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(54) BOOM INCLINATION DETECTING AND STABILIZING SYSTEM

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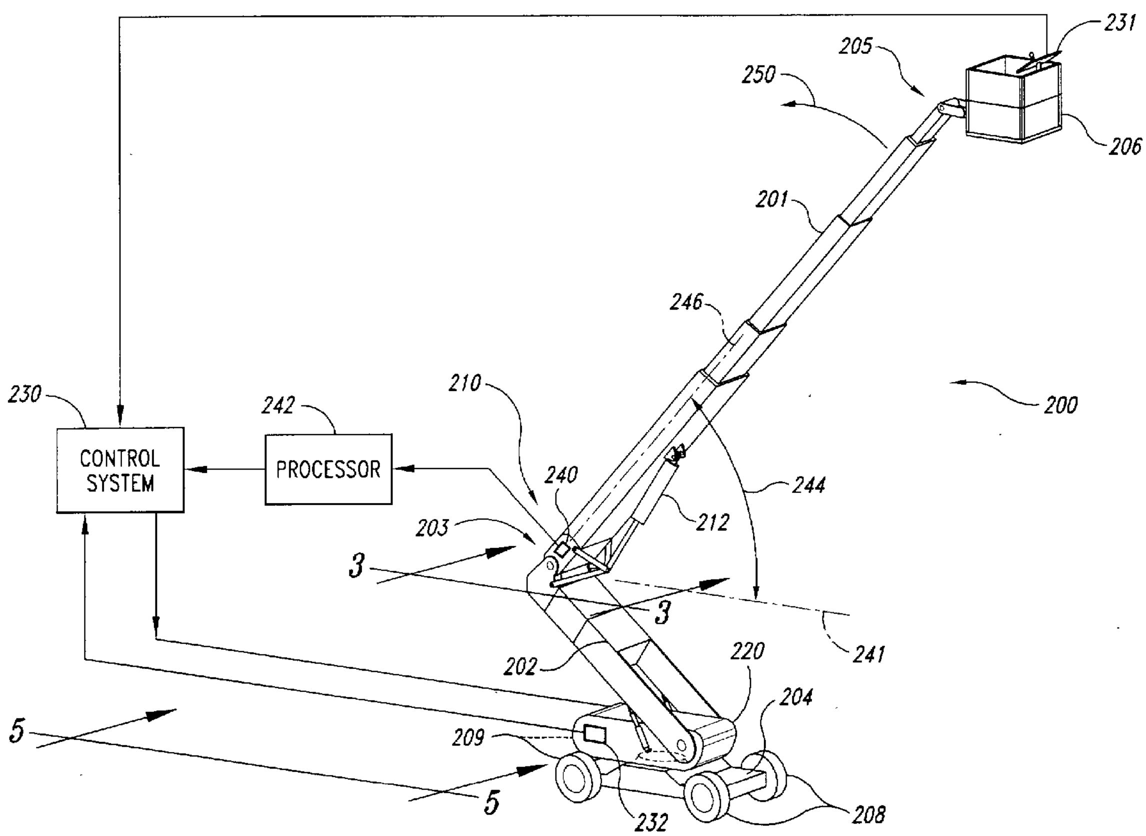
(57) **ABSTRACT**

Apparatuses and methods for controlling the stability of elevating systems, such as personnel lifts. In one embodiment, a stability control apparatus includes an angle detector and a signal processor. The angle detector is mounted to a boom of a personnel lift and configured to detect an angle of inclination of the boom relative to an independent reference frame independent of the personnel lift. The signal processor is operatively connected to the angle detector and is configured to receive a first signal initiated by the angle detector when the angle of inclination reaches a predetermined angle. The signal processor is further configured to output a second signal in response to receiving the first signal causing a boom control system to limit movement of the boom relative to the independent reference frame when the angle of inclination reaches the predetermined angle.



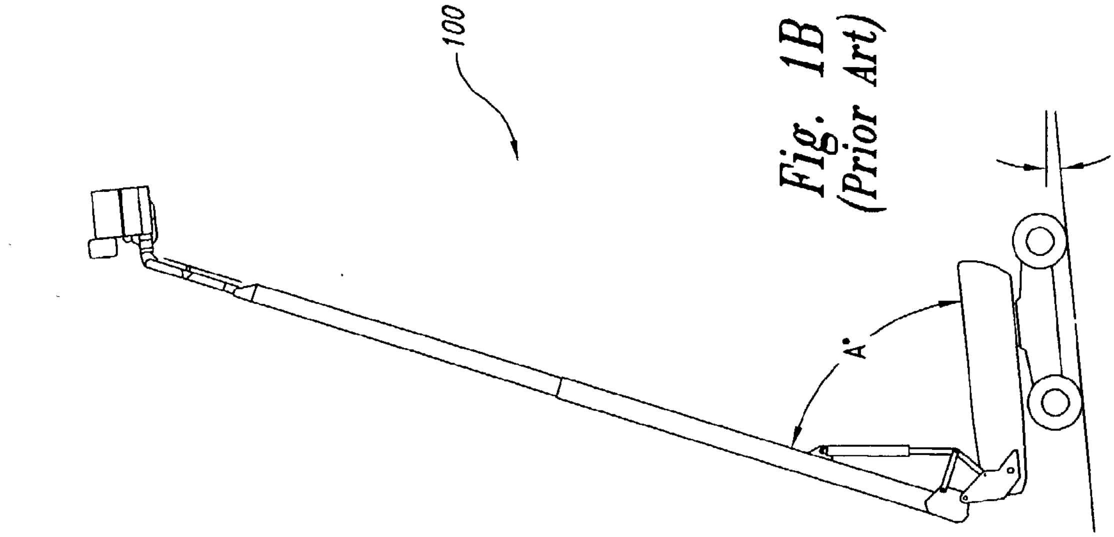


Fig. 1B
(Prior Art)

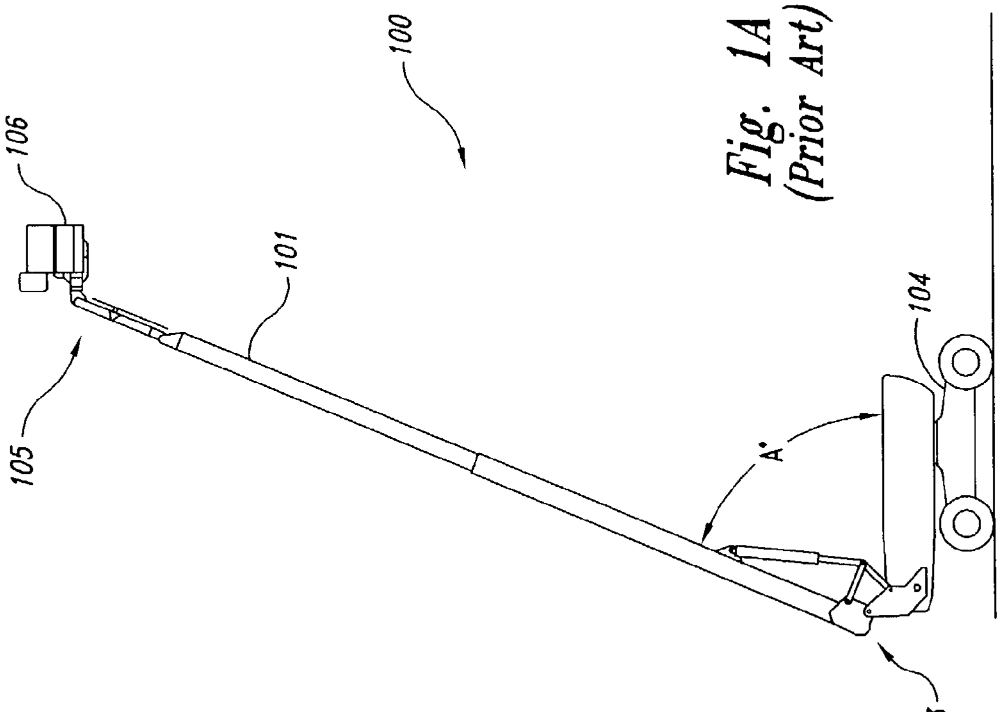


Fig. 1A
(Prior Art)

