



(11) **EP 4 818 104 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**07.10.2026 Bulletin 2026/41**

(51) International Patent Classification (IPC):  
**B66C 15/06** <sup>(2006.01)</sup> **B66C 23/90** <sup>(2006.01)</sup>  
**B66C 13/40** <sup>(2006.01)</sup>

(21) Application number: **26178120.7**

(52) Cooperative Patent Classification (CPC):  
**B66C 23/905; B66C 13/40; B66C 15/065**

(22) Date of filing: **24.03.2025**

(84) Designated Contracting States:  
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB  
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL  
NO PL PT RO RS SE SI SK SM TR**  
Designated Extension States:  
**BA**  
Designated Validation States:  
**GE KH MA MD TN**

- **WEBER, Maximilian**  
83395 Freilassing (DE)
- **HABERLANDNER, Stefan**  
Salzburg (AT)
- **TARAMESHLOOPOUR, Sanaz**  
Salzburg (AT)
- **KASPER, Alexander**  
Salzburg (AT)

(62) Document number(s) of the earlier application(s) in  
accordance with Art. 76 EPC:  
**25165585.8 / 4 813 898**

(74) Representative: **2SPL Patentanwälte PartG mbB**  
**Landaubogen 3a**  
**81373 München (DE)**

(71) Applicant: **Palfinger AG**  
**5101 Bergheim bei Salzburg (AT)**

Remarks:  
This application was filed on 12-05-2025 as a  
divisional application to the application mentioned  
under INID code 62.

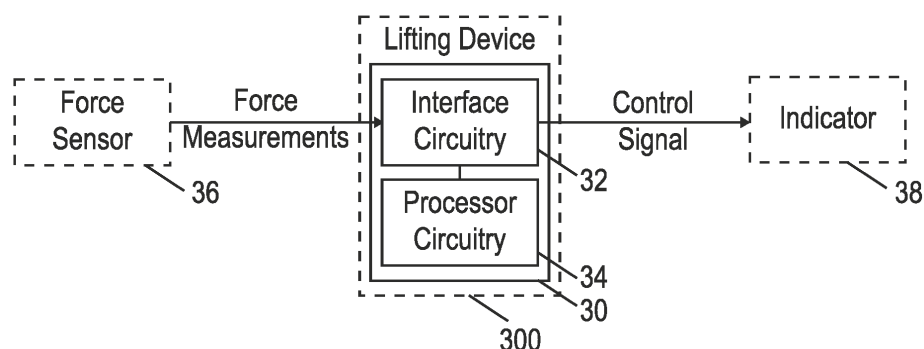
(72) Inventors:  
• **MAYR, Clemens**  
**Salzburg (AT)**

(54) **CONTROL APPARATUS FOR A LIFTING DEVICE, REMOTE-CONTROL DEVICE AND  
CORRESPONDING METHODS AND COMPUTER PROGRAMS**

(57) The present disclosure relates to a control apparatus for a lifting device, to a corresponding method and computer program for a lifting device, to a lifting device comprising the control apparatus, to a system comprising the lifting device and a carrier vehicle, to a remote-control device, and to a corresponding method and computer program for a remote-control device. A control apparatus (30) for a lifting device (300), comprises interface circuitry (32) and processor circuitry

(34), wherein the processor circuitry is configured to receive, via the interface circuitry, force measurements from force sensors (36) associated with support legs being used to stabilize the lifting device, compare the force measurements to at least one force threshold, and provide, via the interface circuitry, a control signal to control at least one indicator (38) based on the comparison.

**FIG. 3a**



**EP 4 818 104 A2**

## Description

### Field

**[0001]** The present disclosure relates to a control apparatus for a lifting device, to a corresponding method and computer program for a lifting device, to a remote-control device, and to a corresponding method and computer program for a remote-control device.

### Background

**[0002]** The determination of the support force in vehicle support devices, such as support legs, is known from the state of the art. One way of measuring this support force is via electrical or electronic force measuring devices, which are preferably arranged in the support plate, i.e. near the point of application of the support force. Another method of determining the support force is to measure the pressure in the cylinder itself (on the piston and rod side). The measured pressures can be used to calculate the support force. Instead of measuring the pressure in the cylinder being used to extend and retract the vehicle support devices, the pressure can also be measured in a separate hydraulic circuit, as shown in EP 2 815 135 B1.

**[0003]** In some systems, the support force being measured is used to limit the operation of a crane. For example, a threshold can be entered for the support forces occurring at the support legs of the crane and, if the current support forces at one of the support legs are exceeded, further movements of the crane that increase this support force can be blocked. In many systems, the threshold being used is the same threshold for every support leg. In EP 2 909 127 B1, separate thresholds are used for the different support legs.

**[0004]** JP2010159148A describes a jack reaction force display device for a work vehicle designed to monitor the safety of outrigger grounding in real time. The system utilizes extension width detectors and jack reaction force detectors to establish a reference reaction force based on the outrigger's extension; it then selects specific display colors or shapes based on the deviation of the actual reaction force from this reference and renders them on a monitor to provide visual safety information.

**[0005]** CN110950248A describes a crane outrigger control system and method utilizing a mobile APP and Bluetooth technology. The system enables the transmission of control commands and the reading of length and pressure parameters via a controller that converts Bluetooth signals to CAN signals for the vehicle controller. It features a safety mechanism where exceeding predefined upper or lower limits triggers vibration alerts on the APP and audible/visual alarms from the controller, while simultaneously issuing motion-limiting commands to enhance operational safety and accuracy.

**[0006]** WO2014059457A1 describes a method for

securing the position of a crane with at least two support legs for supporting said crane on surfaces. At least one threshold is entered for the support legs, and movements which increase the supporting force are blocked if at least one threshold is exceeded by a current supporting force, the thresholds for each of the support legs being entered individually and/or for subgroups of support legs.

**[0007]** There may be a desire for providing an improved concept for operating a lifting device.

### Summary

**[0008]** This desire is addressed by the subject matter of the independent claims.

**[0009]** The proposed concept is based on the insight that the aforementioned systems are based on limiting the movement of the crane when a force exceeding a threshold indicating a maximally tolerable force is detected. These systems are only activated when the maximally tolerable force is reached, effectively shutting down operation of the crane to prevent accidents. For operators of lifting devices, the measured support forces are of major interest well before the threshold is reached, to improve the operation of the lifting device by the operator. Therefore, instead or in addition to waiting for a maximally tolerable threshold to be exceeded (and the operation of the crane being limited accordingly), the user is provided with an indication of the support force, based on the comparison with another threshold (that can be set by the user).

**[0010]** Some aspects of the present disclosure relate to a control apparatus for a lifting device. The control apparatus comprises interface circuitry and processor circuitry. The processor circuitry is configured to receive, via the interface circuitry, force measurements from force sensors associated with support legs being used to stabilize the lifting device. The processor circuitry is configured to compare the force measurements to at least one force threshold. The processor circuitry is configured to provide, via the interface circuitry, a control signal to a remote-control device to control at least one indicator of the remote-control device based on the comparison. By providing a control signal to control an indicator, the operator of the lifting device can be supplied with valuable information on the current support force measured for the support legs. As a result, the operation of the lifting device by the operator can be improved.

**[0011]** In many cases, the operator of a lifting device, such as a vehicle-mounted crane, can be improved if the operator can see the lifting device in the context of its surroundings. For this purpose, the operator may use a remote-control device (e.g., a remote-control device that is communicatively coupled with the control apparatus or lifting device, e.g., via a wired or wireless communication path) to control the lifting device and the support legs. To improve the operation of the lifting device (and the support legs) while the operator is using the remote-control device, the control signal is provided to the remote-control

trol device, to control an indicator of the remote-control device, so that the operator becomes aware of the indication as he or she is controlling the lifting device via the remote-control device. Accordingly, the processor circuitry is configured to provide the control signal to a remote-control device.

**[0012]** There are various modalities that can be used to grab the attention of the operator. For example, the processor circuitry may be configured to provide the control signal to the remote-control device to trigger a vibration at the remote-control device. A vibration can be perceived by the operator even in noisy environments and while having their eyes on the lifting device rather than the remote-control device, thus improving the likelihood that the operator becomes aware of the indication.

**[0013]** Additionally, or alternatively, the indication can be displayed by the remote-control device, e.g., using light-emitting diodes (LEDs) or a display (e.g., of a user interface) of the remote-control device. For example, the processor circuitry may be configured to provide the control signal to the remote-control device to trigger a visual indicator representing the comparison to be displayed by the remote-control device. Visual indications provide a means to provide precise information to the operator, e.g., using numbers to represent the measured forces and the threshold(s). Different colors (e.g., in the user interface, or when using the LEDs) can be used to let the operator take in the urgency of the situation at a glance. For example, a red color can be used to represent scenarios in which the comparison between the at least one threshold and the force measurements indicates a critical situation, e.g., as a highest threshold of the at least one threshold has been reached or surpassed. A yellow color can be used to represent scenarios in which the comparison between the at least one threshold and the force measurements indicate a mildly critical situation, e.g., as a second-highest threshold of the at least one threshold has been reached or surpassed. A green color can be used in noncritical scenarios, e.g., when none of the thresholds have been reached or surpassed.

**[0014]** Another way of grabbing the operator's attention is by using one or more indicators that are arranged at the lifting device or at a carrier vehicle hosting the lifting device. For example, the processor circuitry may be configured to further provide the control signal to an optical system (e.g., LEDs or other types of lights arranged at the lifting device, e.g., at a status board or at the support legs themselves) or acoustic system (e.g., loudspeakers) of the lifting device or to an optical system (e.g., LEDs or other types of lights arranged at the carrier vehicle, e.g., at a status board or at the support legs themselves) or acoustic system of a carrier vehicle hosting the lifting device. This way, the operator can be made aware of the result of the comparison while looking at the lifting device or support legs.

**[0015]** In many cases, lifting devices are used in non-even territory. For example, some of the support legs may be placed on a sidewalk, while others are placed on the

street, or the ground may be sloped. Moreover, due to slight shifts in the center of gravity of the lifting device, different amounts of force may be applied on the support legs. Therefore, force measurements may be obtained, e.g., substantially in real-time, separately for each of the support legs. In other words, the force measurements may comprise, for two or more support legs, separate force measurements being taken by a force sensor associated with the respective support leg. This way, a more precise determination of the respective support forces can be made.

**[0016]** In general, each of the support legs is constrained by the amount of support force it is allowed to take. Therefore, the force measurements may be compared separately to the at least one threshold. In other words, the processor circuitry may be configured to compare the force measurements separately to the at least one force threshold.

**[0017]** In many cases, using a single support force threshold is sufficient, as the condition of the ground and/or the security or legal requirements are the same for each of the support legs. In other words, the processor circuitry may be configured to compare the force measurements to the same force threshold. In some cases, e.g., when some of the support legs are placed on the street while others are placed on the sidewalk, specifying multiple different force thresholds for the different ground structures may be useful. In other words, the processor circuitry may be configured to compare the force measurements to support leg-specific thresholds. This improves operation of the support legs in heterogeneous ground scenarios.

**[0018]** In general, a vital information for the operator is whether the support force of a support leg reaches or surpasses some threshold, e.g., a user-defined threshold, or a threshold derived from laws or regulations. For example, user-defined thresholds may be used that are set below the threshold derived from laws or regulations (e.g., at 75%, 80%, 90% of the security, legal or regulatory threshold), to make the operator aware that the measured forces are close to reaching the legal or regulatory thresholds. Accordingly, the processor circuitry may be configured to provide the control signal such that, if the force measurement for a support leg reaches or surpasses the threshold for the support leg, the at least one indicator is controlled to indicate that the force measurement for the support leg has reached or surpassed the threshold. This way, the operator does not have to check the measured forces but can rely on there being an indication when some relevant threshold is reached, which makes controlling the lifting device or the support legs less cognitively complex.

**[0019]** In some cases, e.g., when the indication is provided via lights that are placed on the support legs themselves, the operator might not see each of the indicators at once. Therefore, if a threshold is surpassed for the force measurements of one support leg, the indicators for multiple support legs may be used to display the

indication, to ensure that the indication is seen by the operator. For example, the processor circuitry may be configured to provide the control signal such that, if the force measurement for a support leg reaches or surpasses the threshold for the support leg, the at least one indicator may be controlled to indicate, at an indicator portion related to at least two support legs, that the force measurement for at least one support leg has reached or surpassed the threshold. This way, the operator is aware of the result of the comparison for several support legs, even if the operator can only perceive the operator for a subset of the support legs.

**[0020]** The proposed concept is particularly useful in combination with operator-defined thresholds (that sit below the security, legal or regulatory thresholds), to enable setting thresholds that indicate to the operator that he or she is to proceed with caution when the respective threshold is reached or surpassed. For example, the processor circuitry may be configured to receive, from a remote-control device, the at least one force threshold. This way, a threshold being used for the comparison can be input by the operator based on the scenario, e.g., ground conditions, at hand.

**[0021]** In some cases, different stabilizer pads, i.e., pads that are attached to or part of the feet of the respective support legs, may be available for use with the support legs. For example, depending on the ground conditions or available space, different stabilizer pads. If the force measurements represent the pressure inside a hydraulic system of the support legs, or if the force measurements represent the force on the support legs (and not on the ground), the size of the stabilizer pads is relevant for interpreting the force measurements. In particular, changing the pad size results in a change in pressure, which allows the pressure of the stabilizers on the ground to be varied or limited. Without using the size of the support pad, the force on the ground can be limited. Using the size of the stabilizer pads, the pressure of the stabilizers on the ground can be limited. Thus, the processor circuitry may be configured to receive, from the remote-control device, information on a size of a stabilizer pad of at least one support leg. The processor circuitry may be configured to adjust, interpret or convert at least one force measurement associated with the at least one support leg based on the size of the stabilizer pad. For example, when comparing the at least one force measurement to the at least one force threshold, the respective forces may be forces and force thresholds that are applied or defined with respect to a unit of area on the ground. This way, the proposed concept can easily be adjusted to differently-sized stabilizer pads and/or to requirements regarding the pressure on the ground (instead of the force on the ground).

**[0022]** In the proposed concept, different levels of thresholds are used. For example, a first threshold and a second threshold being different from the second threshold, e.g., being higher than the first threshold, is used. For example, the first threshold may be the user-

defined threshold, and the second, higher threshold may be the security, legal or regulatory threshold. Alternatively, the first threshold may be a pre-defined fraction (e.g., at least 75%, 80%, or 90%) of the second threshold, which may be user-defined threshold or a security, legal or regulatory threshold. In some cases, a third threshold may be used in addition to the first and second threshold, being higher than the first and second threshold. These thresholds may be distinguished, and different indications may be provided depending on which threshold has been reached or surpassed. In other words, the processor circuitry is configured to compare the force measurements to the first and the second threshold. The processor circuitry is configured to provide the control signal to control the indicator to exhibit a first indication behavior if the force measurements indicate that a respective force exceeds (or reaches) the first threshold and to control the indicator to exhibit a second indication behavior if the force measurements indicate that the respective force exceeds (or reaches) the second threshold. For example, the processor circuitry may be configured to compare the force measurements to the third threshold and control the indicator to exhibit a third indication behavior if the force measurements indicate that a respective force exceeds (or reaches) the third threshold. This can be used to distinguish between scenarios in which the operator has to use caution to proceed (first threshold) and scenarios in which the operator has to cease operating the lifting device (second threshold). This provides the operator with more fine-granular indications that help improve operation of the lifting device by the operator.

