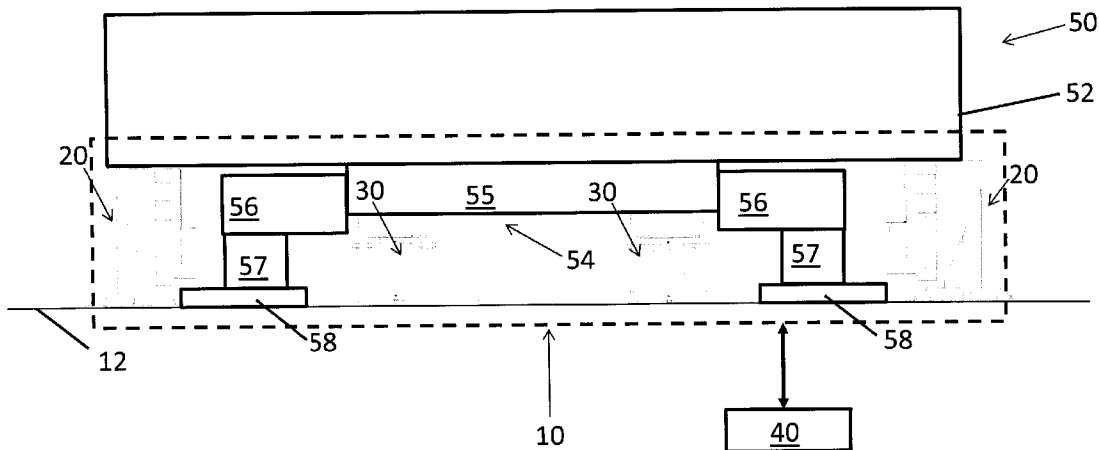




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(57) **Abrégé/Abstract:**

An apparatus and method for lifting heavy machinery from a ground surface. Vertically extendable first lifting devices engage an upper portion of the machinery and displace the upper portion upward. Vertically extending second lifting devices engage a lower portion of the machinery and extend to collectively apply a constant force simultaneously with the upward displacement of the upper portion. A controller sends lift signals to vertically extend the respective lifting devices, and also sends hold signals to maintain the first lifting devices extended and to continue applying the constant force with the second lifting devices.

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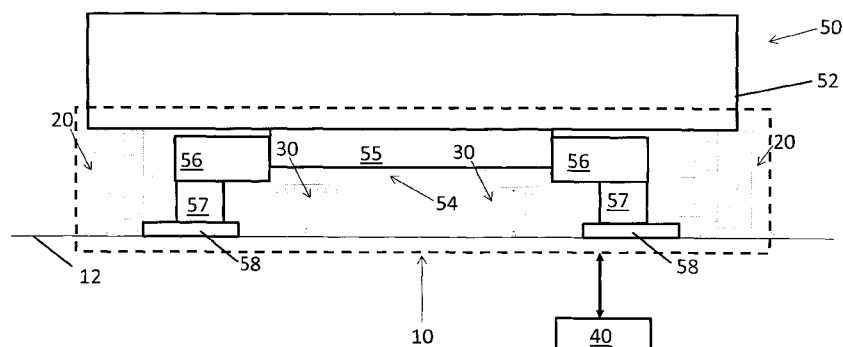
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(54) **Title:** APPARATUS AND METHOD FOR LIFTING HEAVY MACHINERY

FIGURE 1A



(57) **Abstract:** An apparatus and method for lifting heavy machinery from a ground surface. Vertically extendable first lifting devices engage an upper portion of the machinery and displace the upper portion upward. Vertically extending second lifting devices engage a lower portion of the machinery and extend to collectively apply a constant force simultaneously with the upward displacement of the upper portion. A controller sends lift signals to vertically extend the respective lifting devices, and also sends hold signals to maintain the first lifting devices extended and to continue applying the constant force with the second lifting devices.

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APPARATUS AND METHOD FOR LIFTING HEAVY MACHINERY

TECHNICAL FIELD

The application relates generally to raising heavy equipment and, more particularly, to a method and apparatus for synchronizing the lifting of heavy machinery.

5 BACKGROUND OF THE ART

Routine maintenance often requires that heavy equipment such as mechanical shovels, excavators, and transport trucks be raised in elevation. This allows maintenance crews to access the lower components of the heavy equipment so as to perform maintenance and repairs, and saves time and effort by avoiding having to
10 dismantle the heavy equipment.

Consider the example of a large mechanical or electrical shovel having a lower carbody or tractor which uses continuous track motion to displace the shovel. In order to repair or replace the sideframe of the carbody, its treads, or the rollers which turn the treads, it would be desirable to access these components without having to first
15 separate them from the carbody. This can be done by raising the carbody.

Conventional techniques for raising the carbody for maintenance work use high capacity jacks positioned under the carbody in select locations. Raising the entire carbody (and thus the shovel) in this way is certainly possible, but poses safety risks. The carbody is relatively compact in comparison to the shovel itself, and raising just the
20 carbody can affect the lateral and longitudinal stability of the shovel. It may therefore be necessary to compensate for instability issues.

Furthermore, raising the carbody of such a shovel requires special attention. At no time should tension be applied on the center gudgeon or center nut connecting the carbody to the upper works of the shovel. If tension were to be applied, there is a risk of partial
25 extraction and/or damage being caused to these components, which would result in lengthy and/or costly repairs and lead to significant productivity losses due to shovel inactivity.

To avoid these potential hazards, some conventional techniques raise only one part of the shovel at a time, and perform the maintenance work on only that part. This

lengthens considerably the time budgeted for maintenance, and causes significant productivity losses due to shovel inactivity.

SUMMARY

There is described herein an apparatus and method for lifting heavy machinery from a ground surface. Vertically extendable first lifting devices engage an upper portion of the machinery and displace the upper portion upward. Vertically extending second lifting devices engage a lower portion of the machinery and extend to collectively apply a constant force simultaneously with the upward displacement of the upper portion. A controller sends lift signals to vertically extend the respective lifting devices, and also sends hold signals to maintain the first lifting devices extended and to continue applying the constant force with the second lifting devices.

In one aspect, there is provided a method for lifting heavy machinery from a ground surface, the heavy machinery having an upper portion and a lower portion. The method comprises positioning the upper portion to engage a plurality of vertically extendable first lifting devices, and positioning the lower portion to engage a plurality of vertically extendable second lifting devices; lifting the upper and lower portions from the ground surface by vertically extending the first lifting devices; supporting a weight of the lower portion while lifting the upper and lower portions by vertically extending the second lifting devices; and holding the first lifting devices in an extended position and applying a constant lifting force to the lower portion with the second lifting devices.

In still another aspect, there is provided a method for lifting heavy machinery from a ground surface, the heavy machinery having an upper portion and a lower portion. The method comprises: positioning the upper portion above a plurality of vertically extendable first lifting devices, and positioning the lower portion above a plurality of vertically extendable second lifting devices; engaging the plurality of vertically extendable second lifting devices with the lower portion; lifting the upper and lower portions from the ground surface by vertically extending the first lifting devices while simultaneously supporting a weight of the lower portion with the second lifting devices by vertically extending same; and holding the first lifting devices in an extended position and simultaneously supporting the weight of the lower portion with the second lifting devices. In an embodiment, simultaneously supporting the weight of the lower portion with the second lifting devices while holding the first lifting devices in the extended position comprises applying a constant lifting force to the lower portion with the second lifting devices.

In another aspect, there is provided an apparatus for lifting heavy machinery from a ground surface, the heavy machinery having an upper portion and a lower portion. The apparatus comprises first lifting devices engageable with the upper portion and vertically extendable to displace the upper portion upward from the ground surface;
5 second lifting devices engageable with the lower portion and vertically extendable to support the lower portion simultaneously with an upward displacement of the upper portion and to collectively apply a constant force to the lower portion when the first lifting devices are held in an extended position; and a controller operatively coupled to the first lifting devices and the second lifting devices. The controller is configured for
10 providing command signals thereto for vertically extending the first lifting devices to lift the upper and lower portions from the ground surface; vertically extending the second lifting devices to support a weight of the lower portion while lifting the upper and lower portions; and holding the first lifting devices in the extended position while applying the constant lifting force to the lower portion with the second lifting devices.