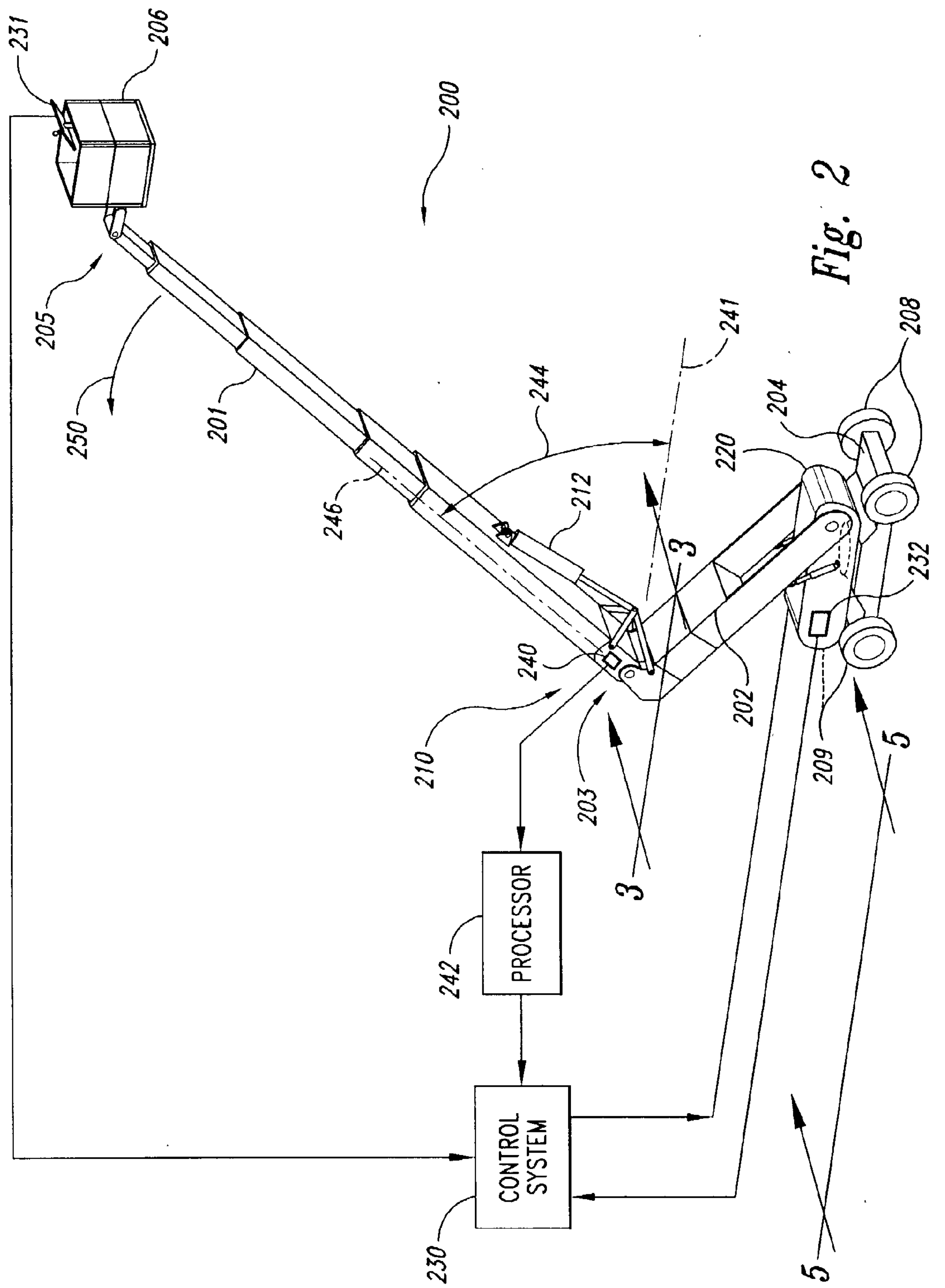

231
206
200
205
250
201
244
241
246
212
3
3
220
204
208
232
240
210
203
202
209
5
5
PROCESSOR
242
CONTROL
SYSTEM
230

Fig. 2

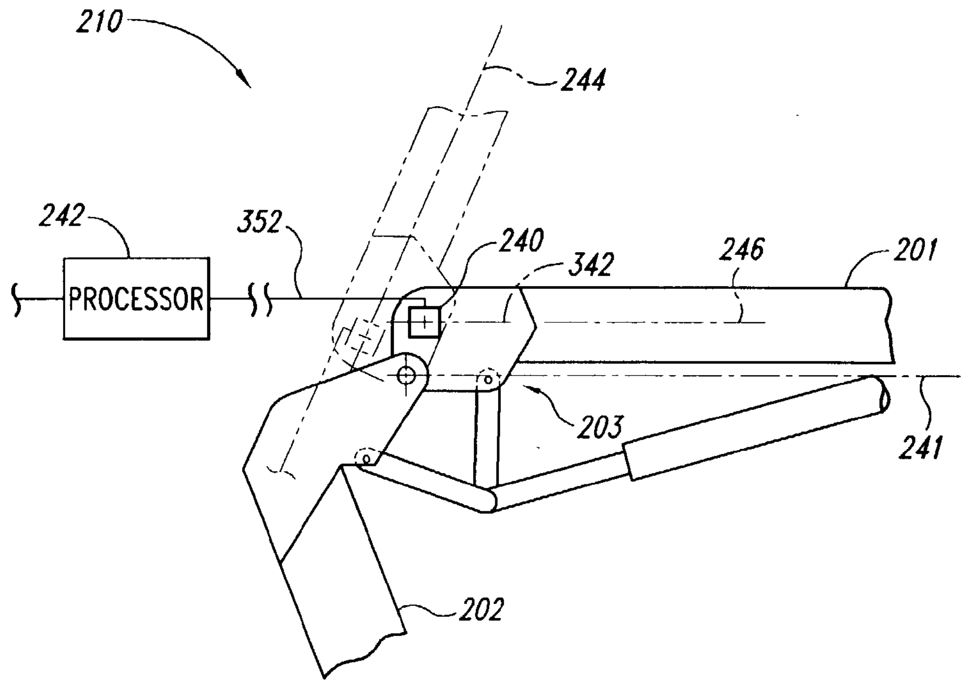

210
244
242
352
240
342
246
201
PROCESSOR
203
241
202

Fig. 3

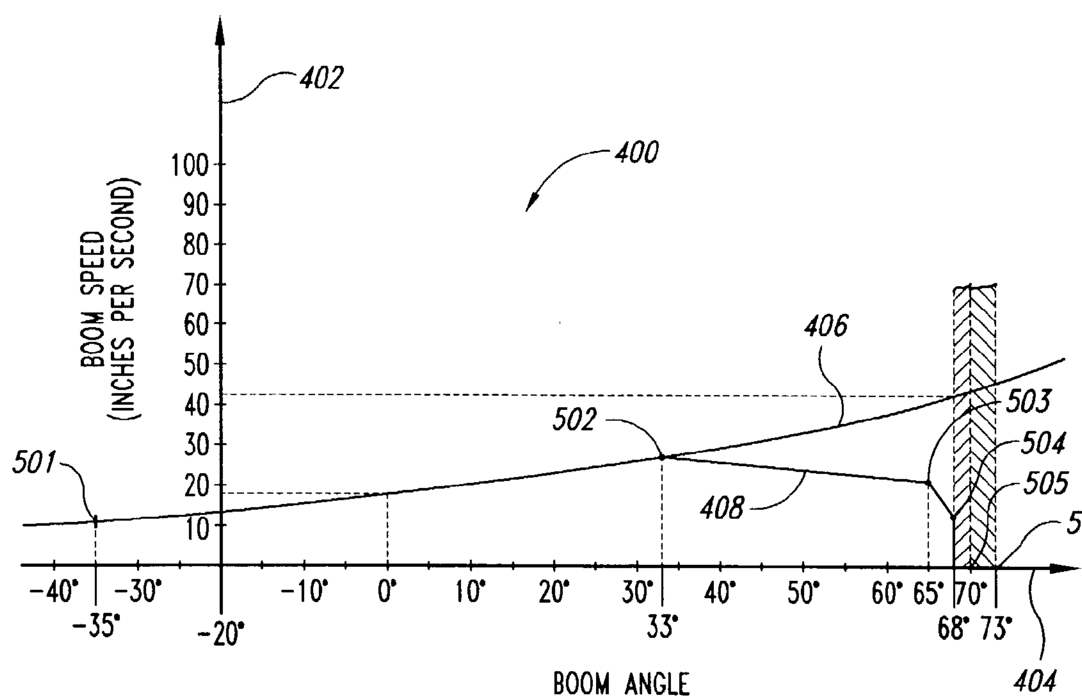

402
400
BOOM SPEED (INCHES PER SECOND)
100
90
80
70
60
50
40
30
20
10
406
502
503
504
505
506
501
408
-40°
-30°
-10°
0°
10°
20°
30°
40°
50°
60°
65°
70°
-35°
-20°
33°
68°
73°
BOOM ANGLE
404