**[0023]** As outlined above, the first and second (and third) indication behavior may be used to inform the operator as to which scenario the operator is operating in (e.g., normal operation, operate with caution, cease operations immediately). These can be distinguished, using the indicator(s), using different means, such as using different colors, different alarm tones, or different vibrations. For example, the first and second (and third) indication may differ with respect to a color to be output by the indicator (e.g., yellow and red). Alternatively, or additionally (if multiple indicators are used), the first and second (and third) indication may differ with respect to a vibrational force, speed or pattern to be output by the indicator. For example, the vibrational force or speed used for the first indication may be lower than the vibrational force or speed used for the second indication etc. Similarly, the vibrational pattern used for the first indication may be less hectic or stressful than the vibrational pattern used for the second indication etc. This way, the operator can sub-consciously distinguish the different scenarios.

**[0024]** In some cases, one of the thresholds being used may be a security, legal or regulatory threshold, or the operator may define a threshold that represents a maximal support force the operator is comfortable with. In this case, if this threshold is surpassed, the operation of the lifting device may be limited (in addition to the respective

indication being shown). In other words, the processor circuitry may be configured to limit the speed of movement of the lifting device based on the comparison. Additionally, or alternatively, the processor circuitry may be configured to limit a selection of movements that can be performed by the lifting device based on the comparison. This way, the safety of operating the lifting device may be improved.

**[0025]** In particular, the processor circuitry may be configured to compare the force measurements to a first and a second threshold, and to limit a speed of movement of the lifting device if the force measurements indicate that a respective force exceeds the first threshold and to limit a selection of movements that can be performed by the lifting device if the force measurements indicate that the respective force exceeds the second threshold. Limiting the speed of movement can improve the safety of operation the lifting device is mildly critical situations, as it decrease the speed at which the measured support forces change, while limiting the selection of movements can ensure that the support forces are not increased. This way, the safety of operating the lifting device may be improved.

**[0026]** For example, the first threshold may be a user-defined threshold. The second threshold may be a security threshold defined by the specifications of the support legs or of the lifting device, e.g., a security, legal or regulatory threshold, or an absolute maximum before complete stop. By distinguishing multiple thresholds, the user can be made aware of mildly critical scenarios before reaching the thresholds defined by the specifications of the support legs or of the lifting device, e.g., a security, legal or regulatory threshold. This way, the operator can be made aware that he or she is to use additional caution after having surpassed the user-defined threshold, without the operation of the lifting device being limited due to having reached the second threshold.

**[0027]** In some examples, the first threshold may be a pre-defined ratio or offset from a user-defined threshold and the second threshold may be the user-defined threshold. For example, the first threshold may be 75% of the second threshold, 80% of the second threshold, or 90% of the second threshold. This way, the user does not have to input multiple thresholds while distinguishing between the three scenarios (normal operation, operating with caution, cede operations). In this case, the security threshold defined by the specifications of the support legs or of the lifting device may be used as a third threshold (being higher than the first and second threshold).

**[0028]** Another aspect of the present disclosure relates to a lifting device comprising the control apparatus. Another aspect of the present disclosure relates to a system comprising a carrier vehicle and the lifting device (comprising the control apparatus), with the lifting device being mounted on the carrier vehicle.

**[0029]** Another aspect of the present disclosure relates

to a corresponding method for a lifting device. The method comprises receiving force measurements from force sensors associated with support legs being used to stabilize the lifting device. The method comprises comparing the force measurements to at least one force threshold. The method comprises providing a control signal to a remote-control device to control at least one indicator of the remote-control device based on the comparison. For example, the method may comprise one or more additional features that have been discussed in connection with the corresponding control apparatus. For example, the method may be performed by the lifting device, e.g., by the control apparatus of the lifting device. Alternatively, the method may be performed by the carrier vehicle, e.g., by a control apparatus of the carrier vehicle.

**[0030]** Another aspect of the present disclosure relates to a computer program having a program code for performing the method, when the computer program may be executed on a computer, a processor, or a programmable hardware component.

**[0031]** Some aspects of the present disclosure relate to a remote-control device for controlling a lifting device. For example, the remote-control device may be a portable device, i.e., a device to be carried around by a user. For example, the remote-control device may be a handheld device or a device carried by a user with the help of a neck strap. For example, the remote-control device might not be a device that is permanently attached to another device, such as a vehicle or the lifting device. The remote-control device comprises an indicator, interface circuitry for communicating with a control apparatus of the lifting device, and processor circuitry. The processor circuitry is configured to receive, from the control apparatus, a control signal to control the indicator of the remote-control device. The control signal is based on a comparison between force measurements of force sensors associated with support legs being used to stabilize the lifting device and at least one force threshold. The processor circuitry is configured to control the indicator of the remote-control device based on the control signal. By obtaining a control signal to control an indicator, the operator of the lifting device can be supplied with valuable information on the current support force measured for the support legs. To improve operation of the lifting device (and the support legs) while the operator is using the remote-control device, the control signal is provided to the remote-control device, to control the indicator of the remote-control device, so that the operator becomes aware of the indication as he or she is controlling the lifting device via the remote-control device.

**[0032]** For example, the indicator may comprise a display or a light-emitting diode. The processor circuitry may be configured to display a color indicator representing the comparison on the display or using the light-emitting diode. Visual indications provide a means to provide precise information to the operator, e.g., using numbers to represent the measured forces and the threshold(s). Different colors (e.g., in the user interface, or when using

the LEDs) can be used to let the operator take in the urgency of the situation at a glance.

**[0033]** Additionally, or alternatively, the indicator may comprise a vibration motor. The processor circuitry may be configured to control the vibration motor based on the control signal. A vibration can be perceived by the operator even in noisy environments and while having their eyes on the lifting device rather than the remote-control device, thus improving the likelihood that the operator becomes aware of the indication.

**[0034]** For example, the remote-control device according to one may comprise a user interface. The processor circuitry may be configured to obtain, via the user interface, an input with respect to the at least one force threshold, and to provide the at least one force threshold to the control apparatus based on the input. This way, a threshold being used for the comparison can be input by the operator based on the scenario, e.g., ground conditions, at hand.

**[0035]** Additionally, or alternatively, the processor circuitry may be configured to obtain, via the user interface, an input with respect to a size of a stabilizer pad of at least one support leg, and to provide the at least one force threshold and/or information on the size of the stabilizer pad to the control apparatus based on the input. This way, the control apparatus can be made aware of the size of the stabilizer pad and can adjust its interpretation of the force measurements accordingly.

**[0036]** Some aspects of the present disclosure relate to a corresponding method for a remote-control device for controlling a lifting device. The method comprises receiving, from a control apparatus for controlling the lifting device, a control signal to control an indicator of the remote-control device. The control signal is based on a comparison between force measurements of force sensors associated with support legs being used to stabilize the lifting device and at least one force threshold. The method comprises controlling the indicator of the remote-control device based on the control signal. For example, the method may comprise one or more additional features that have been discussed in connection with the corresponding remote-control device. For example, the method may be performed by the remote-control device. Alternatively, the method may be performed by a mobile device, such as a tablet computer, being used to control the lifting device and/or the carrier vehicle.

**[0037]** Another aspect of the present disclosure relates to a computer program having a program code for performing the method, when the computer program may be executed on a computer, a processor, or a programmable hardware component.

#### Brief description of the Figures

**[0038]** Some examples of apparatuses and/or methods will be described in the following by way of example only, and with reference to the accompanying figures, in

which

- Fig. 1 shows a schematic drawing of side view a lifting device mounted on a carrier vehicle;
- Fig. 2 shows a schematic drawing of a top view of a lifting device mounted on a carrier vehicle;
- Fig. 3a shows a block diagram of an example of a control apparatus for a lifting device;
- Fig. 3b shows a flow chart of an example of a method for controlling a lifting device;
- Fig. 4a shows a block diagram of an example of a remote-control device for controlling a lifting device;
- Fig. 4b shows a flow chart of an example of a method for a remote-control device for controlling a lifting device;
- Figs. 5a to 7b show flow charts of example flows for controlling at least one indicator representing a support force at at least one support leg of a lifting device or carrier vehicle;
- Fig. 8a shows a user interface screen for activating or selecting a stabilizer mode;
- Fig. 8b shows a user interface screen for setting an input value;
- Figs. 9a to 9c show user interface screens for controlling an operation of support legs of a carrier vehicle; and
- Fig. 10 shows a user interface screen for monitoring a support force while operating a lifting device.

#### Detailed Description

**[0039]** Some examples are now described in more detail with reference to the enclosed figures. However, other possible examples are not limited to the features of these embodiments described in detail. Other examples may include modifications of the features as well as equivalents and alternatives to the features. Furthermore, the terminology used herein to describe certain examples should not be restrictive of further possible examples.

**[0040]** Throughout the description of the figures same or similar reference numerals refer to same or similar

elements and/or features, which may be identical or implemented in a modified form while providing the same or a similar function. The thickness of lines, layers and/or areas in the figures may also be exaggerated for clarification.

**[0041]** When two elements A and B are combined using an "or", this is to be understood as disclosing all possible combinations, i.e. only A, only B as well as A and B, unless expressly defined otherwise in the individual case. As an alternative wording for the same combinations, "at least one of A and B" or "A and/or B" may be used. This applies equivalently to combinations of more than two elements.

**[0042]** If a singular form, such as "a", "an" and "the" is used and the use of only a single element is not defined as mandatory either explicitly or implicitly, further examples may also use several elements to implement the same function. If a function is described below as implemented using multiple elements, further examples may implement the same function using a single element or a single processing entity. It is further understood that the terms "include", "including", "comprise" and/or "comprising", when used, describe the presence of the specified features, integers, steps, operations, processes, elements, components and/or a group thereof, but do not exclude the presence or addition of one or more other features, integers, steps, operations, processes, elements, components and/or a group thereof.

**[0043]** Fig. 1 shows a schematic drawing of side view a lifting device 110 (a knuckle boom crane) mounted on a carrier vehicle 120. The carrier vehicle 120 is parked on an inclined base (angle of inclination approximately 5° in the illustration) with a lifting device 110 in the form of a knuckle boom crane arranged on it. The carrier vehicle 120 has a support system with four support legs 130a, 130b (partially concealed, see also Fig. 2) and a control unit 140 arranged on the carrier vehicle for actuating the drives of the support legs 130a-130b based on a support leg control signal. In Fig. 1, the parked carrier vehicle 120 has been aligned to the horizontal after being supported by the support legs 130a-130b on the surface. The inclination relative to the horizontal is essentially 0° in the illustration. It can be seen that at least one wheel of the carrier vehicle 120 has remained on the ground, i.e. the carrier vehicle 120 has not been completely lifted by the support legs 130a-130b. In contrast to the illustration, the carrier vehicle 120 can also be completely raised. While Fig. 1 shows an inclination of the ground along a center axis of the carrier vehicle 120 spanning the carrier vehicle from back to front (or front to back), the support legs can also be used to compensate for an inclination along other axes of the carrier vehicle 120, e.g., an inclination along an axis that is perpendicular to the center axis.

**[0044]** Fig. 2 shows a schematic drawing of the top view of a lifting device 210 mounted on a carrier vehicle 220. For example, the lifting device 210, carrier vehicle 220 and support legs 230a-230d of Fig. 2 may be implemented similar to the lifting device 110, carrier vehicle

120 and support legs 130a-130b of Fig. 1. As shown, the carrier vehicle has horizontally adjustable support arms on which the support legs 230a-230d are arranged.

**[0045]** The proposed concept is based on using measured support forces measured by force sensors associated with the respective support legs to provide an indication to an operator of the lifting devices. In general, a support force is the force exerted by the support legs, also known as outriggers, to stabilize the lifting device (e.g., the crane) during operation. This force counteracts the weight and movement of the load being lifted, maintaining balance and preventing the vehicle from tipping over. The support force of support legs of a vehicle-mounted lifting device can be measured using load cells or pressure sensors integrated into the support legs. These devices monitor the force exerted by each leg and provide real-time data to ensure stability and safe operation. Accordingly, the support legs 130a-b, 230a-d shown in Fig. 1 and 2 may include force sensors 36 (shown in Fig. 3) being configured to determine, e.g., substantially in real-time, the support force of the respective legs. These force measurements are provided to a control apparatus 30 (also shown in Fig. 3) for controlling the lifting device.

**[0046]** Fig. 3a shows a block diagram of an example of a control apparatus 30 for a lifting device 300, e.g., for the lifting device 110, 210 of Figs. 1 and/or 1b. Fig. 3a further shows the lifting device 300 comprising the control apparatus 30. For example, the lifting device 300 may be implemented similar to the lifting device 110, 210 of Figs. 1 and/or 2. For example, as shown in Fig. 1 and 2, the lifting device 110, 120 (e.g., comprising the control apparatus 30) may be mounted on a carrier vehicle 120, 220 and form a system together with the carrier vehicle.

**[0047]** In general, the lifting device 110, 210, 300 may, for example, be a crane (e.g. a loader crane) or an elevating work platform (e.g. a crane with a lifting platform). The lifting device may be a knuckle boom crane or a stiff boom crane. Cranes having only one boom may also be called stiff boom cranes since they do not exhibit multiple booms that can change their orientation with respect to each other. In the event of cranes having multiple booms, a knuckle can be used to connect the different booms to one another so as to enable them to change their relative orientation, by bending about an axis defined by the knuckle. Cranes having at least two booms connected by a knuckle or hinge offer an additional degree of freedom as compared to stiff boom cranes and may be called knuckle-boom cranes. The booms can be connected by hydraulic cylinders across the knuckle to cause the rotation.

**[0048]** The lifting device may have a crane arm system (e.g. also called crane arm or boom) with arms (e.g. also called crane arm segments) with a variable geometry, whereby the arms of the crane arm system can be moved in relation to each other by at least one actuator in the direction of at least one degree of freedom.

**[0049]** The movements of a degree of freedom can be

performed by an actuator corresponding to the degree of freedom. For example, two arms that are pivotably mounted to each other can be pivoted relative to each other by an actuator. Two arms mounted so that they can be translationally moved relative to each other can, for example, be translationally moved relative to each other by an actuator.

**[0050]** The lifting device can be moved by control of actuators by issuing operating commands by an operator or user, preferably via a suitable user interface (e.g. a remote control). For example, individual actuators of the lifting device can be specifically controlled by corresponding control commands on the basis of operating commands from an operator.

**[0051]** The degrees of freedom of the crane arm system can basically comprise angles of arms of the crane arm system to each other or with respect to a horizontal or vertical axis and lengths of arms that can be changed in length. The actuators can be implemented by hydraulic cylinders or electric drives.

**[0052]** Control commands can generally be issued by the control apparatus 30 in the form of control signals, which may contain control pulses with an amplitude and a pulse duration, whereby control pulses can be used, for example, to switch electric drives and/or control valves for the hydraulic supply of actuators of the lifting device.

**[0053]** In the proposed concept, the control apparatus is used to monitor, and optionally control, the support legs 130a-b, 230a-d of the lifting device or carrier vehicle. The control apparatus 30 comprises interface circuitry 32 and processor circuitry 34. The interface circuitry 32 is coupled with the processor circuitry 34. For example, the processor circuitry 34 may be configured to provide the functionality of the control apparatus 30, e.g., in conjunction with the interface circuitry 32 (for exchanging information with other entities, such as a remote-control device 40 shown in Fig. 4, with one or more force sensors 36 (e.g., directly or via the control apparatus of the carrier vehicle), or with one or more indicators 38). For example, the processors circuitry 34 may be configured to execute machine-readable instructions to provide its functionality. For example, the control apparatus 30 may comprise the machine-readable instructions being executed by the processor circuitry 34.

