angle of the ground surface). By way of example, if one or more of the distances is determined to be different, a determination may be made by the controller **2010** that the ground surface is sloped. By way of another example, if a measured distance between the sensors **2016** and the ground surface is substantially the same for all sensors **2016**, a determination may be made by the controller **2010** that the ground surface is substantially flat.

[0098] According to an exemplary embodiment, the controller **2010** is configured to control operation of one or more components of the fire apparatus **10** based on the position (e.g., orientation, distance, etc.) of the aerial lift assembly **700**, the section **2100**, the work basket **1300**, and/or any other component of the fire apparatus **10** relative to the ground surface and/or the object **2124**. In some embodiments, the controller **2010** is configured to control operation of one or more components of the fire apparatus **10** based on a position range (e.g., a range of heights from the ground surface and/or the object **2124**) in which the work basket **1300** and/or the section **2100** are being operated and/or are positioned. When the controller **2010** determines, based on the sensor data, that the work basket **1300** or the end of the section **2100** is positioned and/or operating within a first range (e.g., greater than a first threshold distance, above a first threshold height, etc.), the controller **2010** may facilitate operating the fire apparatus **10** in a first mode of operation. In the first mode of operation, operation of the rotation actuator **320**, the pivot actuator **710**, the extension actuator **720**, the water turret **1340**, the basket actuator **1350**, and/or any other component of the fire apparatus **10** (e.g., the engine **60**, a driveline, a suspension system, a braking system, etc.) is unrestricted (e.g., normal operation of the fire apparatus **10** is permitted). In some instances (e.g., when the work basket **1300** is lifted high into the air), the sensors **2016** may be unable to record data indicative of a position of the work basket **1300** relative to the ground surface and/or the object **2124** because the work basket **1300** is positioned far enough away therefrom. In such instances, the controller **2010** may permit operation of the fire apparatus **10** in the first mode of operation. In some embodiments, the first threshold distance or height of the first range may be the height h_2, such that the controller **2010** facilitates normal, unrestricted operation of the fire apparatus **10** when the work basket **1300** is positioned at a height equal to or greater than the height h_2 relative to the ground surface and/or the object **2124**. In other embodiments, the first threshold distance or height is a height that is greater or less than the height h_2 (e.g., 3 feet, 1 meter, 4 feet, 8 feet, 10 feet, etc.). In some embodiments, in response to the controller **2010** permitting operation of the fire apparatus **10** in the first mode of operation, the user I/O device **2020** provides an indication (e.g., displays a warning message, flashes a light, emits an audible sound such as a ring, message, tone, or alarm, etc.) indicative of the fire apparatus **10** operating in the first mode of operation.

[0099] In some embodiments, the controller **2010** determines, based on the sensor data, that the work basket **1300** is positioned and/or operating within a second range (e.g., less than the first threshold distance and greater than a second threshold distance, below the first threshold height and above a second threshold height, etc.), the controller **2010** is configured to at least partially limit operation of the fire apparatus **10** in a second mode of operation and/or provide a warning (e.g., visually, audibly, in a tactile manner, etc.). In the second mode of operation, operation of the rotation actuator **320**, the pivot actuator **710**, the extension actuator **720**, the water turret **1340**, the basket actuator **1350**, and any other component of the fire apparatus **10** may be limited. By way of example, the controller **2010** may limit operation of the pivot actuator **710** such that the aerial ladder assembly **700** cannot exceed a threshold speed (e.g., rotational speed) about the lateral pivot axis **42** (e.g., the speed is decreased to 25% of full speed, the power supplied to the pivot actuator **710** is decreased by 75%, etc.). By way of another example, in the second mode of operation, the controller **2010** may limit the speed at which the extension actuator **720** can extend the aerial ladder assembly **700** (e.g., extend the lower middle section **900**, the middle section **1000**, the upper middle section **1100**, and/or the fly section **1200**) (e.g., decreased to 50% of full speed, the power supplied to the extension actuator **720** is decreased by 50%, etc.). By way of yet another example, in the second mode of operation, the controller **2010** may limit operation of one or more other components or systems of the fire apparatus **10**. In some embodiments, the second threshold distance or height of the second range is a height below the height h_2 (e.g., at the height h_3) where at least a portion of the area below the work basket **1300** and/or at least a portion of the object **2124** is outside of the FOV **2120** of the sensors **2016**, and therefore not being actively sensed by the sensors **2016**. In other embodiments, the second threshold distance or height is a different distance or height relative to the ground surface and/or the object **2124** that is less than the first threshold height (e.g., 6 inches, 1 foot, 3 feet, etc.). In some embodiments, in response to the controller **2010** limiting operation of the fire apparatus **10** in the second mode of operation or prior to limiting operating in the second mode of operation (e.g., the second threshold height is being approached), the user I/O device **2020** provides an indication (e.g., displays a warning message, flashes a light, emits an audible sound such as a ring, message, tone, or alarm, etc.) indicative of the fire apparatus **10** operating in the second mode of operation or that operation will start to be limited to due the close proximity to the ground surface or the object **2124**.