15 In a further aspect, there is provided a computer readable medium having stored thereon program code executable by a processor for lifting heavy machinery from a ground surface using first lifting devices engageable with an upper portion of the heavy machinery and second lifting devices engageable with a lower portion of the heavy machinery. The program code comprises instructions for vertically extending the first
20 lifting devices to lift the upper portion and lower portion from the ground surface; vertically extending the second lifting devices to support a weight of the lower portion while lifting the upper portion and the lower portion; and holding the first lifting devices in an extended position while applying a constant lifting force to the lower portion with the second lifting devices.

25 DESCRIPTION OF THE DRAWINGS

Reference is now made to the accompanying figures in which:

Fig. 1a is a rear view of an apparatus for lifting heavy machinery having an upper portion and a lower portion, according to an embodiment of the present disclosure.

Fig. 1b is another rear view of the apparatus of Fig. 1a showing first lifting devices and
30 second lifting devices of the apparatus in a vertically extended position.

Fig. 2a is an exemplary embodiment of the controller of the lifting apparatus, embodied on a computer;

Fig. 2b is an exemplary embodiment of the controller of the lifting apparatus, embodied in a PLC;

- 5 Fig. 3 is a top view of the lifting apparatus without the heavy machinery;
and

Fig. 4 is a flow diagram showing a method for lifting heavy machinery from a ground surface, according to another embodiment of the present disclosure.

DETAILED DESCRIPTION

- 10 There is described herein an apparatus used to lift or raise heavy machinery. The apparatus coordinates the lifting of the heavy machinery so that it can be raised with respect to a ground surface. In so doing, the apparatus provides clearance so that vehicles and maintenance crews can access the lower ends of the heavy machinery, and suspends the heavy machinery at an elevation while the maintenance operation is
15 being performed.

- The heavy machinery can be any type of heavy equipment such as mechanical or electrical shovels, excavators, transport trucks, bulldozers, or other similar devices. The heavy machinery discussed herein includes both immobile equipment and vehicles which can be displaced using their own source of motive power. Irrespective of the
20 type of equipment used, the heavy machinery is characterised by an upper portion and a lower portion.

- Figures 1a and 1b illustrate an exemplary heavy machinery 50, such as a massive mechanical or electrical shovel. An upper portion 52 sits on a lower portion 54 on a ground surface 12. The heavy machinery 50 is provided on a lifting apparatus 10.
25 Figure 1a illustrates the apparatus 10 in an initial position, before extension thereof and lifting of the heavy machinery 50.

The lower portion 54 or lower works of the shovel may comprise a carbody 55 which helps to displace the shovel to different digging areas. The carbody 55 may include a sideframe 56 on each of its sides. Each sideframe 56 contains rollers 57 which turn a

tread 58 allowing the shovel to be moved. The upper portion 52 or upper works of the shovel may include a cabin which is detachably mounted onto the carbody 55 and rotatable relative to the carbody 55. An operator may sit inside the cabin to control the operation of the shovel. The upper portion 52 can also include a boom (not shown) attached to the cabin and attached to the digger for excavating materials.

The apparatus 10 comprises first lifting devices 20 for lifting the heavy machinery 50, second lifting devices 30 for supporting the weight of the lower portion 54 of the machinery 50 as it is being lifted, and a controller 40 for coordinating the lifting operation and the extension of one or more of the first and second lifting devices 20,30.

10 In some embodiments, the apparatus 10 is a combination of first lifting devices 20 and a first controller and second lifting devices 30 that are coupled to the first lifting devices 20 and have their own corresponding second controller. The second lifting devices 30 may be connected to the first lifting devices 20 in a master-slave configuration, and the second controller may be an add-on to the first controller, together forming controller 15 40. For example, the first controller may comprise control logic to selectively extend and contract the first lifting devices. The second controller may be connected into a control panel of the first controller to add control logic to synchronize extension and contraction of the second lifting devices 30 with the first lifting devices 20, and to apply a constant force via the second lifting devices 30 while the first lifting devices are 20 extended. Alternatively, a single controller 40 may be conceived to control both first lifting devices 20 and second lifting devices 30.

The plurality of first lifting devices 20 are responsible for applying a lifting force to displace both the upper portion 52 and the lower portion 54 attached thereto vertically upward. In so doing, the first lifting devices 20 lift the entirety of the heavy machinery 50 25 from the ground surface 12. Each first lifting device 20 can therefore take any form or configuration capable of such functionality, such as hydraulic jacks, mechanical jacks, house jacks, farm jacks, pneumatic jacks, and strand jacks. The first lifting devices 20 may also comprise lifting kits.

Figure 1b illustrates the apparatus 10 in an extended position. The first lifting devices 20 30 may comprise a housing 22 and a shaft 24. The housing 22 forms the corpus of the first lifting device 20 and provides structure thereto. The housing 22 can take many forms. For example, the housing 22 can include a base plate which is placed against the

ground surface 12 and helps to spread the load supported by the first lifting device 20 over a greater surface area. The housing 22 may also have a jack stand projecting from the base plate to house the vertically displaceable shaft 24. The jack stand can be structurally supported by gusset plates mounted to both the jack stand and the base plate.

The shaft 24 contained within the housing 22 extends vertically out of the housing 22. When it extends, the shaft 24 applies the lifting force to the upper portion 52 and causes its upward displacement. In the example illustrated, the shaft 24 extends vertically out of a bottom of the housing 22, such that the lifting force is applied downward. It is therefore the reactive force of the ground surface 12 which causes the upward displacement of the upper portion 52. It will be appreciated that shafts 24 which extend out of the top of the housing 22 are also within the scope of the present disclosure. The output end of the shaft 24 (i.e. the end which extends out of the housing 22) can be provided with an application plate or other similar device to distribute the lifting force.

In operation, the first lifting devices 20 engage the upper portion 52 in order to apply the lifting force to displace the upper portion 52 upward with respect to the ground surface 12. Each shaft 24 extends away from the housing 22 a predetermined length. The predetermined length corresponds to the height to which it is desired to lift the lower portion 54 and/or the shovel 50. It is generally determined prior to commencing the lifting operation, and may be the only input provided to the first lifting devices 20. For example, an operator of the apparatus 10 may input a predetermined length of 12 inches into the controller 40 for each of the first lifting devices 20, this predetermined length being the distance by which the entire shovel 50 should be lifted. The shaft 24 of each of the first lifting devices 20 will therefore have instructions to vertically extend as much as is required to raise the heavy machinery 12 inches.

The predetermined length can be monitored using any appropriate sensor, such as a distance sensor 26 mounted to one or more of the first lifting devices 20. The distance sensors 26 monitor the vertical extension of the shafts 24 with the respect to the ground surface 12. This can prove to be useful information because the ground surface 12 may not be at the same level for all of the first lifting devices 20, or may have shifted during the lifting operation. The operator of the apparatus 10 may therefore wish to know what is the displacement of each first lifting device 20 relative to the ground surface 12 at any

given moment. The shafts 24 of some first lifting devices 20 may consequently need to extend more or less in order to achieve the predetermined length.

The distance sensor 26 may measure the distance that it, or the part of the first lifting device 20 to which it is attached, has risen with respect to the ground surface 12. The distance sensor 26 can employ a laser or radio signals, to name but a few techniques, to achieve such functionality. Prior to the lifting operation, the distance sensors 26 may each set an initial reference point, or zero point, on the ground surface 12 which corresponds to the initial height of the distance sensor 26 from the ground surface 12. The predetermined length is then measured as the distance that the distance sensor 26 has moved relative to this initial reference point, which also corresponds to the vertical extension of the corresponding shaft 24. The lifting operation ceases when the first lifting devices 20 have each achieved the predetermined length. The distance sensors 26 may communicate with the controller 40 so that it can track the progress of the first lifting devices 20.

It will thus be appreciated that the first lifting devices 20 may be actuators. In some embodiments, each first lifting device 20 acts generally as one or more hydraulic actuator, such as a single-acting hydraulic actuator having a counterbalance valve. The counterbalance valves, or holding valves, offer a higher level of hydraulic safety protection. The counterbalance valves may automatically shut off in case of a hydraulic leak and ensure that oil remains trapped inside the hydraulic actuators, thus safely supporting the load while the leak gets fixed. It will be appreciated that the first lifting devices 20 can be other types of actuators as well (e.g. mechanical, electrical, or pneumatic), or combinations of different types of actuators. For example, each of the first lifting devices 20 may include two hydraulic actuators. It will also be understood that the first lifting devices 20 can be other types of lifting devices (e.g. cranes, hoists, elevators, etc.), depending on various factors such as but not limited to the loads to be supported, the space available for the lifting operation, the geometry of the heavy machinery, and the desired level of safety.