**[0054]** The control apparatus 30 comprises interface circuitry 32. For example, the interface circuitry 32 may be used for receiving signals from sensors, a control panel, a control apparatus of a carrier vehicle and/or a remote-control device 40 through a wireless or wired connection. For example, the interface circuitry 32 may be used for transmitting signals to actuators, drivers, controllers of actuators, a control panel, a control apparatus of a carrier vehicle and/or a remote-control device through a wireless or wired connection. For example, the interface circuitry 32 may comprise a single universal input and/or output interface or various different input and/or output interfaces (e.g. a wireless input and/or output interface to be connected to a remote control

and wired input and/or output interfaces for different sensors, actuators or drivers or controllers of actuators) for different data sources.

**[0055]** In embodiments the processor circuitry 34 may be implemented using one or more processing units, one or more processing devices, any means for processing, such as a processor, a computer or a programmable hardware component being operable with accordingly adapted software. In other words, the described function of the processor circuitry 34 may as well be implemented in software, which is then executed on one or more programmable hardware components. Such hardware components may comprise a general-purpose processor, a Digital Signal Processor (DSP), a micro-controller, etc.

**[0056]** The processor circuitry 34 is configured to receive, via the interface circuitry 32, force measurements from force sensors 36 associated with the support legs (e.g., support legs 130a-b, 230a-d of Figs. 1 and/or 2) being used to stabilize the lifting device. The processor circuitry 34 is configured to compare the force measurements to at least one force threshold. The processor circuitry 34 is configured to provide, via the interface circuitry, a control signal to control at least one indicator 38 based on the comparison. The process of receiving the force measurements, comparing the force measurements to at least one force threshold and providing the control signal may be repeated over and over again, e.g., periodically (e.g., every 50 ms, every 100 ms, every 200 ms, every 500 ms, or every second) or when new force measurements are received.

**[0057]** Fig. 3b shows a flow chart of an example of a corresponding method for controlling the lifting device 110, 120, 300. The method comprises receiving 310 force measurements from force sensors associated with support legs being used to stabilize the lifting device. The method comprises comparing 320 the force measurements to at least one force threshold. The method comprises providing 330 a control signal to control at least one indicator based on the comparison. For example, the method may comprise one or more additional features that are described in connection with the control apparatus of Fig. 3a and in connection with the examples of Fig. 5 to 10.

**[0058]** In many cases, a remote-control device, e.g., remote-control device 40 of Fig. 4, is used by an operator, to control the lifting device. For example, the remote-control device 40 may be used to operate the lifting device by sending (wireless) control signals to the crane's control apparatus 30. The control apparatus 30 interprets these signals and directs the lifting device's motors and other components to perform specific actions like lifting, lowering, or rotating the load. This allows the operator to control the lifting devices from a safe distance.

**[0059]** In the proposed concept, the remote-control device can be provided with an indicator. Fig. 4a shows a block diagram of an example of a remote-control device 40 for controlling a lifting device 110, 210, 300 that

comprises one or more indicators 46, 48. The remote-control device 40 further comprises interface circuitry 42 for communicating with the control apparatus 30 of the lifting device, and processor circuitry 44 that is coupled with the interface circuitry 42 and the indicator 46, 48 (e.g., via the interface circuitry 42). The interface circuitry 42 is coupled with the processor circuitry 44. For example, the processor circuitry 44 may be configured to provide the functionality of the control apparatus 40, e.g., in conjunction with the interface circuitry 42 (for exchanging information with other entities, such as the control apparatus 30 of the lifting device 300). For example, the processor circuitry 44 may be configured to execute machine-readable instructions to provide its functionality. For example, the control apparatus 40 may comprise the machine-readable instructions being executed by the processor circuitry 44. For example, the remote-control device 40 may comprise a user interface 48 (with a display) that can be used as an indicator, and/or the remote-control device 40 may comprise an indicator 46 that is separate from the display, such as one or more LEDs and/or a vibration motor.

**[0060]** The interface circuitry 42 may correspond to one or more inputs and/or outputs for receiving and/or transmitting information, which may be in digital (bit) values according to a specified code, within a module, between modules or between modules of different entities. For example, the interface circuitry 42 may comprise interface circuitry configured to receive and/or transmit information. The processor circuitry 44 may be implemented using one or more processing units, one or more processing devices, any means for processing, such as a processor, a computer or a programmable hardware component being operable with accordingly adapted software. In other words, the described function of the processor circuitry 44 may as well be implemented in software, which is then executed on one or more programmable hardware components. Such hardware components may comprise a general-purpose processor, a Digital Signal Processor (DSP), a micro-controller, etc.

**[0061]** The processor circuitry 44 of the remote-control device 40 is configured to receive from the control apparatus 30 and via the interface circuitry 42, the control signal to control the indicator 46, 48 of the remote-control device. The control signal is based on a comparison between force measurements of force sensors 36 associated with the support legs being used to stabilize the lifting device and at least one force threshold. The processor circuitry 44 of the remote-control device 40 is configured to control the indicator of the remote-control device based on the control signal.

**[0062]** Fig. 4a further shows a system comprising the control apparatus 30 and the remote-control device 40. For example, the system may comprise the lifting device with the control apparatus 30.

**[0063]** Fig. 4b shows a flow chart of an example of a corresponding method for a remote-control device for controlling a lifting device. The method comprises receiv-

ing 410, from a control apparatus for controlling the lifting device, the control signal to control an indicator of the remote-control device. The control signal is based on a comparison between force measurements of force sensors associated with support legs being used to stabilize the lifting device and at least one force threshold. The method comprises controlling 420 the indicator of the remote-control device based on the control signal. For example, the method may be performed by the remote-control device 40 of Fig. 4a. Features introduced in connection with the remote-control device 40 of Fig. 4a may likewise be introduced into the corresponding method of Fig. 4b.

**[0064]** More details and aspects of the control apparatus 30, the corresponding method and a corresponding computer program, and of the remote-control device 40, the corresponding method and a corresponding computer program are mentioned in connection with the proposed concept or one or more examples described above or below (e.g. Fig. 1 to 2, 5a to 10). The control apparatus 30, remote-control device 40, and the corresponding methods and computer programs may comprise one or more additional optional features corresponding to one or more aspects of the proposed concept or one or more examples described above or below.

**[0065]** In the following, the functionality of the control apparatus 30 of Fig. 3a and of the remote-control device 40 of Fig. 4 will be explained in more detail together with reference to the examples given in connection with Figs. 5a to 10.

**[0066]** Some lifting devices or carrier vehicles have a force stabilization function, which can be used to stabilize the carrier vehicle or lifting device based on the pressure in the stabilizers (support legs). In addition to automatic stabilization, the pressure in the crane stabilizers can be output as a percentage of their maximum tolerable force, rather than showing the exact force or pressure. Similarly, some lifting devices or carrier vehicles have a frame protection system (FPS) that is used to protect the frame of the carrier vehicle or lifting devices based on the pressure in the front stabilizers. Again, the FPS function can be used to show the pressure in the front stabilizers as a percentage. In both cases, the pressure in the stabilizers is measured, which enables a determination of the support force.

**[0067]** The proposed concept is based on the insight that it would be beneficial, for the operators, to view the actual force exerted by the stabilizers. The proposed concept, in the following also denoted Support Force Limitation (SFL) function allows the operator to see the real-time force of the stabilizers. For example, the operator may input a specific amount of force to the crane via remote control. If the actual stabilizer force exceeds this input, the operator receives a notification. To enable SFL, the lifting device or carrier vehicle may comprise sensors to measure the pressure or support force. This applies to lifting devices that support the force stabilization function, as lifting devices supporting the force sta-

bilization function use stabilizers with pressure sensors. The hardware used for the force stabilization function is thus used by the SFL software discussed in the present disclosure.

**[0068]** The Support Force Limitation function may enable the operator to view the real-time force in the stabilizers and input a specific force. If the real-time force of the stabilizers exceeds this input amount, notifications may be sent to the operator. These notifications may include vibrations from the remote control, changes in the remote control's lights to yellow and red, and flashing lights on the stabilizers, for example.

**[0069]** Examples of the use of the SFL function are now discussed in the context of the flow charts of Figs. 5a to 7b. Figs. 5a to 7b show flow charts of example flows for controlling at least one indicator representing a support force at at least one support leg of a lifting device or carrier vehicle. In Figs. 5a to 7b, user input is denoted by thin, solid lines, while software functions (e.g., performed by the control apparatus 30 of Fig. 3a) are denoted by thick, dashed lines. Figs. 5a and 5b show two portions of the same flow, as do Figs. 6a and 6b and Figs. 7a and 7b, respectively.

**[0070]** The flow presented in Figs. 5a and 5b starts at 501 with switching on the SFL function, and, at 502, saving the SFL status. Concurrently, at 503, the system (e.g., the control apparatus 30) boots up. If SFL is enabled, the system checks if all stabilizers and the crane are in a transport position. If yes, at 504, the user defines a new input value (threshold), e.g., using the remote control, and, at 505, the system saves a new value. In other words, with respect to the control apparatus 30 of Fig. 3a, the processor circuitry of the control apparatus 30 may be configured to receive, from the remote-control device 40, the at least one force threshold. Accordingly, with respect to the remote-control device 40 of Fig. 4a, the remote-control device may comprise a user interface 48, with the processor circuitry of the remote-control device being configured to obtain, via the user interface, an input with respect to the at least one force threshold, and to provide the at least one force threshold to the control apparatus 30 based on the input. In other words, the user (operator) inputs the input value (the input with respect to the at least one force threshold) at the remote-control device 40, which transmits the input value to the control apparatus 30.

**[0071]** In some cases, the support legs can be used with different types of stabilizer pads, which are used as "feet" of the support legs. Depending on their size, the force measurements may be implemented differently, as the overall support force is distributed over the area covered by the stabilizer pad. In other words, depending on the size of the support pad, the force applied by square centimeter square changes, while the overall support force stays the same. As regulations regarding the maximally allowed support force are generally defined for a pre-defined area (e.g., per m<sup>2</sup>, per ft<sup>2</sup> or per cm<sup>2</sup>), the size of the stabilizer pads may be used to adjust (e.g., scale),

interpret or convert (into a force measurement per unit of area) the force measurements. Similar to the at least one force threshold, the size of the stabilizer pads may be input via the remote control device. Accordingly, the processor circuitry of the remote control device may be configured to obtain, via the user interface, an input with respect to the size of a stabilizer pad of at least one support leg, and to provide information on the size of the stabilizer pad to the control apparatus based on the input. For example, the size (e.g., radius, diameter, x-y dimensions or area) may be input numerically, or may be selected from a set of pre-defined sizes. The control apparatus can then use the information on the size of the support legs to process the force measurements. In other words, the processor circuitry of the control apparatus may be configured to receive, from the remote-control device, the information on a size of a stabilizer pad of at least one support leg, and to adjust, interpret or convert the at least one force measurement associated with the at least one support leg based on the size of the stabilizer pad.

**[0072]** If the stabilizers and the crane are not in a transport position, at 506, the user may indicate to use the last saved input value, and, at 507, the system may use the saved value. At 508, the system measures each stabilizer force. The system then compares the measured values with an overload limit (e.g., a second threshold), and if the measured values exceed the overload limit, at 509, the system may stop all dangerous movements and return to measuring the stabilizer force at 508. If the measured values do not exceed the overload limit, at 510, the system may show the force values on a display 48 of the remote-control device, e.g., by transmitting the control signal to the remote-control device 40. At 511, the system may send the measured force to a telematics module (for processing date, time, GPS (Global Positioning System), force, size of support input etc.). The system may compare the measured values with the input value. If the measured values are less than 80% of the input value, at 512, the light on the remote-control device stay green, and, at 513, lights at the stabilizers are permanently on. If the measured values are between 80% of the input value and less than 100% of the input value, at 514, the lights on the remote-control device turn to orange, at 515 the remote-control device vibrates, at 516, the stabilizer lights start blinking, and at 517, the speed of the crane is reduced. If the measured values are larger than 100% of the input value, at 518, the lights on the remote-control device turn to red, at 519 the remote-control device vibrates, at 520, the stabilizer lights blink faster, and at 521, all dangerous movements of the crane are stopped.

**[0073]** This flow illustrates the features of the control apparatus 30 and remote-control device 40. It is evident from blocks 510 and 512-521 that the indicator that is based on the comparison of the force measurements and the at least one thresholds may be provided both to the remote-control device 40 (see blocks 510, 512, 514, 515, 518, 519) and to an optical or acoustic system of the lifting

device or carrier vehicle (blocks 513, 516, 520). In addition, the operation of the lifting device may be slowed (block 517) or limited (block 521).

**[0074]** In various examples, the remote-control device is used to provide the indication to the user. Accordingly, the processor circuitry of the control apparatus may be configured to provide the control signal to the remote-control device 40.

**[0075]** At the remote-control device, the indication may be provided visually, e.g., via lights (e.g., LEDs) or via a display (e.g., a display used to provide the user interface). In particular, the processor circuitry of the control apparatus may be configured to provide the control signal to the remote-control device to trigger a visual indicator representing the comparison to be displayed (e.g., using the LEDs or the display) by the remote-control device. Accordingly, the indicator of the remote-control device may comprise a display and/or at least one LED, with the processor circuitry being configured to display the indication using the at least one LED or the display. In particular, the processor circuitry may be configured to provide a color indicator representing the comparison on the display or using the light-emitting diode. In the example given in Figs. 5a and 5b, three different color indicators are given - green (box 512) in the normal operation case, yellow (box 514) in the "operate with caution" case, and red (box 518) in the "cede operation" case. These color indicators may be output by LEDs on the remote-control device or using the display of the remote-control device (as shown in Figs. 9a to 9c and 10). For example, for each of the support legs, a separate color indicator may be provided (see Figs. 9a to 9c and 10). Alternatively, the color indicator representing the "worst case" (e.g., the highest percentage of the user input in the context of Figs. 5a and 5b) may be used, e.g., if only a single color indicator is provided that is representative of all comparisons.

**[0076]** Additionally, or alternatively, the indication may be provided using vibration. For example, the indicator of the remote-control device may comprise a vibration motor, with the processor circuitry of the remote-control device being configured to control the vibration motor based on the control signal. Accordingly, the processor circuitry of the control apparatus may be configured to provide the control signal to the remote-control device to trigger a vibration at the remote-control device. For example, as shown in Fig. 5b, in the "normal operation" case, no vibration may be caused, in the "operate with caution" case, a vibration with a lower or slower vibrational force, pattern or speed may be used, and in the "cede operation" case, a vibration with a higher or faster vibrational force, pattern or speed may be used. Alternatively, in both the "operate with caution" and the "cede operation" case, the same vibrational force, pattern or speed may be used.

**[0077]** Another modality for providing the indication to the operator is to use an optical system or acoustic system at the lifting device or at the carrier vehicle.

