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(54) **SYSTEM AND METHOD FOR VERTICALLY MOVING WEIGHTS**

(57) The present invention relates to a system for vertically displacing masses, comprising a drive assembly, cable loops consisting of a first and a second portion of cable, wherein each portion of cable comprises coupling assemblies, masses attachable to said coupling assemblies and upper and lower assemblies for deflecting cable loops, displaceable between a first position wherein the first portion of cable is substantially centred in a vertical displacement space, and a second position wherein the second portion of cable is substantially centred in said space. The present invention also relates to methods for vertically displacing masses, which are carried out with the system of the invention.

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Description

TECHNICAL FIELD

[0001] The present invention relates to a system and method for vertically displacing masses that can be applied to generation and storage of energy, as well as for extracting material from a mine. The system of the invention comprises a drive assembly, cable loops, coupling assemblies, masses and assemblies for deflection of the cable loops.

BACKGROUND

[0002] In the state of the art, a number of systems and methods have been described for vertically displacing masses in order to store potential energy and to generate energy thanks to the vertical displacement of said masses.

[0003] The masses may weigh as much as several hundred tons and be displaced through vertical shafts that may be hundreds of metres deep, even reaching depths of 2000 or 3000 metres. Consequently, there are difficulties associated with the vertical displacement of such heavy masses that travel such profound vertical distances.

[0004] In the state of the art, systems have been described for storing energy that comprise masses, cables for suspending the masses, elements for attaching the masses to the cables and an electrical power generator for generating electricity when moving the masses by gravity from a higher level to a lower level of vertical shafts.

[0005] Some of the systems described in the prior art also have mass displacement guidance means. However, despite developments in the state of the art, there is a need to develop improved systems and methods for displacing vertical masses, as well as to develop more efficient systems and methods for storing potential energy and generating energy, associated with the vertical displacement of the masses.

SUMMARY OF THE INVENTION

[0006] For the purposes of the present invention, "rack" refers to a toothed rail.

[0007] For the purposes of the present invention, "friction pulley", also referred to as "Koepe pulley", refers to a special type of large diameter pulley. It is commonly used in mine extraction shafts. It allows a load hanging from one of the cable strands to be vertically displaced without requiring a counterweight on the other, preventing the cable from slipping thanks to the adhesion between the extraction cable and the throat or channel of the pulley, which is increased by covering said throat with hard wood or with another material of high friction coefficient, such as rubber or leather.

[0008] For the purposes of the present invention, "speed reducer", also referred to as "reduction gearbox", refers to one or several pairs of gears mounted in a compact body, which adapt the speed and mechanical power of a machine whose movement is generated by a motor. In this way, the engine speed is adapted to the speed necessary for the correct operation of the machine.

[0009] The technical problem to be solved consists of providing a more efficient system and method for vertically displacing masses because it solves, among others, the following partial problems: (i) avoiding unsteadiness in the displacement of the masses and potential collisions between the masses and the walls of the vertical displacement space due to oscillations, (ii) improving the efficiency and performance of the vertical displacement of the masses, and (iii) improving the efficiency and performance of the displacement of the masses from the vertical displacement space to the storage position and vice versa.

[0010] The invention combines features that solve such partial problems.

[0011] The system of the invention comprises assemblies for deflecting the cables that displace the masses. Both with the system of the invention comprising said assemblies for deflecting, as well as in the method carried out with the system of the invention, the masses are always displaced substantially centred in the vertical displacement space, with ample and uniform clearance to the walls of the vertical displacement space, thus avoiding unsteadiness in the displacement of the masses and increasing safety in the face of potential collisions between the masses and the walls of the vertical displacement space due to oscillations.

[0012] The system of the invention further comprises robust, reliable coupling assemblies of the masses to the cables, without comprising drivers or moving parts therein nor in the masses to which they are coupled. Both with the system of the invention that comprises said coupling assemblies, as well as in the method carried out with the system of the invention, the masses are coupled to the cables quickly and automatically, and stability is ensured in the displacement of the masses.

[0013] The system of the invention further comprises means for displacing the masses from the vertical displacement space to their storage position and vice versa, consisting of tracks and wagons that are quickly and automatically displaced on said tracks. Both with the system of the invention that comprises said mass displacement means, as well as in the method carried out with the system of the invention, improvements in efficiency and performance are achieved.

[0014] The system of the invention can be used in the energy sector, for generating and storing energy. In this type

of application, the system generates energy when lowering the masses and is recharged by raising the masses.

[0015] The system of the invention can also be used in the mining sector, to extract material from a mine.

[0016] The present invention provides a system for vertically displacing masses, comprising:

(a) a drive assembly comprising at least one bi-directional rotary machine driving at least one drive pulley, said drive assembly being located at an upper level of a vertical displacement space;
(b) a plurality of cable loops connecting the drive assembly with a transfer assembly comprising at least one transfer pulley, said transfer assembly being located at a lower level of said vertical displacement space, wherein said transfer assembly maintains tension in the cable loops, wherein the portion of cable of each cable loop disposed between the drive pulley and the transfer pulley defines a first portion of cable and the remaining portion of cable of each cable loop disposed between the drive pulley and the transfer pulley defines a second portion of cable;
(c) each portion of cable comprises a plurality of coupling assemblies;
(d) a plurality of masses that are attached by means of said coupling assemblies to the portions of cable, to be displaced through the vertical displacement space;
(e) an upper assembly for deflecting cable loops comprising a plurality of upper deflector pulleys and a lower assembly for deflecting cable loops comprising a plurality of lower deflector pulleys, wherein said assemblies for deflecting cable loops are displaceable between two positions, a first position wherein the first portion of cable is substantially centred in the vertical displacement space, and a second position wherein the second portion of cable is substantially centred in the vertical displacement space.

[0017] In the system of the invention, each cable loop consists of a first and a second portion of cable, without physical division between the cable portions. The first portion of cable is defined by the portion of cable of each cable loop disposed between the drive pulley and the transfer pulley, and the second portion of cable is defined by the remaining portion of each cable loop disposed between the drive pulley and the transfer pulley.

[0018] In a preferred embodiment of the system of the invention, said assemblies for deflecting cable loops comprise means for linearly displacing the deflector pulleys.

[0019] Preferably, said means for linearly displacing the deflector pulleys are selected from the group consisting of a carriage, a rack, a linear actuator and one or more tracks.

[0020] In another preferred embodiment of the system of the invention, the drive pulley is disposed in a lower position with respect to the position of the upper assembly for deflecting cable loops, said assemblies for deflecting the cable loops comprising means for linearly displacing the deflector pulleys and the system further comprises fixed pulleys.

[0021] In another preferred embodiment of the system of the invention, the upper assembly for deflecting cable loops comprises a swing arm that displaces said upper assembly for deflecting cable loops between a first position and a second position.

[0022] In a more preferred embodiment of the system of the invention, the drive pulley is a friction pulley.

[0023] In the system of the invention, the coupling of the drive pulley and the bi-directional rotary machine may be direct or via a speed reducer.

[0024] In a more preferred embodiment of the system of the invention, the bi-directional rotary machine is an electric motor.

[0025] In a more preferred embodiment of the system of the invention, the bi-directional rotary machine is an electric machine capable of operating as a motor or as a generator.

[0026] In another more preferred embodiment, the system of the invention has a plurality of bi-directional rotary machines, at least one of which is an electrical generator and at least one of which is an electric motor.

[0027] In another more preferred embodiment of the system of the invention, the bi-directional rotary machine is connected to the power grid via an electronic power converter equipped with a control device.

[0028] In another more preferred embodiment, the system of the invention comprises a braking system. Said braking system makes it possible to halt the system of the invention in emergency situations.

[0029] In another preferred embodiment of the system of the invention, the coupling assemblies comprise upper couplings and lower couplings and the masses comprise a few holes and a few upper supports, wherein additionally, when the coupling assemblies are coupled to the masses, the upper supports rest on the upper couplings, said upper couplings and the lower couplings being radially confined in the holes, wherein in addition, the upper supports and the masses comprise slots through which the masses are horizontally displaced with respect to the portions of cable, in the direction opposite to that of the other portion of cable, when the coupling assemblies are not coupled to the masses.

[0030] In the system of the invention, said upper supports may be disposed on, or integrated into, the masses.

[0031] In another preferred embodiment of the system of the invention, the coupling assemblies comprise upper couplings and lower couplings and the masses comprise upper supports and lower supports, disposed on the exterior thereof, comprising a vertical hole wherein, when the coupling assemblies are coupled to the masses, the upper supports rest on the upper couplings and radially confine said upper supports in their hole, and wherein the lower supports radially

confine the lower couplings in their hole, wherein the upper supports and the lower supports comprise slots through which the masses are horizontally displaced with respect to the portions of cable, in the opposite direction to the other portion of cable, when the coupling assemblies are not coupled to the masses.

[0032] In another preferred embodiment, the system of the invention comprises means for the extraction of the masses, consisting of a few wagons that are displaced on a few tracks, disposed in at least one substantially horizontal gallery on each side of the vertical displacement space or on the surface of the ground, wherein platforms for storage of the masses are disposed in said gallery or on said surface of the ground.

[0033] In another preferred embodiment of the system of the invention, the means for extraction of the masses comprises a wagon which in turn comprises an overhang extending linearly over a few wheels located at one of the ends of said wagon such that, when said wheels rest at the end of one of the tracks, the masses rest on a platform disposed on said overhang, and where said wagon further comprises a counterweight at the end of the wagon opposite the overhang.

[0034] In another preferred embodiment of the system of the invention, the means for extraction of the masses comprises a wagon configured to be able to simultaneously have at least one of its axles on each one of the tracks, wherein said wagon comprises a platform upon which the masses rest that is displaced along said wagon via linear displacement means.

[0035] In another preferred embodiment, the system of the invention comprises a wagon configured so that the end of the wagon can rest on the opposite side of the vertical displacement space to that on which the wagon is located, by means of an element that rests on a platform disposed on said side of the shaft, wherein said wagon comprises a platform upon which the masses rest that is displaced along said wagon via linear displacement means.

[0036] Preferably, said linear displacement means is selected from the group consisting of a carriage, a rack, a linear actuator, a track and a plurality of tracks.

[0037] In another preferred embodiment, the system of the invention comprises a retractable or swing bridge for communicating the tracks on both sides of the vertical displacement space.

[0038] In another preferred embodiment of the system of the invention, the wagons comprise a platform comprising lifting means, upon which the masses rest.

[0039] Preferably, said lifting means is a hydraulic thruster, a plurality of hydraulic thrusters, a spindle actuator driven by a motor, and a plurality of spindle actuators each driven by a motor.

[0040] In a more preferred embodiment of the system of the invention, the wagons comprise slots.

[0041] In another more preferred embodiment of the system of the invention, the at least one gallery comprises supports for the storage of the masses.

[0042] In another more preferred embodiment of the system of the invention, a portion of said tracks is disposed on a number of bridge beams.

[0043] In the system of the invention, the tracks may be continuous or discontinuous.

[0044] In another preferred embodiment, the system of the invention comprises a system for monitoring and controlling the operation of the various elements, comprising sensors and communication and control devices.

[0045] Said system for monitoring and controlling synchronizes the movement of the wagons with the vertical displacement of the masses and ensures the correct positioning of the wagons for the masses to be attached to the cables of the system of the inventionfor the masses to be released from the cables of the system of the invention, for the masses to be unloaded in their storage position and for the masses to be collected from the storage position. The monitoring and control system has limit switches, position sensors, an industrial computer or PLC that captures these signals and automatically sends the corresponding commands to the different systems.

[0046] In addition, the system of the invention has a Supervisory Control and Data Acquisition system (SCADA), which allows its correct operation to be monitored and certain operating instructions to be modified. All this makes it possible for the system of the invention to operate automatically, without direct intervention of operators, and in a very quick and reliable way, without compromising safety.

[0047] Preferably, said system for monitoring and controlling comprises a programmable logic controller (PLC).

[0048] The system and method of the invention allows the manoeuvres of insertion of the masses into the vertical displacement space and their attachment to the cables, as well as their uncoupling and extraction upon reaching the destination level to be carried out with great rapidity. However, these manoeuvres make the system of the invention unable to deliver energy continuously and constantly. Advantageously, the system of the invention can be hybridized with an auxiliary energy storage system (consisting, for example, of batteries with their corresponding charger), which can be recharged with a fraction of the power generated by the system of the invention during the descent of the masses and which is discharged during these transitions to maintain the overall power delivered constant.

[0049] Accordingly, preferably, the system of the invention comprises an energy storage device.

[0050] In another preferred embodiment of the system of the invention, the lower level transfer pulley is coupled to an electrical generator (directly or via a reduction gearbox), which can be connected to produce the energy required to power the equipment installed at said lower level: wagons and system for monitoring and controlling, which may in turn have rechargeable energy storage devices.

[0051] In another preferred embodiment of the system of the invention, the masses consist of containers that can accommodate a granular material or a liquid. For their use in storage and generation of energy, once the masses complete their vertical displacement, the containers can be taken to their storage position when filled with this material, or unloaded into tanks disposed for this purpose, from which, subsequently, the containers would be refilled, before performing the reverse vertical displacement. Conveyor belts or other means of continuous displacement may be used to displace the containers from their emptying position to their filling position.

[0052] The present invention also provides a method for vertically displacing masses between a starting level and a destination level, carried out with the system of the invention, comprising:

(a) disposing the upper assembly for deflecting cable loops and the lower assembly for deflecting cable loops in the first position, where the first portion of each cable loop is substantially centred in the vertical displacement space;
(b) at the starting level, inserting a mass into the vertical displacement space;
(c) coupling said mass to the first portion of each cable loop by means of the coupling assemblies;
(d) rotating the at least one drive pulley in one direction until the mass reaches its destination level;
(e) uncoupling the mass from the coupling assemblies;
(f) extracting the mass from the vertical displacement space at said destination level;
(g) disposing the upper assembly for deflecting cable loops and the lower assembly for deflecting cable loops in the second position, wherein the second portion of each cable loop is substantially centred in the vertical displacement space;
(h) at the starting level, inserting a new mass into the vertical displacement space;
(i) coupling said mass to the second portion of cable by means of the coupling assemblies;
(j) rotating the at least one drive pulley in a second direction, opposite to the direction of rotation indicated in step (d), until the mass reaches its destination level;
(k) uncoupling the mass from the coupling assemblies;
(l) extracting the mass from the vertical displacement space at said destination level; and
(m) repeating steps (a) to (l).

[0053] In a preferred embodiment, the method of the invention, which is performed with the system of the invention, comprises:

- performing step (a);
- performing step (b) according to the following sub-steps:
  - rotating the at least one drive pulley in a direction wherein the coupling assemblies with which the mass is intended to be engaged descend to a level at which, when inserting said mass into the vertical displacement space, said coupling assemblies do not interfere with said mass and/or its supports, nor with the extraction means; and
  - inserting the extraction means into the vertical displacement space, with the mass resting thereon, in the direction going from the first portion to the second portion of each cable loop, such that the portions of cable are inserted into the slots of the mass and/or its supports, until the upper supports, as well as the holes or lower supports, are on the same vertical as the upper couplings and the lower couplings;
- performing step (c) according to the following sub-steps:
  - rotating the at least one drive pulley in a direction wherein the coupling assemblies with which the mass is to be coupled ascend, entering into the housing of its upper supports and of its holes or lower supports;
  - continuing to rotate the at least one drive pulley in that direction, causing the upper couplings to abut against the upper supports and to draw the mass upward until it detaches from the extraction means; and
  - extracting the extraction means, withdrawing it from the vertical displacement space, toward its original position;
- performing step (d);
- performing step (e) according to the following sub-steps:
  - if the destination level is the upper one, continuing to rotate the at least one drive pulley in the same direction as in step (d) such that the mass ascends above the height at which the extraction means of the upper level is located, and inserting the extraction means into the vertical displacement space, until it is on the vertical of the mass;
  - if the destination level is the lower one, before the mass reaches the height at which the extraction means of

the lower level is located, inserting said extraction means into the vertical displacement space, until it is on the vertical of the mass; and

- for either of the destination levels, and subsequent to the previous sub-steps, rotating the at least one drive pulley in the direction that causes the mass to descend, until it rests on the extraction means, the upper couplings ceasing to abut against the upper supports;

- performing step (f) according to the following sub-steps:

  - continuing to rotate the at least one drive pulley in the direction in which it was rotating at the end of step (e), such that the coupling assemblies continue to descend to a level at which, when extracting the mass from the vertical displacement space, said coupling assemblies do not interfere with the mass nor with the extraction means; and
  - extracting the extraction means with the mass resting thereon, in the direction going from the second portion to the first portion of each cable loop, such that relative displacement of the first portions of cable is produced with respect to the mass towards the opening of the slots of said mass and/or of its supports, until said mass and said extraction means are completely withdrawn from the vertical displacement space;

- performing step (g);
- performing step (h) according to the following sub-steps:

  - rotating the at least one drive pulley in the direction wherein the coupling assemblies with which the mass is to be engaged descend to a level at which, when inserting said mass into the vertical displacement space, said coupling assemblies do not interfere with said mass and/or its supports, nor with the extraction means; and
  - inserting the extraction means into the vertical displacement space, with the mass resting thereon, in the direction going from the first portion of cable to the second portion of cable of each cable loop, such that the portions of cable are inserted into the slots of the mass and/or of its supports, until the upper supports as well as the holes or lower supports are on the same vertical as the upper couplings and the lower couplings;

- performing step (i) according to the following sub-steps:

  - rotating the at least one drive pulley in the direction in which the coupling assemblies with which the mass is to be coupled ascend, becoming inserted into the housing of its upper supports and of its holes or lower supports;
  - continuing to rotate the at least one drive pulley in that direction, causing the upper couplings to abut against the upper supports and to draw the mass upward until it detaches from the extraction means; and
  - extracting the extraction means, withdrawing it from the vertical displacement space;

- performing step (j);
- performing step (k) according to the following sub-steps:

  - if the destination level is the upper one, continuing to rotate the at least one drive pulley in the same direction as in step (d) so that the mass ascends above the height at which the upper level extraction means is located, and inserting the extraction means into the vertical displacement space, until it is on the vertical of the mass;
  - if the destination level is the lower one, before the mass reaches the height at which the extraction means of the lower level is located, inserting said extraction means into the vertical displacement space, until it is on the vertical of the mass; and
  - for either of the destination levels, and subsequent to the previous sub-steps, rotating the at least one drive pulley in the direction that causes the mass to descend, until it rests on the extraction means, the upper couplings ceasing to abut against the upper supports;

- performing step (l) according to the following sub-steps:

  - continuing to rotate the at least one drive pulley in the direction in which it was rotating at the end of step (k), such that the coupling assemblies continue to descend to a level where, when extracting the mass from the vertical displacement space, said coupling assemblies do not interfere with the mass nor with the extraction means; and
  - extracting the extraction means with the mass resting thereon, in the direction going from the first portion to the second portion of each cable loop, such that that relative displacement of the second portions of cable is produced with respect to the mass, towards the opening of the slots of said mass and/or of its supports, until

said mass and said extraction means are completely withdrawn from the vertical displacement space; and

- performing step (m).