Fig. 4

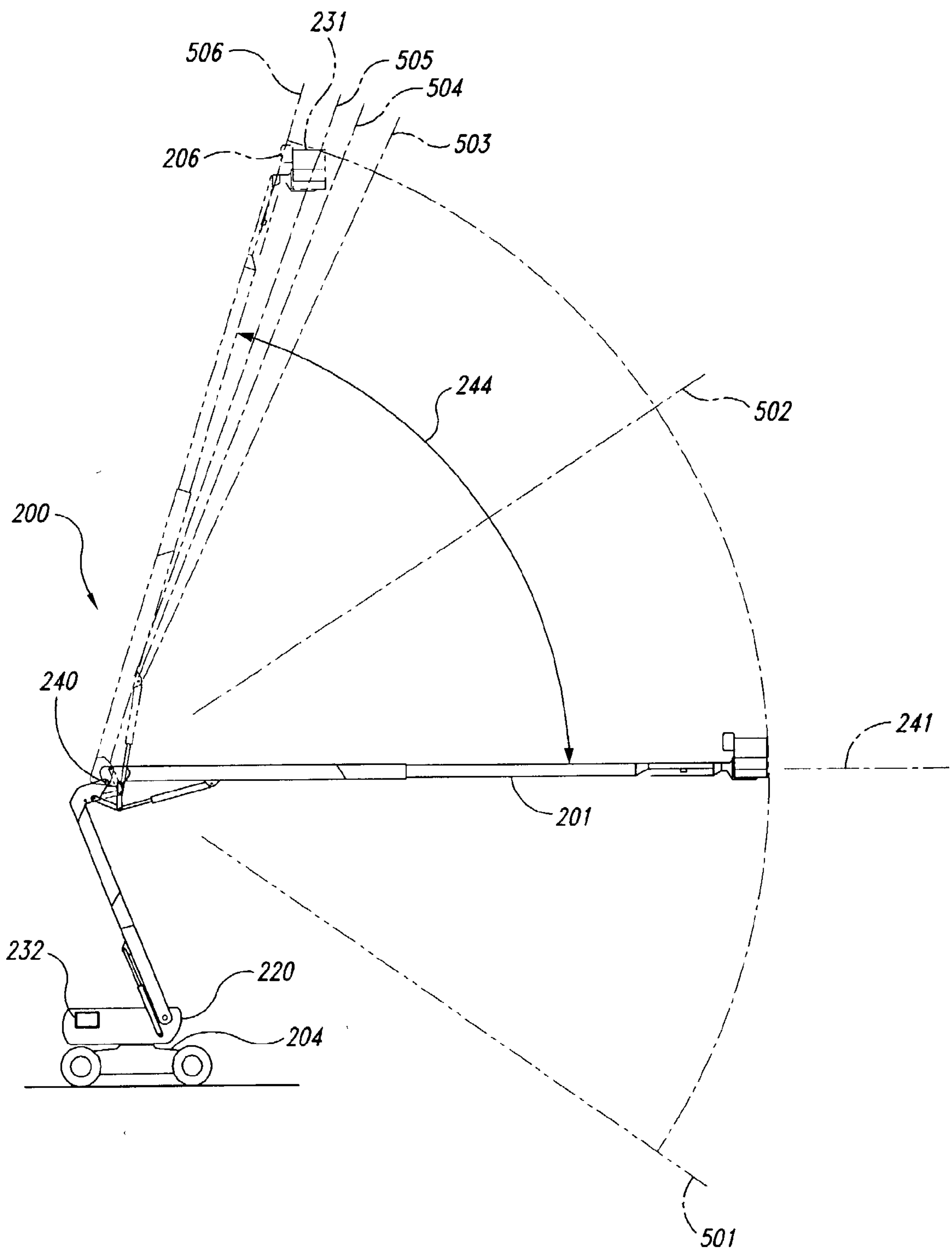


Fig. 5

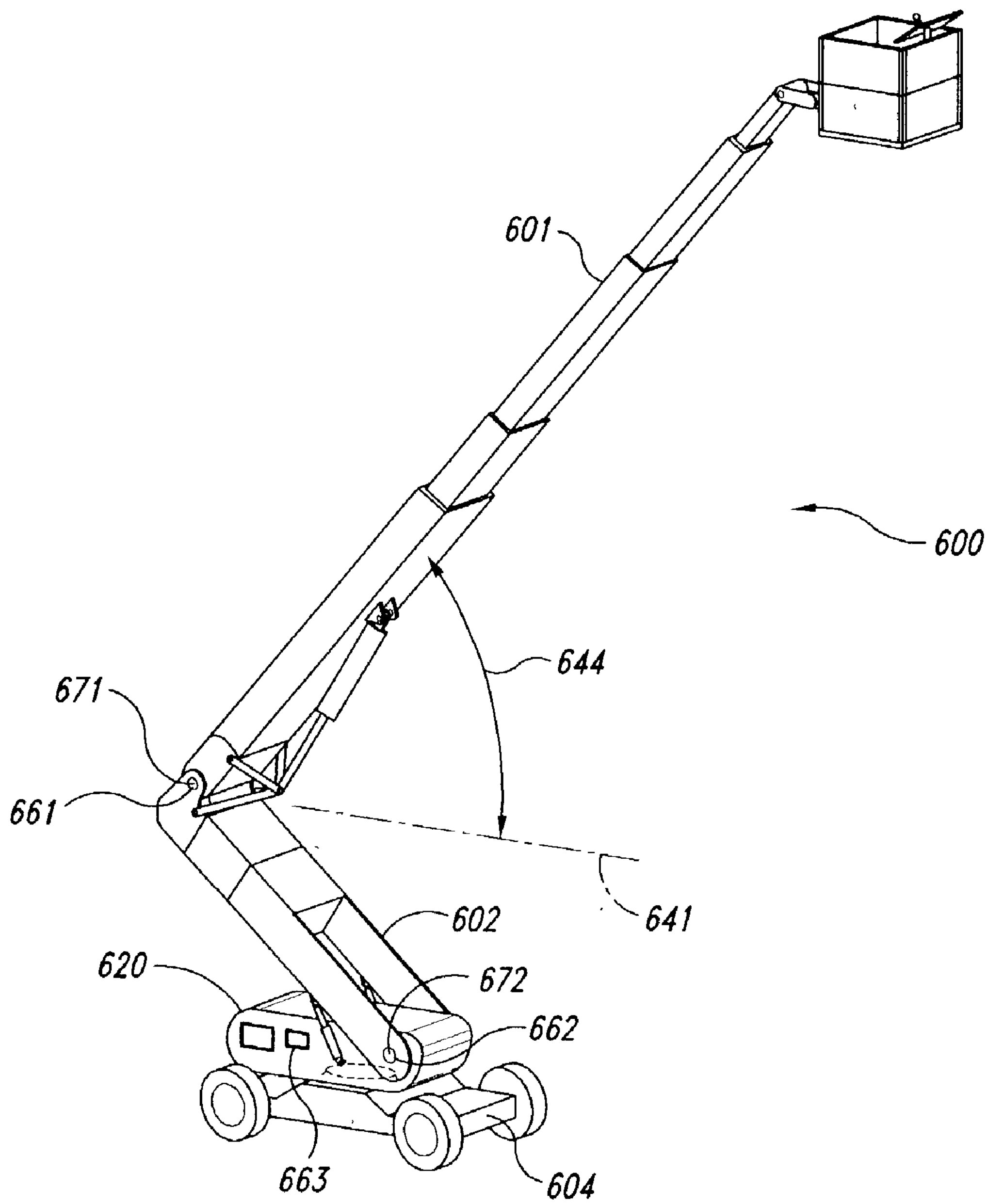


Fig. 6

BOOM INCLINATION DETECTING AND STABILIZING SYSTEM

TECHNICAL FIELD

[0001] The present invention is directed to apparatuses and methods for controlling the stability of elevating systems and, more particularly, to apparatuses and methods for controlling the stability of personnel lifts by detecting angles of boom inclination.

BACKGROUND

[0002] Personnel lifts and other elevating systems are widely used to provide persons, machines, and materials with temporary access to elevated or otherwise inaccessible work areas. Typical personnel lifts include a work platform mounted to a distal end of an extendible boom or other type of lift assembly. A proximal end of the extendible boom is often pivotally connected to a base or other structure so that the boom can pivot in a vertical plane relative to the base to vertically position the work platform. In addition, the base is often rotatably mounted to a chassis so that the base can rotate in a horizontal plane relative to the chassis to horizontally position the work platform. Such rotatable bases are commonly referred to as "turntables." The pivoting boom and rotating base enable the personnel lift to reach a wide range of elevated locations without having to reposition the chassis. However, many personnel lift chassis are equipped with wheel-sets to facilitate repositioning of the personnel lifts when desired. Examples include both self-propelled and trailerable personnel lifts.

[0003] **FIGS. 1A and 1B** are side elevational views of a conventional personnel lift **100** in accordance with the prior art. As shown in **FIG.** 1A, the prior art personnel lift **100** includes an extendible boom **101** pivotally connected to a chassis **104** at a proximal end **103**. A work platform **106** is supported by the boom **101** at a distal end **105**. In operation, the boom **101** can pivot about the proximal end **103** relative to the chassis **104** to position an operator (not shown) in the work platform **106** at a desired elevation.