Accordingly, the processor circuitry may be configured to provide the control signal to an optical system or acoustic system of the lifting device or to an optical system or acoustic system of a carrier vehicle hosting the lifting device. In particular, as shown in boxes 513, 516 and 520 of Fig. 5b, lights may be placed on the stabilizers (support legs) as optical system, to indicate the comparison between the measured forces and the at least one force threshold. Additionally, or alternatively, lights or a display may be arranged at a status board mounted on the lifting device or carrier vehicle. For example, similar to the example with respect to the remote-control device, color indicators may be used to display an indication representing the comparison. Alternatively, a blinking rate (permanently on or off, slower blinking, faster blinking, as shown in boxes 513, 516, 520) of the optical system (i.e., lights) may be used as indication of the comparison. Furthermore, in addition or instead of the optical system, an acoustic system may be used (e.g., loudspeakers). For example, no acoustic signal might be provided in the "normal operation" case, a first lower sound or lower repetition rate of an alarm sound might be provided in the "operation with caution" case, and a second higher sound or higher repetition rate of an alarm sound might be provided in the "cede operation" case etc.

**[0078]** The proposed concept is based on the comparison of the measured forces with at least one (operator-defined, user-defined) threshold. In particular, the comparison may be performed separately for each of the support legs. In other words, the force measurements may comprise, for two or more support legs, separate force measurements being taken by a force sensor associated with the respective support leg. These force measurements may be compared separately to the at least one threshold. For example, the processor circuitry may be configured to compare the force measurements separately to the at least one force threshold. The same threshold or thresholds may be used for comparison for each of the support legs, or a different threshold or different thresholds may be used. In other words, the processor circuitry may be configured to compare the force measurements to the same force threshold, or to compare the force measurements to support leg-specific thresholds.

**[0079]** In the example of Figs. 5a and 5b, it is not specified whether the indications are provided on a per-support leg basis or whether the indication(s) is/are provided for the entirety of the support legs (without showing indications for the separate support legs). In the former case, the processor circuitry may be configured to provide the control signal such, that, if the comparison of a force measurement for a support leg reaches or surpasses the threshold for the support leg, the at least one indicator may be controlled to indicate that the force measurement for the support leg (i.e., this particular support leg) has reached or surpassed the threshold. Accordingly, separate indicators or indicator regions may be used to provide indications for the individual support

legs. In the latter case, one indication (e.g., per modality) may be provided, even if multiple indicators are used (e.g., at the support legs). For example, the processor circuitry of the control apparatus may be configured to provide the control signal such, that, if the comparison of a force measurement for a support leg reaches or surpasses the threshold for the support leg, the at least one indicator is controlled to indicate, at an indicator portion related to at least two support legs, that the force measurement for at least one support leg has reached or surpassed the threshold. In other words, if the measured force for one of the support legs (but not the others) reaches or surpasses a threshold, the indicator portions for all of the support legs may be changed, e.g., according to the highest force measurement. For example, if the support force of one support leg reaches the respective threshold, all light indicators may start to blink with the same indication sequence. Alternatively, if the support force of one support leg reaches the respective threshold, the indication sequence on each leg may be different. For example, the closer the support force of a leg is to the respective threshold, the quicker the lights may blink (which may differ between countries). In other words, the processor circuitry of the control apparatus may be configured to provide the control signal such, that a blinking rate of a light indicator (of the remote-control device or of a light (LED) mounted to the lifting device or carrier vehicle (e.g., mounted to a support leg) is based on a difference between the support force indicated by the force measurement of the respective leg and the at least one threshold. For example, a smaller difference may result in a higher blinking frequency than a larger difference.

**[0080]** In the example shown in Figs. 5a and 5b, several different thresholds are used. For example, in Figs. 5a and 5b, a user input (a single threshold) is obtained, and another threshold (80% of the user input) is derived from the user input, resulting in a first (lower) threshold (80% of the user input) and in a second (higher) threshold (100% of the user input). In other words, the first threshold may be a pre-defined ratio (80%) or offset (e.g., a pre-defined amount of kN) from a user-defined threshold and the second threshold may be the user-defined threshold. Alternatively, the first threshold may be a user-defined (operator-defined) threshold, and the second threshold may be a security threshold defined by the specifications of the support legs or of the lifting device (e.g., a security, legal or regulatory threshold).

**[0081]** As a result, the force measurements may be compared to at least two thresholds (i.e., the first and the second threshold). Depending on the comparison, different indications may be triggered, as shown in Fig. 5b. In other words, the processor circuitry may be configured to compare the force measurements to a first and a second threshold, and to provide the control signal to control the indicator to exhibit a first indication behavior if the force measurements indicate that a respective force exceeds the first threshold and to control the indicator to exhibit a

second indication behavior if the force measurements indicate that the respective force exceeds the second threshold. In Fig. 5b, the first indication behavior is provided if the measured force is at least 80% and below 100% of the user input. The first indication behavior includes the lights of the remote-control device turning orange (box 514), the remote-control device vibrating (box 515) and the lights of the stabilizer lights starting to blink (with a first slower pattern, box 516). The second indication behavior includes the lights of the remote-control device turning red (box 518). The remote-control device vibrating (e.g., with a higher vibrational force, with a more intense pattern or with a higher speed, box 519), and the stabilizer lights blinking faster (box 520). In other words, the first and second indication may differ with respect to a color to be output by the indicator, with respect to a blinking pattern/speed, or with respect to a vibrational force, speed or pattern to be output by the indicator.

**[0082]** In Fig. 5b, a third indication behavior is also shown, which is triggered, in this case, when the measured force is below (each of) the thresholds). This third indication behavior includes the lights of the remote-control device being green (box 512) and the stabilizer lights being permanently on (box 513). Accordingly, the processor circuitry of the control apparatus may be configured to provide the control signal to control the indicator to exhibit the third indication behavior if the force measurements indicate that the respective force is below or at most the first and second threshold.

**[0083]** In Fig. 5b, in addition to providing the indication representing the comparison, the operation of the lifting device (or support legs) may be adjusted based on the comparison. In particular, as shown in box 517, the processor circuitry of the control apparatus may be configured to limit a speed of movement of the lifting device based on the comparison. Additionally, or alternatively, as shown in box 521, the processor circuitry may be configured to limit a selection of movements that can be performed by the lifting device based on the comparison. In particular, as further shown in Fig. 5b, the processor circuitry may be configured to limit a speed of movement of the lifting device if the force measurements indicate that a respective force exceeds the first threshold and to limit a selection of movements that can be performed by the lifting device if the force measurements indicate that the respective force exceeds the second threshold.

**[0084]** In some examples, as shown in Fig. 5a, the force measurements may additionally be compared to a third threshold ("overload limit" in Fig. 5a). For example, the processor circuitry of the control apparatus may be configured to stop all dangerous movements if the force measurements (e.g., if one force measurement) reaches or surpasses the third threshold.

**[0085]** At 522, the user may change between different crane modes (crane, stabilizers, radio remote, workman basked) at the remote-control device. At 523, the system

may use the same SFL value and status. At 524, the user may switch off the SFL function. At 525, the system may save the SFL status (ON/OFF). When the SFL is switched off, the flow ends.

**[0086]** The flow of Figs. 6a and 6b is substantially similar to the flow of Fig. 5a and 5b, with the flow of Figs. 6a and 6b lacking the check of whether the crane and the support legs are in a transport position and with the flow of Figs. 6a and 6b lacking the actions "limiting the speed of movement of the crane" and "stopping all dangerous movements".

**[0087]** The flow presented in Figs. 6a and 6b starts at 601 with switching on the SFL function, and, at 602, saving the SFL status. Concurrently, at 605, the system (e.g., the control apparatus 30) boots up. If SFL is enabled, at 603, the user may define a new input value (threshold), e.g., using the remote control, and, at 604, the system saves a new value. Alternatively, at 607, the user may indicate to use the last saved input value, and, at 608, the system may use the saved value.

**[0088]** At 609, the system measures each stabilizer force. The system then compares the measured values with an overload limit (e.g., a second threshold), and if the measured values exceed the overload limit, at 610, the system may stop all dangerous movements and return to measuring the stabilizer force at 609. If the measured values do not exceed the overload limit, at 611, the system may show the force values on a display 48 of the remote-control device, e.g., by transmitting the control signal to the remote-control device 40. At 612, the system may send the measured force to a telematics module (for processing date, time, GPS (Global Positioning System), force, size of support input etc.). The system may compare the measured values with the input value. If the measured values are less than 80% of the input value, at 613, the light on the remote-control device stays green, and, at 614, lights at the stabilizers are permanently on. If the measured values are between 80% of the input value and less than 100% of the input value, at 615, the lights on the remote-control device turn to orange, at 616 the remote-control device vibrates, and at 617, the stabilizer lights start blinking. If the measured values are larger than 100% of the input value, at 618, the lights on the remote-control device turn to red, at 619 the remote-control device vibrates, and at 620, the stabilizer lights blink faster.

**[0089]** At 621, the user may change between different crane modes (crane, stabilizers, radio remote, workman basked) at the remote-control device. At 622, the system may use the same SFL value and status. At 623, the user may switch off the SFL function. At 624, the system may save the SFL status (ON/OFF). When the SFL is switched off, the flow ends.

**[0090]** Figs. 7a and 7b show a flow that is similar to the flow of Fig. 6a and 6b, without the user inputting a new input value or selecting the previously input value, and with only the "raw" force measurements being provided (without comparison to an input value, with the force

measurements only being compared to the overload limit.

**[0091]** The flow presented in Figs. 7a and 7b starts at 701 with switching on the SFL function, and, at 702, saving the SFL status. Concurrently, at 703, the system (e.g., the control apparatus 30) boots up.

**[0092]** At 704, the system measures each stabilizer force. The system then compares the measured values with an overload limit (e.g., a second threshold), and if the measured values exceed the overload limit, at 705, the system may stop all dangerous movements and return to measuring the stabilizer force at 704. If the measured values do not exceed the overload limit, at 706, the system may show the force values on a display 48 of the remote-control device, e.g., by transmitting the control signal to the remote-control device 40. At 707, the system may send the measured force to a telematics module (for processing date, time, GPS (Global Positioning System), force, size of support input etc.).

**[0093]** At 708, the user may change between different crane modes (crane, stabilizers, radio remote, workman basked) at the remote-control device. At 709, the system may use the same SFL value and status. At 710, the user may switch off the SFL function. At 711, the system may save the SFL status (ON/OFF). When the SFL is switched off, the flow ends.

**[0094]** As outlined in connection with Figs. 3a to 7b, in some cases, the indication may be provided via a display of the remote-control device 40, and the at least one threshold may be input via the user interface (e.g., touchscreen display) of the remote-control device 40. In Figs. 8a to 10, various user interface screens are provided that illustrate this functionality.

**[0095]** Fig. 8a shows a user interface screen for activating or selecting a stabilizer mode. When the operator activates the SFL functionality, the comparisons between the measured force values and the at least one threshold and the provision of the control signal may be started.

**[0096]** Fig. 8b shows a user interface screen for setting an input value. This input value may be used to set a threshold, e.g., the first and second threshold (with the first threshold being a ratio or offset from the user input and the second threshold being the user input), or the first threshold, with the second threshold being a pre-defined threshold (security, legal, regularity or pre-defined threshold for the support legs).

**[0097]** Figs. 9a to 9c show user interface screens for controlling an operation of support legs of a carrier vehicle. In Fig. 9a, using touchscreen buttons 900, vertical movement of the front support legs 910a, 910b can be activated. The measured force values are displayed next to the front support legs 910a, 910b. Color indicators (yellow, red, green) are used per support leg, to identify a match between the support legs and the touchscreen buttons. The user input (SFL) value 920 (threshold) is displayed on top.

**[0098]** In Fig. 9b, using touchscreen buttons 900, vertical and horizontal movement of the back support legs

910c, 910d can be activated, with illustration 930 showing the horizontal extension of the back support legs. The measured force values are displayed next to the back support legs 910c, 910d. Color indicators (red, green) are used per support leg, to identify a match between the support legs and the touchscreen buttons. The user input (SFL) value 920 (threshold) is displayed on top.

**[0099]** In Fig. 9c, using touchscreen buttons 900, vertical and horizontal movements of the side support legs 910e to 910h can be controlled. Color indicators are used per side support leg (along the horizontal extension of the respective support legs (which is also indicated in the user interface), to identify a match between the support legs and the touchscreen buttons. Next to the front, back and side support legs 910a-910h, the measured force values are displayed. In addition, color indicators (red, yellow and green) are used as color indicators at the circular portions of the respective support legs, to indicate the comparison between the force measurements and two thresholds (user input value 920 of 50 kN, 80% of the user input value). Support legs 910b, 910d, 910h at 10 kN, 21 kN and 28 kN, respectively, are shown in green, support legs 910c, 910f and 910g at 42 kN, 45 kN, and 45 kN, respectively are shown in yellow (as the measured support force is larger than 80% of the user input value), and support legs 910a, 910e at 50 kN each are shown in red (as the measured support force has reached 100% of the user input). In the middle, at 940, the center of gravity (and deviation from a base center of gravity) is shown.

**[0100]** Fig. 10 shows a user interface screen for monitoring a support force while operating a lifting device. The user interface screen of Fig. 10 is similar to the screen shown in Fig. 9c, without the touchscreen buttons (and corresponding color indicators) for controlling operation of the support legs. Next to the front, back and side support legs 1010a-910h, the measured force values are displayed. In addition, color indicators (red, yellow and green) are used as color indicators at the circular portions of the respective support legs, to indicate the comparison between the force measurements and two thresholds (user input value 1020 of 50 kN, 80% of the user input value). Support legs 1010b, 1010d, 1010h at 10 kN, 21 kN and 28 kN, respectively, are shown in green, support legs 1010c, 1010f and 1010g at 42 kN, 45 kN, and 45 kN, respectively are shown in yellow (as the measured support force is larger than 80% of the user input value), and support legs 1010a, 1010e at 50 kN each are shown in red (as the measured support force has reached 100% of the user input). In the middle, at 1040, the center of gravity (and deviation from a base center of gravity) is shown.

**[0101]** In the following, some examples of the proposed concept are presented:

An example (e.g., example 1) relates to a control apparatus (30) for a lifting device (110, 210, 300), the control apparatus comprising interface circuitry (32) and processor circuitry (34), wherein the processor circuitry is configured to receive, via the interface circuitry, force mea-

surements from force sensors (36) associated with support legs (130a, 130b, 230a, 230b, 230c, 230d) being used to stabilize the lifting device, compare the force measurements to at least one force threshold, and provide, via the interface circuitry, a control signal to control at least one indicator (38, 46, 48) based on the comparison.

**[0102]** Another example (e.g., example 2) relates to a previous example (e.g., example 1) or to any other example, further comprising that the processor circuitry is configured to provide the control signal to a remote-control device (40).

**[0103]** Another example (e.g., example 3) relates to a previous example (e.g., example 2) or to any other example, further comprising that the processor circuitry is configured to provide the control signal to the remote-control device to trigger a vibration at the remote-control device.

**[0104]** Another example (e.g., example 4) relates to a previous example (e.g., one of the examples 2 or 3) or to any other example, further comprising that the processor circuitry is configured to provide the control signal to the remote-control device to trigger a visual indicator representing the comparison to be displayed by the remote-control device.

**[0105]** Another example (e.g., example 5) relates to a previous example (e.g., one of the examples 1 to 4) or to any other example, further comprising that the processor circuitry is configured to provide the control signal to an optical system or acoustic system of the lifting device or to an optical system or acoustic system of a carrier vehicle hosting the lifting device.

**[0106]** Another example (e.g., example 6) relates to a previous example (e.g., one of the examples 1 to 5) or to any other example, further comprising that the force measurements comprise, for two or more support legs, separate force measurements being taken by a force sensor associated with the respective support leg.