[0054] In another preferred embodiment, the method of the invention, which is carried out with the system of the invention, comprises:

- from the completion of step (c) of a cycle until step (b) of the next cycle is commenced, the following operations are performed:
  - at the starting level, lowering the platform of the wagon to its lowered position, once there is no longer a mass thereon;
  - displacing said wagon along the starting level tracks, until it is located with its platform below a mass stored in the upper/lower level structure for storage of masses;
  - raising the platform of said wagon, causing the mass to rest on the platform and to separate from the support beams; and
  - displacing said wagon along the tracks towards the vertical displacement space, with the mass resting on its platform, which remains in its raised position, such that said mass is held above the support beams;
- from the completion of step (f) of a cycle until step (e) of the next cycle is commenced, the following operations are performed:
  - at the destination level, displacing the wagon along the tracks of said level towards the mass storage position in the upper/lower level structure for storage of masses, with said mass resting on the wagon platform, which remains raised, such that said mass is maintained above the supporting beams;
  - lowering the platform of the wagon, causing the mass to rest on the support beams and to no longer rest on said platform;
  - displacing the wagon along the tracks with its platform in its lowered position, towards the vertical displacement space; and
  - raising the platform of the wagon, which does not yet have a mass on it, to its raised position;
- from the completion of step (i) of a cycle until step (h) of the next cycle is commenced, the following operations are performed:
  - at the starting level, lowering the wagon platform to its lowered position, once there is no longer a mass thereon.
  - displacing said wagon along the starting level tracks, until it is located with its platform below a mass stored in the upper/lower level structure for storage of masses;
  - raising the platform of said wagon, causing the mass to rest on the platform and to separate from the support beams; and
  - displacing said wagon along the tracks towards the vertical displacement space, with the mass 300b resting on its platform, which remains in its raised position, so that said mass is maintained above the support beams;
- from the completion of step (l) of a cycle until step (k) of the next cycle is commenced, the following operations are carried out:
  - at the destination level, moving the wagon along the tracks of that level up to the mass storage position in the upper/lower level structure for storage of masses, with said mass resting on the platform of the wagon, which remains raised, such that said mass is maintained above the supporting beams;
  - lowering the platform of the wagon, causing the mass to rest on the support beams and no longer rest on said platform;
  - moving the wagon along the tracks with its platform in its lowered position, towards the vertical displacement space; and
  - raising the platform of the wagon, which does not yet have a mass on it, to its raised position.

[0055] In a preferred embodiment of the method of the invention, the masses are raised to store potential energy by means of the bi-directional rotary machine of the drive assembly acting as a motor, and/or when the masses descend, the bi-directional rotary machine, acting as a generator, produces energy.

[0056] In another preferred embodiment of the method of the invention, the masses are displaced to extract material

from a mine.

[0057] Throughout the description and the claims, the term "comprising", "that comprises" and their variants are of a non-limiting nature and, therefore, do not seek to exclude other technical features. The term "comprises", "comprising" and its variants, throughout the description and the claims, specifically include the term "consists of", "consisting of" and their variants.

[0058] As used in this description and in the claims, the singular form "the" includes references to the plural forms unless the content clearly indicates otherwise.

[0059] Unless defined otherwise, all the technical and scientific terms used throughout the description and claims have the same meaning as those customarily understood by a person skilled in the field of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0060] In order to aid in a better understanding of the features of the invention, a series of drawings are provided where, by way of illustrative and non-limiting character, the following has been represented:

Figure 1 portrays a longitudinal cross-sectional view of the system for vertically displacing masses according to an embodiment of the invention. Thus, the layout of the cable loops is portrayed in three-dimensional views of details A, B, and C.

Figures 2 to 5 portray enlarged views of details A and B of the system for vertically displacing masses, according to embodiments of the invention, according to a longitudinal cross-sectional view (Figures 2 and 4) and in three-dimensional views (Figures 3 and 5).

Figures 6 and 7 show an enlarged view of detail A of the system for vertically displacing masses according to an embodiment of the invention, according to a longitudinal cross-sectional view and in three-dimensional views.

Figures 8A to 8C show cross-sectional views of the coupling assemblies and of the mass with which they are coupled, according to an embodiment of the invention.

Figures 9A to 9C show a sequence of insertion and coupling of a mass in the vertical displacement space, in cross-sectional and plan views. Figures 9D to 9F show a sequence of uncoupling and extracting a mass from the vertical displacement space, in cross-sectional and plan views.

Figures 10A to 10D show vertical forces in a cross-sectional view (Figure 10A), horizontal forces in a cross-sectional view (Figure 10B), pitching moments in a cross-sectional view (Figure 10C), and torsional moments (Figure 10D) in a plan view (Figure 10D).

Figures 11A and 11B show the coupling assemblies and the mass to which they are coupled in cross-sectional and plan views according to an embodiment of the invention.

Figure 12 shows details of the means employed at the lower level of the vertical displacement space for the extraction, transport and storage of the masses, where horizontal galleries that extend to each side of said space are disposed, in which the masses that have reached the lower level are alternately stored, according to an embodiment of the system of the invention.

Figures 13A and 13B show details of the galleries of the lower level of the vertical displacement space in a cross-sectional view (Figure 13A) and in a three-dimensional view (Figure 13B), according to an embodiment of the invention.

Figures 14A to 14C show the sequence of extraction, transport and unloading of a mass by means of a wagon having a movable platform, in elevational and cross-sectional views, according to an embodiment of the invention.

Figures 15A to 15D show the uncoupling, extraction, transport and unloading sequence of the masses at the lower level of the vertical displacement space, according to an embodiment of the invention.

Figures 16A and 16B show details of the means employed at the upper level of the vertical displacement space for the extraction, transport and storage of the masses at the surface, in a cross-sectional view (Figure 16A) and in a three-dimensional view (Figure 16B), according to an embodiment of the invention.

Figure 17A shows a plan view detail of the upper level, portraying a continuous track and a mass with a width less than that of the rails of said track, according to an embodiment of the invention, and Figure 17B shows a plan view detail of the upper level, portraying a track that is interrupted upon reaching the vertical displacement space, according to an embodiment of the invention.

Figures 18A to 18D show the uncoupling, extraction, transport and unloading sequence of the masses at the upper level of the vertical displacement space, according to an embodiment of the invention.

Figure 19 shows a wagon having an overhang in front of the wheels closest to the vertical displacement space, at the end of which a platform is located, and having a counterweight of sufficient weight at the end opposite the platform, according to an embodiment of the system of the invention.

Figures 20A to 20D show the uncoupling and extraction sequence of a mass at the upper level of the displacement space, using a wagon such as that shown in Figure 19, according to an embodiment of the system of the invention.

Figure 21 shows a wagon having a platform disposed on a motorized trolley that can travel between one end of the wagon and the other. The wheel arrangement of the wagon enables it to approach the vertical displacement space and to cross it, according to an embodiment of the system of the invention.

Figures 22A to 22D show the uncoupling and extraction sequence of a mass at the upper level of the vertical displacement space, using a wagon such as that shown in Figure 21, according to an embodiment of the system of the invention.

DESCRIPTION OF EMBODIMENTS

[0061] The figures portray preferred embodiments of the invention.

[0062] Figures 1 to 5 schematically show the system and method for vertically displacing masses, according to various embodiments of the invention.

[0063] Figure 1 shows a scale overview, with the cross-section of a vertical displacement space 100 of a depth of several hundred metres. The vertical displacement space 100 may be the shaft of a disused mine or may have been bored for the purpose.

[0064] As shown in detail C of Figure 1, the masses are displaced one by one from the lower level of the vertical displacement space to the upper level of the vertical displacement space, or vice versa, by a plurality of cable loops 260, 260' disposed on parallel planes, as also seen in details A and B of said figure, and driven and guided by a series of elements that are grouped into an upper assembly 200 and a lower assembly 210, which are not shown in details A and B of said figure but which will be shown in detail in the subsequent figures.

[0065] In order to better observe all these elements, Figures 2 to 7 show enlargements of detail A, corresponding to the upper level of the vertical displacement space and/or detail B, corresponding to the lower level of the vertical displacement space. These details are shown in views according to a longitudinal cross-section of the vertical displacement space and the corresponding three-dimensional view. All of these portray the system according to an embodiment of the invention, which includes two cable loops, operating to raise masses from the lower level of the vertical displacement space to the upper level. However, the system according to an embodiment of the invention is reversible and likewise serves to lower the masses from the upper level of the vertical displacement space to the lower level. Figures 2 to 7 would describe the operation of the system for lowering masses by simply changing the direction shown by the arrows.

[0066] In Figure 3, both cable loops are observed, while in Figure 2 they are superimposed. Each of the cable loops 260 and 260' shown in Figure 1, consists of a first and a second portion of cable, with no physical division between the portions of cable. In the first cable loop 260, the first portion of cable 260a is defined by the portion of cable of each cable loop disposed between the drive pulley 221 and the transfer pulley 241, and the second portion of cable 260b is defined by the remaining portion of cable of each cable loop disposed between the drive pulley 221 and the transfer pulley 241. Similarly, in the second cable loop 260', the first portion of cable 260a' is defined by the portion of cable of each cable loop disposed between the drive pulley 221 and the transfer pulley 241, and the second portion of cable 260b' is defined by the remaining portion of cable of each cable loop disposed between the drive pulley 221 and the transfer pulley 241.

[0067] Each of these loops in turn bears an assembly of couplings on the portion of cable at each side of the loop, 261a on the portion of cable 260a and 261b on the portion of cable 260b of the cable loop 260; 261a' on the portion of cable 260a' and 261b' on the portion of cable 260b' of the loop 260', such that, when the pair of coupling assemblies 261a and 261a' is at the upper level of the vertical displacement space, the pair of coupling assemblies 261b and 261b' on the other side of the pulley is at the lower level of the vertical displacement space.

[0068] In Figures 2 and 3 the upper assembly 200 of the system according to an embodiment of the invention is included. This upper assembly 200 consists of a load-bearing structure 202 that is anchored on a foundation 201 and at whose upper part a drive assembly 220 is disposed, wherein a drive pulley 221, such as a friction pulley or Koepe pulley, is integrated, which moves the cable loops, driven by a bi-directional rotary machine 223, which can operate as a motor to raise the masses and also operate as a generator and generate energy when the masses descend in the application of the system of the invention to the energy sector.

[0069] Depending on the operating speeds of the drive pulley 221 and the bi-directional rotary machine 223, the coupling between the two may be direct or via a speed reducer (not shown in the figures).

[0070] To regulate the movement, the bi-directional rotary machine 223 may be connected to the power grid by means of an electronic power converter, equipped with a control device (not shown in the figures).

[0071] The drive assembly 220 has a braking system (not shown in the figures), in order to be able to halt it in emergency situations.

[0072] Below the drive assembly 220, the upper assembly for deflecting 230 is disposed, comprising deflector pulleys 231, which are displaced by means of a deflector 232 along a number of beams 233 in solidarity with the load-bearing structure 202.

[0073] At the lower part of the vertical displacement space a chamber 104 has been equipped, wherein the lower assembly 210 is disposed. The lower assembly 210 includes the transfer assembly 240 equipped with a transfer pulley 241 that rotates, pulled by the cable loops, maintaining certain tension therein, limiting the oscillations of the mass. Above the transfer assembly 240, the lower assembly for deflecting 250 is located, equipped with a few deflector pulleys 251 joined to a trolley 252 that travels along a few beams 253. This lower assembly for deflecting 250 is equivalent to the upper assembly for deflecting 230, both moving in coordination, such that the cables remain vertical throughout the vertical displacement space. Both the transfer assembly 240 and the lower assembly for deflecting 250 have a beam, which may be common or independent for each assembly (242, 253, respectively), that anchors said assemblies to the walls of the chamber 104.

[0074] In the position shown in Figures 2 and 3, the upper assembly for deflecting 230 and the lower assembly for deflecting 250 have their deflectors 232 and 252 in the appropriate position for the cables that guide the deflector pulleys 231 and 251 to transfer the mass 300a centrally in the vertical displacement space, by means of the coupling assemblies 261a and 261a', since the portions of cable 260a and 260a' run through the centre of said displacement space. Meanwhile, the other pair of coupling assemblies 261b and 261b' are free of load and move downward, following the path close to the wall 103 defined by the portion of cable 260b and 260b', respectively. In this way, the mass maintains ample and uniform clearance to the walls of the vertical displacement space, which avoids unsteadiness and potential collisions due to oscillations.

[0075] Once the mass 300a has reached the upper level of the vertical displacement space and the couplings carrying the same 261a and 261a' have been released from their load, the deflectors 232 and 252 displace the transfer pulleys 231 and 251 to the position shown in Figures 4 and 5, wherein the other portions of cable 260b and 260b' become those located in the central plane of the vertical displacement space. This allows the next mass to be transferred 300b to be coupled by means of the coupling assemblies 261b and 261b' and, when the drive pulley 221 begins to rotate in the opposite direction to that of the first displacement, this mass 300b is raised centrally in the vertical displacement space.

[0076] In this way, the system allows the masses to be transferred successively and continuously from one level to the opposite level, with a path always centred in the vertical displacement space, and in such a way that all displacements of the cable are used to transfer a mass. For this purpose, one pair of coupling assemblies 261a and 261a' and the other pair of coupling assemblies 261b and 261b' are alternately employed, of which the pair carrying the mass is always centred in the vertical displacement space. This is achieved thanks to changing the position of the transfer pulleys 231 and 251 at the end of each travel path, after which the direction of rotation of the drive pulley 221 is reversed.

[0077] In Figure 6 an enlarged detail A of Figure 1 according to an alternative embodiment of the system of the invention is shown, wherein the drive pulley 221 is located on the ground to one side of the vertical displacement space, in a disposition similar to that commonly used in mining facilities. This configuration includes an additional assembly of deflector pulleys 203 at the upper level of the vertical displacement space which, unlike the deflector pulleys 231, remain fixed, since their function is to transfer the cables arriving from the drive pulley 221 to the deflector pulleys 231.

[0078] In Figure 7 another alternative embodiment of the system of the invention is shown, wherein the drive pulley 221 is also located on the ground to one side of the vertical displacement space, but the need for the additional assembly of deflector pulleys 203 is avoided, and the turret-like structure supporting all the pulleys disposed over the vertical of the vertical displacement space is dispensed with, using instead a forked swing arm 234, on which a single set of deflector pulleys 231 is disposed, capable of bringing one or another portion of the cable to the position centred in the vertical displacement space by means of adjustment of the angle of the arm, regulatable by means of actuators 235 or other equivalent elements. This swing arm may be anchored to the ground by means of a foundation 201 for each of its joints, by means of a foundation common to both joints or by means of a single foundation that serves as an anchor both for said joints and for the drive assembly 220.

[0079] The system according to an embodiment of the invention further comprises coupling assemblies which, together with a specific design of the masses, allows the automatic coupling and uncoupling and releasing of said masses at the ends of their vertical travel path to be carried out, without the need for intervention by operators, and in a rapid manner, which is particularly important for the application of storage of energy, to minimize the impact of transitions in which the flow of energy delivered (or consumed, during the recharge of the installation) is affected. In addition, the system according to this embodiment is very robust and reliable, since for the coupling and uncoupling of the masses it is not necessary to use drives or moving parts in the coupling assemblies nor in the masses, guaranteeing the safety of operations and minimizing the possibility of failures.

[0080] In Figure 8A, it is observed that each portion of cable 260a and 260a' has a coupling assembly 261a and 261a', which in turn consists of an upper element 262 and 262' and a lower element 272 and 272'. The upper and lower element of each coupling assembly may form part of a single component or be manufactured independently and then installed on the cable at the appropriate distance. The coupling assemblies 261b and 261b' of the other portions of cable 260b and 260b' are identical to those described.

[0081] In Figure 8B an embodiment is shown wherein the mass 300a has holes 301 and 301' for each coupling assembly, through which it can be inserted and over which are located a few upper supports 362 and 362', which can be independent items or be included in a single support disposed over the mass or even replaced by a narrowing of the holes in the upper part of the mass itself. The upper supports block the holes of the mass 301 and 301', except for the gap necessary for the cable to pass through. The mass 300b has a few holes 301 and 301' and a few upper supports 362 and 362' identical to those described.

[0082] As may be seen in Figure 8C, when the coupling assembly is coupled with the mass, the upper supports 362 and 362' rest on the upper couplings 262 and 262', preventing relative vertical displacements between mass and cable. Simultaneously, the small radial clearance between each coupling and the hole in which it is housed restricts horizontal movements in both the upper couplings 262 and 262' as well as in the lower couplings 272 and 272', this allowing the mass to be stably suspended.