[0004] With many prior art personnel lifts, as the boom **101** is pivoted upwardly, its rotational speed increases. This increase in rotational speed can be attributed to a number of factors related to a boom angle A between the boom **101** and the chassis **104**. One such factor is a decrease in load-moment: As the boom angle A increases, the load-moment acting on the boom decreases, thereby making it progressively easier for the boom lift mechanism (typically a hydraulic cylinder) to lift the boom. Another such factor is an increase in lifting force: Increasing the boom angle A can improve the geometric relationship between the lift mechanism and the boom, thereby increasing the lifting force applied to the boom.

[0005] The increased rotational speed of the boom **101** as it nears the top of its arc can impart considerable rotational inertia to the boom. As a result, if the boom **101** is stopped abruptly near the top of its arc this rotational inertia can cause the personnel lift **100** to experience a jolt in the direction of boom rotation that is resisted by the chassis **104**. On level ground, such as that shown in **FIG.** 1A, this jolt may not be sufficient to destabilize the personnel lift **100**. However, if the chassis **104** is positioned on a sloped surface, such as that shown in **FIG.** 1B, then this jolt could be sufficient to reduce the stability of the personnel lift **100**.

SUMMARY

[0006] The present invention is directed toward apparatuses and methods for controlling the stability of elevating systems, such as personnel lifts. In one embodiment of the invention, a stability control apparatus is usable with an elevating system having a boom operatively connected to a chassis and a control system operatively connected to the boom for controlling movement of the boom relative to the chassis. In one aspect of this embodiment, the stability control apparatus includes an angle detector and a signal processor. The angle detector is adapted to be operatively mounted to the elevating system and is configured to detect an angle of inclination between a portion of the elevating system and an independent reference frame independent of the chassis. The signal processor is operatively connected to the angle detector and is configured to receive a first signal initiated by the angle detector and output a second signal in response to receiving the first signal; the second signal causing the control system to limit or otherwise modify movement of the boom relative to the independent reference frame.

[0007] In another embodiment of the invention, a method for moving a boom from a first position to a second position is usable with a boom operatively connected to a chassis and a control system, the control system controlling movement of the boom relative to the chassis. In one aspect of this embodiment, the method includes detecting a boom angle relative to an independent reference frame independent of the chassis, and allowing pivotal movement of the boom relative to the independent reference frame when the boom angle relative to the independent reference frame is within a first range of angles. The method further includes limiting pivotal movement of the boom relative to the independent reference frame when the boom angle relative to the independent reference frame is within a second range of angles, the second range of angles including steeper angles of inclination than the first range of angles.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] **FIGS. 1A and 1B** are side elevational views of a conventional personnel lift in accordance with the prior art.

[0009] **FIG. 2** is a partial schematic isometric view of a personnel lift having a stability control apparatus in accordance with an embodiment of the invention.

[0010] **FIG. 3** is an enlarged partial schematic side elevational view of the stability control apparatus of **FIG. 2** taken substantially along line **3-3** in **FIG. 2** in accordance with an embodiment of the invention.

[0011] **FIG. 4** is a graph illustrating a plot of boom speed verses boom angle relative to an independent reference frame, provided by a method of boom control in accordance with an embodiment of the invention.

[0012] **FIG. 5** is a side elevational view of the personnel lift of **FIG. 2** taken substantially along line **5-5** in **FIG. 2** illustrating various boom positions relating to the graph of **FIG. 4** in accordance with an embodiment of the invention.

[0013] **FIG. 6** is an isometric view of a personnel lift having a stability control apparatus in accordance with another embodiment of the invention.

DETAILED DESCRIPTION

[0014] The following disclosure describes apparatuses and methods for controlling the stability of elevating systems, such as personnel lifts. Certain specific details are set forth in the following description and in **FIGS. 2 through 6** to provide a thorough understanding of various embodiments of the invention. Those of skill in the relevant art will understand, however, that the present invention may have additional embodiments, or that the invention may be practiced without several of the details described below. In other instances, well-known structures associated with personnel lifts, such as extendible booms, hydraulic control systems and the like, have not been shown or described in detail here to avoid unnecessarily obscuring the description of the embodiments of the invention.

[0015] **FIG. 2** is a partial schematic isometric view of a personnel lift **200** having a stability control apparatus **210** in accordance with an embodiment of the invention. In the illustrated embodiment, the personnel lift **200** includes a primary boom **201** pivotally connected to a secondary boom **202** at a proximal end **203** of the primary boom. A lift mechanism **212** (e.g., a lift cylinder) provides the force that pivots the primary boom **201** upwardly and downwardly relative to the secondary boom **202**. The primary boom **201** supports a platform **206** at a distal end **205** of the primary boom. The secondary boom **202** is pivotally connected to a base **220**, which in turn is rotatably mounted to a chassis **204**. The rotatable base **220** of the illustrated embodiment is commonly referred to as a "turntable." Accordingly, the base **220** will be referred to in the following disclosure as the "turntable"**220**. The chassis **204** is a self-propelled and stearable "drive chassis" that includes a forward wheel-set **208** and a rear wheel-set **209**.

[0016] Platform controls **231** (e.g., one or more joysticks, levers, switches and the like) are mounted on the platform **206** to enable an operator on the platform (not shown) to control movement of the personnel lift **200**. In addition, similar ground controls **232** are mounted on the turntable **220** to enable an operator on the ground (also not shown) to control movement of the personnel lift **200**. Such movements of the personnel lift **200** can include pivotal articulation and extension/retraction of the primary boom **201** and the secondary boom **202** relative to the turntable **220**, rotational motion of the turntable relative to the drive chassis **204**, and rolling motion of the drive chassis relative to the ground. As illustrated in **FIG. 2**, both of the operator controls (i.e., the platform controls **231** and the ground controls **232**) are operatively connected to a personnel lift control system **230** (shown schematically) contained within the turntable **220** and operatively connected to the systems providing motive power to the personnel lift **200** (such as an internal combustion engine and/or a boom hydraulic system). The control system **230** receives operator control inputs via the operator controls and controls movement of the personnel lift **200** (i.e., the primary boom **201**, the secondary boom **202**, the turntable **220**, and/or the drive chassis **204**) in response to the operator control inputs.

[0017] In one aspect of this embodiment, the stability control apparatus **210** includes an angle detector **240** mounted toward the proximal end **203** of the primary boom **201**. As will be explained in greater detail below, the angle detector **240** is configured to detect an angle of inclination **244** of the primary boom **201**. The angle of inclination **244** is defined, for purposes of this disclosure, to be the angle formed between a longitudinal axis **246** of the primary boom **201** and an independent reference frame **241**. The independent reference frame **241** of the illustrated embodiment is represented by a horizontal line positioned normal to the direction of gravitational force. Accordingly, the independent reference frame **241** is independent of the position or orientation of the chassis **204** or other components of the personnel lift **200**.

[0018] In a further aspect of this embodiment, the angle detector **240** is operatively connected to a processor **242** (shown schematically), and is configured to send the processor a first signal related to the detected angle of inclination **244**. In one embodiment, the first signal can be an analog signal such as a voltage signal that is proportional to the gravitational acceleration acting on the angle detector **240**. In other embodiments, the first signal can be other types of signals indicative of the angle of inclination **244**. The processor **242** may be contained in the turntable **220** and is operatively connected to the control system **230**. The processor **242** is configured to send the control system **230** a second signal related to the first signal in response to receiving the first signal from the angle detector **240**. As will be explained in greater detail below, in one embodiment, the second signal can be a digital signal configured to cause the control system **230** to limit movement of the personnel lift **200** based on the detected angle of inclination **244**.

[0019] During transport or periods of nonuse of the personnel lift **200**, the primary and secondary booms **201** and **202** can be retracted and collapsed into a stowed configuration (not shown). When use is desired, persons and/or materials can be loaded onto the platform **206** and an operator, positioned at either the platform controls **231** or the ground controls **232**, can position the platform **206** at a desired elevation by controlling the angle and/or extension of one or both of the primary and secondary booms **201** and **202** relative to the chassis **204**. As the primary boom **201** pivots in a direction **250**, the angle detector **240** detects the increasing angle of inclination and sends a signal to the processor **242** relating to the angle of inclination. When the angle of inclination **244** reaches a predetermined angle (such as an upper operational limit of boom rotation), the processor **242** sends a signal to the control system **230** causing the control system **230** to limit movement of the personnel lift **200**. In one embodiment, the control system **230** limits movement of the primary and secondary booms **201** and **202** and/or movement of the drive chassis **204** to only those movements which tend to maintain or increase the stability of the personnel lift. In one aspect of this embodiment, such limited movements can include 1) gradually reducing the rotational speed of the primary boom **201** in the direction **250** to slowly dissipate the rotational inertia of the primary boom, 2) stopping rotation of the primary boom in the direction **250** at the upper operational limit of boom rotation, and 3) disabling the drive chassis **204** to prevent repositioning of the drive chassis on unfavorably inclined surfaces.