The apparatus 10 also includes second lifting devices 30, which collectively apply a constant force by vertically extending, thereby supporting at least the weight of the lower portion 54 while the first lifting devices 20 are displacing the upper portion 52. In so doing, the second lifting devices 30 ensure that the heavy machinery 50 does not

experience tension during the lifting operation, and that the lower portion 54 does not pull or cause a tension to be applied to the upper portion 52.

The first lifting devices 20 and second lifting devices 30 may thus operate (or extend) simultaneously or substantially simultaneously. The term "simultaneously" refers to the coordination of the movement of the second lifting devices 30 with that of the first lifting devices 20. More particularly, the first and second lifting devices 20,30 may have a "master-slave" relationship, in that the second lifting devices 30 will only vertically extend if the first lifting devices 20 are also vertically extending. Stated differently, if the shafts 24 of the first lifting devices 20 stop vertically extending, so too will the second lifting devices 30. Even when not vertically extending, the second lifting devices 30 continue to apply the constant force to ensure that the lower portion 54 is continually supported.

Each of the second lifting devices 30 may have a lower housing 32 and a lower shaft 34. The lower housing 32 and lower shaft 34 of each second lifting device 30 may be similar to the housing 22 and shaft 24 of each first lifting device 20. The description given above for these components of the first lifting device 20 therefore applies *mutatis mutandis* to the lower housing 32 and the lower shaft 34. In some embodiments, the stroke of the shaft 24 of the first lifting devices 20 will be greater than the stroke of the lower shaft 34 of the second lifting devices 30. This is reflective of the role of the first lifting devices 20, which is to displace the shovel 50 upwards. In contrast, the second lifting devices 30 are intended in most instances to support at least the weight of the lower portion 54 while it is being lifted upward by the first lifting devices 20.

In operation, each second lifting device 30 engages, or is engageable with, the lower portion 54, in the same ways as described above for the first lifting devices 20 with respect to the upper portion 52. The second lifting devices 30 are disposed within a perimeter defined by the position of the first lifting devices 20. In Figs. 1a and 1b, each of the second lifting devices 30 are shown disposed directly underneath a lower surface of the lower portion 54 so that the output ends of the lower shafts 34 can abut directly against this lower surface in order to apply the constant force. It will be appreciated, however, that the second lifting devices 30 can be arranged differently than as shown, provided that they collectively apply the constant force to the lower portion 54.

When being used to support the lower portion 54, each of the lower shafts 34 extends away from their lower housings 32 in synchronization with the upward displacement of the upper portion 52 by the first lifting devices 20. Stated differently, the second lifting devices 30, and thus their lower shafts 34, are not vertically extending if the shafts 24 of the first lifting devices 20 are inactive. If desired, shims 31 can be placed in the space between the output end of one or more lower shafts 34 and the lower portion 54 to further reduce the distance that the lower shafts 34 need to vertically extend. One or more mechanical locks 36 may be mounted about the vertically extended lower shafts 34 to help them support the lower portion 54. Once tightened about the exterior surface of the lower shafts 34, each mechanical lock 36 may hold the lower shaft 34 solidly in place after the required extension has been reached. The load will therefore be supported structurally as well as hydraulically, thus allowing for safe access under the lower portion 54 during maintenance work.

The second lifting devices 30 collectively apply the constant force to the lower portion 54. The constant force may remain constant throughout and after the lifting operation. The term "collectively" when used to describe the application of the constant force refers to a constant force value which is the sum of forces applied by all of the second lifting devices 30. For example, an operator of the apparatus 10 can input a constant force value of about 500 tons into the controller 40, which will control the vertical extension of the lower shafts 34 such that their combined force output is 500 tons. This force output will remain constant throughout the lifting operation, and is also applied after the lifting operation has ceased in order to support at least the weight of the lower portion 54. Such a constant force value is generally determined prior to commencing the lifting operation, and may be the only input provided to the second lifting devices 30. The collective application of the constant force is in contrast with the operation of the first lifting devices 20, whose sole input is generally the predetermined length. Each of the first lifting devices 20 may apply a varying lifting force in order to achieve the predetermined length, and to compensate for any instabilities which may arise during the lifting operation.

The number of second lifting devices 30 which apply the collective constant force, and their position with respect to the lower portion 54, can vary. For example, the apparatus 10 can include four second lifting devices 30. Two of the four second lifting devices 30 may be disposed towards a front of the lower portion 54 and directly underneath, while

the other two may be disposed underneath and towards a rear. Such a disposition of the second lifting devices 30 provides stability to the lifting operation, and helps to distribute the constant force. It will be appreciated that more or fewer second lifting devices 30 can also be used. For example, three second lifting devices 30 may be positioned underneath the lower portion 54 in a triangular configuration and spaced 120° from one another.

The constant force can be distributed to the second lifting devices 30 in different ways. For example, an operator may select a constant force value of about 500 tons. The controller 40 may divide this constant force value equally amongst the number of second lifting devices 30. Therefore, in an embodiment where the apparatus 10 has four second lifting devices 30, each one may apply a fractioned constant force value of 125 tons. The controller 40 and/or operator may also divide the constant force value unequally. In an embodiment where the apparatus 10 has four second lifting devices 30, three of them can apply a fractioned constant force value of 150 tons each, while the last one can apply 50 tons. This unequal distribution of the constant force value is particularly useful when the operator wants to verify if all of the second lifting devices 30 are operational. In some embodiments, the forces are distributed amongst the second lifting devices 30 as a function of a configuration thereof. For example, in a square configuration, the forces may be applied equally. Alternatively, the second lifting devices 30 may be positioned with a pair of second lifting devices 30 on one side and an individual second lifting device 30 on another side. The forces may be distributed so that half of the total force is applied to the individual second lifting device 30 and the other half is split between the pair of second lifting devices 30. Other configurations for the second lifting devices 30 and/or the distribution of forces, will be readily understood.

The actual value of the constant force may be calculated in different ways. In some embodiments, the constant force value may be set such that it is greater than the weight of the lower portion 54 of the heavy machinery, but still less than the overall weight of the heavy machinery. For example, if the lower portion 54 weighs about 470 tons and the heavy machinery as a whole weighs about 1,500 tons, the constant force value may be set to 500 tons. This allows the second lifting devices 30 to support the weight of the lower portion 54 as it is raised and after the lifting operation has ceased, while not necessarily being able to lift the entire heavy machinery. It is subsequently

easier to lower the lower shafts 34 when the heavy machinery is brought back to the ground surface 12. As a general rule, the constant force value may be calculated to be at least the weight of the lower portion 54, multiplied by a safety factor. Some possible safety factors range between about 1.10 to about 1.30, but other safety factors are also within the scope of the present disclosure.

It will be appreciated that the unit of constant force outputted by each of the first and second lifting devices 20,30 can include tons/tonnes, psi/Pa, lbs/N depending on the type of lifting device 20,30. Indeed, and as with the first lifting devices 20, each of the second lifting devices 30 may be an actuator. In some embodiments, each second lifting device 30 is a hydraulic actuator, such as a double-acting hydraulic actuator having a lower counterbalance valve similar to the one described above. It will be appreciated that the second lifting devices 30 can be other types of actuators as well (e.g. mechanical, electrical, or pneumatic), or combinations of different types of actuators, as well as other types of lifting devices as well (e.g. cranes, hoists, elevators, etc.).

The apparatus 10 also comprises a controller 40, which communicates commands to one or more of the components of the apparatus 10 and may also receive feedback therefrom. More particularly, the controller 40 communicates with one or more of the first lifting devices 20 and the second lifting devices 30. The controller 40 sends lift signals 44 to both the first and second lifting devices 20,30 to command them to vertically extend the shafts 24 and lower shafts 34, respectively, and effect the lifting operation.