[0083] In Figures 9A to 9C the sequence of insertion and coupling of the mass 300a is shown by means of cross-sectional and plan views, wherein, in addition to the involvement of the coupling assembly described, an extraction means is used, which enables the insertion and extraction of the masses in the vertical displacement space. In its basic configuration, said extraction means shall consist of a platform capable of being horizontally displaced between the vertical displacement space and a space adjacent to the same, at least one extraction means being disposed at the starting level and another at the destination level of mass displacement. However, more detailed embodiments of the extraction means will be described in subsequent figures. The sequence for the mass 300b is defined by the same figures, by simply rotating the plan views 180°.

[0084] The insertion of a mass at the starting level requires that the coupling assemblies with which it is to be coupled are below the coupling position, as seen in Figure 9A, where the upper couplings 262, 262' and lower couplings 272, 272' are below the mass 300a to be coupled, which will have been achieved by rotating the drive pulley in the appropriate direction. Once these couplings are at the appropriate height, the mass 300a is inserted into the space of vertical displacement, resting on an extraction means 500. When the mass is inserted into the vertical displacement space, the portions of cable 260a and 260a' are inserted and displaced along slots 303 and 303' executed in the mass (and in its supports) in the direction of the insertion movement, shown in the plan view, and which are sufficiently wide to allow the passage of the cable, but not that of the couplings. The insertion movement continues until the mass is in the coupling position, centred in the vertical displacement space. The mass 300b has identical slots 303 and 303', but when inserted into the vertical displacement space, this occurs rotated by 180°, such that its slots are oriented with their open end towards the portions of cable 260a and 260a'. Therefore, the masses 300a and 300b will be inserted into the vertical displacement space from opposite sides.

[0085] Once the mass has been positioned, as may be seen in Figure 9B, the cables begin their ascent, so that the couplings are inserted into the holes of the mass 300, 301' until they reach their coupling position and, as the ascent continues, the upper coupling draws the mass upwards, as shown in Figure 9C, and it is then possible to remove the extraction means whereon the mass was resting.

[0086] Similarly, in Figures 9D to 9F the uncoupling and extraction sequence of the mass 300a, is shown via cross-sectional and plan views. The sequence for the mass 300b is defined by the same figures, by simply rotating the plan views 180°.

[0087] The uncoupling of a mass 300a requires that it be at a higher level than the extraction means 500, as may be seen in Figure 9D. In the event that the destination level is the lower level, the mass 300a will already be higher than the extraction means 500 throughout the entire vertical displacement, but in the event that the destination level is the higher level, it will be necessary that the mass that is ascending should continue to rise until it reaches a sufficient height above the extraction means. Once said height is reached, the extraction means 500 is inserted into the vertical displacement space, as may be seen in Figure 9D, and the mass 300a begins to descend, coupled to the portions of cable 260a and 260a' by means of the couplings 262, 262', 272 and 272', approaching the extraction means 500.

[0088] As seen in Figure 9E, as its descent continues, the base of the mass 300a rests on the extraction element 500, but the portions of cable 260a and 260a' continue to descend and draw the couplings downward, as these can pass through the holes in the mass 301 and 301'.

[0089] In Figure 9F it is seen that the couplings have continued their descent until they completely exit from the holes, at which time the mass 300a can now be displaced in a horizontal direction, in the opposite direction to where the portions of cable 260b and 260b' are found, and can be extracted from the vertical displacement space by means of the extraction element, thanks to the slots 303 and 303' (shown in the plan view) that allow sufficient clearance to be maintained with the portions of cable 260a and 260a'. Thus, each mass 300a is inserted into and extracted from the vertical displacement space on the same side. The mass 300b, since it will have been inserted into the vertical displacement space rotated 180° with respect to the position of the mass 300a shown in Figure 9F, will have the opening of its slots inverted, so the masses 300a and 300b will be extracted from the vertical displacement space towards opposite sides.

[0090] In Figures 10A to 10D it is shown that one of the advantages of the method of coupling between the coupling assemblies and the masses according to this embodiment of the invention is the stability it provides without the need to use mechanisms or moving parts, since the couplings are capable of generating the necessary reactions (white arrows) in the face of all types of external loads (grey arrows) that may act upon the masses.

[0091] In Figure 10a the force diagram due to vertical loads is shown, such as the weight of the mass and inertial loads during acceleration and deceleration transitions.

[0092] In the following figures the different possible types of destabilizing loads and the reactions generated by the coupling assemblies to maintain stability are shown: horizontal forces (Figure 10B), pitch moments (Figure 10C) and torsional moments (Figure 10D, in which the mass-coupling assembly is shown in a plan view).

[0093] In Figure 11A an embodiment of the invention is shown wherein a hole in the mass is not employed rather, as may be seen in the cross-sectional view of this figure, the upper supports 362 and 362', which engage with the upper couplings 262 and 262', are elements disposed on the exterior of the mass 300a, and there are additionally lower supports 372 and 372', also disposed on the exterior of the mass, to engage with the lower couplings 272 and 272'. The upper and lower supports may be fixed to the mass independently or in combination, or indeed form part of a structure that is in turn fixed on the mass. On the other hand, as is seen in the plan view, the slots in the mass are substituted by slots 303 and 303' in the supports themselves, which can also incorporate grooved elements, which have the function of facilitating the guiding of the cable to the lifting position. This embodiment has the advantage that, in order to insert or extract the mass, it is sufficient that the couplings are below their corresponding support, as is observed in Figure 11B, without the need that all of them have to come to be below the mass, which makes the coupling/uncoupling operation faster. Another advantage is that, by maximizing the distance between cables, stability is improved in the face of any tendency of the mass to rotate around a vertical axis (see Figure 10D).

[0094] As already mentioned previously, in certain embodiments of the invention, the extraction means at the starting level and at the destination level are configured in a more complex way than that shown in Figures 9A to 9F, with the aim of making their use possible not only for the insertion and extraction of the masses, but also for the loading, transport and unloading thereof. In the following figures these extraction means will be shown together with other elements necessary to carry out all these tasks. The embodiments for the lower level of the vertical displacement space are described first, and the embodiments for the upper level of the vertical displacement space and their particularities and differences with respect to those of the lower level are shown subsequently.

[0095] In Figure 12 it is observed that at the lower level of the vertical displacement space there are horizontal galleries 110a and 110b that extend to each side thereof, wherein the masses 300a, 300b that have reached said lower level are stored alternately, since, as previously indicated, the masses 300a and 300b have to be inserted into and extracted from the vertical displacement space on opposite sides. These galleries may be upgraded from those existing in a disused mine shaft or may have been purpose-built. For the application of storage of energy, it may be advantageous for the galleries to have a small incline, the level being slightly lower at the ends opposite the vertical displacement space. In this way, when the installation is working in discharge mode, the passage of the masses through the galleries to their storage position generates additional energy to that obtained during the vertical displacement. Conversely, when the installation is being recharged, the energy consumption is increased due to the passage of the masses from their storage position to the vertical displacement space, before being raised to the upper level of the vertical displacement space.

[0096] A few details of these galleries and of the lower part of the space of vertical displacement are shown in Figure 13A, and are also shown in the three-dimensional view in Figure 13B.

[0097] On the floor of the galleries a few tracks similar to railway tracks 410a and 410b are disposed, which rest on the bridge beams 430 at the vertical of the vertical displacement space, which could be replaced by a single slab on which both rails rest, provided that this is sufficiently narrow so as not to interfere with the cables of the cable assemblies 260 and 260', or that said slab has a few holes to allow the passage of said cables with sufficient clearance, even during their change of position due to the action of the assemblies for deflecting 230 and 250.

[0098] One or more motorized wagons 510a and 510b are displaced along the tracks, which can access the vertical of the vertical displacement space to alternately receive the masses 300a and 300b that descend through the vertical

displacement space and subsequently transfer them along the corresponding gallery until they are unloaded in their position on a lower level structure for storage of masses 610a and 610b.

[0099] Reciprocally, when it is desired to bring the masses to the upper level of the vertical displacement space, the wagons move them from their storage position to the lifting position, where they will be collected by the couplings of the cables in their ascending movement.

[0100] In the embodiment shown, due to the width of the wagons, these have a few slots upon which those of the masses are superimposed, to allow the wagon to be able to access the hoisting position on the vertical of the vertical displacement space without interfering with the cables. The wagons 510a and 510b are identical, although they are positioned on the tracks so that their slots are oriented oppositely, always open towards the vertical displacement space. In this way, the wagon 510a performs the operations of extraction, transport and unloading, and loading, transporting and insertion of the masses 300a, on the track 410a disposed in the gallery 110a, while the wagon 510b performs the operations of extraction, transport and unloading, and loading, transporting and insertion of the masses 300b, on the track 410b disposed in the gallery 110b. In other embodiments, the wagon will be narrower than the separation between cables, making these slots unnecessary.

[0101] The wagons are capable of both unloading the mass at the lower level structure for storage of masses, and loading the same therefrom. In Figures 14A to 14C the method of extraction, transporting, and unloading the mass 300a at the lower level structure for storage of masses 610a, carried out by the wagon 510a, according to a preferred embodiment is observed. The procedure of extracting, transporting and unloading the mass 300b at the lower level structure for storage of masses 610b by the wagon 510b would be the same. For the better understanding thereof, the wagon is shown in elevation and in a profile cross-section, in different working positions.

[0102] In this embodiment, the wagons have a platform 554, which is narrower than the space between the coupling assemblies 261a and 261a', and which can be lifted by a few thrusters 553 or an equivalent system.

[0103] In Figure 14A, the wagon 510a is positioned on the bridge beams 430 and with its raised platform 554 collects a mass 300a which, when lowered, rests on the platform 554, while the coupling assemblies 261a and 261a', which attached it to the cables, continue to descend, passing through the holes disposed in the chassis 551 of the wagon 510a, as is appreciated from section A of this figure. As is the case with the slots, in other embodiments, wherein the wagon is narrower than the gap between couplings, these holes are not necessary.

[0104] In Figure 14B, the wagon 510a is transferring the mass 300a along the gallery, thanks to the rotation of its wheels 552 along the track 410a. During its travel, the wagon runs through the interior of the gantries 621 of the lower level structure for storage of masses 610a, maintaining its platform 554 elevated to prevent the mass from interfering with the support beams 623, as is appreciated from section B of this figure.

[0105] When it arrives at its destination, the wagon 510a halts and the thrusters 553 lower the platform 554 until the mass 300a rests on the support beams 623 in its storage position, as is seen in section C of Figure 14C. These support beams rest on brackets 622, solidary to the gantries 621. Once the mass is resting on said support beams, the wagon can now return to the vertical displacement space, maintaining the platform in its lowered position.

[0106] The procedure of loading, transporting and inserting the mass 300a from the storage structure 610a, carried out by the wagon 510a, would be described by the same figures, arranged in the reverse order, from Figure 14C to 14A. As is seen in Figure 14C, the wagon 510a travels with its platform 554 in its lowered position up to the location where the mass 300a is stored. Once this position is reached, as shown in Figure 14B, the thrusters 553 are actuated to raise the platform 554, so that the mass 300a rests thereon, becoming separated from the support beams 623. Finally, the wagon 510a is displaced with the mass loaded on its platform 554, which remains in the raised position to avoid that the mass interferes with the support beams 623, until the mass is inserted into the vertical displacement space, as may be seen in Figure 14A.

[0107] The movement of the wagons and their platforms can be achieved by electric motors integrated in the wagon, which would be powered via a third rail system, equivalent to that used in some railway or underground railway lines, or indeed by equipping the wagon with batteries that would be charged at a charging point located at a certain point of the track, to which the wagon would move when not working. Another alternative for moving the wagon would be to use a system of external cables and pulleys, similar to the procedure used in funicular railways.

[0108] The sequence of uncoupling, extraction, transport and unloading of the masses at the lower level of the vertical displacement space is shown in Figures 15A to 15D. The arrows indicate the movements of the elements with the system of the invention operating to disengage the masses that descend via the cables and to take them to their storage position. If the order of the figures and the direction of the arrows are reversed, the sequence of loading, transport, insertion and coupling of the masses at the lower level is obtained, wherein the masses will be taken from their storage position to the vertical displacement space, where they are coupled for lifting.

[0109] In Figure 15A, the wagon 510a in the right-hand gallery travels toward the vertical displacement space to collect the mass 300a that descends through the vertical displacement space, while the wagon 510b in the left-hand gallery is taking the previously lowered mass 300b to its storage position.

[0110] In Figure 15B, the first wagon 510a has already been located on the vertical of the vertical displacement space,

waiting for the mass 300a to complete its descent, while the second wagon 510b has reached the position where the mass 300b is to be stored.

[0111] In Figure 15C, the first wagon 510a already has the mass 300a resting thereon, while its couplings continue to descend to a position in which they do not interfere with the removal of the wagon loaded with the mass. Meanwhile, the second wagon 510b unloads the mass 300b into the lower level structure for storage of masses.

[0112] In Figure 15D, the first wagon 510a begins to be displaced to take its mass 300a to its storage position, while the second wagon 510b, already freed from its load, returns toward the vertical of the vertical displacement space to collect the next mass to descend to the lower level of the vertical displacement space.

[0113] The embodiments of the upper level of the vertical displacement space will in many respects be similar to those of the lower level, although they will also have certain differences.

[0114] As was the case at the lower level, the masses 300a and 300b have to be inserted into and extracted from the vertical displacement space on opposite sides, so it is necessary for the tracks 400a and 400b, on which the wagons 500a, 500b will be displaced, to be disposed on opposite sides of the vertical displacement space, as shown in Figure 16A. In some cases it is not necessary to build galleries for the transport and storage of the masses, since it is advantageous to do so on the surface, as is observed in the embodiment shown in Figure 16A. In said figure it is observed that the tracks are on bridge beams 420 in the part of their travel path that crosses the vertical displacement space. Finally, in Figure 16A the upper level structures for storage of masses 600a and 600b are also shown, disposed on the corresponding side of the vertical displacement space.

[0115] As in the lower level of the vertical displacement space, for the application of storage of energy, it can be advantageous for the galleries to have a small incline, the level being in this case slightly higher at the ends opposite to the vertical displacement space. In this way, when the installation is working in discharge mode, additional energy to that of the vertical displacement is generated in the passage of the masses through the galleries from their storage position until they are coupled for their descent down the vertical displacement space,. On the contrary, when the installation is being recharged, the energy consumption will increase due to the movement of the masses from the vertical displacement space to their storage position.

[0116] As the coupling and uncoupling manoeuvre of the masses is common on both levels, the masses that rise to the upper level of the vertical displacement space have to continue to ascend to a level slightly higher than that of their removal, in order to be able to subsequently uncouple them in their downward movement. Likewise, after inserting them into the vertical displacement space, the masses must make a short upward movement to engage them, prior to proceeding with their descent to the lower level of the vertical displacement space.

[0117] According to a preferred embodiment, the transport and unloading of the masses on the upper level structures for storage of masses 600a and 600b, and the loading and transport of the masses from said structures, will be carried out in the same way as at the lower level, as described in Figures 14A, 14B and 14C, thus incorporating in said structures and in the wagons employed the same elements as their lower level counterparts. However, in certain more preferred embodiments, the structures for storage of masses and/or the wagons may have geometric differences or additional elements with respect to those of the upper level, as a consequence of the fact that, at the upper level, the masses in their vertical movement must cross the section of the vertical displacement space located at the level of the tracks, which implies a difficulty so that the masses do not interfere with the tracks nor with the bridge beams.

[0118] In Figures 17A and 17B, in a plan view, two embodiments specially designed to solve this problem are shown.

[0119] In Figure 17A, interference is avoided by employing a mass 300a with a reduced width, while a track with a very large separation between rails is utilised, such that the mass can be accommodated between the bridge beams. The cables run through the space that is between the rails, and the masses and wagons have to be slotted for their extraction. Figure 16B shows this solution in a three-dimensional view.

[0120] In Figure 17B, the track is interrupted in its passage through the vertical displacement space, therefore a track with standard separation can be employed. In this case, the mass can be wider and the cables are further apart, being carried on the outside of the mass by means of artificial supports equivalent to those shown in Figures 11A and 11B, so therefore neither the mass nor the wagons have to be slotted.

[0121] In the embodiment shown in Figure 17A, the wheels that rest on each rail must have independent axles, so that they do not interfere with said cables.

[0122] In the embodiment shown in Figure 17B, a conventional wagon cannot be located on the vertical of the vertical displacement space for collecting or delivering masses to the system. In this case, the masses can be transferred from the vertical of the vertical displacement space to the wagons and vice versa by means of a bridge crane or other auxiliary equipment. Another option is to have a retractable or swing bridge that is deployed to bridge the gap on the vertical of the displacement space, enabling conventional wagons to be placed in the position necessary for the coupling or uncoupling of the masses, and that folds back after completing these manoeuvres, thus preventing interference in the vertical displacement of the masses.

[0123] In Figures 18A to 18D the sequence of uncoupling, extraction, transport and unloading of the masses at the upper level of the vertical displacement space is shown, using a configuration such as that shown in Figure 17A. The

arrows indicate the movements of the elements with the system operating to uncouple the masses that ascend via the cables and to take them to their storage position. If the sequence and direction of the arrows are reversed, the sequence of loading, transport, insertion and coupling of the masses at the upper level is obtained, with the system operating to move the masses from their storage position to the vertical displacement space, where they are coupled for their descent towards the lower level.

[0124] In Figure 18A, the wagon 500a on the right-hand track travels into the vertical displacement space to collect the mass 300a that ascends through the vertical displacement space, and which, thanks to the large separation between rails, can pass between the bridge beams without interference. Meanwhile, the wagon 500b on the left-hand track is taking the mass 300b, that has previously been raised, to its storage position.

[0125] In Figure 18B, the first wagon 500a has already been located on the vertical of the vertical displacement space, once the mass 300a has reached its maximum level, while the second wagon 510b has reached the position wherein the mass 300b is to be stored.