[0020] As will be apparent to those of ordinary skill in the art, one advantage of the personnel lift **200** of the present invention is that the angle of inclination **244** is detected by the angle detector **240** irrespective of the position or orientation of the chassis **204**. As a result, positioning the drive chassis **204** on an inclined surface will not compromise the ability of the stability control apparatus **210** to detect a potentially unstable boom position. These and other aspects of the stability control apparatus **210** will be described in greater detail below in reference to the Figures that follow.

[**0021**] **FIG. 3** is an enlarged partial schematic side elevational view of the stability control apparatus **210** taken substantially along line **3-3** in **FIG. 2** in accordance with an embodiment of the invention. In one aspect of this embodiment, the angle detector **240** is a uniaxial accelerometer or other instrument capable of measuring axial accelerations along a functional axis **342**. In the illustrated embodiment, the angle detector **240** is fixedly mounted toward the proximal end **203** of the primary boom **201** in functional alignment with the longitudinal axis **246** of the primary boom. In other embodiments, the angle detector **240** can be mounted to the primary boom **201** at different locations on the primary boom. However, regardless of the mounting location of the angle detector on the primary boom, in accordance with one aspect of the invention, the functional axis **342** of the angle detector **240** should be at least approximately parallel to the longitudinal axis **246** of the primary boom **201**.

[**0022**] As shown in **FIG. 3**, the angle detector **240** is operatively coupled to the processor **242** via an electrical link **352**, such as an electrical cable. Although not shown in **FIG. 3**, in one aspect of this embodiment, the electrical link **352** is routed along the primary boom **201** and the secondary boom **202** to the processor **242** in the turntable **220** in such a way as to prevent the electrical link from sustaining damage during boom operation.

[**0023**] In operation, the angle detector **240** measures the component of gravitational acceleration acting parallel to the longitudinal axis **246** as a function of the angle of inclination **244** of the primary boom **201**. For example, when the primary boom **201** is positioned with its longitudinal axis **246** substantially parallel to the horizontal line **241**, as shown by the solid lines in **FIG. 3**, the angle detector **240** measures a gravitational acceleration along its functional axis **342** of zero. In contrast, when the primary boom **201** is pivoted into a more vertical position, as shown by the dotted lines in **FIG. 3**, the angle detector **240** measures a gravitational acceleration along its functional axis **342** approaching one G (i.e., the gravitational constant G of 32.2 ft/sec^2). Accordingly, as the primary boom **201** pivots through its arcuate range of motion, the angle detector **240** measures gravitational accelerations ranging from zero to about one G, and sends a signal corresponding to the measured accelerations to the processor **242**.

[**0024**] In one aspect of this embodiment, the processor **242** is configured to convert the measured gravitational accelerations into corresponding angles of inclination **244** of the primary boom **201**. For example, a measured gravitational acceleration of zero Gs would correspond to an angle of inclination **244** of zero degrees and, accordingly, a measured acceleration of one G would correspond to an angle of inclination of 90 degrees. In a further aspect of this embodiment, essentially any angle of inclination **244** can be found by using equation 1 below:

$$\text{Angle of inclination} = \text{Sin}^{-1}\left(\frac{\text{Measured Accel}}{G}\right) \tag{1}$$

[**0025**] Thus, for example, if the angle detector **240** measures a gravitational acceleration of 0.707Gs, then the corresponding angle of inclination **244** would be equal to 45 degrees.

[**0026**] In a further aspect of this embodiment, once the processor **242** has converted the gravitational acceleration measurement from the angle detector **240** into a corresponding angle of inclination **244**, the processor sends a corresponding signal to the control system **230** (not shown). As will be explained in greater detail below with reference to **FIGS. 4 and 5**, the control system **230** can utilize the second signal from the processor **242** to control the stability of the personnel lift **200** (**FIG. 2**) by controlling movement of the primary boom **201**, the secondary boom **202**, and/or the drive chassis **204**.

[**0027**] Although the angle detector **240** illustrated in **FIG. 3** in one embodiment is an accelerometer, those of ordinary skill in the relevant art will recognize that the angle detector **240** can be other types of angle detectors without departing from the spirit or scope of the present disclosure. For example, in one such alternate embodiment, the angle detector **240** can be a pendulum switch. Rather than measuring gravitational accelerations, a pendulum switch measures angle of inclination using a pendulum-type member operatively connected to a measuring device to measure the angle between the pendulum-type member and, for example, the longitudinal axis **246** of the primary boom **201**. This angle can then be used to determine the angle of inclination **244** of the primary boom **201**. In other embodiments, other types of angle detectors can be utilized consistent with this disclosure as necessary to suit the particular application.

[**0028**] **FIG. 4** illustrates a graph **400** showing boom speed verses boom angle provided by one method of boom control in accordance with an embodiment of the invention. In one aspect of this embodiment, boom speed is measured along a vertical axis **402** in inches per second and boom angle is measured along a horizontal axis **404** in degrees. The term "boom speed," for purposes of this discussion, refers to the speed of the primary boom **201** at the distal end **205** (**FIG. 2**). Accordingly, "boom speed" is proportional to the rotational speed of the primary boom **201** and the length of the primary boom. The term "boom angle," for purposes of this discussion, refers to the angle of inclination **244** (**FIGS. 2 and 3**).

[**0029**] As discussed above with reference to **FIG. 2, a** common characteristic of personnel lifts utilizing extendible booms is that the rotational speed of the primary boom **201** increases as the angle of inclination **244** approaches the vertical position. As explained above, this increasing rotational speed can be due to a number of factors including, for example, the reduction in load-moment acting on the boom lift mechanism as well as the more favorable geometric relationship that may exist between the lift mechanism and the primary boom **201** as the primary boom approaches the vertical position. A plot **406** on the graph **400** corresponds to the maximum normal operating speed of the primary boom

201 (**FIG. 2**) and illustrates the increase in rotational speed of the primary boom as the boom angle increases. As can be seen, when the lifting force on the primary boom **201** from the lifting mechanism **212** (**FIG. 2**) remains constant, the boom speed is relatively low at low boom angles and gradually increases as the boom angle increases. For example, at zero degrees (i.e., where the primary boom **201** is horizontal) the boom speed is approximately 10-15 inches per second, while at 70 degrees the boom speed is approximately 40 inches per second. As explained above, a high boom speed may have unfavorable consequences at high angles of inclination because the rotational inertia of the primary boom **201** may cause the personnel lift **200** (**FIG. 2**) to experience a jolt in the direction of rotation when the boom motion is stopped. This jolt may not be problematic when the chassis **204** is positioned on a relatively horizontal surface. However, if the chassis is maneuvered onto an inclined surface, this jolt could reduce the stability of the personnel lift **200**.

[**0030**] In recognition of this problem, one aspect of an embodiment of the present invention is to limit the boom speed of the primary boom **201** as the primary boom approaches a vertical position. Accordingly, a plot **408** on the graph **400** illustrates one method for controlling boom speed in accordance with this embodiment. As can be seen with reference to the plot **408**, this method entails gradually reducing the boom speed between about 35 degrees and 65 degrees, substantially reducing boom speed between about 65 degrees and 70 degrees, and preventing boom rotation beyond 73 degrees. In one embodiment, boom speed can be reduced via the control system **230** by reducing the lifting force applied by the lift mechanism **212** (**FIG. 2**). As will be understood by those of ordinary skill in the relevant art, the plot **408** represents only one of many possible methods for controlling boom speed in accordance with this disclosure. In other embodiments, other methods of boom control can be implemented to suit the particular applications. The plot **408** will be further described in conjunction with the description of **FIG. 5** that follows.

[**0031**] **FIG. 5** is a side elevational view of the personnel lift **200** of **FIG. 2** taken substantially along line **5-5** in **FIG. 2** for the purpose of describing the method of boom control illustrated in **FIG. 4** in accordance with an embodiment of the invention. In one aspect of the illustrated embodiment, the primary boom **201** has a total range of motion relative to the independent reference frame **241** between a first boom position **501** and a sixth boom position **506**. However, the operational range of motion of the primary boom **201** is between the first boom position **501** and a fourth boom position **504**. In a further aspect of this embodiment, the first boom position **501** is a mechanical stop determined by the lift mechanism configuration and is about 35 degrees below the independent reference frame **241**. In yet another aspect of this embodiment, the fourth boom position **504** is about 68 degrees above the independent reference frame **241**. In other embodiments, the first and forth boom positions **501** and **504** can be other angles.