**[0107]** Another example (e.g., example 7) relates to a previous example (e.g., example 6) or to any other example, further comprising that the processor circuitry is configured to compare the force measurements separately to the at least one force threshold.

**[0108]** Another example (e.g., example 8) relates to a previous example (e.g., example 7) or to any other example, further comprising that the processor circuitry is configured to compare the force measurements to the same force threshold, or to compare the force measurements to support leg-specific thresholds.

**[0109]** Another example (e.g., example 9) relates to a previous example (e.g., one of the examples 7 or 8) or to any other example, further comprising that the processor circuitry is configured to provide the control signal such that, if the comparison of a force measurement for a support leg reaches or surpasses the threshold for the support leg, the at least one indicator is controlled to indicate that the force measurement for the support leg has reached or surpassed the threshold.

**[0110]** Another example (e.g., example 10) relates to a previous example (e.g., one of the examples 7 or 8) or to any other example, further comprising that the processor circuitry is configured to provide the control signal such, that, if the comparison of a force measurement for a support leg reaches or surpasses the threshold for the support leg, the at least one indicator is controlled to indicate, at an indicator portion related to at least two support legs, that the force measurement for at least one support leg has reached or surpassed the threshold.

**[0111]** Another example (e.g., example 11) relates to a previous example (e.g., one of the examples 1 to 10) or to any other example, further comprising that the processor circuitry is configured to receive, from a remote-control device, the at least one force threshold.

**[0112]** Another example (e.g., example 12) relates to a previous example (e.g., one of the examples 1 to 11) or to any other example, further comprising that the processor circuitry is configured to receive, from the remote-control device, information on a size of a stabilizer pad of at least one support leg, with the processor circuitry being configured to adjust, interpret or convert at least one force measurement associated with the at least one support leg based on the size of the stabilizer pad

**[0113]** Another example (e.g., example 13) relates to a previous example (e.g., one of the examples 1 to 12) or to any other example, further comprising that the processor circuitry is configured to compare the force measurements to a first and a second threshold, and to provide the control signal to control the indicator to exhibit a first indication behavior if the force measurements indicate that a respective force exceeds the first threshold and to control the indicator to exhibit a second indication behavior if the force measurements indicate that the respective force exceeds the second threshold.

**[0114]** Another example (e.g., example 14) relates to a previous example (e.g., example 13) or to any other example, further comprising that the first and second indication differ with respect to a color to be output by the indicator, or wherein the first and second indication differ with respect to a vibrational force, speed or pattern to be output by the indicator.

**[0115]** Another example (e.g., example 15) relates to a previous example (e.g., one of the examples 1 to 14) or to any other example, further comprising that the processor circuitry is configured to limit a speed of movement of the lifting device based on the comparison, and/or wherein the processor circuitry is configured to limit a selection of movements that can be performed by the lifting device based on the comparison.

**[0116]** Another example (e.g., example 16) relates to a previous example (e.g., one of the examples 1 to 15) or to any other example, further comprising that the processor circuitry is configured to compare the force measurements to a first and a second threshold, and to limit a speed of movement of the lifting device if the force measurements indicate that a respective force exceeds the first threshold and to limit a selection of movements

that can be performed by the lifting device if the force measurements indicate that the respective force exceeds the second threshold.

**[0117]** Another example (e.g., example 17) relates to a previous example (e.g., one of the examples 13, 14, or 16) or to any other example, further comprising that the first threshold is a user-defined threshold and the second threshold is a security threshold defined by the specifications of the support legs or of the lifting device.

**[0118]** Another example (e.g., example 18) relates to a previous example (e.g., one of the examples 13, 14, or 16) or to any other example, further comprising that the first threshold is a pre-defined ratio or offset from a user-defined threshold and the second threshold is the user-defined threshold.

**[0119]** Another example (e.g., example 19) relates to a lifting device (110, 210) comprising the control apparatus (30) according to one of the examples 1 to 18.

**[0120]** Another example (e.g., example 20) relates to a system comprising a carrier vehicle (120, 220) and the lifting device (110, 210) according to example 19 mounted on the carrier vehicle.

**[0121]** An example (e.g., example 21) relates to a remote-control device (40) for controlling a lifting device (110, 210, 300), comprising an indicator (46, 48), interface circuitry (42) for communicating with a control apparatus (30) of the lifting device, and processor circuitry (44) configured to receive, from the control apparatus, a control signal to control the indicator of the remote-control device, wherein the control signal is based on a comparison between force measurements of force sensors associated with support legs (130a, 130b, 230a, 230b, 230c, 230d) being used to stabilize the lifting device and at least one force threshold, and control the indicator of the remote-control device based on the control signal.

**[0122]** Another example (e.g., example 22) relates to a previous example (e.g., example 21) or to any other example, further comprising that the indicator comprises a display or a light-emitting diode, the processor circuitry being configured to display a color indicator representing the comparison on the display or using the light-emitting diode.

**[0123]** Another example (e.g., example 23) relates to a previous example (e.g., one of the examples 21 or 22) or to any other example, further comprising that the indicator comprises a vibration motor, the processor circuitry being configured to control the vibration motor based on the control signal.

**[0124]** Another example (e.g., example 24) relates to a previous example (e.g., one of the examples 21 to 23) or to any other example, further comprising a user interface (48), with the processor circuitry being configured to obtain, via the user interface, an input with respect to the at least one force threshold and/or an input with respect to a size of a stabilizer pad of at least one support leg, and to provide the at least one force threshold and/or information on the size of the stabilizer pad to the control

apparatus based on the input.

**[0125]** An example (e.g., example 25) relates to a method for a lifting device, comprising receiving (310) force measurements from force sensors associated with support legs being used to stabilize the lifting device, comparing (320) the force measurements to at least one force threshold, and providing (330) a control signal to control at least one indicator based on the comparison.

**[0126]** An example (e.g., example 26) relates to a method for a remote-control device for controlling a lifting device, comprising receiving (410), from a control apparatus for controlling the lifting device, a control signal to control an indicator of the remote-control device, wherein the control signal is based on a comparison between force measurements of force sensors associated with support legs being used to stabilize the lifting device and at least one force threshold, and controlling (420) the indicator of the remote-control device based on the control signal.

**[0127]** Another example (e.g., example 27) relates to a computer program having a program code for performing the method of one of the examples 25 or 26, when the computer program is executed on a computer, a processor, or a programmable hardware component.

**[0128]** The aspects and features described in relation to a particular one of the previous examples may also be combined with one or more of the further examples to replace an identical or similar feature of that further example or to additionally introduce the features into the further example.

**[0129]** Examples may further be or relate to a (computer) program including a program code to execute one or more of the above methods when the program is executed on a computer, processor or other programmable hardware component. Thus, steps, operations or processes of different ones of the methods described above may also be executed by programmed computers, processors or other programmable hardware components. Examples may also cover program storage devices, such as digital data storage media, which are machine-, processor- or computer-readable and encode and/or contain machine-executable, processor-executable or computer-executable programs and instructions. Program storage devices may include or be digital storage devices, magnetic storage media such as magnetic disks and magnetic tapes, hard disk drives, or optically readable digital data storage media, for example. Other examples may also include computers, processors, control units, (field) programmable logic arrays ((F)PLAs), (field) programmable gate arrays ((F)PGAs), graphics processor units (GPU), application-specific integrated circuits (ASICs), integrated circuits (ICs) or system-on-a-chip (SoCs) systems programmed to execute the steps of the methods described above.

**[0130]** It is further understood that the disclosure of several steps, processes, operations or functions disclosed in the description or claims shall not be construed to imply that these operations are necessarily dependent

on the order described, unless explicitly stated in the individual case or necessary for technical reasons. Therefore, the previous description does not limit the execution of several steps or functions to a certain order. Furthermore, in further examples, a single step, function, process or operation may include and/or be broken up into several sub-steps, -functions, -processes or -operations.

**[0131]** If some aspects have been described in relation to a device or system, these aspects should also be understood as a description of the corresponding method. For example, a block, device or functional aspect of the device or system may correspond to a feature, such as a method step, of the corresponding method. Accordingly, aspects described in relation to a method shall also be understood as a description of a corresponding block, a corresponding element, a property or a functional feature of a corresponding device or a corresponding system.

**[0132]** The following claims are hereby incorporated in the detailed description, wherein each claim may stand on its own as a separate example. It should also be noted that although in the claims a dependent claim refers to a particular combination with one or more other claims, other examples may also include a combination of the dependent claim with the subject matter of any other dependent or independent claim. Such combinations are hereby explicitly proposed, unless it is stated in the individual case that a particular combination is not intended. Furthermore, features of a claim should also be included for any other independent claim, even if that claim is not directly defined as dependent on that other independent claim.

## Claims

1. A control apparatus (30) for a lifting device (110, 210, 300), the control apparatus comprising interface circuitry (32) and processor circuitry (34), wherein the processor circuitry is configured to:

receive, via the interface circuitry, force measurements from force sensors (36) associated with support legs (130a, 130b, 230a, 230b, 230c, 230d) being used to stabilize the lifting device,

compare the force measurements to at least one force threshold, and

provide, via the interface circuitry, a control signal to a remote-control device (40) to control at least one indicator (46, 48) of the remote-control device based on the comparison,

wherein the processor circuitry is configured to compare the force measurements to a first and a second threshold, and to provide the control signal to control the indicator to exhibit a first indication behavior if the force measurements

- indicate that a respective force exceeds the first threshold and to control the indicator to exhibit a second indication behavior if the force measurements indicate that the respective force exceeds the second threshold,
- wherein the first threshold is a user-defined threshold and the second threshold is a security threshold defined by the specifications of the support legs or of the lifting device, or wherein the first threshold is a pre-defined ratio or offset from a user-defined threshold and the second threshold is the user-defined threshold.
2. The control apparatus according to claim 1, wherein the processor circuitry is configured to provide the control signal to the remote-control device to trigger a vibration at the remote-control device and/or to trigger a visual indicator representing the comparison to be displayed by the remote-control device.
  3. The control apparatus according to one of the claims 1 or 2, wherein the processor circuitry is configured to further provide the control signal to an optical system or acoustic system of the lifting device or to an optical system or acoustic system of a carrier vehicle hosting the lifting device.
  4. The control apparatus according to one of the claims 1 to 3, wherein the force measurements comprise, for two or more support legs, separate force measurements being taken by a force sensor associated with the respective support leg, wherein the processor circuitry is configured to compare the force measurements separately to the at least one force threshold.
  5. The control apparatus according to claim 4, wherein the processor circuitry is configured to provide the control signal such, that, if the force measurement for a support leg reaches or surpasses the threshold for the support leg, the at least one indicator is controlled to indicate that the force measurement for the support leg has reached or surpassed the threshold.
  6. The control apparatus according to one of the claims 1 to 5, wherein the processor circuitry is configured to receive, from a remote-control device, the at least one force threshold, and/or wherein the processor circuitry is configured to receive, from the remote-control device, information on a size of a stabilizer pad of at least one support leg, with the processor circuitry being configured to adjust, interpret or convert at least one force measurement associated with the at least one support leg based on the size of the stabilizer pad.
  7. The control apparatus according to one of the claims 1 to 6, wherein the first and second indication differ

with respect to a color to be output by the indicator, or wherein the first and second indication differ with respect to a vibrational force, speed or pattern to be output by the indicator.

8. The control apparatus according to one of the claims 1 to 7, wherein the processor circuitry is configured to compare the force measurements to a first and a second threshold, and to limit a speed of movement of the lifting device if the force measurements indicate that a respective force exceeds the first threshold and to limit a selection of movements that can be performed by the lifting device if the force measurements indicate that the respective force exceeds the second threshold.
9. A remote-control device (40) for controlling a lifting device (110, 210, 300), comprising an indicator (46, 48), interface circuitry (42) for communicating with a control apparatus (30) of the lifting device, and processor circuitry (44) configured to:

receive, from the control apparatus, a control signal to control the indicator of the remote-control device, wherein the control signal is based on a comparison between force measurements of force sensors associated with support legs (130a, 130b, 230a, 230b, 230c, 230d) being used to stabilize the lifting device and at least one force threshold, wherein the force measurements are compared to a first and a second threshold, wherein the control signal is configured to control the indicator to exhibit a first indication behavior if the force measurements indicate that a respective force exceeds the first threshold and to control the indicator to exhibit a second indication behavior if the force measurements indicate that the respective force exceeds the second threshold, wherein the first threshold is a user-defined threshold and the second threshold is a security threshold defined by the specifications of the support legs or of the lifting device, or wherein the first threshold is a pre-defined ratio or offset from a user-defined threshold and the second threshold is the user-defined threshold; and control the indicator of the remote-control device based on the control signal.

10. A method for a lifting device, comprising

receiving (310) force measurements from force sensors associated with support legs being used to stabilize the lifting device;  
 comparing (320) the force measurements to at least one force threshold, and  
 providing (330) a control signal to a remote-

control device to control at least one indicator of the remote-control device based on the comparison,  
 wherein the force measurements are compared to a first and a second threshold, wherein the control signal is provided to control the indicator to exhibit a first indication behavior if the force measurements indicate that a respective force exceeds the first threshold and to control the indicator to exhibit a second indication behavior if the force measurements indicate that the respective force exceeds the second threshold, wherein the first threshold is a user-defined threshold and the second threshold is a security threshold defined by the specifications of the support legs or of the lifting device, or wherein the first threshold is a pre-defined ratio or offset from a user-defined threshold and the second threshold is the user-defined threshold.

**11.** A method for a remote-control device for controlling a lifting device, comprising:

receiving (410), from a control apparatus for controlling the lifting device, a control signal to control an indicator of the remote-control device, wherein the control signal is based on a comparison between force measurements of force sensors associated with support legs being used to stabilize the lifting device and at least one force threshold; and  
 controlling (420) the indicator of the remote-control device based on the control signal, wherein the force measurements are compared to a first and a second threshold, wherein the control signal is configured to control the indicator to exhibit a first indication behavior if the force measurements indicate that a respective force exceeds the first threshold and to control the indicator to exhibit a second indication behavior if the force measurements indicate that the respective force exceeds the second threshold,  
 wherein the first threshold is a user-defined threshold and the second threshold is a security threshold defined by the specifications of the support legs or of the lifting device, or wherein the first threshold is a pre-defined ratio or offset from a user-defined threshold and the second threshold is the user-defined threshold.

**12.** A computer program having a program code for performing the method of one of the claims 10 or 11, when the computer program is executed on a computer, a processor, or a programmable hardware component.