[0126] In Figure 18C, the mass 300a has descended to be collected by the first wagon 500a, while its couplings continue to descend toward the lower level of the vertical displacement space. Meanwhile, the second wagon 500b unloads the mass 300b at the upper level structure for storage of masses.

[0127] In Figure 18D, the first wagon 500a begins to be displaced to take the mass 300a to its storage position, while the second wagon 500b, now freed from its load, is again conducted toward the vertical of the vertical displacement space to collect the next mass that rises to the upper level.

[0128] In preferred embodiments of the system of the invention, it is proposed to employ a few special wagons described below.

[0129] In Figure 19 a special wagon, according to an embodiment of the system of the invention, is shown, that can be employed with a configuration such as that of the embodiment shown in Figure 17B, being able to collect and deliver masses on the vertical of the vertical displacement space, despite the track being interrupted in this section.

[0130] The wagon 520 is considerably longer than conventional wagons, as it has an overhang ahead of the wheels closest to the vertical displacement space, at the end of which the platform 554 is located. In this way, the wagon can collect the masses on its platform on the vertical of the vertical displacement space, even though the track 400a is interrupted in this space.

[0131] To maintain the stability of the wagon, at the end opposite the platform, the wagon incorporates a counterweight 521 of sufficient weight.

[0132] As can be observed, in this embodiment, thanks to the separation between cables, the wagon does not require slots nor holes to be able to extract the masses from the vertical displacement space.

[0133] In Figures 20A to 20D the uncoupling and extraction sequence of a mass at the upper level of the vertical displacement space, using this type of special wagon is shown.

[0134] In Figure 20A, the mass 300a has reached its maximum height, whereby the wagon 520 travels into the vertical displacement space.

[0135] In Figure 20B, the wagon has reached the collection position, with its overhang on the vertical of the vertical displacement space so that the platform is below the mass, which begins to descend.

[0136] In Figure 20C, the mass is already resting on the platform of the wagon, but the cables continue to descend, so that the coupling assemblies are uncoupled from the mass to enable their extraction.

[0137] In Figure 20D, the wagon has already extracted the mass from the vertical displacement space and is taking it to the storage position, while the coupling assemblies continue their descent to collect a new mass from the lower level of the vertical displacement space.

[0138] Next, the mass transport and unloading manoeuvre is performed at the corresponding upper level structure for the storage of masses, which is not detailed in this sequence of figures, since it is equivalent to that of conventional wagons, shown in previous figures.

[0139] If the order of Figures 20A to 20D and the direction of the arrows are reversed, the sequence of insertion and coupling of the mass at the upper level of the vertical displacement space is obtained.

[0140] In Figure 21 a special wagon according to another embodiment of the invention is shown, which can be employed with a configuration such as that shown in the embodiment of Figure 17B, which is capable of collecting and delivering masses at the vertical of the vertical displacement space, even though the track is interrputed in this section.

[0141] The wagon 530 is longer than a conventional one. In this case, the platform 554 is mounted on a trolley 531 that can be displaced between one end of the wagon and the other.

[0142] On the other hand, the arrangement of the wagon wheels enables it to approach the vertical displacement space and cross it, although certain pairs of wheels remain temporarily in the air, since those that do rest on the track 400a or 400b give it sufficient stability. Alternatively, the front wheels could be replaced by support elements, so that the rest of the wheels of the wagon are indeed always kept on a section of track, while these support elements would reach the other side of the vertical displacement space, and could rest on a surface prepared for this purpose, adjacent to the vertical displacement space. In this embodiment, the wagon could only carry masses along one of the tracks 400a

or 400b, it being necessary to use at least one such wagon on each.

[0143] The separation between cables means that this wagon does not need slots or holes to be able to extract the masses from the vertical displacement space.

[0144] In Figures 22A to 22D the complete sequence of uncoupling and extracting a mass at the upper level of the vertical displacement space using this type of special wagon is shown.

[0145] In Figure 22A, the mass 300a has reached its maximum height, while the wagon 530 travels to cross the vertical displacement space, the wheels that are above the vertical displacement space remain in the air. During this passage of the wagon, its trolley 531 remains at the end opposite the vertical displacement space, so that the weight of the trolley and the distribution of masses of the wagon cause it not to lose its stability.

[0146] As they continue their movement, the wheels that were in the air come to rest on the track on the other side of the vertical displacement space, as may be seen in Figure 22B, at which point the trolley moves along the wagon towards the central position.

[0147] In Figure 22C, the platform is already in the collection position and the mass begins to descend towards it.

[0148] Once the mass is supported, the cables continue to descend and the coupling assemblies are uncoupled from the mass, which can now be extracted, as shown in Figure 22D.

[0149] To do this, as can be seen in Figure 22E, the trolley returns to its initial position at the end of the wagon, at which time the wagon can begin its movement towards the storage area, as may be seen in Figure 22F, taking advantage of the weight of the mass to increase its stability while the wheels that are over the vertical displacement space remain in the air. Next, the mass transport and unloading manoeuvre is performed at the corresponding upper level structure for the storage of masses, which is not detailed in this sequence of figures, since it is equivalent to that of conventional wagons, shown in previous figures.

[0150] If the order of Figures 22A to 22E and the direction of the arrows are reversed, the sequence of insertion and coupling of the mass at the upper level of the vertical displacement space is obtained.

[0151] As a clarification, it is noted that, as may be seen in the previous figures, the successive displacement of masses is performed alternating between one mass 300a and another 300b, so that the masses 300a are displaced vertically by means of the first portions of cable 260a and 260a' and, horizontally, according to the level considered, by the tracks 400a and 410a, located on the side of the vertical displacement space closest to said portions of cable, and subsequently unloaded into the corresponding storage structures 600a and 610a. Similarly, the masses 300b are always displaced vertically by the second portions of cable 260b and 260b' and, horizontally, according to the level considered, along the tracks 400b and 410b, located on the side of the vertical displacement space closest to said portions of cable, and then unloaded onto the corresponding storage structures 600b and 610b.

[0152] Notwithstanding the foregoing, it should be noted that the geometry and subcomponents of the masses 300a and 300b will be substantially alike, therefore their subcomponents are designated with the same references for both. The same applies to carriages 500a, 500b, 510a, 510b, 520 and 530, and to storage structures 600a, 600b, 610a and 610b.

LIST OF REFERENCE NUMBERS

[0153]

100	vertical displacement space
103	wall
104	chamber
110a, 110b	horizontal gallery
200	upper assembly of the system
201	foundation
202	load-bearing structure
203	additional deflector pulleys
210	lower assembly of the system
220	drive assembly
221	drive pulley
223	bi-directional rotary machine
230	upper assembly for deflecting cable loops
231	upper deflector pulley
232	deflector
233	beam
234	swing arm
235	actuator
240	transfer assembly

241	transfer pulley
242	beam
250	lower assembly for deflecting cable loops
251	lower deflector pulley
252	deflector
253	beam
260, 260'	cable loop
260a, 260a'	first portion of cable
260b, 260b'	second portion of cable
261a, 261b, 261a', 261b'	coupling assembly
262, 262'	upper coupling
272, 272'	lower coupling
300a, 300b	mass
301, 301'	hole
303, 303'	slot
362, 362'	upper support
372, 372'	lower support
400a, 400b	upper level track
410a, 410b	lower level track
420	upper level bridge beams
430	lower level bridge beams
500	extraction means
500a, 500b, 510a, 510b, 520, 530	wagon
521	counterweight
531	trolley
551	wagon chassis
552	wheels
553	thruster
554	platform
600a, 600b	upper level structure for storage of masses
610a, 610b	lower level structure for storage of masses
621	gantry
622	bracket
623	support beam

Claims

1. A system for vertically displacing masses, comprising:

(a) a drive assembly (220) comprising at least one bi-directional rotary machine (223) driving at least one drive pulley (221), said drive assembly being located at an upper level of a vertical displacement space (100);
(b) a plurality of cable loops (260, 260') connecting the drive assembly (220) with a transfer assembly (240) comprising at least one transfer pulley (241), said transfer assembly (240) being located at a lower level of said vertical displacement space (100), wherein said transfer assembly (240) maintains tension in the cable loops (260, 260'), wherein the portion of cable of each cable loop (260, 260') disposed between the drive pulley (221) and the transfer pulley (241) defines a first portion of cable (260a) and the remaining portion of cable of each cable loop (260, 260') disposed between the drive pulley (221) and the transfer pulley (241) defines a second portion of cable (260b);
(c) each portion of cable (260a, 260b) comprises a plurality of coupling assemblies (261a, 261b, 261a', 261b');
(d) a plurality of masses (300a, 300b) that are attached by means of said coupling assemblies (261a, 261b, 261a', 261b') to the portions of cable (260a, 260b) to be displaced through the vertical displacement space;
(e) an upper assembly for deflecting cable loops (230) comprising a plurality of upper deflector pulleys (231) and a lower assembly for deflecting cable loops (250) comprising a plurality of lower deflector pulleys (251), wherein said assemblies for deflecting cable loops (230, 250) are displaceable between two positions, a first position wherein the first portion of cable (260a) is substantially centred in the vertical displacement space (100), and a second position wherein the second portion of cable (260b) is substantially centred in the vertical displacement space (100).

2. The system according to claim 1, where said assemblies for deflecting cable loops (230, 250) comprise means for linearly displacing the deflector pulleys (231, 251).

3. The system according to claim 1 or 2, where the upper assembly for deflecting cable loops (230) comprises a swing arm (234) that displaces said upper assembly for deflecting cable loops (230) between said first position and said second position.

4. The system according to any of claims 1 to 3, where the coupling assemblies (261a, 261a', 261b, 261b') comprise upper couplings (262, 262') and lower couplings (272, 272') and the masses (300a, 300b) comprise a few holes (301, 301'), and a few upper supports (362, 362'), wherein additionally, when the coupling assemblies (261a, 261a', 261b, 261b') are coupled to the masses (300a, 300b), the upper supports (362, 362 ') rest on the upper couplings (262, 262'), said upper couplings (262, 262') and lower couplings (272, 272') being radially confined in the holes (301, 301'), wherein in addition, the upper supports (362, 362') and the masses (300, 300b) comprise slots (303, 303') through which the masses are horizontally displaced with respect to the portions of cable (260a, 260a', 260b, 260b'), in the direction opposite to that of the other portion of cable (260b, 260b', 260a, 260a'), when the coupling assemblies (261a, 261a', 261b, 261b') are not coupled to the masses (300a, 300b).

5. The system according to any of claims 1 to 3, where the coupling assemblies (261a, 261a', 261b, 261b') comprise upper couplings (262, 262 ') and lower couplings (272, 272') and the masses (300a, 300b) comprise upper supports (362, 362') and lower supports (372, 372'), disposed on the exterior thereof, comprising a vertical hole wherein, when the coupling assemblies (261a, 261a', 261b, 261b') are coupled to the masses (300a, 300b), the upper supports (362, 362') rest on the upper couplings (262, 262') and radially confine said upper supports (362, 362') in their hole; and wherein the lower supports (372, 372') radially confine the lower couplings (272, 272') in their hole, wherein the upper supports (362, 362') and the lower supports (372, 372') comprise slots (303, 303') through which the masses (300a, 300b) are horizontally displaced with respect to the portions of cable (260a, 260a', 260b, 260b'), in a direction opposite that of the other portion of cable (260b, 260b', 260a, 260a'), when the coupling assemblies (261a, 261a', 261b, 261b') are not coupled to the masses (300a, 300b).

6. The system according to any of claims 1 to 5, comprising means for extraction of the masses (500) consisting of a few wagons (500a, 500b, 520, 530, 510a, 510b) that are displaced on a few tracks (400a, 400b, 410a, 410b), disposed in at least one substantially horizontal gallery (110a, 110b) to each side of the vertical displacement space (100) or on the surface of the ground, wherein platforms (600a, 600b, 610a, 610b) for storage of the masses are disposed in said gallery or on said surface of the ground.

7. The system according to any of claims 1 to 6, wherein the means for extraction of the masses (500) comprises a wagon (520) which in turn comprises an overhang extending linearly over a few wheels located at one of the ends of said wagon (520), such that, when said wheels rest at the end of one of the tracks (400a, 400b), the masses (300a, 300b) rest on a platform (554) disposed on said overhang and wherein said wagon (520) further comprises a counterweight (521) at the end of the wagon (520) opposite the overhang.

8. The system according to any of claims 1 to 6, wherein the means for extraction of the masses (500) comprises a wagon (530) configured to be able to simultaneously have at least one of its axles on each one of the tracks (400a, 400b), wherein said wagon (530) comprises a platform (554), upon which the masses (300a, 300b) rest, that is displaced along said wagon (530) via linear displacement means (531).

9. The system according to any of claims 1 to 8, where the masses consist of containers that can accommodate a granular material or a liquid.

10. The system according to any of claims 1 to 9, comprising a system for monitoring and controlling the operation of the various elements, comprising sensors and communication and control devices.

11. A method for vertically displacing masses between a starting level and a destination level, carried out with the system of any of claims 1 to 10, comprising:

(a) disposing the upper assembly for deflecting cable loops (230) and the lower assembly for deflecting cable loops (250) in the first position, wherein the first portion of cable (260a, 260a') of each cable loop (260, 260') is substantially centred in the vertical displacement space (100);
(b) at the starting level, inserting a mass (300a) into the vertical displacement space (100);

(c) coupling said mass (300a) to the first portion of cable (260a, 260a') of each cable loop (260, 260') by means of the coupling assemblies (261a, 261a');
(d) rotating the at least one drive pulley (221) in a direction until the mass (300a) reaches its destination level;
(e) uncoupling the mass (300a) from the coupling assemblies (261a, 261a');
(f) extracting the mass (300a) from the vertical displacement space (100) at said destination level;
(g) disposing the upper assembly for deflecting cable loops (230) and the lower assembly for deflecting cable loops (250) in the second position, wherein the second portion of cable (260b, 260b') of each cable loop (260, 260') is substantially centred in the vertical displacement space (100);
(h) at the starting level, inserting a new mass (300b) into the vertical displacement space (100);
(i) coupling said mass (300b) to the second portion of cable (260b) by means of the coupling assemblies (261b, 261b');
(j) rotating the at least one drive pulley (221) in a second direction, opposite to the direction of rotation indicated in step (d), until the mass (300b) reaches its destination level;
(k) uncoupling the mass (300b) from the coupling assemblies (261b, 261b');
(l) extracting the mass (300b) from the vertical displacement space (100) at said destination level; and
(m) repeating steps (a) to (l).

12. The method according to claim 11, carried out with the system of any of claims 6 to 10, comprising:

- performing step (a);
- performing step (b) according to the following sub-steps:

  - rotating the at least one drive pulley (221) in a direction wherein the coupling assemblies (261a, 261a') with which the mass (300a) is to be coupled descend to a level at which, when inserting said mass into the vertical displacement space (100), said coupling assemblies do not interfere with said mass and/or its supports (362, 362', 372, 372'), nor with the extraction means (500); and
  - inserting the extraction means (500) into the vertical displacement space (100), with the mass (300a) resting thereon, in the direction going from the first portion of cable (260a, 260a') towards the second portion of cable (260b, 260b') of each cable loop (260, 260'), such that the portions of cable (260a, 260a') are inserted into the slots (303, 303') of the mass (300a) and/or its supports (362, 362', 372, 372'), until the upper supports (362, 362') as well as the holes (301, 301') or lower supports (372, 372') are on the same vertical as the upper couplings (262, 262') and the lower couplings (272, 272');

- performing step (c) according to the following sub-steps:

  - rotating the at least one drive pulley (221) in a direction wherein the coupling assemblies (261a, 261a') to which the mass (300a) is to be coupled ascend, becoming inserted into the housing of its upper supports (362, 362') and of its holes (301, 301') or lower supports (372, 372');
  - continuing to rotate the at least one drive pulley (221) in said direction, causing the upper couplings (262, 262') to abut against the upper supports (362, 362') and draw the mass (300a) upward until it detaches from the extraction means (500); and
  - extracting the extraction means (500), withdrawing it from the vertical displacement space (100), to its original position;

- performing step (d);
- performing step (e) according to the following sub-steps:

  - if the destination level is the upper one, continuing to rotate the at least one drive pulley (221) in the same direction as in step (d) such that the mass (300a, 300b) ascends above the height at which the upper level extraction means is located, and inserting the extraction means (500) into the vertical displacement space (100), until it is on the vertical of the mass (300a);
  - if the destination level is the lower one, before the mass (300a) reaches the height at which the lower level extraction means (500) is located, inserting said extraction means into the vertical displacement space (100), until it is on the vertical of the mass (300a); and
  - for either of the destination levels, and subsequent to the previous sub-steps, rotating the at least one drive pulley (221) in the direction wherein the mass (300a) descends, until it rests on the extraction means (500), the upper couplings (262, 262') ceasing to abut against the upper supports (362, 362');

- performing step (f) according to the following sub-steps:

  - continuing to rotate the at least one drive pulley (221) in the direction in which it was rotating at the end of step (e), such that the coupling assemblies (261a, 261a') continue to descend to a level at which, when extracting the mass from the vertical displacement space (100), said coupling assemblies do not interfere with the mass (300a) nor with the extraction means (500); and
  - extracting the extraction means (500) with the mass (300a) resting thereon, in the direction going from the second portion of cable (260b, 260b') towards the first portion of cable (260a, 260a') of each cable loop (260, 260'), such that relative displacement of the first portions of cable (260a, 260a') is produced with respect to the mass (300a) towards the opening of the slots (303, 303') of said mass (300a) and/or of its supports (362, 362', 372, 372'), until said mass and said extraction means are completely withdrawn from the vertical displacement space (100);

- performing step (g);
- performing step (h) according to the following sub-steps:

  - rotating the at least one drive pulley (221) in a direction in which the coupling assemblies (261a, 261a') with which the mass (300b) is to be coupled descend to a level at which, when inserting said mass into the vertical displacement space (100), said coupling assemblies do not interfere with said mass and/or its supports (362, 362', 372, 372'), nor with the extraction means (500); and
  - inserting the extraction means (500) into the vertical displacement space (100), with the mass (300b) resting thereon, in the direction going from the first portion of cable (260b, 260b') towards the second portion of cable (260b, 260b') of each cable loop (260, 260'), such that the second portions of cable (260b, 260b') are inserted into the slots (303, 303') of the mass (300b) and/or of its supports (362, 362', 372, 372'), until the upper supports (362, 362') and likewise the holes (301, 301') or lower supports (372, 372') are on the same vertical as the upper couplings (262, 262') and the lower couplings (272, 272');

- performing step (i) according to the following sub-steps:

  - rotating the at least one drive pulley (221) in the direction wherein the coupling assemblies (261b, 261b') with which the mass (300b) is to be coupled ascend, becoming inserted into the housing of its upper supports (362, 362') and of its holes (301, 301') or lower supports (372, 372');
  - continuing to rotate the at least one drive pulley (221) in said direction, causing the upper couplings (262, 262') to abut against the upper supports (362, 362') and draw the mass (300b) upward until it detaches from the extraction means (500); and
  - extracting the extraction means (500), withdrawing it from the vertical displacement space (100);

- performing step (j);
- performing step (k) according to the following sub-steps:

  - if the destination level is the upper one, continuing to rotate the at least one drive pulley (221) in the same direction as in step (d) so that the mass (300b, 300b) ascends above the height at which the upper level extraction means is located, and inserting the extraction means (500) into the vertical displacement space (100), until it is on the vertical of the mass (300b);
  - if the destination level is the lower one, before the mass (300b) reaches the height at which the lower level extraction means (500) is located, inserting said extraction means into the vertical displacement space (100), until it is on the vertical of the mass (300b); and
  - for either of the destination levels, and subsequent to the previous sub-steps, rotating the at least one drive pulley (221) in the direction that causes the mass (300b) to descend, until it rests on the extraction means (500), the upper couplings (262, 262') ceasing to abut against the upper supports (362, 362');

- performing step (l) according to the following sub-steps:

  - continuing to rotate the at least one drive pulley (221) in the direction in which it was rotating at the end of step (k), such that the coupling assemblies (261b, 261b') continue to descend to a level at which, when extracting the mass from the vertical displacement space (100), said coupling assemblies do not interfere with the mass (300b) nor with the extraction means (500); and
  - extracting the extraction means (500) with the mass (300b) resting thereon, in the direction going from

the first portion of cable (260a, 260a') towards the second portion of cable (260b, 260b') of each cable loop (260, 260'), such that relative displacement of the second portions of cable (260b, 260b') is produced with respect to the mass (300b), towards the opening of the slots (303, 303') of said mass (300a) and/or of its supports (362, 362', 372, 372'), until said mass and said extraction means are completely withdrawn from the vertical displacement space (100); and

- performing step (m).

13. The method according to claim 11 or 12, carried out with the according to any of claims 6 to 10, wherein:

- from the completion of step (c) of a cycle until step (b) of the next cycle is commenced, the following operations are performed:

  - at the starting level, lowering the platform (554) of the wagon (500a, 520, 530, 510a) to its lowered position, once there is no longer a mass thereon;
  - displacing said wagon along the tracks (400a, 410a) of the starting level, until it is located with its platform (554) below a mass (300a) stored in the upper/lower level structure for storage of masses (600a, 610a);
  - raising the platform (554) of said wagon, causing the mass (300a, 300b) to rest on the platform (554) and separate from the support beams (623); and
  - displacing said wagon (500a, 520, 530, 510a) along the tracks (400a, 410a) towards the vertical displacement space (100), with the mass (300a) resting on its platform (554), which remains in its raised position, such that said mass is maintained above the support beams (623);

- from the completion of step (f) of a cycle until step (e) of the next cycle is commenced, the following operations are performed:

  - at the destination level, displacing the wagon (500a, 520, 530, 510a) along the tracks (400a, 410a) of said level towards the mass storage position (300a) in the upper/lower level structure for storage of masses (600a, 610a), with said mass resting on the platform (554) of the wagon, which remains raised, such that said mass is maintained above the support beams;
  - lowering the platform (554) of the wagon, causing the mass (300a) to rest on the support beams (623) and no longer rest on said platform (554);
  - displacing the wagon (500a, 520, 530, 510a) along the tracks (400a, 410a) with its platform (554) in its lowered position, towards the vertical displacement space (100); and
  - raising the platform (554) of the wagon (500a, 520, 530, 510a), which does not yet have a mass on it, to its raised position;

- from the completion of step (i) of a cycle until step (h) of the next cycle is commenced, the following operations are performed:

  - at the starting level, lowering the platform (554) of the wagon (500b, 520, 530, 510b) to its lowered position, once there is no longer a mass thereon;
  - displacing said wagon along the tracks (400b, 410b) of the starting level, until it is located with its platform below a mass (300b) stored in the upper/lower level structure for storage of masses (600b, 610b);
  - raising the platform (554) of said wagon, causing the mass (300b, 300b) to rest on the platform (554) and to separate from the support beams (623); and
  - displacing said wagon (500b, 520, 530, 510b) along the tracks (400b, 410b) towards the vertical displacement space (100), with the mass (300b) resting on its platform (554), which remains in its raised position, so that said mass is maintained above the support beams (623);

- from the completion of step (l) of a cycle until step (k) of the next cycle is commenced, the following operations are carried out:

  - at the destination level, displacing the wagon (500b, 520, 530, 510b) along the tracks (400b, 410b) of said level towards the mass storage position (300b) in the upper/lower level structure for storage of masses (600b, 610b), with said mass resting on the platform (554) of the wagon, which remains raised, so that said mass is maintained above the support beams (623);
  - lowering the platform (554) of the wagon, causing the mass (300b) to rest on the support beams (623)

and no longer rest on said platform (554);
- moving the wagon (500b, 520, 530, 510b) along the tracks (400b, 410b) with its platform (554) in its lowered position, towards the vertical displacement space (100); and
- raising the platform (554) of the wagon (500b, 520, 530, 510b), which does not yet have a mass on it, to its raised position.

14. The method according to any of claims 11 to 13, wherein the masses (300a, 300b) are raised to store potential energy by means of the bi-directional rotary machine (223) of the drive assembly (220) acting as a motor, and/or when the masses (300a, 300b) descend, the bi-directional rotary machine (223), acting as a generator, produces power.

15. The method according to any of claims 11 to 13, wherein the masses are displaced to extract material from a mine.

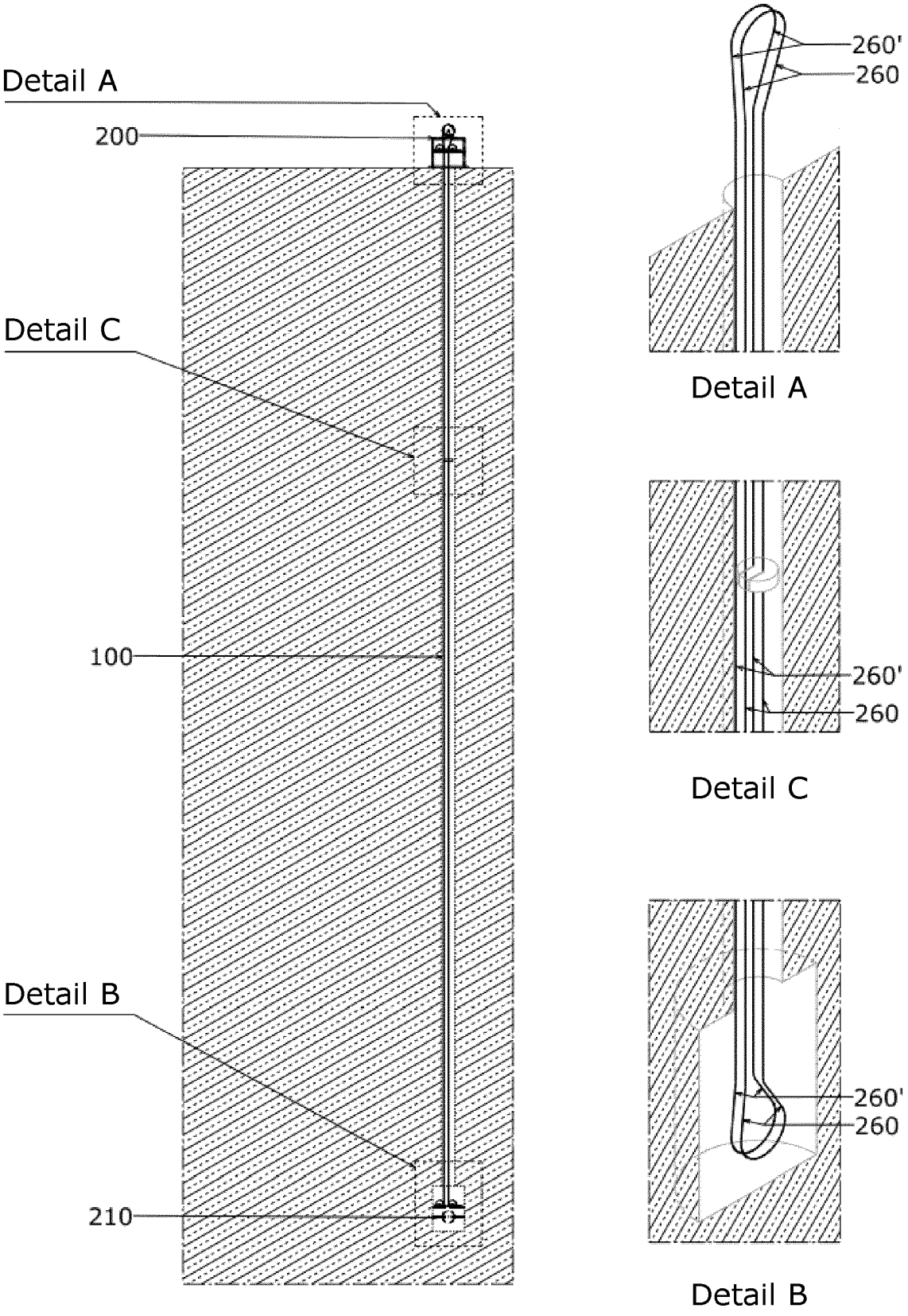

Detail A
200
Detail C
100
Detail B
210
260'
260
Detail A
260'
260
Detail C
260'
260
Detail B

FIG. 1

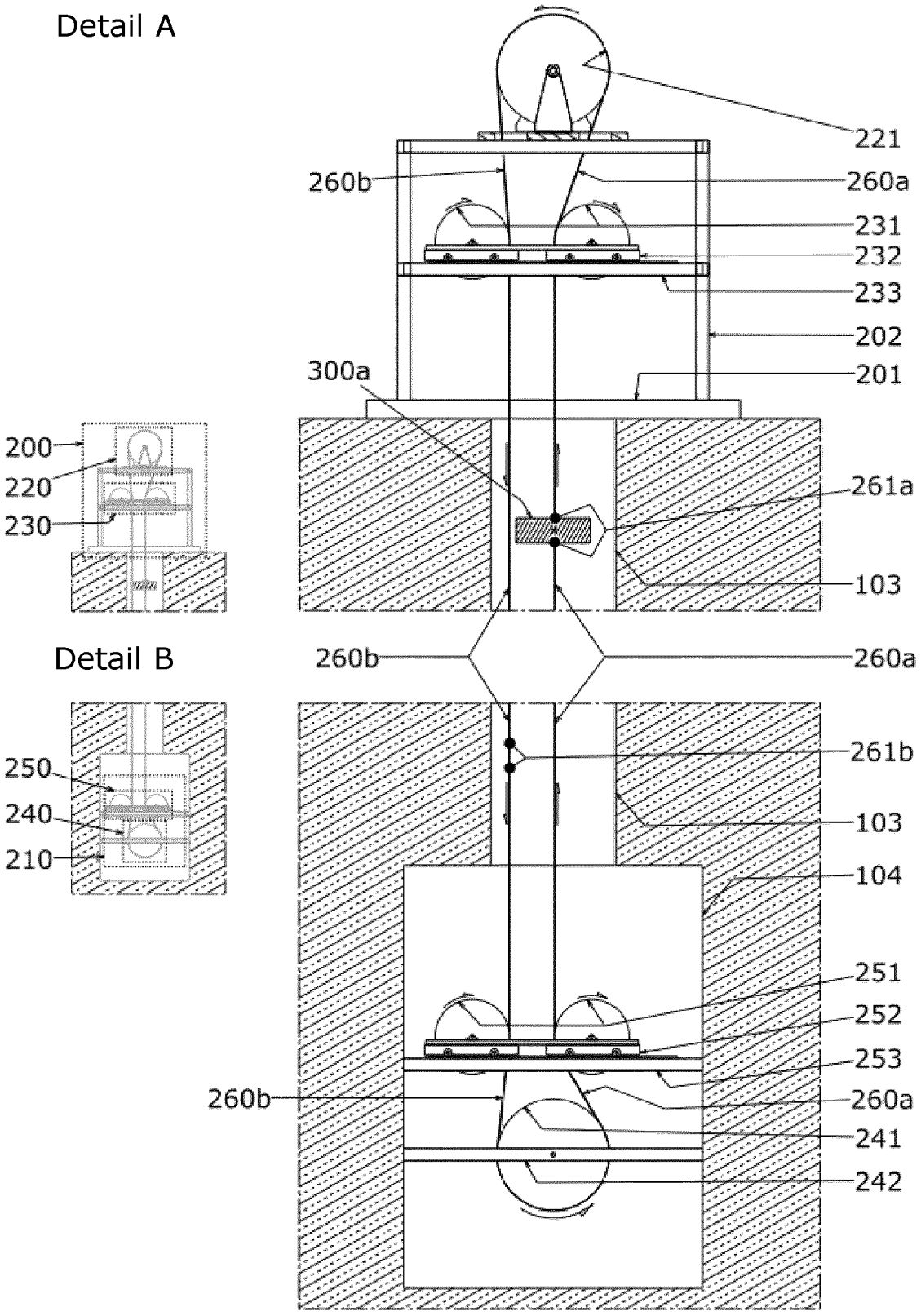

Detail A
200
220
230
Detail B
250
240
210
221
260b
260a
231
232
233
202
300a
201
261a
103
260b
260a
261b
103
104
251
252
253
260b
260a
241
242