The controller 40 also sends hold signals 42 to command the first lifting devices 20 and/or their shafts 24 to cease displacing the upper portion 52, and thus, cease lifting the heavy machinery 50 as a whole. The length at which the shafts 24 are stopped is their extension length, which may or may not correspond to the predetermined length. The hold signals 42 may also be sent to the second lifting devices 30 to command them to continue applying the constant lifting force. The controller 40 sends the hold signals 42 when either one of the two following conditions occur: one of the second lifting devices 30 has reached a vertical extension limit, and the first lifting devices 20 are vertically extended to the predetermined length. The first condition is an added safety measure, and builds redundancy into the apparatus 10. The vertical extension limit is

the maximum distance that the lower shafts 34 of the second lifting devices 30 can extend to before they are no longer able to abut against the lower portion 54 to apply the constant force. When one of the second lifting devices 30 reaches this distance, it is no longer contributing to the collective application of the constant force. While the other
5 second lifting devices 30 can generally compensate for the loss of force output from one or more of the second lifting devices 30, it may be desired to instead stop the lifting operation altogether out of an abundance of caution. Therefore, the first of the second lifting devices 30 which is close to and/or risks exceeding its vertical extension limit may signal the controller 40, and the first lifting devices 20 will cease applying the lifting force
10 to thereby stop the lifting operation. This ensures that all of the second lifting devices 30 are applying the constant force to support the lower portion 54. The vertical extension limit may or may not correspond to the maximum stroke of each of the lower shafts 34, and can also vary for each second lifting device 30.

The second condition involves the first lifting devices 20 reaching the predetermined
15 length, which as explained above, corresponds to the height to which the heavy machinery 50 is lifted. Once the shafts 24 have each extended to the predetermined length, the lifting operation has been achieved and it is no longer necessary to continue lifting. In such a case, the extension length of each shaft corresponds to the predetermined length. The shafts 24 may therefore signal the controller 40 that the
20 desired height has been achieved, and the controller 40 may respond with the hold signals 42 instructing the shafts 24 to cease vertically extending.

It will be appreciated that the controller 40 can send other signals as well. For example, the controller 40 can send a constant force input signal to all of the second lifting devices 30 actuating their lower shafts 34 to exert a specific constant force value.
25 Similarly, the controller 40 can send a predetermined length input signal to each of the first lifting devices 30, actuating their shafts 24 to exert the lifting force required to extend to the predetermined length. Other such signals are also within the scope of the present disclosure.

The controller 40 can take many different physical forms. Figure 2a is an exemplary
30 embodiment of the controller 40, which may comprise, amongst other things, a plurality of applications 206a...206n running on a processor 204 coupled to a memory 202. One such application may be configured for lifting the upper portion 52 of the heavy

machinery. Another application may be configured for applying the constant force to the lower portion 54 of the heavy machinery. In some embodiments, a single application may be provided for lifting the upper portion 52 and applying the constant force to the lower portion 54. It should be understood that while the applications 206a ... 206n
5 presented herein are illustrated and described as separate entities, they may be combined or separated in a variety of ways.

The memory 202 accessible by the processor 204 may receive and store data, such as but not limited to extension lengths of the first lifting devices 20, extension lengths of the second lifting devices, forces to be applied, and force distribution among lifting devices.
10 The memory 202 may be a main memory, such as a high speed Random Access Memory (RAM), or an auxiliary storage unit, such as a hard disk, a floppy disk, or a magnetic tape drive. The memory 202 may be any other type of memory, such as a Read-Only Memory (ROM), flash memory, or optical storage media such as a videodisc and a compact disc. The processor 204 may access the memory 202 to retrieve data.
15 The processor 204 may be any device that can perform operations on data. Examples are a central processing unit (CPU), a front-end processor, a microprocessor, and a network processor. The applications 206a ... 206n are coupled to the processor 804 and configured to perform various tasks.

In an alternative embodiment, the controller 40 may comprise an industrial control
20 system, such as a distributed control system (DCS) or a programmable logic controller (PLC). An example is illustrated in figure 2b, where the controller 40 comprises an operator interface 208, a memory 202, a control unit 210, and an arithmetic-logic unit (ALU) 212. PLC programs may be downloaded onto the memory 202 via an input port (not shown) such as Ethernet, RS-232, RS-485, or RS-422. In some embodiments, the
25 PLC programs may also be provided through a programming board which writes the program into a memory 202 in the form of a removable chip such as an Electrically Erasable Programmable Read-Only Memory (EEPROM) or an Erasable Programmable Read-Only Memory (EPROM). The control unit 210 selects and calls up instructions from the memory 202 in appropriate sequence and relays the proper commands. Other
30 embodiments are also feasible for the controller 40, such as Programmable Logic Relays (PLR), electronic boards with microcontrollers, and other such devices.

In some embodiments, the controller 40 comprises one or more control panels, each having its own PLC. For example, a first control panel may communicate with, and receive feedback from, the first lifting devices 20. A second control panel may also be in communication with the first control panel to receive commands based on the movement of the first lifting devices 20. The second control panel can also communicate with, and receive feedback from, the second lifting devices 30, so that they move in synchronicity with the first lifting devices 20. An operator can input variables into one or more of the control panels via the operator interface 208. These input values can be, for example, the constant force to apply with the second lifting devices 30, and/or the predetermined length of the first lifting devices 20. In some embodiments, the operator may manually select one of the first lifting devices 20 and/or one of the second lifting devices 30 and input a predetermined height or a force, respectively, to be applied. The inputs may be provided as any integer value or selected from a list or a drop-down menu. Appropriate hydraulic and electronic cabling can extend to and from the lifters 20,30 and the control panels. Alternatively, the controller 40 may communicate with the apparatus 10 wirelessly, via any sort of network such as the Internet, a cellular network, Wi-Fi, or others known to those skilled in the art.

In some embodiments, the controller 40 is configured to be accessible from any one of a plurality of devices, such as a laptop computer, a personal digital assistant (PDA), a smartphone, or the like, adapted to communicate over the network. Alternatively, the controller 40 may be provided in part or in its entirety directly on the devices, as a native application or a web application. It should be understood that cloud computing may also be used such that the controller 40 is provided partially or entirely in the cloud. In some embodiments, an application 206a may be downloaded directly onto a device and application 206n communicates with application 206a via the network.

The apparatus 10 may be operated as follows. Prior to setting up the apparatus 10, the ground surface 12 can be compacted to further improve its solidity and provide adequate bearing pressure. At least some of the first lifting devices 20 and the second lifting devices 30 are put into position. Furthermore, one or more layers of raised support racks can be laid on the ground surface 12. The support racks provide an easy and inexpensive way to raise the heavy machinery 50 an initial amount (e.g. 12 in., or integer multiples thereof) by simply driving the lower portion 54 over the support racks and bringing it to rest thereon. The upper and lower portions 52,54 are therefore

positioned over, or near, the first lifting devices 20 and the second lifting devices 30 that are already in position.

5 The remaining first lifting devices 20 and/or second lifting devices 30 can now be put into place so that they are positioned to effect the lifting operation and support the lower portion 54, respectively. The operator can determine the height to lift the heavy machinery depending on the maintenance to be performed, and input it into the controller 40 (e.g. 12 in.). In some embodiments, any integer value may be input into the controller 40. Alternatively, the operator may choose from a set of predetermined values, such as 10 inches, 20 inches, and 30 inches.

10 In some embodiments, shims 31 may be placed between the output end of the lower shafts 34 and the lower portion 54. If the weight of the lower portion 54 and the upper portion 52 are known, the operator can determine the desired constant force to be collectively applied by the second lifting devices 30, and input the constant force value into the controller 40 (e.g. 500 tons). Alternatively, the weight may be input into the
15 controller 40 and the constant force may be determined by the controller 40 as a function of the weight and the height to which the heavy machinery is to be lifted.

The controller 40 may send lift signals 44 to the first lifting devices 20 to command them to vertically extend their shafts 24. The controller 40 may simultaneously send lift signals 44 to the second lifting devices 30 so that they support the weight of the lower
20 portion 54 while the shafts 24 of the first lifting devices 20 are vertically extending. Alternatively, the first lifting devices 20 and the second lifting devices 30 are operatively connected together such that when the first lifting devices 20 receive lift signals 44 from the controller 40, they in turn instruct the second lifting devices 30 to support the weight of the lower portion 54.