[0100] In some embodiments, the controller **2010** determines, based on the sensor data, that the work basket **1300** is positioned and/or operating within a third range (e.g., less than the second threshold distance and not contacting the ground surface and/or the object **2124**, below the second threshold height and above the ground surface and/or the object **2124**, etc.), the controller **2010** is configured to further limit operation of the fire apparatus **10** in a third mode of operation more limiting (e.g., restrictive) than the second mode of operation. In the third mode of operation, operation of the rotation actuator **320**, the pivot actuator **710**, the extension actuator **720**, the water turret **1340**, the basket actuator **1350**, and any other component of the fire apparatus **10** may be inhibited (e.g., prevented, stopped, halted, etc.). By way of example, in the third mode of operation, the controller **2010** may inhibit operation of the pivot actuator **710** to prevent rotation of the aerial ladder assembly **700** about the lateral pivot axis **42** in a direction towards the ground surface and/or the object **2124** (e.g., prevented from rotating the aerial ladder assembly **700** such that the depression angle θ is not able to be increased and the work basket **1300** cannot move closer towards the ground surface and/or the object **2124**). By way of another example, in the third mode of operation, the controller **2010** may inhibit operation of the extension actuator **720** to prevent the aerial ladder assembly **700** from extending (e.g., extending the lower middle section **900**, the middle section **1000**, the upper middle section **1100**, and/or the fly section **1200** further away from the body **110**). By way of yet another example, in the third mode of operation, the controller **2010** may further limit or prevent operation of one or more other components or systems of the fire apparatus **10**. In some embodiments, the third range is a range of distances or heights between the second threshold distance or height of the second range and the ground surface and/or the object **2124** (e.g., 6 inches, 1 foot, 3 feet, etc.). In some embodiments, in response to the controller **2010** limiting operation of the fire apparatus **10** in the third mode of operation, the user I/O device **2020** provides an indication (e.g., displays a warning message, flashes a light, emits an audible sound such as a ring, message, tone, or alarm, etc.) indicative of the fire apparatus **10** operating in the third mode of operation.

[0101] According to an exemplary embodiment, the user I/O device **2020** includes an override switch configured to override a command from the controller **2010** to limit operation of the one or more components of the fire apparatus **10** (e.g., in the second mode of operation or the third mode of operation based on the data acquired from the sensors **2016**). In such an embodiment, when the override switch is engaged (e.g., when the switch is being held by an operator), the monitoring system **2104** is not activated such that operation of the fire apparatus **10** is not limited (e.g., permitting operation in the first mode of operation). In some embodiments, in response to the override switch being engaged, the user I/O device **2020** provides an indication (e.g., displays a warning message, flashes a light, emits an audible sound such as a ring, message, tone, or alarm, etc.) indicative of the fire apparatus **10** operating in the first mode of operation.

[0102] According to an exemplary embodiment, a bedding sequence may be initiated by an operator of the fire apparatus **10**. The bedding sequence may include a predefined sequence of operations for intentionally contacting (e.g., laying) the work basket **1300** on the ground surface or with the object **2124**. In response to initiating the bedding sequence (e.g., in response to an input to the I/O device **2020**), the monitoring system **2104** may not be activated such that operation of the fire apparatus **10** is not limited to the second mode of operation or the third mode of operation (e.g., the controller **2010** permits operation of the fire apparatus **10** in the first mode of operation). By way of example, when the bedding sequence is initiated and a determination is made that the work basket **1300** is positioned within the second range or the third range, operation of the fire apparatus **10** may not be limited. In such an example, while operation of the fire apparatus **10** may be permitted in the first mode of operation, operation of the fire apparatus **10** may still be assisted by the controller **2010** (e.g., to prevent the operator from continuing to bed the work basket **1300** into the ground after initial contact, to limit the speed at which the bedding operation can take place as the work basket **1300** gets closer to the ground, etc.). In some embodiments, in response to initiating the bedding sequence, the monitoring system **2104** may be activated such that operation of the fire apparatus **10** is limited to the second mode of operation. By way of example, when the bedding sequence is initiated and a determination is made that the work basket **1300** is positioned within the second range or the third range, operation of the fire apparatus **10** may be limited to the second mode of operation. In such an example, the fire apparatus **10** may be limited to the second mode of operation until the work basket **1300** contacts the ground (e.g., based on data from the sensors **2016**), at which point the operation of the fire apparatus **10** may be limited to the third mode of operation (e.g., to prevent the operator from continuing to bed the work basket **1300** into the ground after initial contact).