FIG. 2

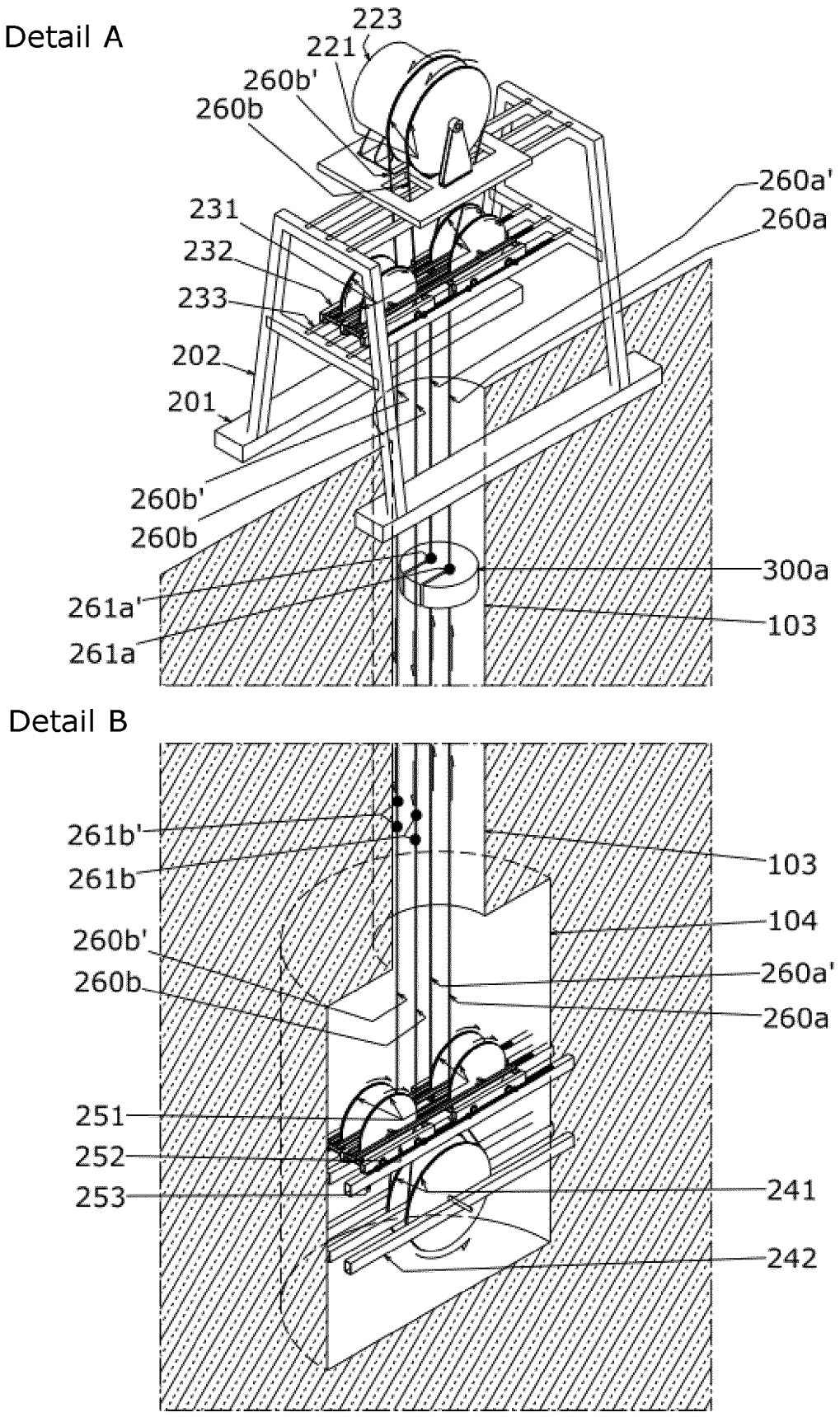
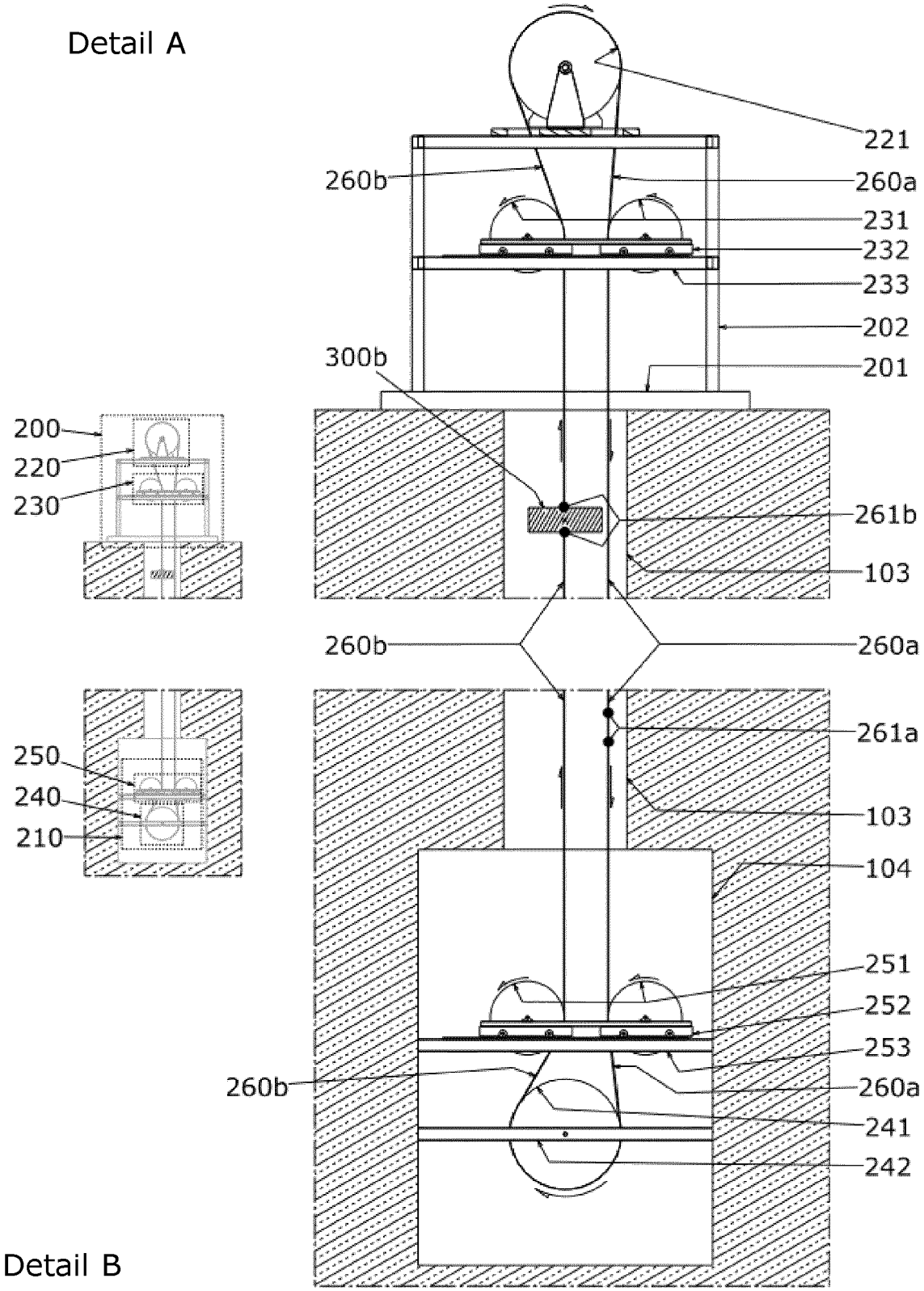

Detail A
223
221
260b'
260b
260a'
260a
231
232
233
202
201
260b'
260b
300a
261a'
261a
103
Detail B
261b'
261b
103
104
260b'
260b
260a'
260a
251
252
253
241
242

FIG. 3


Detail A
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260b
260a
231
232
233
202
300b
201
200
220
230
261b
103
260b
260a
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240
210
261a
103
104
251
252
253
260b
260a
241
242
Detail B

FIG. 4

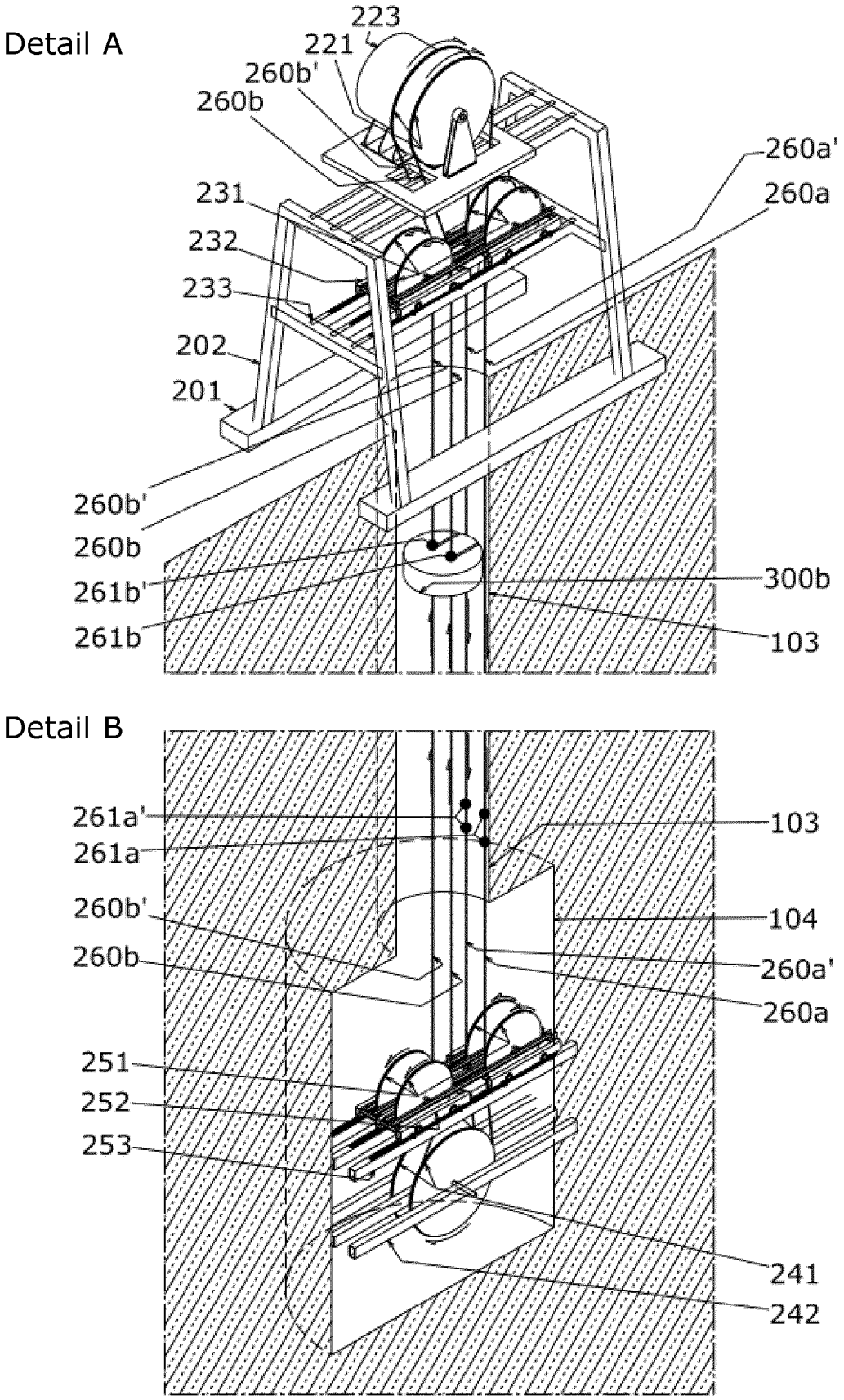

Detail A
223
221
260b'
260b
260a'
260a
231
232
233
202
201
260b'
260b
261b'
261b
300b
103
Detail B
261a'
261a
260b'
260b
103
104
260a'
260a
251
252
253
241
242

FIG. 5

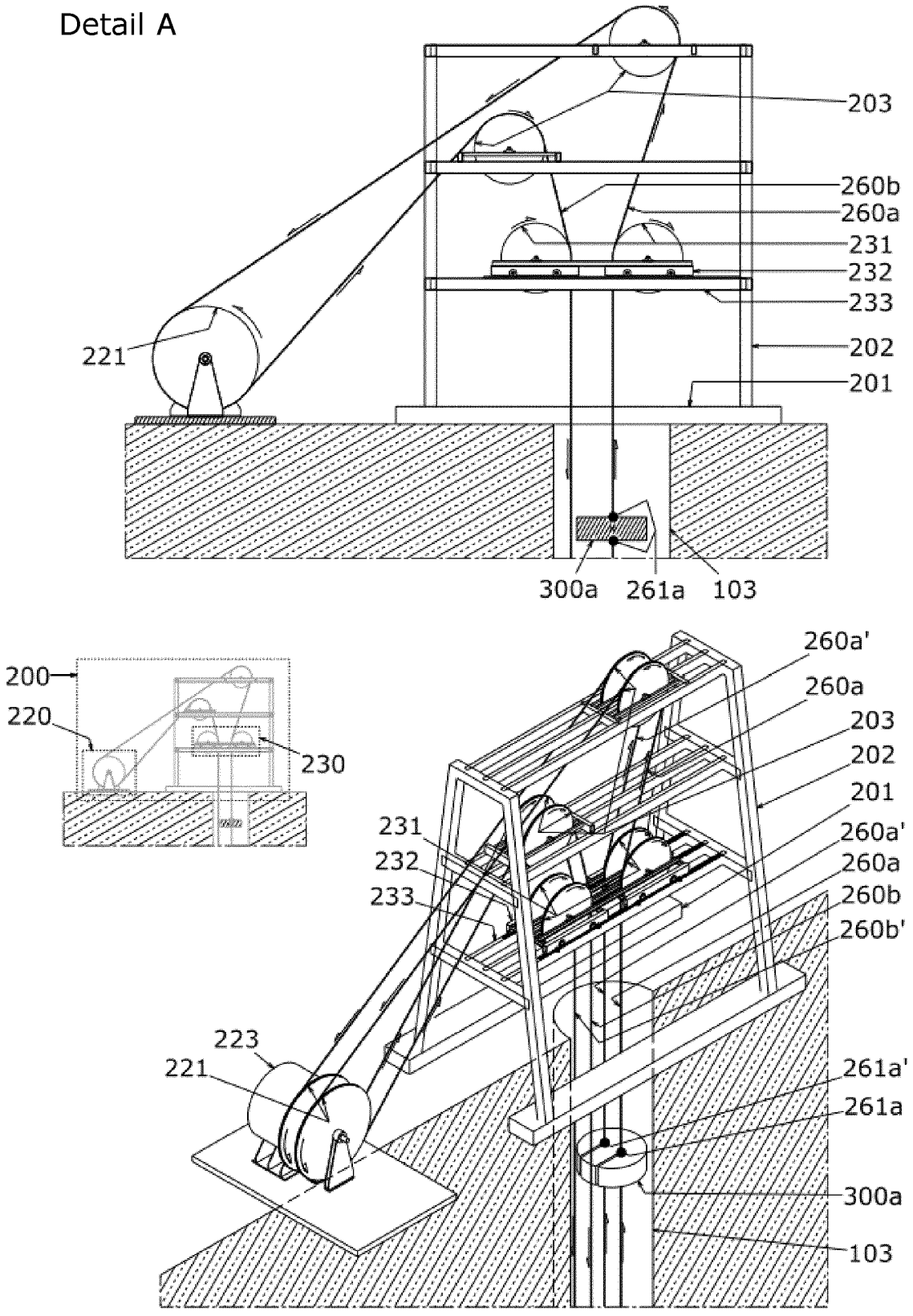
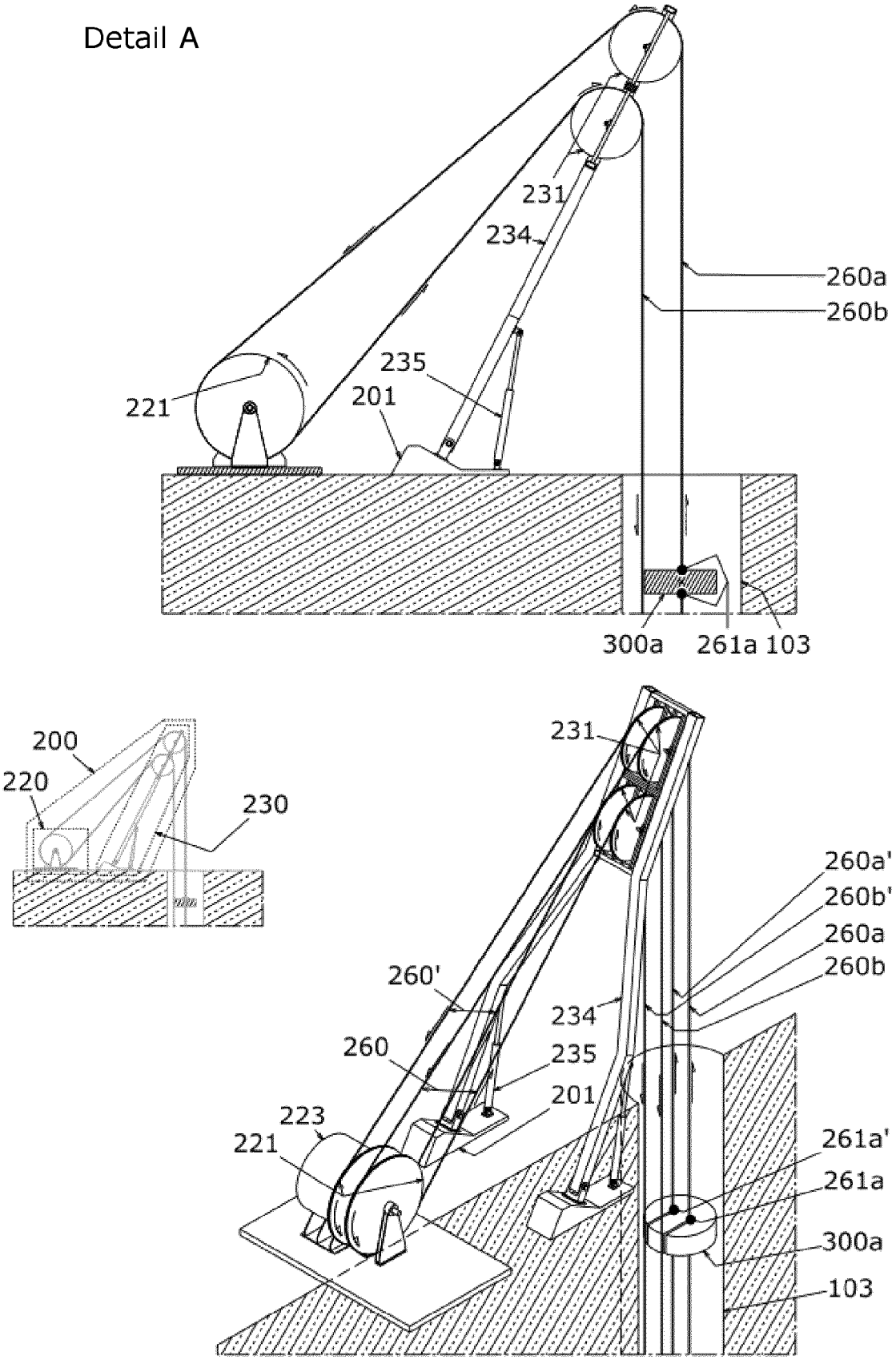

Detail A
203
260b
260a
231
232
233
202
201
221
300a
261a
103
200
220
230
260a'
260a
203
202
201
231
232
233
260a'
260a
260b
260b'
223
221
261a'
261a
300a
103

FIG. 6


Detail A
231
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300a
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FIG. 7