[**0032**] As the primary boom **201** sweeps through its arc between the first boom position **501** and the fourth boom position **504**, the angle detector **240** measures the corresponding angle of inclination **244** relative to the independent reference frame **241** (i.e., relative to a horizontal line normal to the direction of gravitational force). The angle of inclination **244** measured by the angle detector **240** is sent to the control system **230** via the processor **242** (**FIG. 2**). In one aspect of this embodiment, the control system **230** controls movement of the primary boom **201** in accordance with the plot **408** shown in **FIG. 4** based on the angle of inclination **244** received from the processor **242**. In an alternate embodiment, the processor **242** can be utilized to determine the rotational velocity of the primary boom **201** by determining the rate of change of the angle of inclination of the primary boom **201** (i.e., the first derivative of the angle). In this alternate embodiment, the control system **230** controls movement of the primary boom **201** based on the rotational velocity of the primary boom received from the processor **242**.

[**0033**] Referring to **FIGS. 4 and 5** together, in the illustrated embodiment, the primary boom **201** is free to move between the range of angles including the first boom position **501** and a second boom position **502** substantially without any imposed constraints on motion. In one aspect of this embodiment, the angle detector **240** becomes active at the second boom position **502**. In a further aspect of this embodiment, the second boom position **502** can be between about 30 degrees and about 90 degrees above the independent reference frame **241**. In the illustrated embodiment, for example, the second boom position **502** is approximately 33 degrees above the independent reference frame **241**. In other embodiments, the second boom position **502** can be other angles.

[**0034**] As shown in **FIG. 4**, at the second boom position **502**, if the primary boom **201** is travelling at or near its maximum normal operating speed (as indicated by the plot **406**), the control system **230** (not shown) begins to limit or reduce the maximum speed of the primary boom **201** based on the signal initiated from the angle detector **240** as the primary boom continues to pivot upwardly through the range of angles including a third boom position **503**. At the third boom position **503**, the control system **230** slows the primary boom **201** even further until the primary boom reaches the fourth boom position **504** (i.e., the upper operational limit). In one aspect of this embodiment, the third boom position **503** can be between about 60 degrees and about 80 degrees above the independent reference frame **241**. In the illustrated embodiment, for example, the third boom position **503** is about 65 degrees. In a further aspect of this embodiment, the fourth boom position **504** can be between about 60 degrees and 90 degrees above the independent reference frame **241**. In the illustrated embodiment, for example, the fourth boom position **504** is about 68 degrees. In other embodiments, other angles can be used.

[**0035**] In another aspect of this embodiment, the control system **230** prevents the lift mechanism **212** (**FIG. 2**) from pivoting the primary boom **201** any further upwardly when the primary boom is at the upper operational limit of about 68 degrees corresponding to the fourth boom position **504**. Thus, further motion of the primary boom **201** upwardly relative to the chassis **204** from this position is no longer possible using the boom lift mechanism **212**. However, the control system **230** is configured to permit downwardly movement of the primary boom **201** away from the fourth boom **504** toward shallower angles of inclination. In addition, an audible alarm sounds at both the ground controls **232** and the platform controls **231**. Such an audible alarm can include a loud beep or a series of beeps at a preset rate.

In a further aspect of this embodiment, a number of visual alarms or indicators can also be implemented at the ground controls **232** and/or the platform controls **231**. For example, the platform controls **231** can include a flashing "boom down" light indicating to the operator (not shown) that the boom should be lowered. Similarly, the ground controls **232** could include a flashing "lower boom" light with similar import. In yet another aspect of this embodiment, the foregoing audible/visual alarms can be configured to flash and sound as long as one or more of the boom controls, such as a joystick, is held in an "up boom" position.

[**0036**] Should the primary boom **201** move past the fourth boom position **504** and approach a fifth boom position **505**, for example, by driving the chassis **204** onto a slope that increases the angle of inclination **244**, the audible and/or visual alarms shall continue to flash and sound in more amplified modes to notify the operator that the personnel lift **200** may be in, or approaching, an unstable condition. In one aspect of this embodiment, the fifth boom position **505** can be between about 65 degrees and about 90 degrees above the independent reference frame **241**. In the illustrated embodiment, for example, the fifth boom position **505** is about 70 degrees. In other embodiments, the fifth boom position **505** can be other angles steeper than the fourth boom position **504** (i.e., the upper operational limit). In another aspect of this embodiment, when the primary boom **201** is in the fifth boom position **505**, the drive chassis **204** is disabled so that it cannot continue to propel the personnel lift **200**. At this point, to continue operation, the operator must lower the primary boom **201**. Accordingly, this is the only boom movement allowed by the control system **230** (**FIG. 2**). When the primary boom **201** is lowered to within the operational range (i.e., between boom positions **501** and **504**) all of the alarms are deactivated and the drive chassis **204** is again enabled, allowing the operator to reposition the personnel lift **200**.

[**0037**] If, however, the primary boom **201** somehow reaches a sixth boom position **506**, the control system **230** will shut down or otherwise disable the main power systems on the personnel lift **200** (such as a boom hydraulic system and the ignition and fuel solenoid for a diesel engine housed within the turntable **220**). In addition, all audible and/or visual alarms will continue to sound and flash in the amplified modes. In this situation, the only way to lower the primary boom **201** to a more stable configuration is to utilize an auxiliary power system (e.g., an auxiliary hydraulic system driven by an electric motor) to bleed down the boom lift mechanism and lower the boom. Such an auxiliary power system can be started and operated by an operator located either on the ground or on the personnel lift platform. Once the boom has been lowered to within the operable range (i.e., at or below the fourth boom position **504**), the main power systems can be restarted and normal use can resume. In one aspect of this embodiment, the sixth boom position **506** can be between about 65 degrees and about 90 degrees above the independent reference frame **241**. In the illustrated embodiment, for example, the sixth boom position **506** is about 73 degrees. In other embodiments, the sixth boom position **506** can be other angles steeper than the fifth boom position **505**.

[**0038**] Those of ordinary skill in the relevant art will understand that the method of boom control described above in accordance with **FIGS. 5 and 6** is but one possible embodiment consistent with this disclosure. In other embodiments, other angles can be used for the respective ranges of motion without departing from the spirit and scope of the present invention. For example, in one such alternate embodiment, the fourth boom position **504** can be about 68 degrees, the fifth boom position **505** can be about 69 degrees, and the sixth boom position **506** can be about 70 degrees. Therefore, the invention should not be construed as limited to the particular embodiment illustrated in **FIGS. 4 and 5**. Instead, the invention should be construed to include all stability control methods and apparatuses that control stability of elevating systems, such as personnel lifts, by detecting angles of inclination relative to independent reference frames.

[**0039**] In accordance with the foregoing description, the stability control apparatus **210** described above with reference to FIGS. **2-5** can prevent the personnel lift **200** from being operated in an unstable manner by reducing the boom speed as the primary boom **201** approaches the top of its arc and, ultimately, by preventing the primary boom from pivoting beyond a predetermined angle. Although the foregoing embodiment represents one possible embodiment of the present invention, those of ordinary skill in the art will understand that other embodiments exist. For example, instead of controlling the rotational speed of the primary boom **201**, an alternate embodiment of the stability control system **210** could instead control the rate of extension of the primary boom **201** along its longitudinal axis. In one aspect of this alternate embodiment, the various angles defining the different modes of operation of the primary boom **201** could vary depending on the amount of extension of the primary boom. For example, if the primary boom **201** was at full extension, then the limits of motion could be similar to those illustrated in **FIG. 5**. In contrast, if the primary boom **201** was less extended, then the ranges in motion could be somewhat broader than those shown in **FIG. 5**. These and other modifications can be made to the stability control apparatus **210** (**FIGS. 2 and 3**) in accordance with this disclosure.

[**0040**] **FIG. 6** is an isometric view of a personnel lift **600** in accordance with an alternate embodiment of the invention. In one aspect of this embodiment, a primary boom **601** is pivotally connected to a secondary boom **602** at a first pivot point **671**, and the secondary boom **602** is pivotally mounted to a turntable **620** at a second pivot point **672**. The turntable **620** is rotatably mounted to a drive chassis **604**. In a further aspect of this embodiment, a first angle detector **661** is operatively mounted to the personnel lift **600** proximate to the first pivot point **671** to detect the angle between the primary and secondary booms **601** and **602**, and a second angle detector **662** is operatively mounted to the personnel lift proximate to the second pivot point **672** to detect the angle between the secondary boom **602** and the turntable **620**. Similarly, a third angle detector **663** is mounted to the turntable **620** to detect the angle (positive or negative) between the turntable and an independent reference frame **641**. In the illustrated embodiment of **FIG. 6**, the independent reference frame **641** is represented by a horizontal line normal to the direction of gravitational force. Accordingly, the independent reference frame **641** is independent from and unrelated to the position of the drive chassis **604**.