FIG. 1

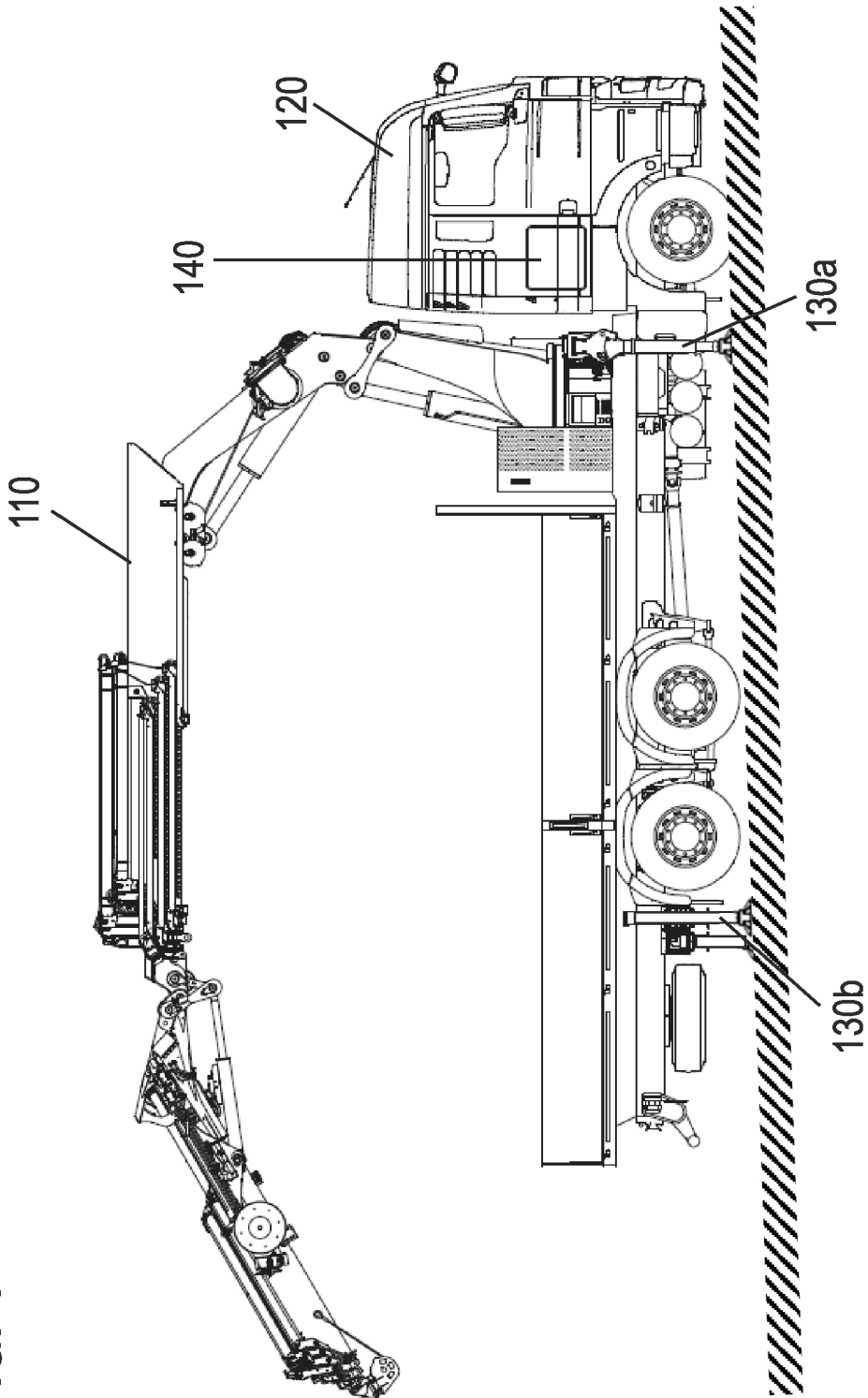


FIG. 2

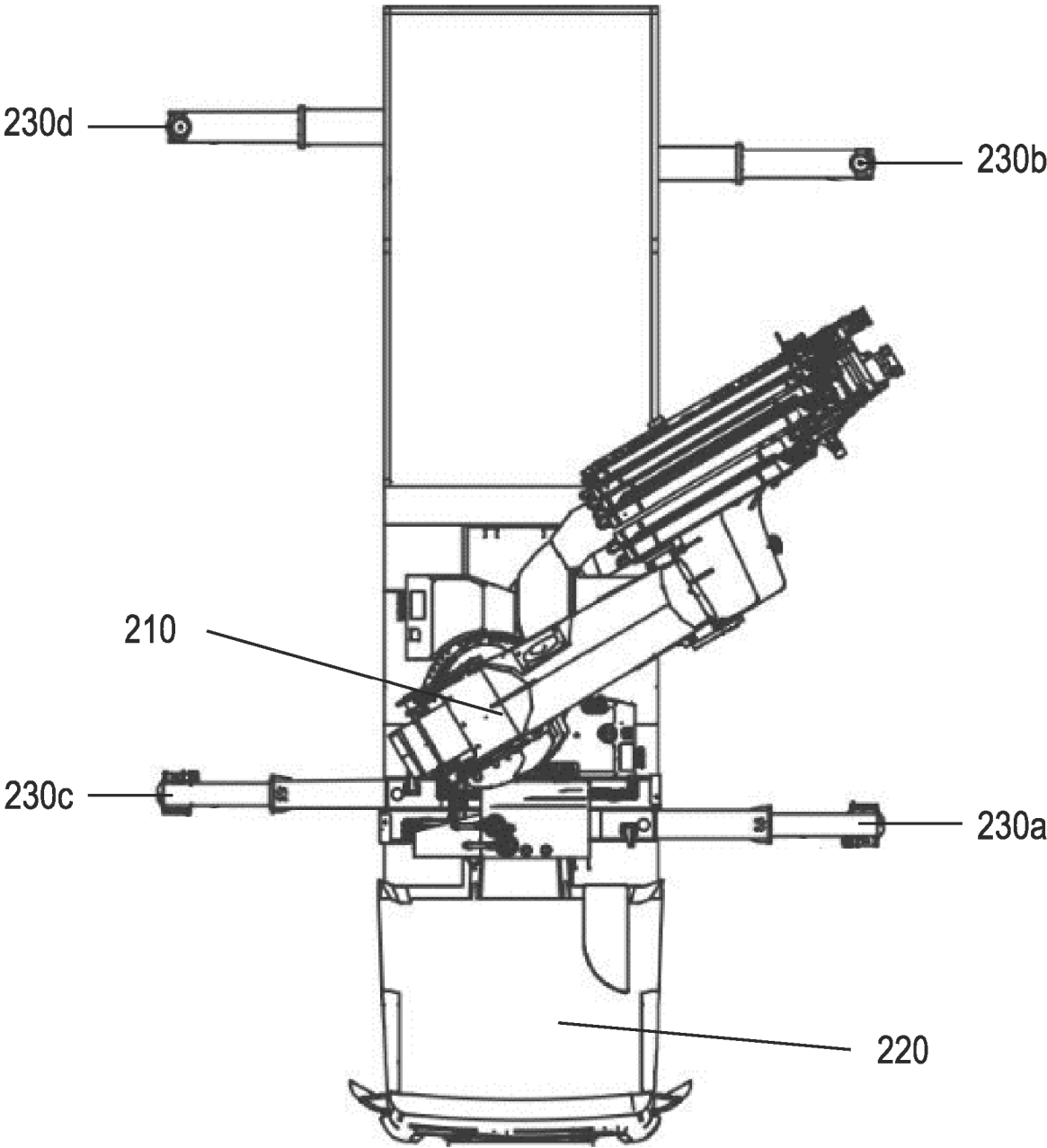


FIG. 3a

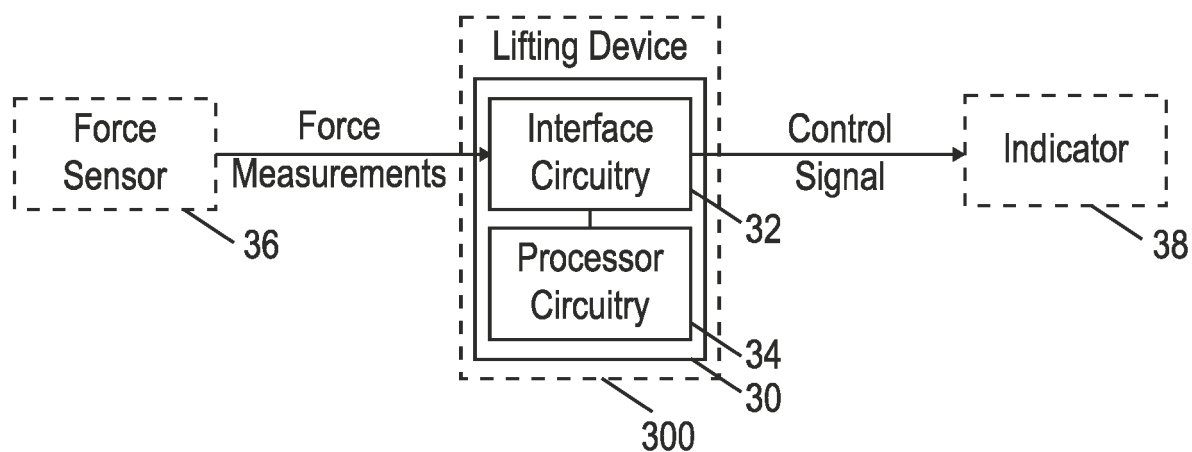


FIG. 3b

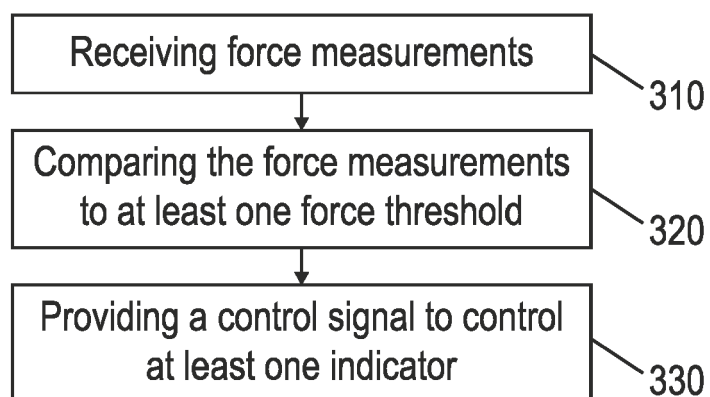


FIG. 4a

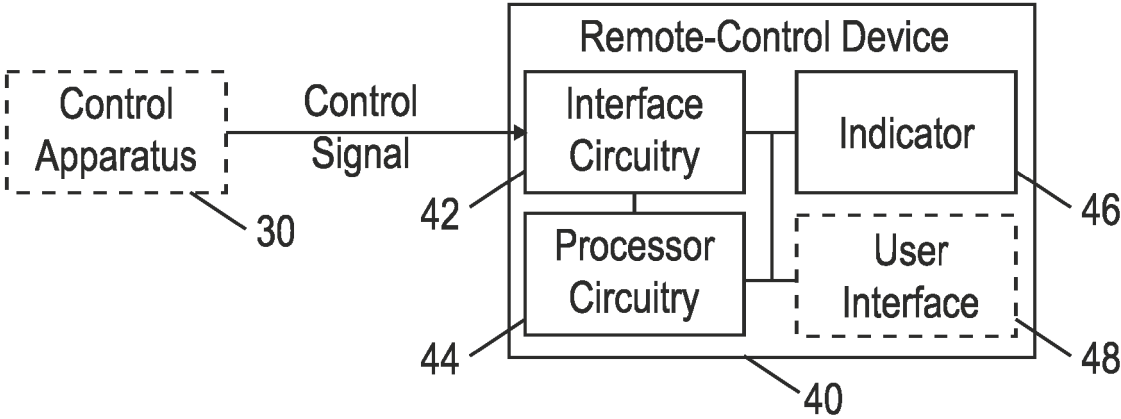


FIG. 4b

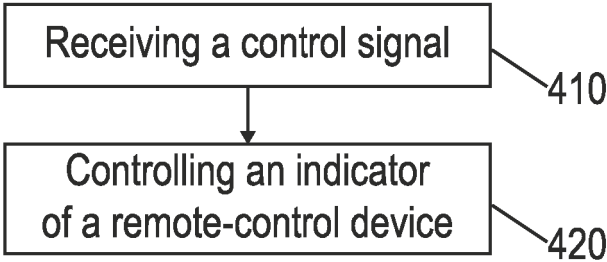


FIG. 5a

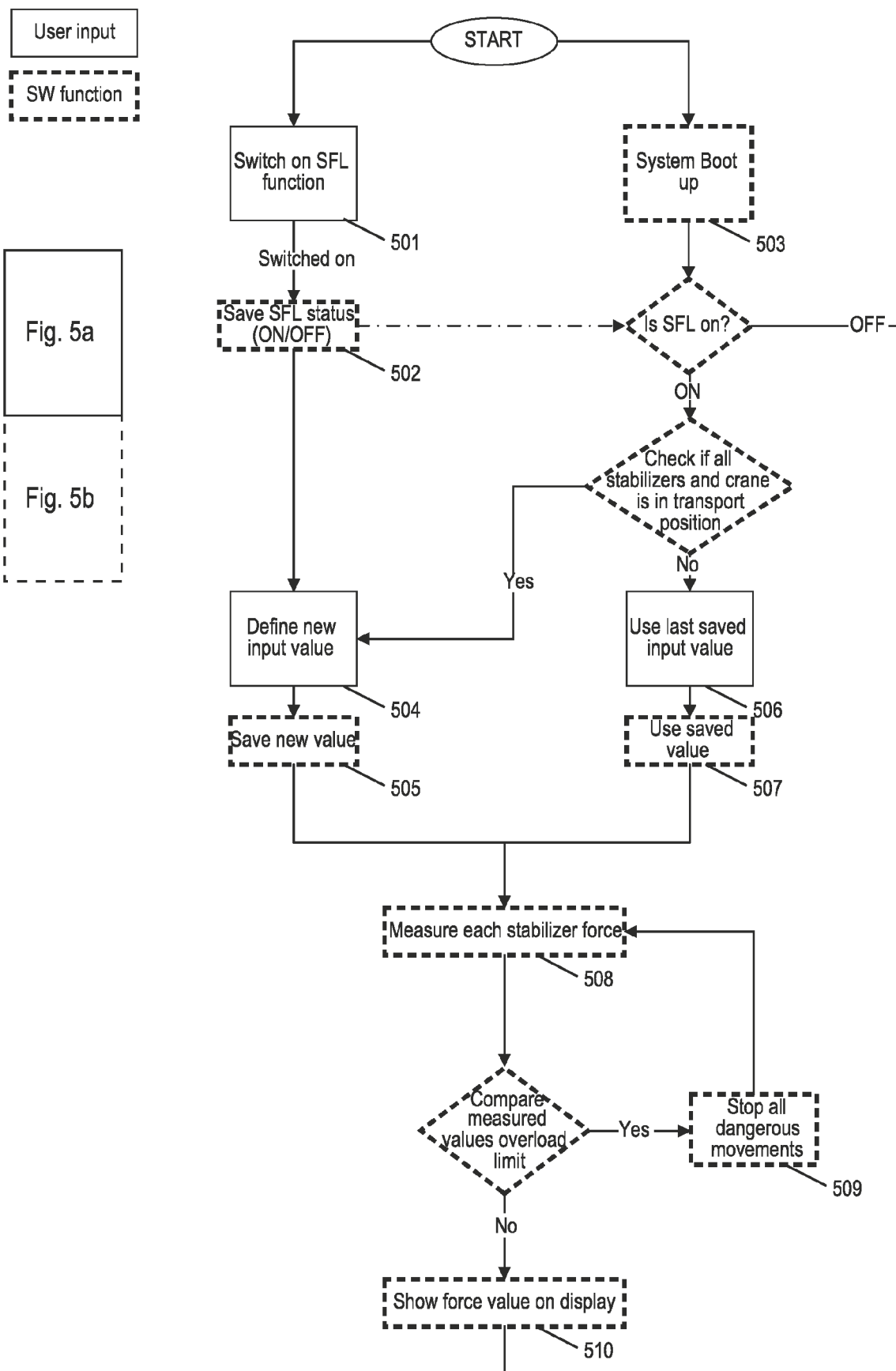


FIG. 5b

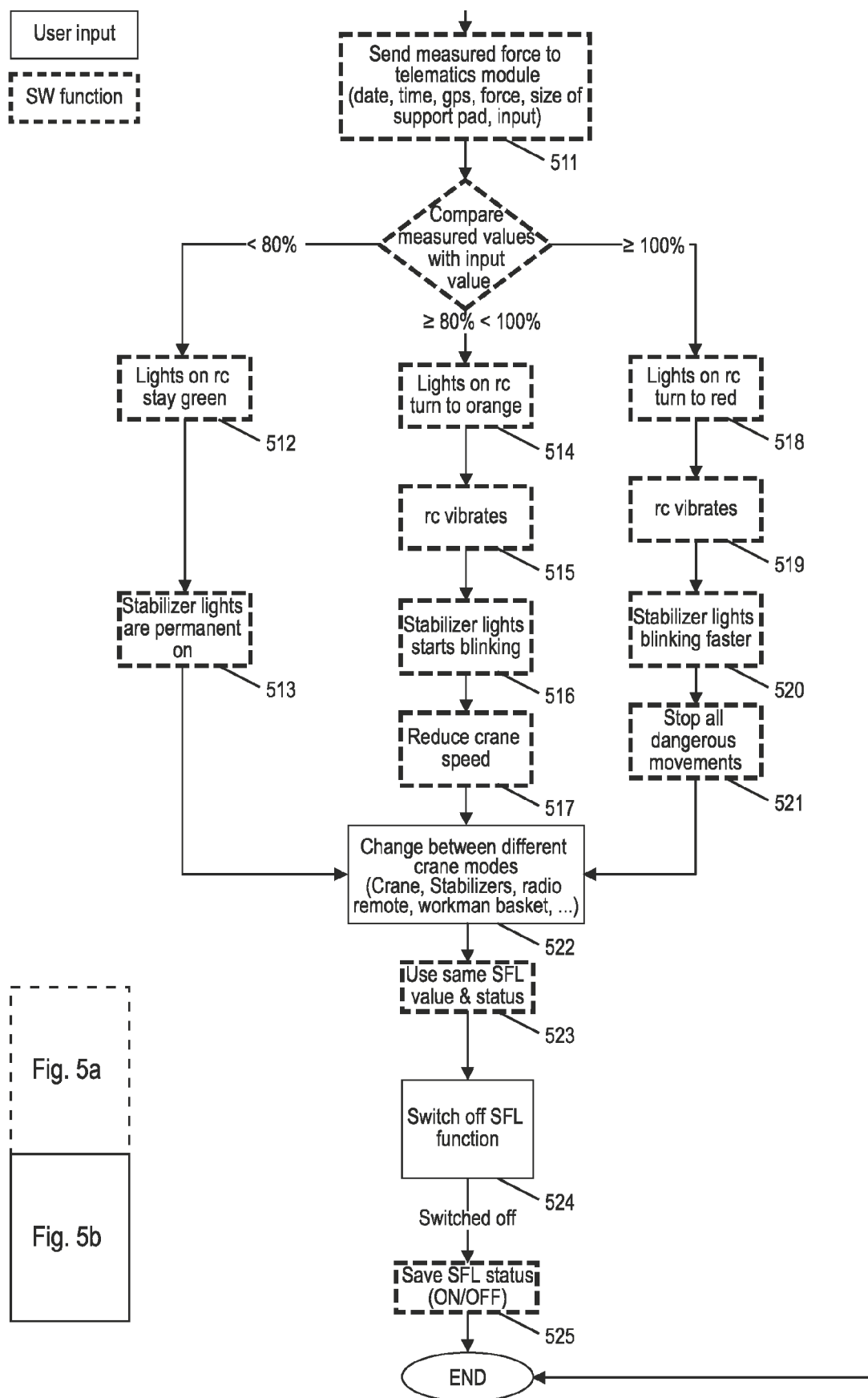