25 The apparatus 10 therefore allows for a useful division of labour between the lifting devices 20,30. More particularly, first lifting devices 20 are allowed to concentrate on the lifting operation and to counteract any systemic lateral instabilities (e.g. wind, ground shake, proximity mine blasts, sudden ground bearing capacity failure, etc.), thus balancing the heavy machinery 50 against perturbations. The second lifting devices 30
30 are meanwhile allowed to focus only on supporting the lower portion 54 so as to eliminate any tension acting thereon.

The shafts 24 and lower shafts 34 continue to vertically extend, and the second lifting devices 30 apply the constant force, until the predetermined length of 12 in. has been achieved with each of the first lifting devices 20, or until the lower shaft 34 of one of the second lifting devices 30 has reached its vertical extension limit. Once either one of these situations occur, one or more of the lifting devices 20,30 signals the controller 40. The controller 40 responds by sending the hold signals 42 to the first lifting devices 20 to maintain their vertical extension, and to the second lifting devices 30 to continue applying the constant force of 500 tons. In some embodiments, the lower shafts 34 of the second lifting devices 30 can be braced with the mechanical locks 36. The shovel 50 is now raised with respect to the ground surface 12, as shown in Fig. 1B. The apparatus 10 allows work to be performed on both sides of the raised heavy machinery 50 simultaneously, which ultimately helps to lower the downtime of the equipment.

Should any of the second lifting devices 30 fail, the collective force can be distributed amongst the second lifting device(s) 30 which remain functional and/or the first lifting devices 20 can add more capacity because of their ability to collectively support the full weight of the heavy machinery 50. Similarly, in the event that one or more of the first lifting devices 20 fail, the second lifting devices 30 can apply extra force to support the weight of the upper portion 52, or the entire heavy machinery 50.

After maintenance has been performed on the lower portion 54, the heavy machinery 50 can be lowered back to the ground surface 12. The raised support racks can be placed back into position below the heavy machinery 50. The locking nuts 36 can be removed from the lower shafts 34, and the controller 40 can command the first lifting devices 20 to steadily reduce the lifting force so that a controlled descent of the upper portion 52 (and thus of the entire heavy machinery 50) can be achieved. During descent, the second lifting devices 30 continue to collectively apply the constant force until the lower portion 54 is supported by the ground surface 12 or raised support racks. The heavy machinery 50 can then be driven or towed off the support racks.

Fig. 3 is a top view of an exemplary embodiment of the apparatus 10 without the heavy machinery 50 provided thereon. In this exemplary configuration, four first lifting devices 20 are arranged in spaced apart pairs. The spacing of the first lifting devices 20 from one another define a perimeter 23. Four second lifting devices 30 are located within the perimeter 23 defined by the first lifting devices 20. The first lifting devices 20 can be

positioned around the sides of the upper portion 52 and linked together. For example, the first lifting devices 20 can be linked with transverse lifting beams 28, which can extend between spaced apart first lifting devices 20 and underneath the upper portion 52. The transverse lifting beams 28 may therefore be abutted against one or more of the lower surfaces of the upper portion 52. Therefore, the vertical extension of the shafts of the first lifting devices 20 will cause the upward displacement of the upper portion 52. Such a configuration provides stability during lifting. Also shown, two of the four second lifting devices 30 are disposed towards a front of the lower portion 54 and directly underneath, while the other two are disposed underneath and towards a rear of the lower portion 54. Such a disposition of the second lifting devices 30 provides stability to the lifting operation, and helps to distribute the constant force.

It will be appreciated that the disposition of first lifting devices 20 is not limited to the embodiment shown in Fig. 3. In some embodiments, another technique for engaging the upper portion of the heavy machinery includes positioning the unextended shaft of one or more first lifting devices 20 at a height from the ground surface greater than the height of the lowest part of the upper portion. The output end of each shaft can be linked together and to the upper portion such that the vertical extension of the output ends causes the upward displacement of the upper portion. Yet another technique includes positioning the first lifting devices 20 directly underneath the upper portion, such that the shafts vertically extend to abut against a lower surface of the upper portion and transmit the lifting force thereto. Many more of these ways are within the scope of the present disclosure provided that they allow the vertical extension of the shafts, irrespective of where they are applied or where their movement originates, to displace the upper portion upward from the ground surface.

Referring now to Fig. 4, there is also provided a method 100 for lifting heavy machinery from a ground surface. The method 100 comprises a first step 102 of positioning the upper portion to engage a plurality of vertically extendable first lifting devices and positioning the lower portion to engage a plurality of vertically extendable second lifting devices. The first lifting devices can be positioned directly underneath a lower surface of the upper portion, or to the sides thereof. Indeed, the upper portion can engage two first lifting devices disposed towards a first end, or front, of the upper portion, and also engage two first lifting devices disposed towards a second end, or rear, of the upper portion. Positioning the upper portion may also include displacing the heavy machinery

over a pair of raised support racks. The second lifting devices can be spaced apart from each other underneath the lower portion to provide stability thereto.

As per step 104, the upper and lower portions are lifted from the ground surface by vertically extending the first lifting devices a predetermined length. This can include providing each of the first lifting devices with a maximum extension height, where the maximum extension height is less than the vertical extension limit of the second lifting device. This may help to ensure that the first lifting devices never vertically extend a length greater than the vertical extension limit of any one of the second lifting devices.

Lifting in step 104 may also comprise determining a lifting force value and dividing the lifting force value evenly or unevenly amongst the first lifting devices. In order to measure the length that the first lifting devices have extended, step 104 may also include monitoring a vertical extension of each of the first lifting devices with respect to the ground surface. An initial reference point (i.e. a zero point) can be set on the ground surface, and the vertical extension of each of the first lifting devices can be monitored with respect to the initial reference point. The first lifting devices may then be vertically extended the predetermined length measured with respect to this initial reference point. Vertical extension can be accomplished to maintain the upper portion substantially level with the ground surface.

As per step 106, a weight of the lower portion may be held while lifting the upper and lower portions by vertically extending the second lifting devices to apply a constant force to the lower portion. As explained above, the second lifting devices collectively apply the constant force. Therefore, step 106 may include determining a constant force value and dividing the constant force value equally, or unequally, amongst the second lifting devices. The constant force value may be calculated to be greater than the weight of the lower portion and less than an overall weight of the machinery. Therefore, the second lifting devices only need to apply a constant force value equal to at least the weight of the lower portion. The constant force value can also be calculated as the weight of the lower portion multiplied by a safety factor between about 1.10 and about 1.30.

The method 100 may also include holding the first lifting devices at an extension length and continuing to apply the constant lifting force with the second lifting devices when at least one of the following occurs: one of the second lifting devices has reached a

vertical extension limit, and the first lifting devices are vertically extended to the predetermined length. The holding of the second lifting devices may include bracing, using the mechanical locks, the vertically extended second lifting devices. In order to support the large machinery, a lifting force value equal to the weight of the upper portion
5 may be determined. This helps to maintains the upper portion in a raised position and prevent it from descending.

While illustrated in figures 2a and 2b as groups of discrete components communicating with each other via distinct data signal connections, it will be understood by those skilled in the art that the present embodiments of the controller 40 are provided by a
10 combination of hardware and software components, with some components being implemented by a given function or operation of a hardware or software system, and many of the data paths illustrated being implemented by data communication within a computer application or operating system. The structure illustrated is thus provided for efficiency of teaching the present embodiment.

15 It should be noted that the present invention can be carried out as a method, can be embodied in an apparatus, or can be provided on a computer readable medium having stored thereon program code executable by a processor. The above description is meant to be exemplary only, and one skilled in the art will recognize that changes may be made to the embodiments described without departing from the scope of the
20 invention disclosed. Still other modifications which fall within the scope of the present invention will be apparent to those skilled in the art, in light of a review of this disclosure, and such modifications are intended to fall within the appended claims.

CLAIMS

1. A method for lifting heavy machinery from a ground surface, the heavy machinery having an upper portion and a lower portion, the method comprising:

positioning the upper portion to engage a plurality of vertically extendable first lifting devices, and positioning the lower portion to engage a plurality of vertically extendable second lifting devices;

lifting the upper and lower portions from the ground surface by vertically extending the first lifting devices;

supporting a weight of the lower portion while lifting the upper and lower portions by vertically extending the second lifting devices; and

holding the first lifting devices in an extended position and applying a constant lifting force to the lower portion with the second lifting devices.