[0103] The system monitoring **2104** may be used for error checking. In some embodiments, the monitoring system **2104** is used to monitor operation of one or more hydraulic components (e.g., the rotation actuator **320**, the pivot actuator **710**, the extension actuator **720**, the basket actuator **1350**) of the fire apparatus **10**. By way of example, when the controller **2010** receives an input (e.g., an operator provides an input to the user I/O device **2020**), or lack thereof, to control the hydraulic components (e.g., extension and retraction of the aerial ladder assembly **700** via the extension actuator **720**, manipulation of the work basket **1300** via the basket actuator **1350**, rotation of the aerial ladder assembly **700** via the pivot actuator **710**, rotation of the aerial assembly **500** about the vertical pivot axis **40** via the rotation actuator **320**, etc.), the controller **2010** may be configured to determine, based on the sensor data acquired by the sensors **2016**, whether the output of the hydraulic components matches the input, or lack thereof, received by the controller **2010**. If the controller **2010** determines that the output of the hydraulic components does not match the input, or lack thereof, received by the controller **2010** (e.g., the hydraulic components are actuating when no input is being received by the controller **2010**, the hydraulic components are not actuating when an actuating input is being received by the controller **2010**, the hydraulic components are actuating in a direction that is different than an actuation direction indicated by the input being received by the controller **2010**), the controller **2010** may be configured to initiate one or more preventative actions. The preventative actions initiated by the controller **2010** may include limiting operation of the fire apparatus **10** to the second or third mode of operation by activating a diverter valve to divert a supply of hydraulic fluid to the one or more hydraulic components to stop actuation thereof.

[0104] Further, while the operations of the monitoring system **2104** have mainly been described herein in relation to monitoring beneath the work basket **1300** and adjusting operations of the aerial ladder assembly **1300** based thereon, it should be understood that such disclosure similarly applies to monitoring in front, behind, to the sides, and above the work basket **1300** and adjusting operations of the aerial ladder assembly **1300** based thereon.

[0105] As utilized herein, the terms "approximately," "about," "substantially", and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features described and claimed without restricting the scope of these features to the precise numerical ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and claimed are considered to be within the scope of the disclosure as recited in the appended claims.

[0106] It should be noted that the term "exemplary" and variations thereof, as used herein to describe various embodiments, are intended to indicate that such embodiments are possible examples, representations, or illustrations of possible embodiments (and such terms are not intended to connote that such embodiments are necessarily extraordinary or superlative examples).

[0107] The term "coupled" and variations thereof, as used herein, means the joining of two members directly or indirectly to one another. Such joining may be stationary (e.g., permanent or fixed) or moveable (e.g., removable or releasable). Such joining may be achieved with the two members coupled directly to each other, with the two members coupled to each other using a separate intervening member and any additional intermediate members coupled with one another, or with the two members coupled to each other using an intervening member that is integrally formed as a single unitary body with one of the two members. If "coupled" or variations thereof are modified by an additional term (e.g., directly coupled), the generic definition of "coupled" provided above is modified by the plain language meaning of the additional term (e.g., "directly coupled" means the joining of two members without any separate intervening member), resulting in a narrower definition than the generic definition of "coupled" provided above. Such coupling may be mechanical, electrical, or fluidic.

[0108] The term "or," as used herein, is used in its inclusive sense (and not in its exclusive sense) so that when used to connect a list of elements, the term "or" means one, some, or all of the elements in the list. Conjunctive language such as the phrase "at least one of X, Y, and Z," unless specifically stated otherwise, is understood to convey that an element may be either X; Y; Z; X and Y; X and Z; Y and Z; or X, Y, and Z (i.e., any combination of X, Y, and Z). Thus, such conjunctive language is not generally intended to imply that certain embodiments require at least one of X, at least one of Y, and at least one of Z to each be present, unless otherwise indicated.