FIG. 6a

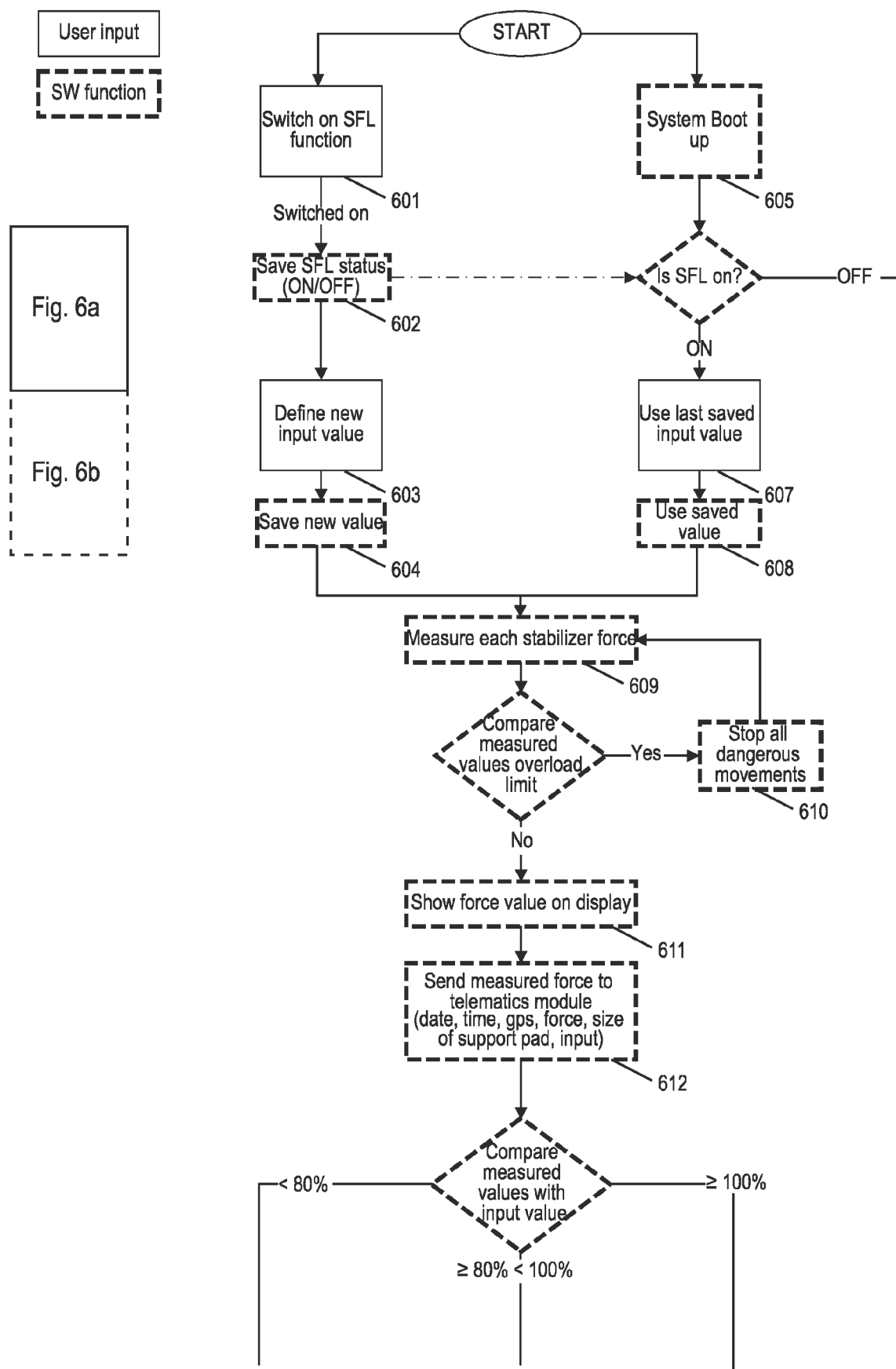


FIG. 6b

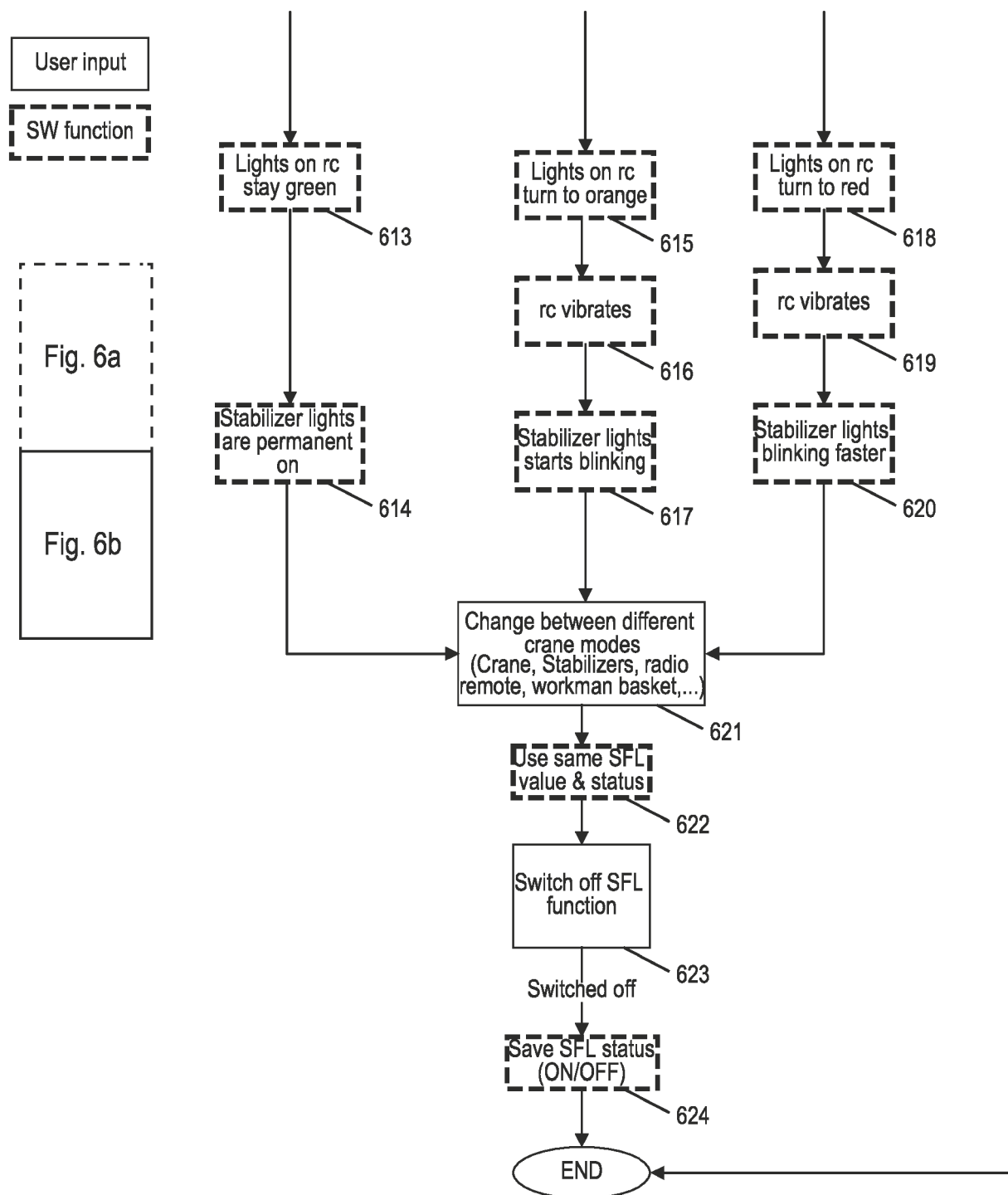


FIG. 7a

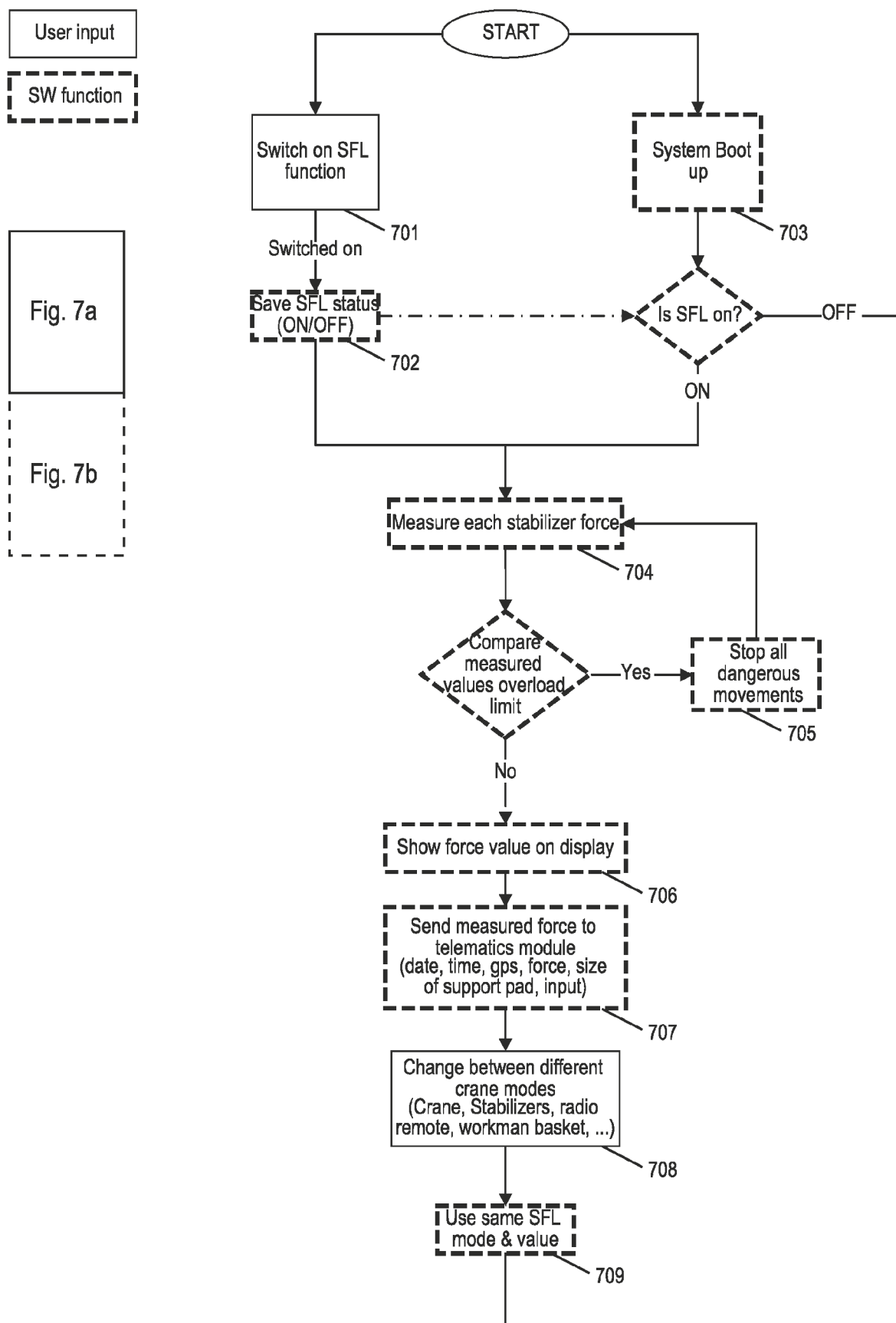


FIG. 7b

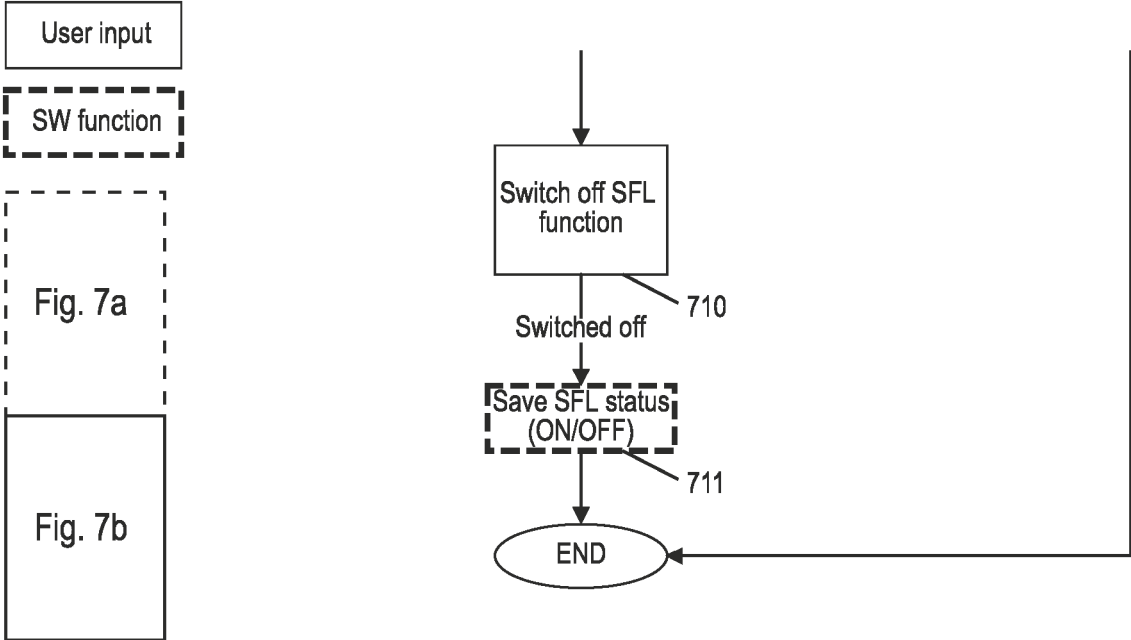


FIG. 8a

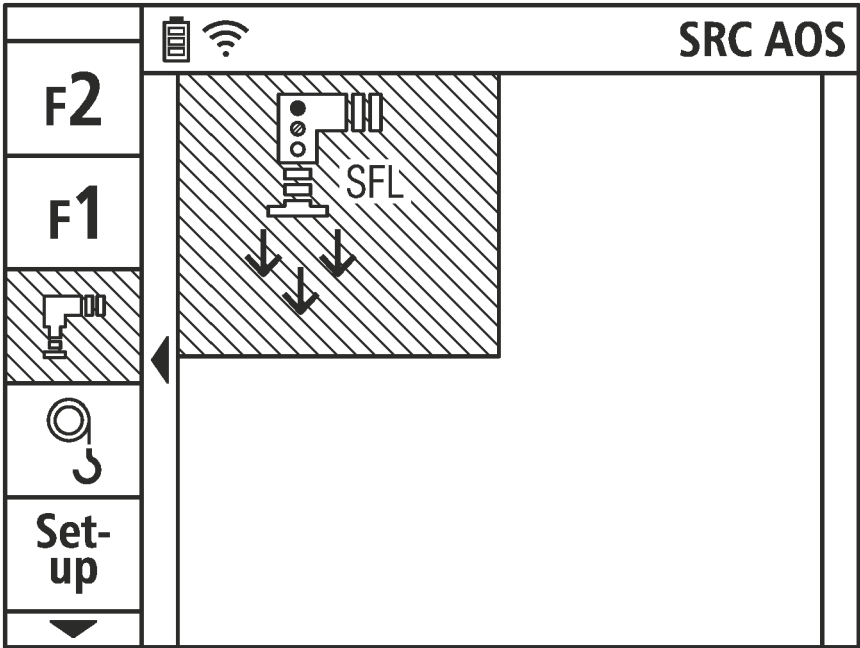


FIG. 8b

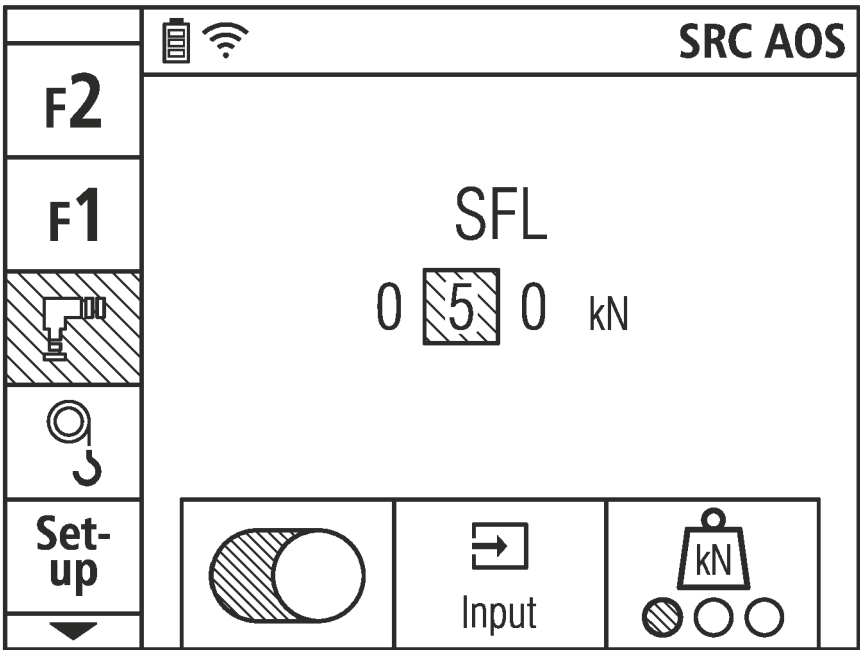


FIG. 9a

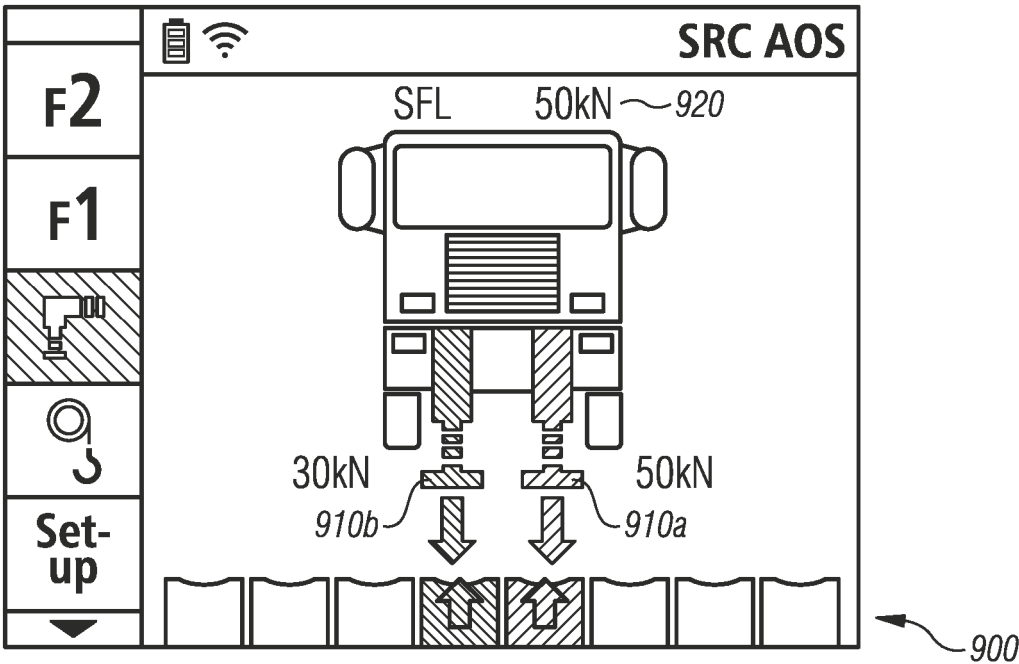


FIG. 9b

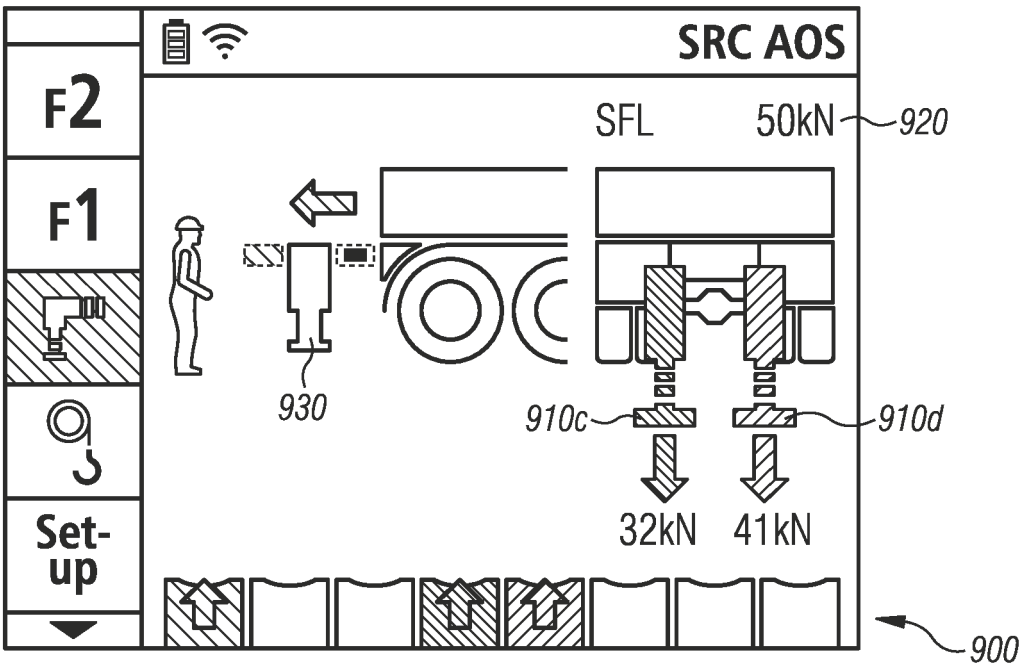