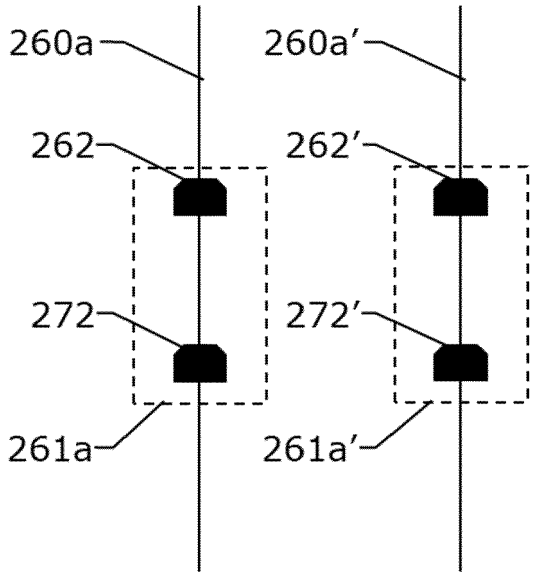


FIG. 8A

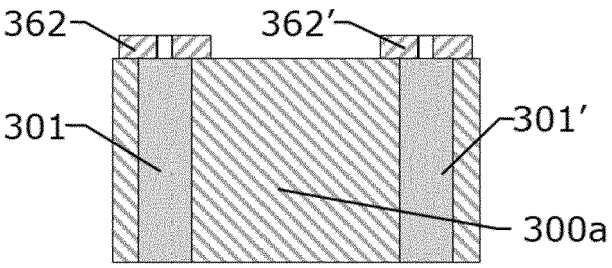


Fig. 8B

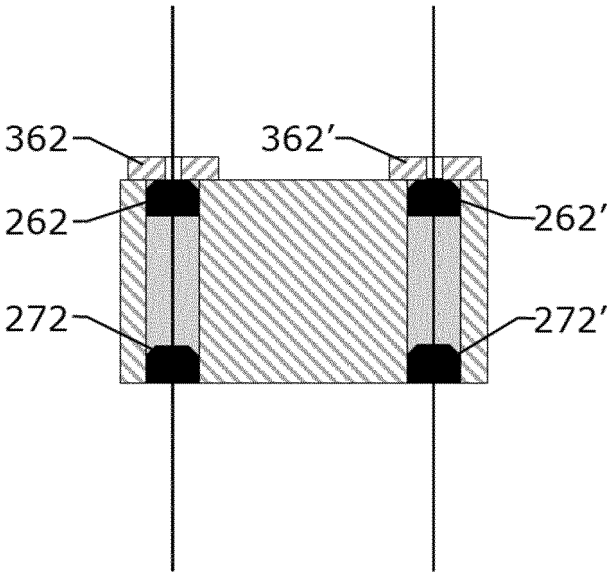
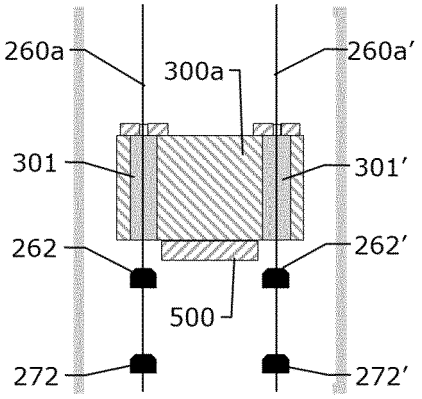
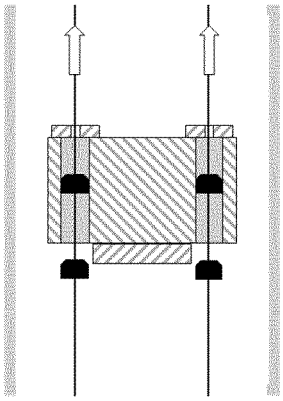
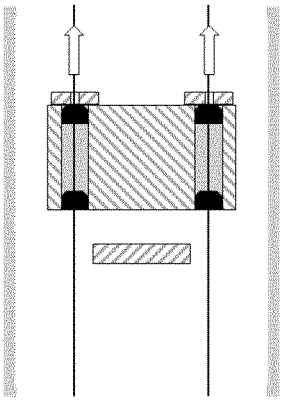


FIG. 8C







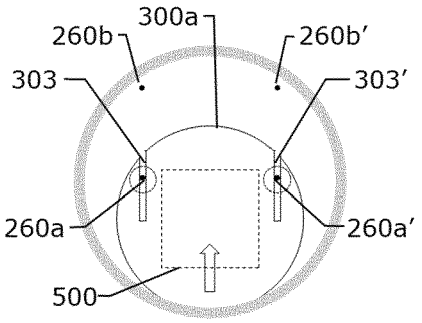


FIG. 9A

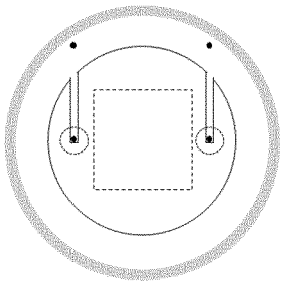


FIG. 9B

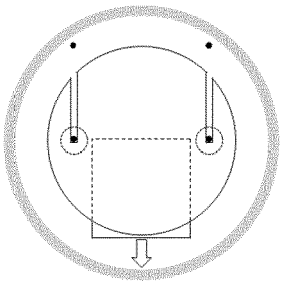
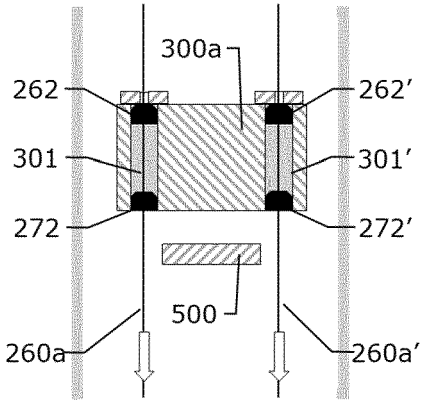
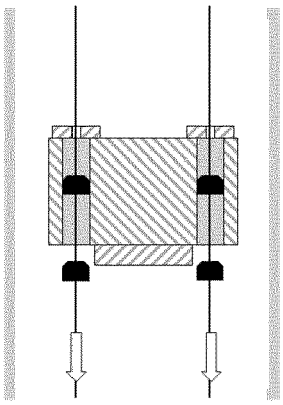
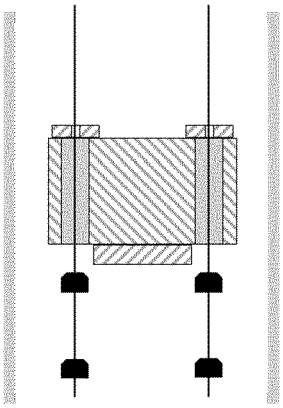