[0109] References herein to the positions of elements (e.g., "top," "bottom," "above," "below") are merely used to describe the orientation of various elements in the FIGURES. It should be noted that the orientation of various elements may differ according to other exemplary embodiments, and that such variations are intended to be encompassed by the present disclosure.

[0110] The hardware and data processing components used to implement the various processes, operations, illustrative logics, logical blocks, modules and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose single- or multi-chip processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, or, any conventional processor, controller, microcontroller, or state machine. A processor also may be implemented as a combination of computing devices, such as a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. In some embodiments, particular processes and methods may be performed by circuitry that is specific to a given function. The memory (e.g., memory, memory unit, storage device) may include one or more devices (e.g., RAM, ROM, Flash memory, hard disk storage) for storing data and/or computer code for completing or facilitating the various processes, layers and modules described in the present disclosure. The memory may be or include volatile memory or non-volatile memory, and may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described in the present disclosure. According to an exemplary embodiment, the memory is communicably connected to the processor via a processing circuit and includes computer code for executing (e.g., by the processing circuit or the processor) the one or more processes described herein.

[0111] The present disclosure contemplates methods, systems and program products on any machine-readable media for accomplishing various operations. The embodiments of the present disclosure may be implemented using existing computer processors, or by a special purpose computer processor for an appropriate system, incorporated for this or another purpose, or by a hardwired system. Embodiments within the scope of the present disclosure include program products comprising machine-readable media for carrying or having machine-executable instructions or data structures stored thereon. Such machine-readable media can be any available media that can be accessed by a general purpose or special purpose computer or other machine with a processor. By way of example, such machine-readable media can comprise RAM, ROM, EPROM, EEPROM, or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer or other machine with a processor. Combinations of the above are also included within the scope of machine-readable media. Machine-executable instructions include, for example, instructions and data which cause a general purpose computer, special purpose computer, or special purpose processing machines to perform a certain function or group of functions.

[0112] Although the figures and description may illustrate a specific order of method steps, the order of such steps may differ from what is depicted and described, unless specified differently above. Also, two or more steps may be performed concurrently or with partial concurrence, unless specified differently above. Such variation may depend, for example, on the software and hardware systems chosen and on designer choice. All such variations are within the scope of the disclosure. Likewise, software implementations of the described methods could be accomplished with standard programming techniques with rule-based logic and other logic to accomplish the various connection steps, processing steps, comparison steps, and decision steps.

[0113] It is important to note that the construction and arrangement of the fire apparatus **10** and the systems and components thereof as shown in the various exemplary embodiments is illustrative only. Additionally, any element disclosed in one embodiment may be incorporated or utilized with any other embodiment disclosed herein. Although only one example of an element from one embodiment that can be incorporated or utilized in another embodiment has been described above, it should be appreciated that other elements of the various embodiments may be incorporated or utilized with any of the other embodiments disclosed herein.

1. A vehicle comprising:
a chassis;
a body assembly coupled to the chassis;
an implement coupled to the body assembly;
at least one sensor configured to facilitate monitoring a position of the implement relative to a ground surface or an object; and
one or more processing circuits configured to:
determine, based on sensor data acquired by the at least one sensor, the position of the implement relative to the ground surface or the object;
permit operation of the implement in a first mode of operation in response to a determination that the position of the implement relative to the ground surface or the object is greater than a threshold distance; and
limit operation of the implement in a second mode of operation in response to a determination that the position of the implement relative to the ground surface or the object is less than the threshold distance.

2. The vehicle of claim **1**, wherein the implement includes a work basket.

3. The vehicle of claim **2**, wherein the at least one sensor is positioned on the work basket.

4. The vehicle of claim **2**, wherein the implement includes a ladder assembly including at least one extensible ladder section configured to reposition the work basket relative to the body assembly.

5. The vehicle of claim **2**, wherein the vehicle is a fire apparatus.

6. The vehicle of claim **1**, wherein limiting operation of the implement in the second mode of operation includes limiting a movement speed of the implement.

7. The vehicle of claim **1**, wherein the threshold distance is a first threshold distance, wherein the one or more processing circuits are configured to limit operation of the implement in a third mode of operation in response to a determination that the position of the implement relative to the ground surface or the object is at or less than a second threshold distance.