[**0041**] In operation, the first, second and third angle detectors **661**, **662** and **663** can be used to determine an angle of inclination **644** between the primary boom **601** and the independent reference frame **641**. This angle of inclination **644** can then be used to control the stability of the personnel lift **600** using methods substantially similar to those described above in reference to **FIGS. 4 and 5**. For example, subtracting the angle between the secondary boom **602** and the drive chassis **604** from the angle between the primary boom **601** and the secondary boom **602** results in the angle between the primary boom **601** and the turntable **620**. Once this angle is known, the angle between the turntable **620** and the independent reference frame **641** can be added or subtracted to it (as appropriate) to determine the angle of the primary boom **601** relative to the independent reference frame. As stated above, the angle between the primary boom **601** and the independent reference frame **641** can then be utilized as described above with reference to **FIGS. 4 and 5** to control the stability of the personnel lift **600**. As the foregoing example illustrates, various other angle detector configurations can be used to control the stability of a personnel lift in accordance with this disclosure. For example, as those of ordinary skill in the art will understand, the third angle detector **663** can be mounted to the chassis **604** and used substantially in accordance with the method described above to detect the angle between the primary boom **601** and the independent reference frame **641**. Thus, for purposes of the discussion of **FIG. 6**, the turntable **620** may be considered to be part of the chassis **604**, such that references to the "chassis" in this context would include both the chassis **604** and the turntable.

[**0042**] Although specific embodiments of, and examples for, the present invention are described here for illustrative purposes, various modifications can be made without departing from the spirit or scope of the present invention, as will be readily appreciated by those of ordinary skill in the relevant art. For example, the teachings provided here for a stability control apparatus can be applied not only to the personnel lift described above, but to other extendable systems where an instability may result from over extension or unfavorable chassis positioning. For example, the stability control apparatus disclosed here is equally suitable for use with personnel lifts not having extendable (e.g., telescoping) booms. Similarly, the stability control apparatus could also be used with extendable ladders for fire or rescue vehicles, in addition to elevators for transporting working materials to elevated locations.

[**0043**] These and other changes can be made to the invention in light of the above-detailed description. Therefore, the terms used in the following claims should be not construed to limit the invention to the specific embodiments enclosed, but in general should be construed to include all stability control apparatuses that operate in accordance with the claims. Accordingly, the invention is not limited by this disclosure, but instead its scope is to be determined entirely by the following claims.

We claim:

1. A stability control apparatus usable with a personnel lift, the personnel lift having a boom operatively connected to a chassis and a control system operatively connected to the boom for controlling movement of the boom relative to the chassis, the apparatus comprising:

an angle detector adapted to be operatively mounted to the boom, the angle detector configured to detect an angle of inclination of the boom, the angle of inclination being an angle between a longitudinal axis of the boom and an independent reference frame independent of the chassis; and

a signal processor operatively connected to the angle detector and adapted to be operatively connected to the control system, the signal processor configured to receive a first signal initiated by the angle detector when the angle of inclination reaches a predetermined angle, the signal processor further configured to output a second signal in response to receiving the first signal, the second signal causing the control system to limit movement of the boom relative to the independent reference frame when the angle of inclination reaches the predetermined angle.

2. The stability control apparatus of claim 1 wherein the angle detector is configured to detect the angle of inclination between the longitudinal axis of the boom and a horizontal line at least substantially normal to the direction of gravitational force.

3. The stability control apparatus of claim 1 wherein the angle detector is an accelerometer.

4. The stability control apparatus of claim 1 wherein the angle detector is a pendulum switch.

5. The stability control apparatus of claim 1 wherein the second signal causes the control system to limit pivotal movement of the boom relative to the independent reference frame when the angle of inclination reaches the predetermined angle.

6. The stability control apparatus of claim 1 wherein the chassis is a drive chassis configured for repositioning of the personnel lift, wherein the control system is operatively connected to the drive chassis for controlling repositioning of the drive chassis, and wherein the second signal causes the control system to limit repositioning of the drive chassis when the angle of inclination reaches the predetermined angle.

7. The stability control apparatus of claim 6 wherein the second signal causes the control system to prevent movement of the drive chassis from a first position to a second position when the angle of inclination reaches the predetermined angle.

8. The stability control apparatus of claim 7 wherein the second signal causes the control system to prevent movement of the drive chassis from a first position having a first slope to a second position having a second slope greater than the first slope when the angle of inclination reaches the predetermined angle.

9. The stability control apparatus of claim 1 further comprising an alarm system operatively connected to the signal processor, wherein the second signal causes the alarm system to activate when the angle of inclination reaches the predetermined angle.

10. The stability control apparatus of claim 9 wherein the alarm system is a visual alarm system.

11. The stability control apparatus of claim 10 wherein the visual alarm system includes flashing lights.

12. The stability control apparatus of claim 9 wherein the alarm system is an audible alarm system.

13. The stability control apparatus of claim 1 wherein the processor determines a boom speed based on the first signal received from the angle detector and outputs the second signal related to the boom speed.

14. The stability control apparatus of claim 1 wherein the angle detector is configured to detect the angle of inclination between the longitudinal axis of the boom and a horizontal line at least substantially normal to the direction of gravitational force, and wherein the predetermined angle is between about 30 degrees and about 90 degrees.

15. The stability control apparatus of claim 1 wherein the angle detector is configured to detect the angle of inclination between the longitudinal axis of the boom and a horizontal line at least substantially normal to the direction of gravitational force, and wherein the predetermined angle is between about 60 degrees and about 80 degrees.

16. The stability control apparatus of claim 1 wherein the predetermined angle is a first predetermined angle, wherein the second signal causes the control system to reduce boom speed when the angle of inclination reaches the first predetermined angle, wherein the signal processor is further configured to receive a third signal initiated by the angle detector when the angle of inclination reaches a second predetermined angle, the signal processor further configured to output a fourth signal in response to receiving the third signal, the fourth signal causing the control system to stop movement of the boom relative to the independent reference frame when the angle of inclination reaches the second predetermined angle.

17. A stability control apparatus usable with an elevating system, the elevating system having a boom operatively connected to a chassis and a control system operatively connected to the boom for controlling movement of the boom relative to the chassis, the apparatus comprising:

an angle detector adapted to be operatively mounted to the elevating system, the angle detector configured to detect an angle of inclination, the angle of inclination being an angle between a portion of the elevating system and an independent reference frame independent of the chassis; and

a signal processor operatively connected to the angle detector and adapted to be operatively connected to the control system, the signal processor configured to receive a first signal initiated by the angle detector and output a second signal in response to receiving the first signal, the second signal causing the control system to limit movement of the boom relative to the independent reference frame.

18. The stability control apparatus of claim 17 wherein the angle detector is adapted to be operatively mounted to the boom and is configured to detect the angle of inclination between the boom and the independent reference frame.

19. The stability control apparatus of claim 17 wherein the angle detector is adapted to be operatively mounted to the chassis and is configured to detect the angle of inclination between the chassis and the independent reference frame.

20. The stability control apparatus of claim 17 wherein the angle detector is configured to detect the angle of inclination between a portion of the elevating system and a horizontal line at least substantially normal to the direction of gravitational force.

21. The stability control apparatus of claim 17 wherein the second signal causes the control system to limit pivotal movement of the boom relative to the independent reference frame.

22. The stability control apparatus of claim 17 wherein the chassis is a drive chassis configured for repositioning of the personnel lift, wherein the control system is operatively connected to the drive chassis for controlling repositioning of the drive chassis, and wherein the second signal causes the control system to limit repositioning of the drive chassis.

23. The stability control apparatus of claim 22 wherein the second signal causes the control system to prevent movement of the drive chassis from a first position to a second position.

24. The stability control apparatus of claim 23 wherein the second signal causes the control system to prevent movement of the drive chassis from a first position having a first slope to a second position having a second slope greater than the first slope.

25. The stability control apparatus of claim 17 further comprising an alarm system operatively connected to the signal processor, wherein the second signal causes the alarm system to activate.

26. The stability control apparatus of claim 17 wherein the processor determines a boom speed based on the first signal received from the angle detector and outputs the second signal related to the boom speed.

27. A personnel lift comprising:

a chassis;

a boom pivotally connected relative to the chassis;

a boom control system operatively connected to the boom for controlling movement of the boom relative to the chassis;

an angle detector operatively mounted to the boom, the angle detector configured to detect an angle of inclination of the boom, the angle of inclination being an angle between a longitudinal axis of the boom and an independent reference frame independent of the chassis; and

a signal processor operatively connected to the angle detector and the control system, the signal processor configured to receive a first signal initiated by the angle detector when the angle of inclination reaches a predetermined angle, the signal processor further configured to output a second signal in response to receiving the first signal, the second signal causing the control system to limit movement of the boom relative to the independent reference frame when the angle of inclination reaches the predetermined angle.