2. A method for lifting heavy machinery from a ground surface, the heavy machinery having an upper portion and a lower portion, the method comprising:

positioning the upper portion above a plurality of vertically extendable first lifting devices, and positioning the lower portion above a plurality of vertically extendable second lifting devices;

engaging the plurality of vertically extendable second lifting devices with the lower portion;

lifting the upper and lower portions from the ground surface by vertically extending the first lifting devices while simultaneously supporting a weight of the lower portion with the second lifting devices by vertically extending same; and

holding the first lifting devices in an extended position and simultaneously supporting the weight of the lower portion with the second lifting devices.

3. The method of claim 1 or 2, wherein vertically extending the first lifting devices comprises extending until at least one of the first lifting devices reaches a predetermined length received as input.

4. The method of claim 1 or 2, wherein vertically extending the first lifting devices comprises extending until at least one of the second lifting devices reaches a vertical extension limit.

5. The method of claim 2, wherein simultaneously supporting the weight of the lower portion with the second lifting devices while holding the first lifting devices in the extended position comprises applying a constant lifting force to the lower portion with the second lifting devices.
6. The method of claim 1 or 5, wherein applying a constant lifting force comprises determining a constant force value and dividing the constant force value equally amongst the second lifting devices.
7. The method of claim 1 or 5, wherein applying a constant lifting force comprises determining a constant force value and apportioning the constant force value unequally amongst the second lifting devices.
8. The method of claim 6 or 7, wherein determining the constant force value comprises calculating the constant force value to be greater than a weight of the lower portion and less than a total weight of the heavy machinery.
9. The method of claim 6 or 7, wherein determining the constant force value comprises calculating the constant force value to be at least a weight of the lower portion multiplied by a safety factor between 1.10 and 1.30.
10. The method of any one of claims 1 to 9 wherein lifting the upper and lower portions comprises monitoring a vertical extension of each of the first lifting devices with respect to the ground surface.
11. The method of claim 1, wherein positioning the upper portion to engage the first lifting devices comprises displacing the machinery over a pair of raised support racks.
12. The method of claim 2, wherein positioning the upper portion above a plurality of vertically extendable first lifting devices comprises displacing the machinery over a pair of raised support racks.
13. The method of claim 1, wherein positioning the upper portion to engage the first lifting devices comprises positioning the first lifting devices underneath the upper portion while the machinery is stationary.

14. An apparatus for lifting heavy machinery from a ground surface, the heavy machinery having an upper portion and a lower portion, the apparatus comprising:

first lifting devices engageable with the upper portion and vertically extendable to displace the upper portion upward from the ground surface;

second lifting devices engageable with the lower portion and vertically extendable to support the lower portion simultaneously with an upward displacement of the upper portion and to collectively apply a constant force to the lower portion when the first lifting devices are held in an extended position; and

a controller operatively coupled to the first lifting devices and the second lifting devices and configured for providing command signals thereto for:

vertically extending the first lifting devices to lift the upper and lower portions from the ground surface;

vertically extending the second lifting devices to support a weight of the lower portion while lifting the upper and lower portions; and

holding the first lifting devices in the extended position while applying the constant lifting force to the lower portion with the second lifting devices.

15. The apparatus of claim 14, wherein the controller is configured to hold the first lifting devices in the extended position when at least one of the second lifting devices has reached a vertical extension limit.

16. The apparatus of claim 14, wherein the controller is configured to hold the first lifting devices in the extended position when at least one of the first lifting devices has reached a predetermined length received as input.

17. The apparatus of any one of claims 14 to 16, wherein the constant force is divided unequally amongst the second lifting devices.

18. The apparatus of any one of claims 14 to 17, wherein the constant force is at least the weight of the lower portion multiplied by a safety factor between 1.10 and 1.30.

19. The apparatus of any one of claims 14 to 18, wherein the second lifting devices comprise two second lifting devices disposed towards a front of the lower portion and two second lifting devices disposed towards a rear of the lower portion.

20. The apparatus of any one of claims 14 to 19, further comprising mechanical locks mountable about the second lifting devices.
21. The apparatus of any one of claims 14 to 20, further comprising a distance sensor mountable to each of the first lifting devices, for monitoring a vertical extension with respect to the ground surface.
22. The apparatus of any one of claims 14 to 21, further comprising a plurality of raised support racks positionable beneath the heavy machinery.
23. The apparatus of any one of claims 14 to 22 further comprising transverse lifting beams abutable against the upper portion and positioned between pairs of the first lifting devices.
24. The apparatus of any one of claims 14 to 23, wherein the first lifting devices are single-action hydraulic actuators each having a counterbalance valve.
25. The apparatus of any one of claims 14 to 24, wherein the second lifting devices are double-action hydraulic actuators each having a lower counterbalance valve.
26. The apparatus of any one of claims 14 to 25, wherein the controller comprises a programmable logic controller and an operator interface.
27. A computer readable medium having stored thereon program code executable by a processor for lifting heavy machinery from a ground surface using first lifting devices engageable with an upper portion of the heavy machinery and second lifting devices engageable with a lower portion of the heavy machinery, the program code comprising instructions for:
- vertically extending the first lifting devices to lift the upper portion and lower portion from the ground surface;
 - vertically extending the second lifting devices to support a weight of the lower portion while lifting the upper portion and the lower portion; and
 - holding the first lifting devices in an extended position while applying a constant lifting force to the lower portion with the second lifting devices.

28. The computer readable medium of claim 27, wherein vertically extending the first lifting devices comprises extending until at least one of the first lifting devices reaches a predetermined length received as input.

29. The computer readable medium of claim 27, wherein vertically extending the first lifting devices comprises extending until at least one of the second lifting devices reaches a vertical extension limit.

30. The computer readable medium of any one of claims 27 to 29, wherein applying a constant force comprises dividing a total force substantially equally among the second lifting devices.