8. The vehicle of claim **7**, wherein the second threshold distance is less than the first threshold distance, and wherein the third mode of operation is more restrictive than the second mode of operation.

9. The vehicle of claim **8**, wherein the position of the implement relative to the ground surface or the object contacts the ground surface or the object at the second threshold distance, and wherein limiting operation of the implement in the third mode of operation includes preventing movement of the implement.

10. The vehicle of claim **1**, wherein the sensor data includes point cloud data of the object, and wherein the one or more processing circuits are configured to control operation of the implement based on the point cloud data when at least a portion of the object is not sensed by the at least one sensor.

11. The vehicle of claim **10**, wherein the at least one sensor is configured to facilitate monitoring a substantial entirety of an area under the implement when the implement is positioned at or greater than the threshold distance relative to the object.

12. The vehicle of claim **11**, wherein the object is positioned below the implement, and wherein the portion of the object is not sensed by the at least one sensor when the implement is positioned less than the threshold distance relative to the object.

13. The vehicle of claim **1**, further comprising an output device, and wherein the one or more processing circuits are configured to provide an indication of the second mode of operation using the output device in response to limiting operation of the implement in the second mode of operation.

14. The vehicle of claim **1**, further comprising an input device configured to receive an input from an operator, and wherein the one or more processing circuits are configured to permit operation of the implement in the first mode of operation in response to (i) the determination that the position of the implement relative to the ground surface or the object is less than the threshold distance and (ii) the input device receiving the input.

15. The vehicle of claim **1**, further comprising one or more hydraulic components coupled with the implement, and wherein the one or more processing circuits are configured to:

control the one or more hydraulic components to cause movement of the implement;

monitor movement of the implement based on the sensor data;

determine whether the movement of the implement caused by controlling the one or more hydraulic components matches the movement of the implement based on the sensor data; and

initiate one or more preventative actions in response to a determination that the movement of the implement caused by controlling the one or more hydraulic components does not match the movement of the implement based on the sensor data.

16. A vehicle system comprising:

one or more processing circuits configured to:

acquire sensor data of an area including at least one of a ground surface or an object;

monitor a position of a portion of a ladder assembly of a fire apparatus relative to the ground surface or the object based on the sensor data;

permit operation of the ladder assembly in a first mode of operation in response to a determination that the position of the portion of the ladder assembly relative to the ground surface or the object is greater than a threshold distance; and

limit operation of the ladder assembly in a second mode of operation in response to a determination that the position of the portion of the ladder assembly relative to the ground surface or the object is less than the threshold distance.

17. The vehicle system of claim **16**, wherein the sensor data includes point cloud data of the object, and wherein the one or more processing circuits are configured to control operation of the ladder assembly based on the point cloud data when at least a portion of the object is obstructed.

18. The vehicle system of claim **16**, wherein the ladder assembly includes a work basket and at least one extensible ladder section configured to reposition the work basket relative to the fire apparatus.

19. The vehicle system of claim **18**, wherein limiting operation of the ladder assembly in the second mode of operation includes at least one of limiting (i) a movement speed of the ladder assembly or (ii) an extension distance of the at least one extensible ladder section.

20. A fire apparatus comprising:

a chassis;

a body assembly coupled to the chassis;

a ladder assembly coupled to the body assembly and including at least one extensible ladder section and a work basket coupled to a distal end of the ladder assembly;

at least one sensor coupled to the ladder assembly and configured to acquire sensor data of an area surrounding the ladder assembly; and

one or more processing circuits configured to:

determine a position of a portion of the ladder assembly relative to an object in the area based on the sensor data;

permit operation of the ladder assembly in a first mode of operation in response to a determination that the position of the portion of the ladder assembly relative to the object is greater than a first threshold distance;

limit operation of the ladder assembly in a second mode of operation in response to a determination that the position of the portion of the ladder assembly relative to the object is less than the first threshold distance;

limit operation of the ladder assembly in a third mode of operation in response to a determination that the position of the portion of the ladder assembly relative to the object is at or less than a second threshold distance; and

control operation of the ladder assembly in the first mode of operation, the second mode of operation, or the third mode of operation based on point cloud data of the object included in the sensor data when at least a portion of the object is not sensed by the at least one sensor;

wherein the second threshold distance is less than the first threshold distance; and

wherein the third mode of operation is more restrictive than the second mode of operation.

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