FIG. 9c

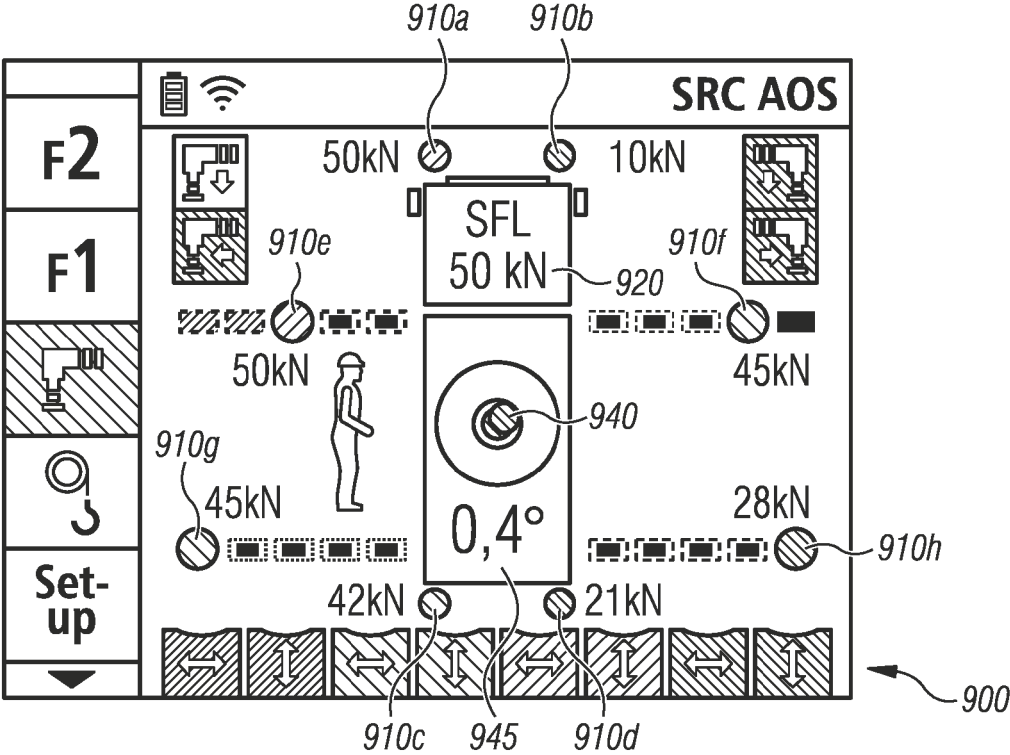
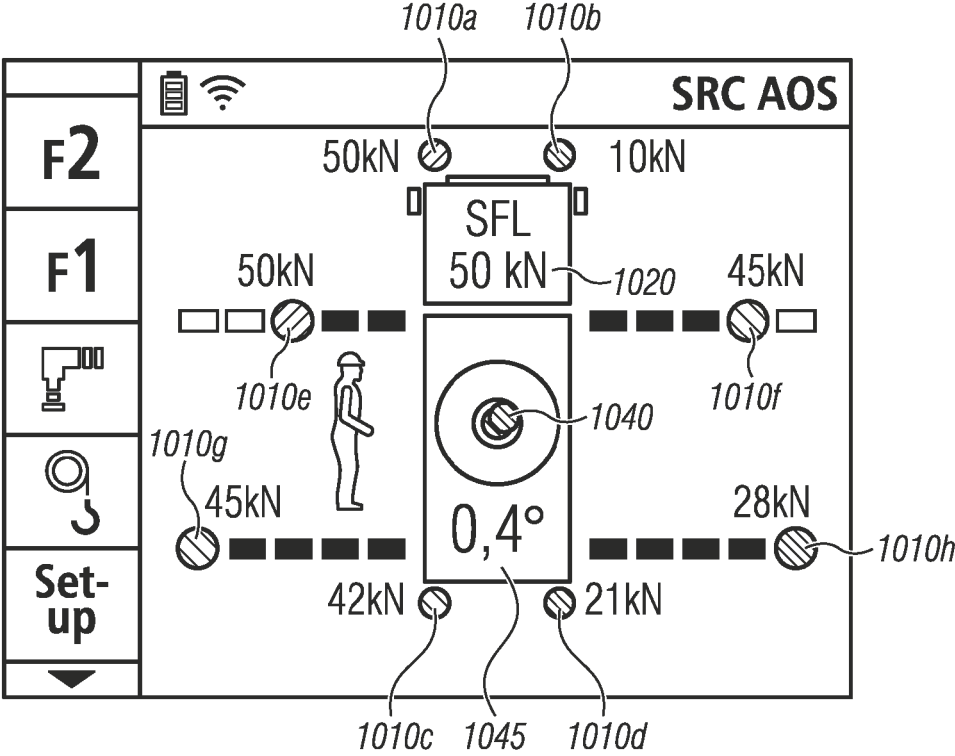


FIG. 10



**REFERENCES CITED IN THE DESCRIPTION**

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

**Patent documents cited in the description**

- EP 2815135 B1 **[0002]**
- EP 2909127 B1 **[0003]**
- JP 2010159148 A **[0004]**
- CN 110950248 A **[0005]**
- WO 2014059457 A1 **[0006]**