FIGURE 1A

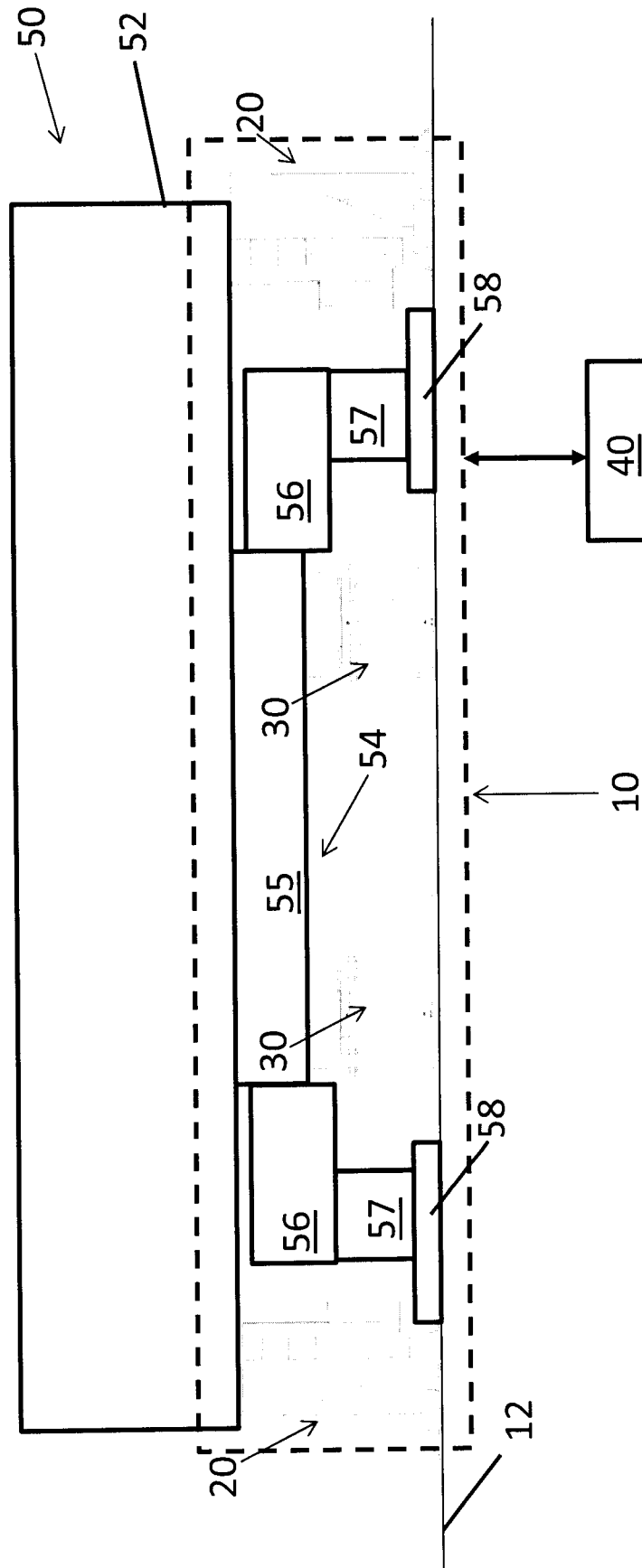
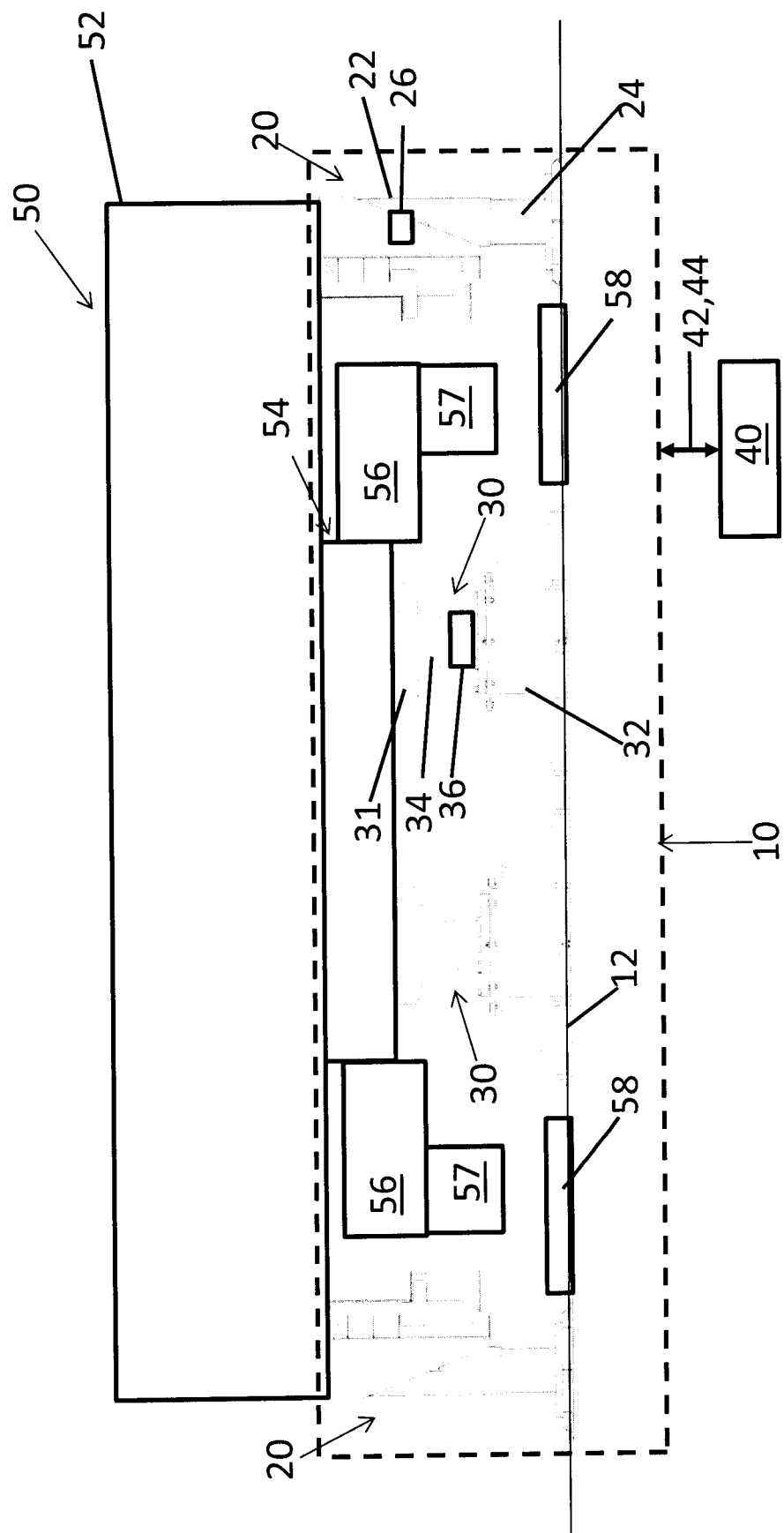