28. The personnel lift of claim 27 wherein the boom is a primary boom having a first proximal end and a first distal end spaced apart from the first proximal end, and wherein the personnel lift further includes a secondary boom, the secondary boom having a second proximal end and a second distal end spaced apart from the second proximal end, the second proximal end of the secondary boom being pivotally connected adjacent to the chassis, and the first proximal end of the primary boom being pivotally connected to the second distal end of the secondary boom.

29. The personnel lift of claim 27 wherein the boom is an extendable boom and the personnel lift further includes a lift cylinder operatively connected to the extendable boom and the boom control system for pivoting the boom relative to the chassis.

30. The personnel lift of claim 27 wherein the angle detector is configured to detect the angle of inclination between the longitudinal axis of the boom and a horizontal line at least substantially normal to the direction of gravitational force.

31. The personnel lift of claim 27 wherein the second signal causes the control system to limit pivotal movement of the boom relative to the independent reference frame when the angle of inclination reaches the predetermined angle.

32. The personnel lift of claim 27 wherein the chassis is a drive chassis configured for repositioning of the personnel lift, wherein the control system is operatively connected to the drive chassis for controlling repositioning of the drive chassis, and wherein the second signal causes the control system to limit repositioning of the drive chassis when the angle of inclination reaches the predetermined angle.

33. The personnel lift of claim 32 wherein the second signal causes the control system to prevent movement of the drive chassis from a first position having a first slope to a second position having a second slope greater than the first slope when the angle of inclination reaches the predetermined angle.

34. The personnel lift of claim 27 further comprising an alarm system operatively connected to the signal processor, wherein the second signal causes the alarm system to activate when the angle of inclination reaches the predetermined angle.

35. The personnel lift of claim 27 wherein the processor determines a boom speed based on the first signal received from the angle detector and outputs the second signal related to the boom speed.

36. The personnel lift of claim 27 wherein the predetermined angle is a first predetermined angle, wherein the second signal causes the control system to reduce boom speed when the angle of inclination reaches the first predetermined angle, wherein the signal processor is further configured to receive a third signal initiated by the angle detector when the angle of inclination reaches a second predetermined angle, the signal processor further configured to output a fourth signal in response to receiving the third signal, the fourth signal causing the control system to stop movement of the boom relative to the independent reference frame when the angle of inclination reaches the second predetermined angle.

37. The personnel lift of claim 27 wherein the boom is a primary boom having a first proximal end and a first distal end spaced apart from the first proximal end, and wherein the personnel lift further comprises:

a base mounted to the chassis; and

a secondary boom, the secondary boom having a second proximal end and a second distal end spaced apart from the second proximal end, the second proximal end of the secondary boom being pivotally connected to the base, and the first proximal end of the primary boom being pivotally connected to the second distal end of the secondary boom.

38. The personnel lift of claim 27 wherein the boom is a primary boom having a first proximal end and a first distal end spaced apart from the first proximal end, and wherein the personnel lift further comprises:

a rotatable base rotatably mounted to the chassis; and

a secondary boom, the secondary boom having a second proximal end and a second distal end spaced apart from the second proximal end, the second proximal end of the secondary boom being pivotally connected to the base, and the first proximal end of the primary boom being pivotally connected to the second distal end of the secondary boom.

39. An elevating system comprising:

a chassis;

a boom pivotally connected relative to the chassis;

a control system operatively connected to the boom for controlling movement of the boom;

an angle detector adapted to be operatively mounted to the elevating system, the angle detector configured to detect an angle of inclination, the angle of inclination being an angle between a portion of the elevating system and an independent reference frame independent of the chassis; and

a signal processor operatively connected to the angle detector and adapted to be operatively connected to the control system, the signal processor configured to receive a first signal initiated by the angle detector and output a second signal in response to receiving the first signal, the second signal causing the control system to limit movement of the boom relative to the independent reference frame.

40. The elevating system of claim 39 wherein the angle detector is adapted to be operatively mounted to the boom and is configured to detect the angle of inclination between the boom and the independent reference frame.

41. The elevating system of claim 39 wherein the angle detector is adapted to be operatively mounted to the chassis and is configured to detect the angle of inclination between the chassis and the independent reference frame.

42. The elevating system of claim 39 wherein the angle detector is configured to detect the angle of inclination between a portion of the elevating system and a horizontal line at least substantially normal to the direction of gravitational force.

43. The elevating system of claim 39 wherein the second signal causes the control system to limit pivotal movement of the boom relative to the independent reference frame.

44. The elevating system of claim 39 wherein the chassis is a drive chassis configured for repositioning of the personnel lift wherein the control system is operatively connected to the drive chassis for controlling repositioning of the drive chassis, and wherein the second signal causes the control system to limit repositioning of the drive chassis.

45. The elevating system of claim 44 wherein the second signal causes the control system to prevent movement of the drive chassis from a first position to a second position.

46. The elevating system of claim 44 wherein the second signal causes the control system to prevent movement of the drive chassis from a first position having a first slope to a second position having a second slope greater than the first slope.

47. The elevating system of claim 39 further comprising an alarm system operatively connected to the signal processor, wherein the second signal causes the alarm system to activate.

48. The elevating system of claim 39 wherein the processor determines a boom speed based on the first signal received from the angle detector and outputs the second signal related to the boom speed.

49. A method for controlling the stability of a personnel lift, the personnel lift having a boom operatively connected

to a chassis and a boom control system operatively connected to the boom for controlling movement of the boom relative to the chassis, the method comprising:

providing an angle detector adapted to be operatively mounted to the boom, the angle detector configured to detect an angle of inclination of the boom, the angle of inclination being an angle between a longitudinal axis of the boom and an independent reference frame independent of the chassis;

providing a signal processor operatively connected to the angle detector and adapted to be operatively connected to the control system, the signal processor configured to receive a first signal initiated by the angle detector when the angle of inclination reaches a predetermined angle, the signal processor further configured to output a second signal in response to receiving the first signal, the second signal causing the control system to limit movement of the boom relative to the independent reference frame when the angle of inclination reaches the predetermined angle;

detecting when the boom has pivoted to the predetermined angle; and

limiting movement of the boom when the boom has pivoted to the predetermined angle.

50. The method of claim 49 wherein providing an angle detector includes providing an angle detector configured to detect the angle of inclination between the longitudinal axis of the boom and a horizontal line at least substantially normal to the direction of gravitational force.

51. The method of claim 49 wherein providing an angle detector includes providing an accelerometer.

52. The method of claim 49 wherein limiting movement of the boom when the boom has pivoted to the predetermined angle includes limiting pivotal movement of the boom relative to the independent reference frame.

53. The method of claim 49 wherein limiting movement of the boom when the boom has pivoted to the predetermined angle includes limiting repositioning of the chassis.

54. The method of claim 49 further comprising activating an alarm system when the boom has pivoted to the predetermined angle.

55. The method of claim 49 further comprising determining a boom speed when the boom has pivoted to the predetermined angle.

56. The method of claim 49 wherein limiting movement of the boom when the boom has pivoted to the predetermined angle includes limiting movement of the boom when the boom has pivoted to an angle between about 30 degrees and about 90 degrees.

57. The method of claim 49 wherein limiting movement of the boom when the boom has pivoted to the predetermined angle includes limiting movement of the boom when the boom has pivoted to an angle between about 60 degrees and about 80 degrees.

58. The method of claim 49 wherein limiting movement of the boom when the boom has pivoted to the predetermined angle includes reducing boom speed when the angle of inclination reaches a first predetermined angle, wherein providing the signal processor includes providing a signal processor further configured to receive a third signal initiated by the angle detector when the angle of inclination reaches a second predetermined angle, the signal processor further configured to output a fourth signal in response to receiving the third signal, the fourth signal causing the control system to further limit movement of the boom relative to the independent reference frame when the angle of inclination reaches the second predetermined angle, and wherein the method further comprises further limiting movement of the boom when the angle of inclination reaches the second predetermined angle.

59. The method of claim 58 wherein further limiting movement of the boom when the angle of inclination reaches the second predetermined angle includes stopping boom movement.

60. The method of claim 58 wherein further limiting movement of the boom when the angle of inclination reaches the second predetermined angle includes stopping chassis movement.

61. A method of moving a boom from a first position to a second position, the boom being operatively connected to a chassis and a control system, the control system controlling movement of the boom relative to the chassis, the method comprising:

detecting a boom angle relative to an independent reference frame independent of the chassis;

allowing pivotal movement of the boom relative to the independent reference frame when the boom angle relative to the independent reference frame is within a first range; and

limiting pivotal movement of the boom relative to the independent reference frame when the boom angle relative to the independent reference frame is within a second range, the second range including steeper angles of inclination than the first range.

62. The method of claim 61 wherein limiting pivotal movement of the boom includes reducing boom speed relative to the independent reference frame.

63. The method of claim 61 further comprising preventing pivotal movement of the boom when the boom angle relative to the independent reference frame is within a third range, the third range including steeper angles of inclination than the second range.

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