FIGURE 1B



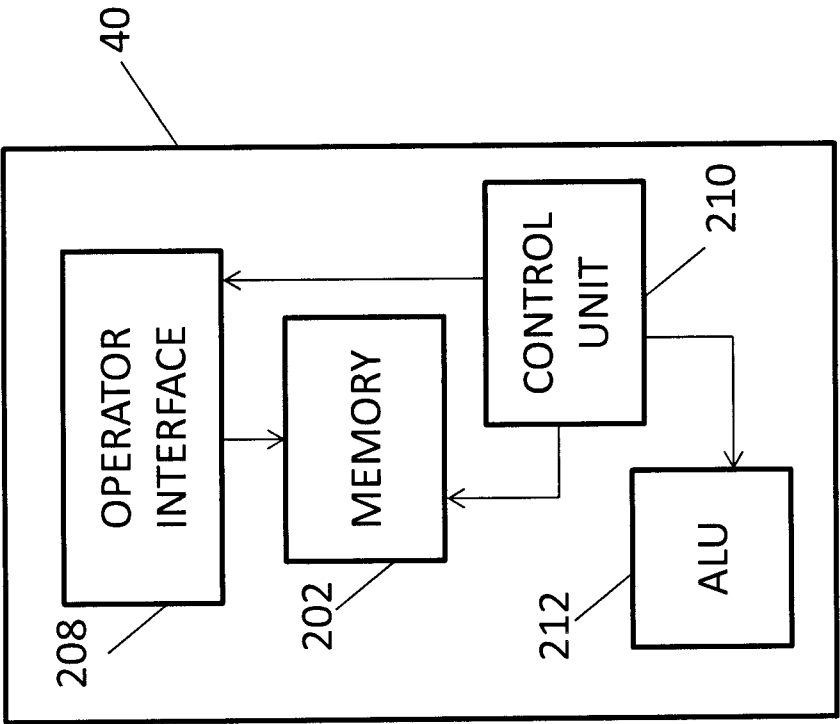


FIGURE 2B

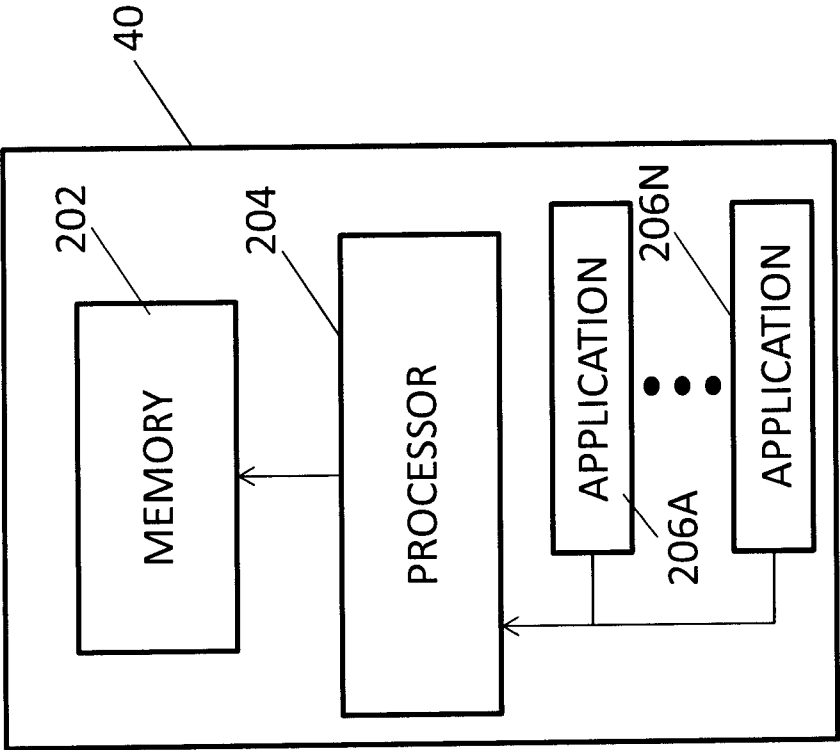
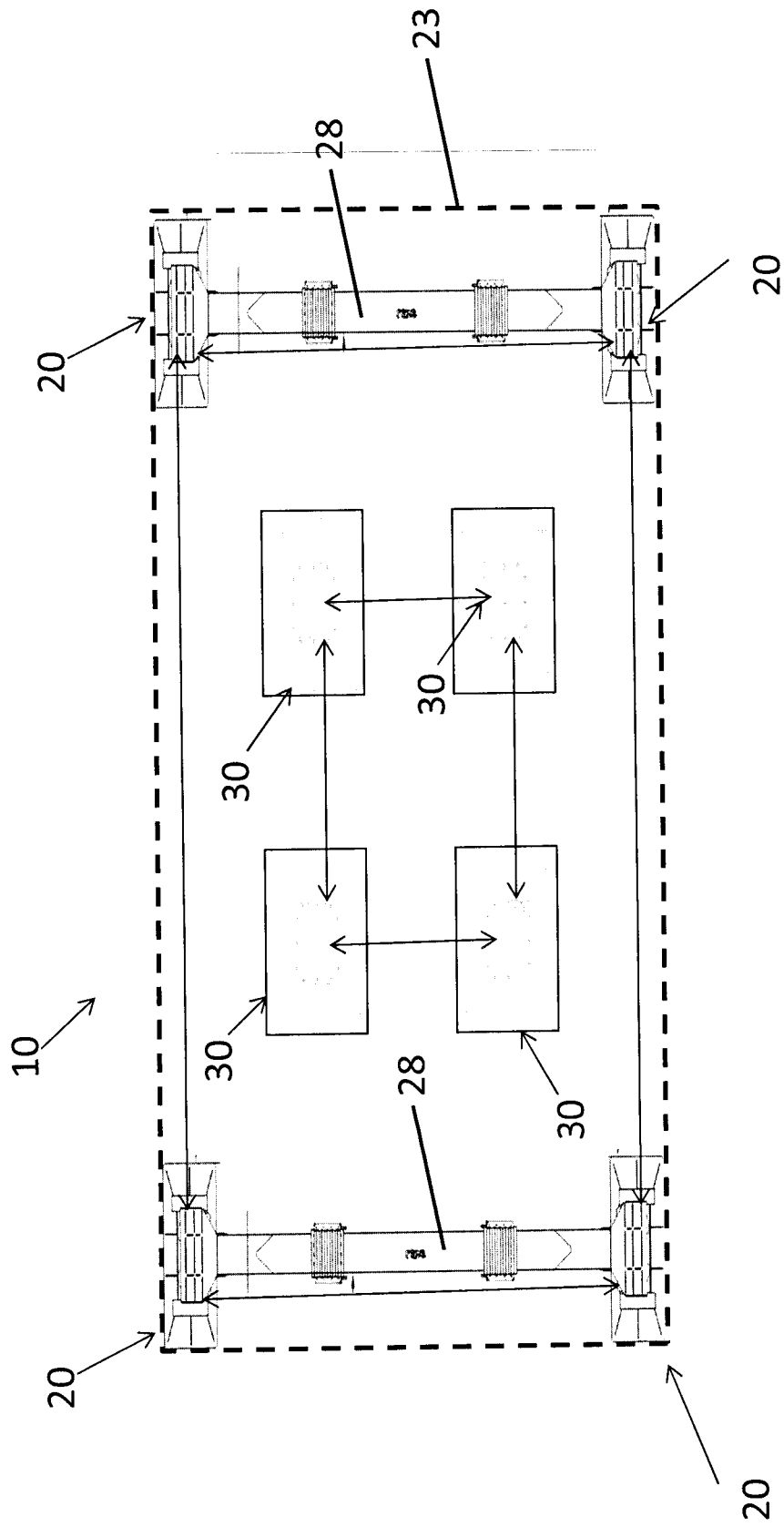


FIGURE 2A

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FIGURE 3



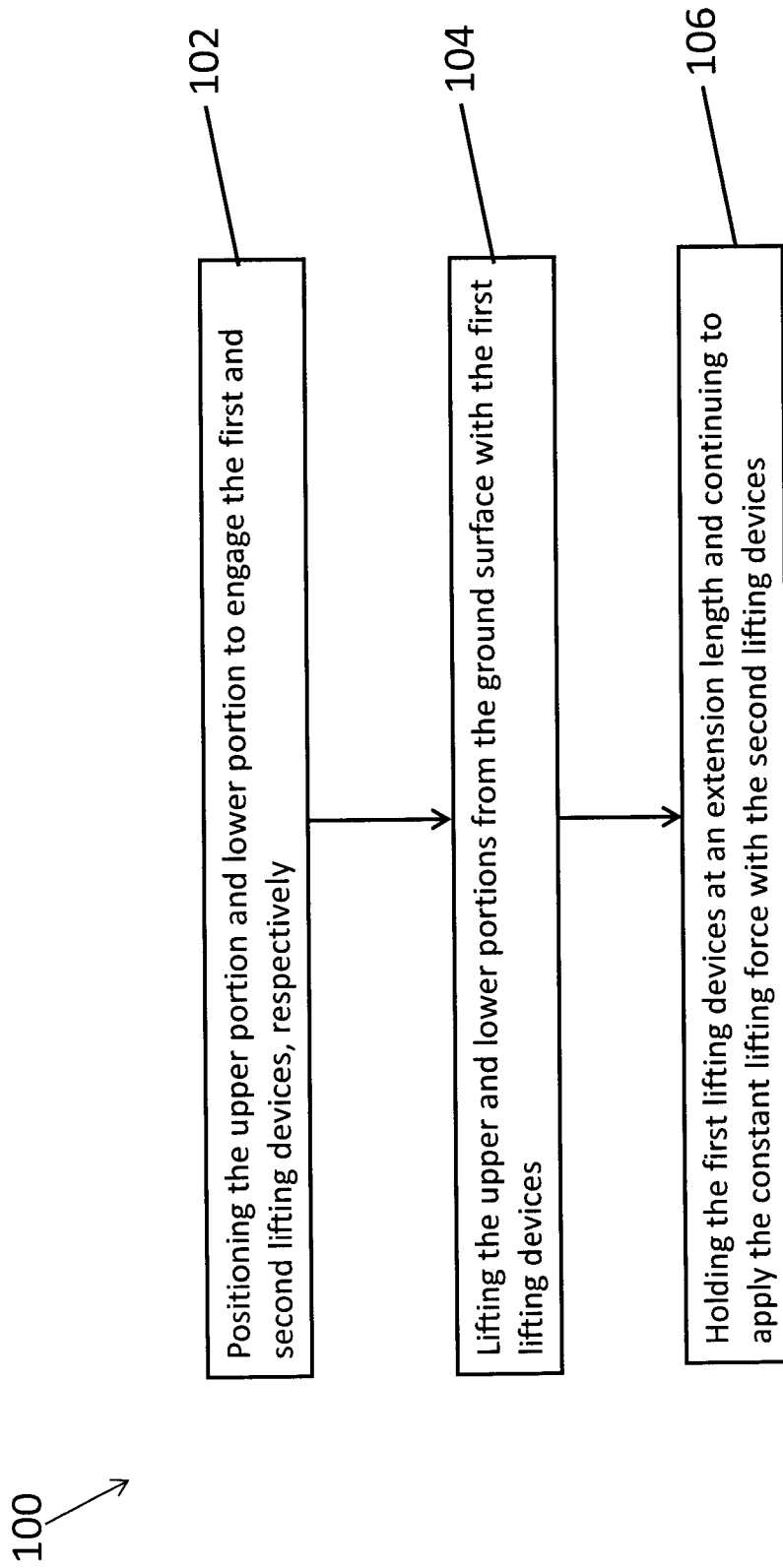


FIGURE 4