FIG. 9C







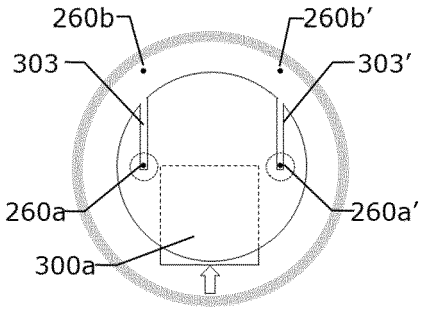


FIG. 9D

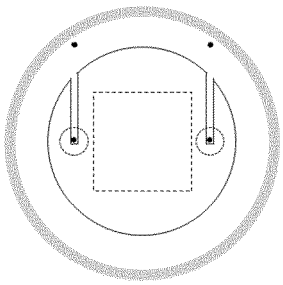


FIG. 9E

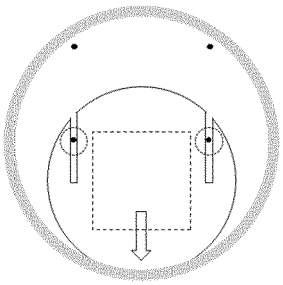


FIG. 9F

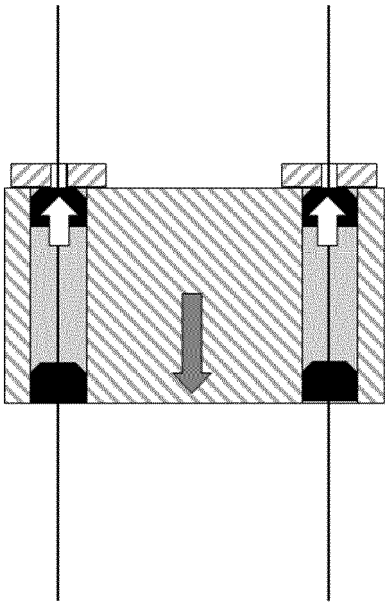


FIG. 10A

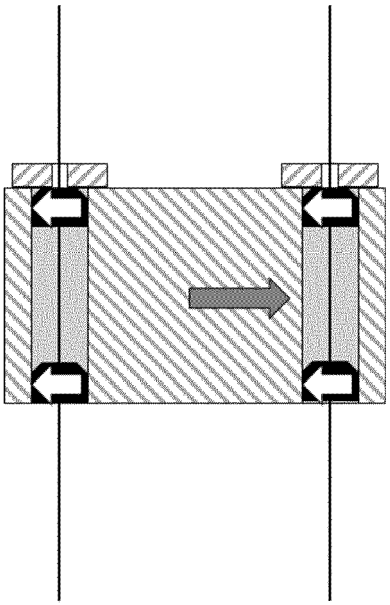


FIG. 10B

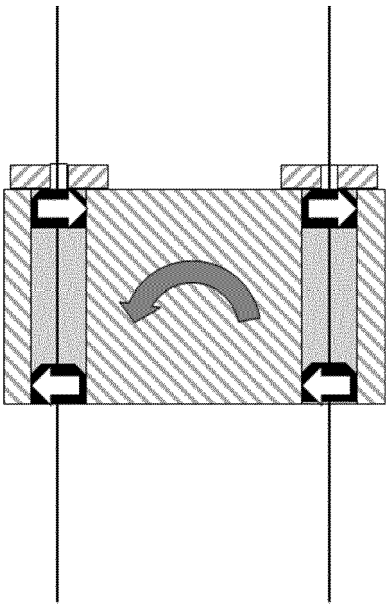


FIG. 10C

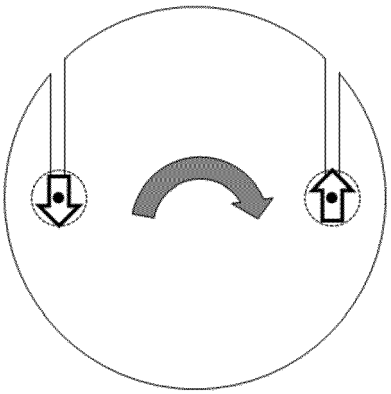


FIG. 10D

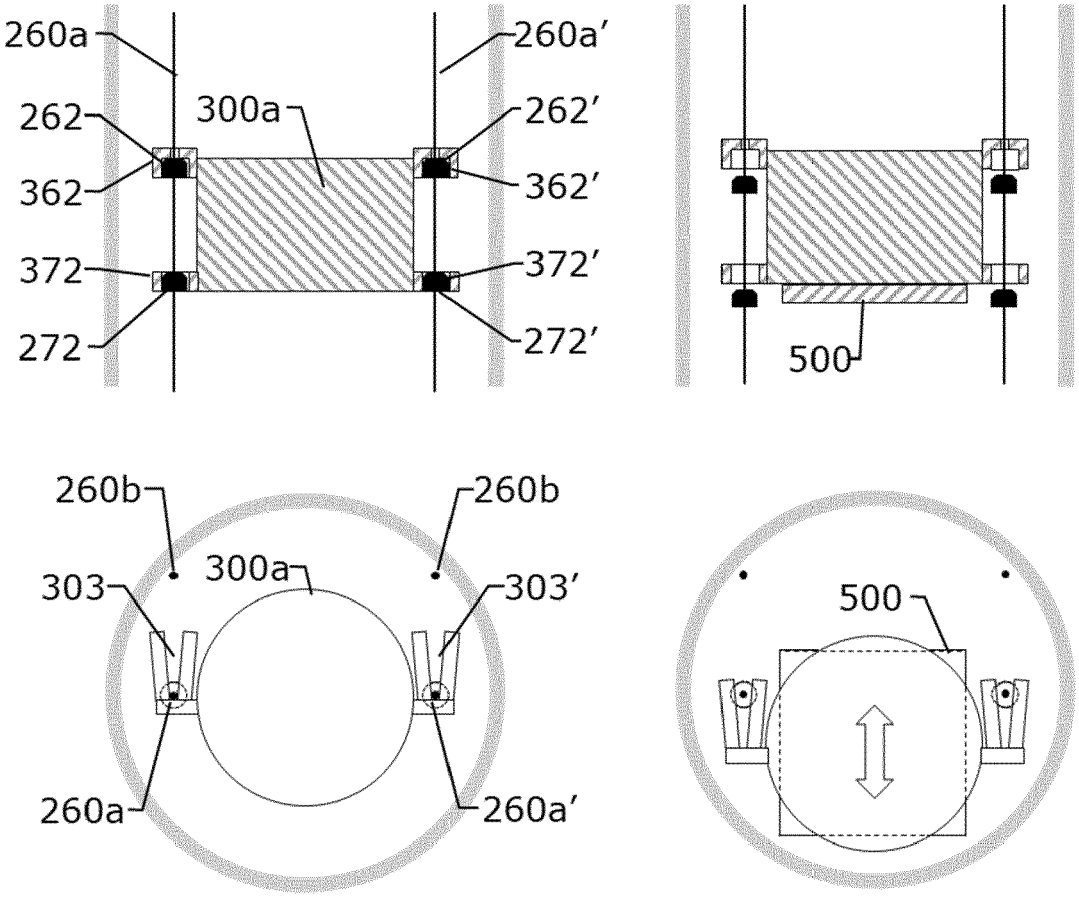


FIG. 11A

FIG. 11B

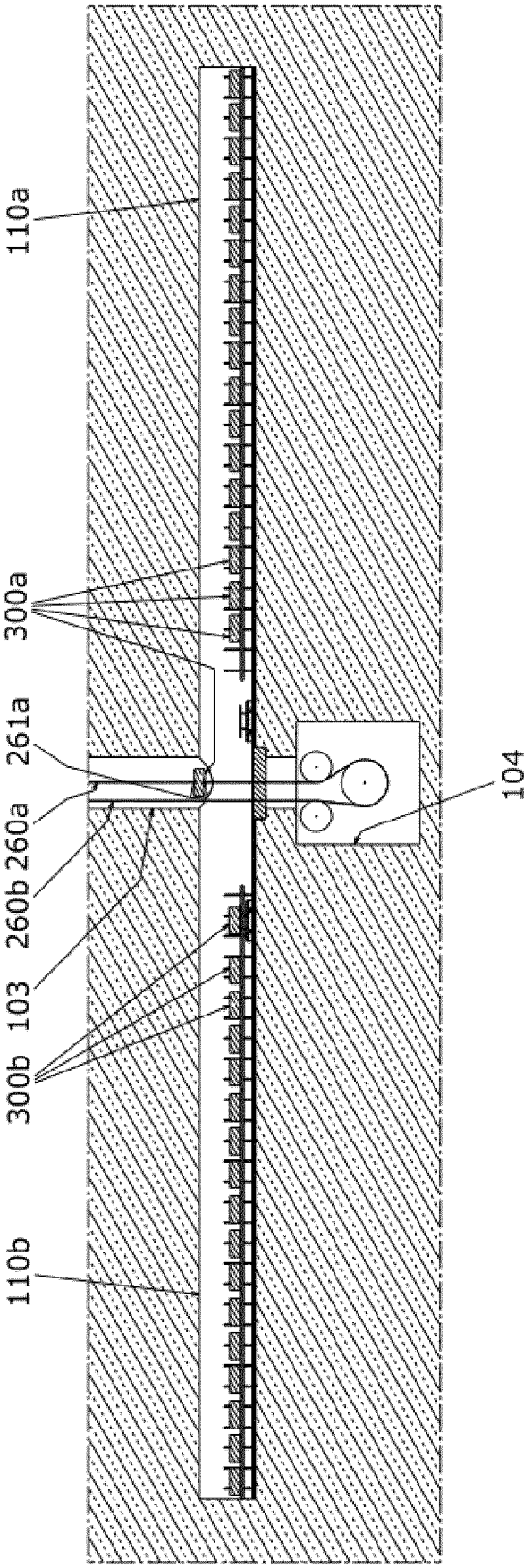


FIG. 12

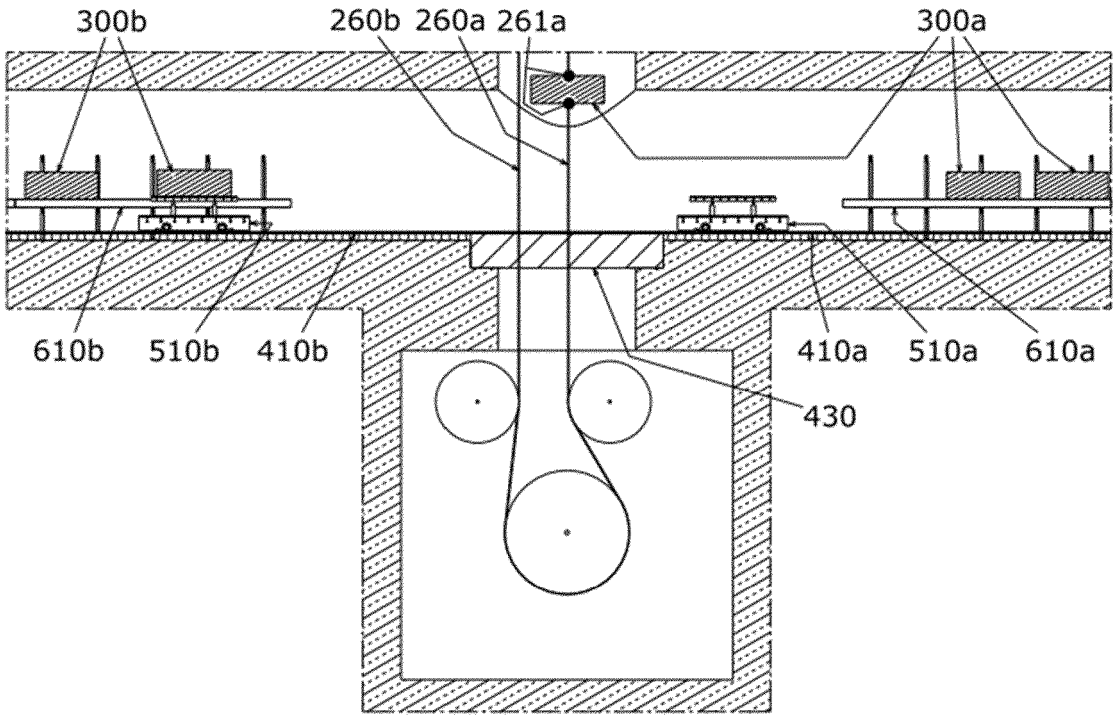


FIG. 13A

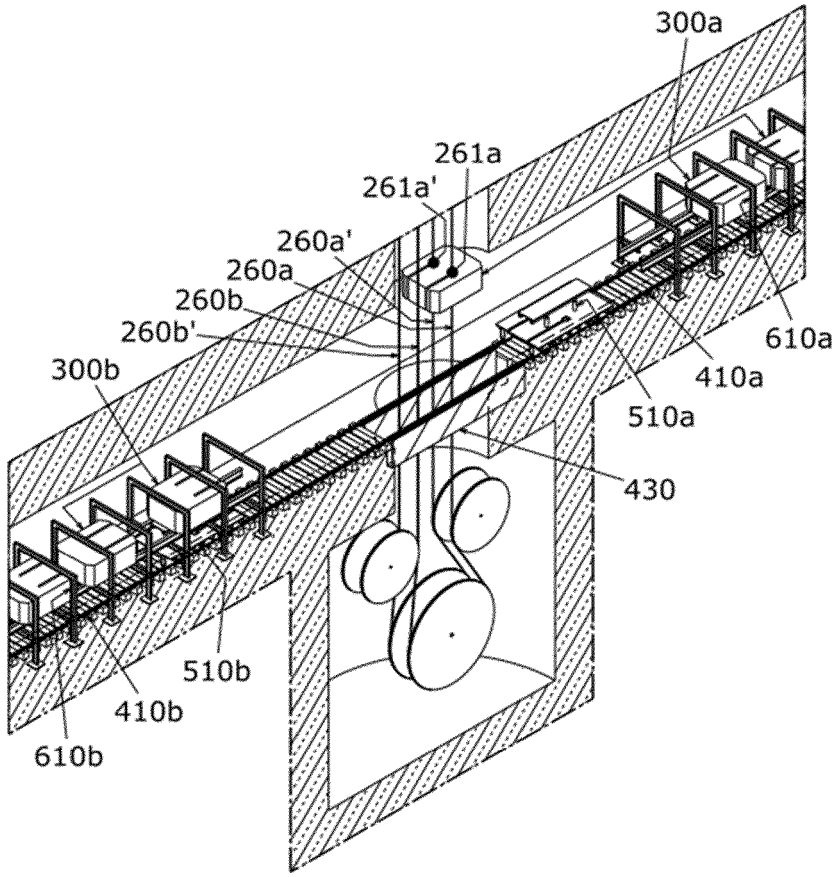


FIG. 13B

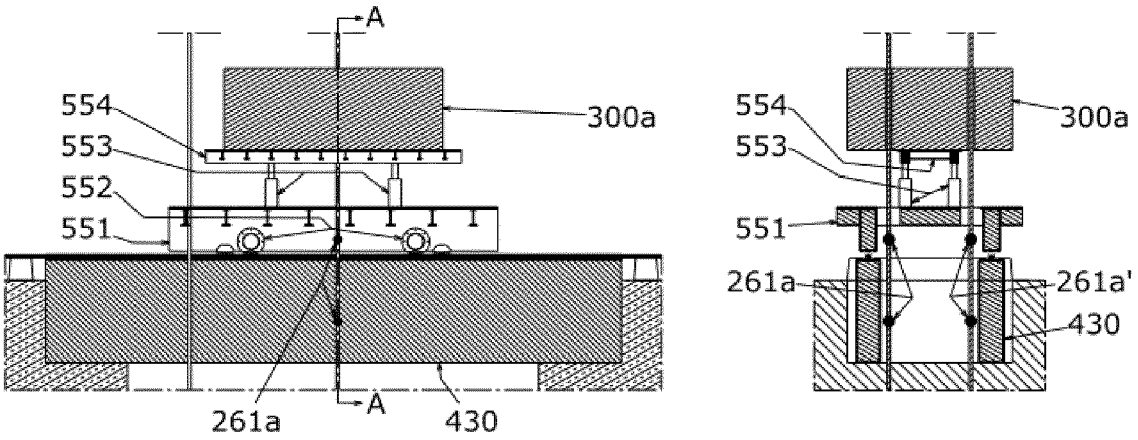


FIG. 14A

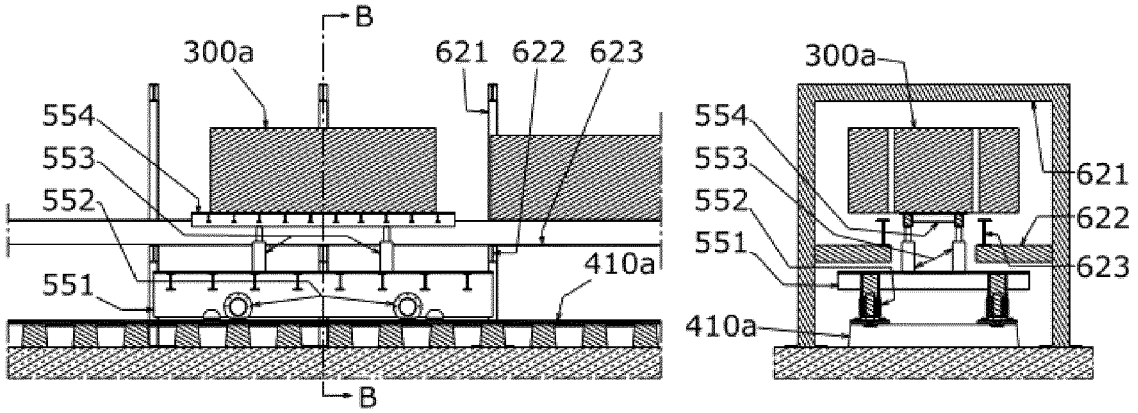


FIG. 14B

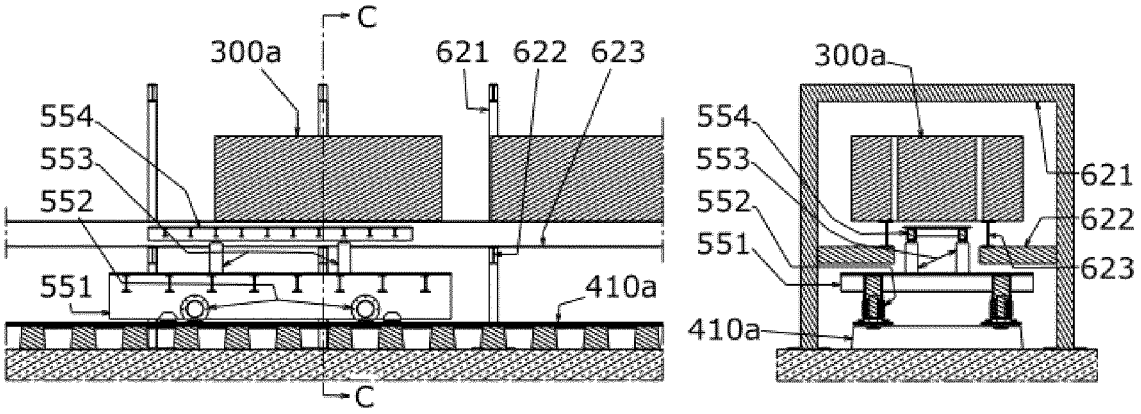


FIG. 14C

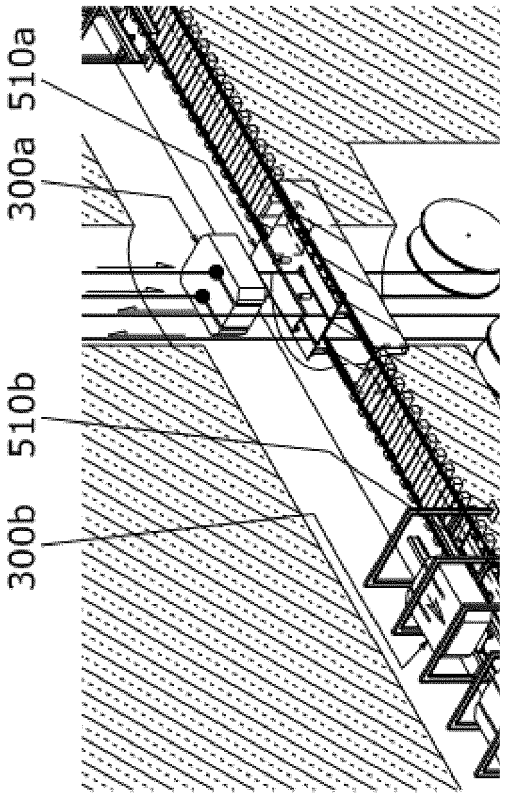


FIG. 15B

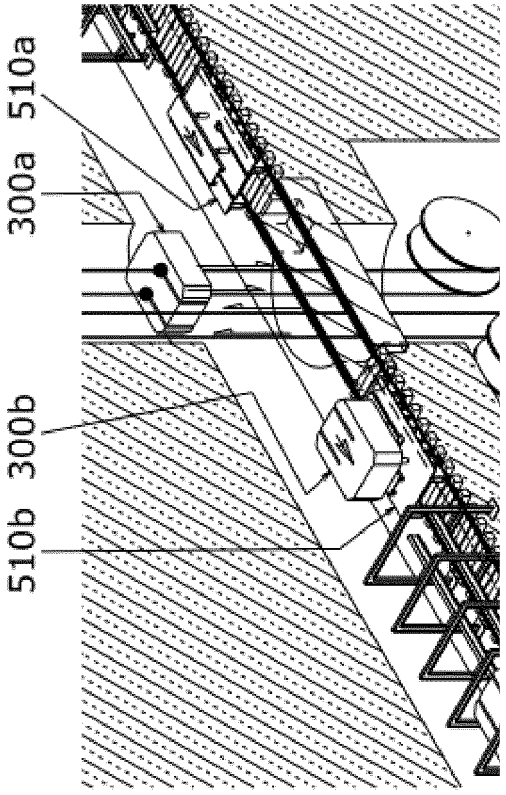


FIG. 15A

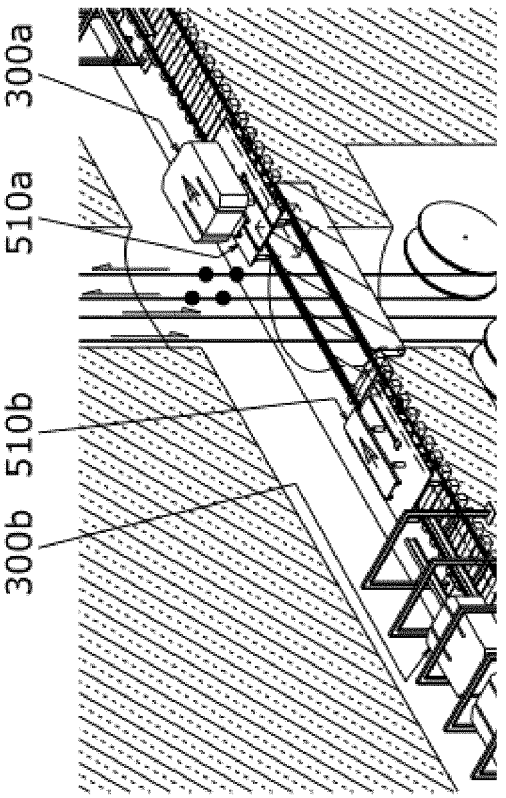


FIG. 15D

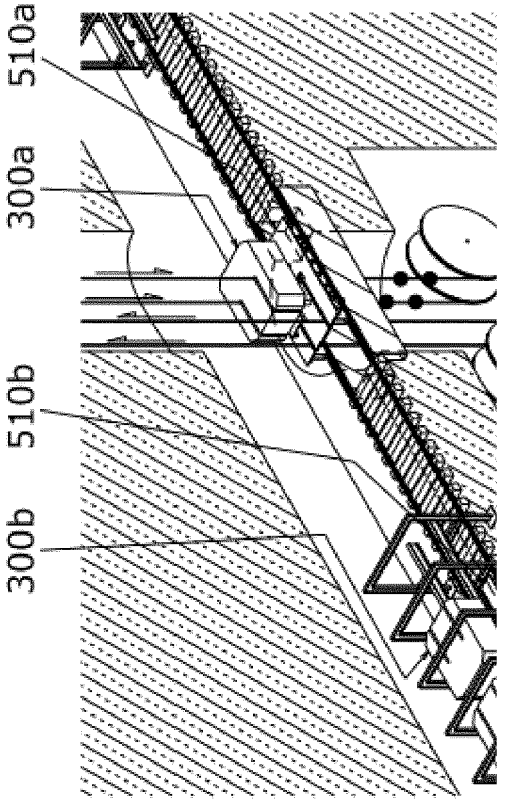


FIG. 15C

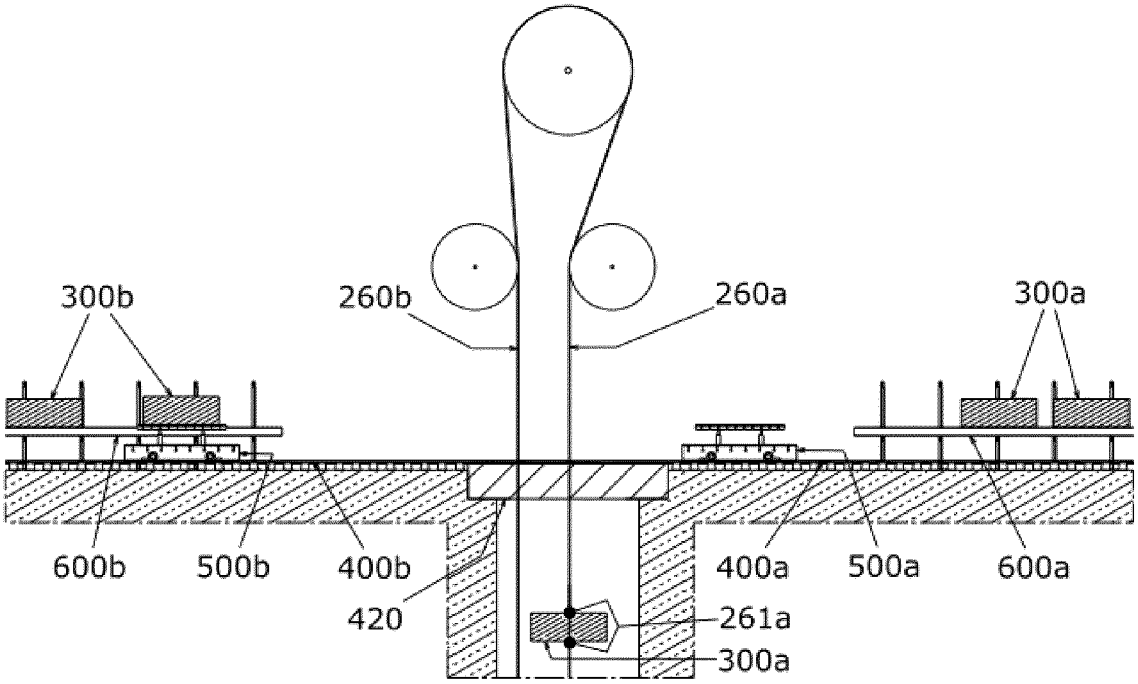


FIG. 16A

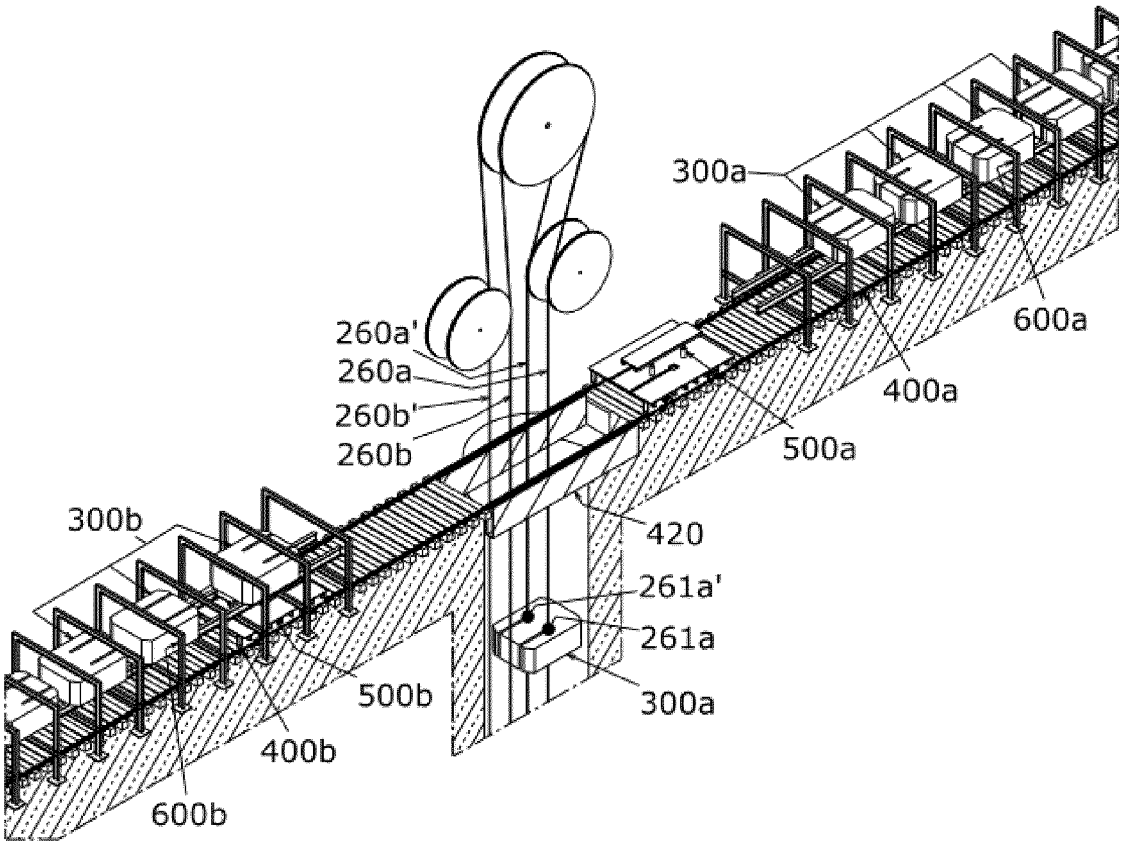
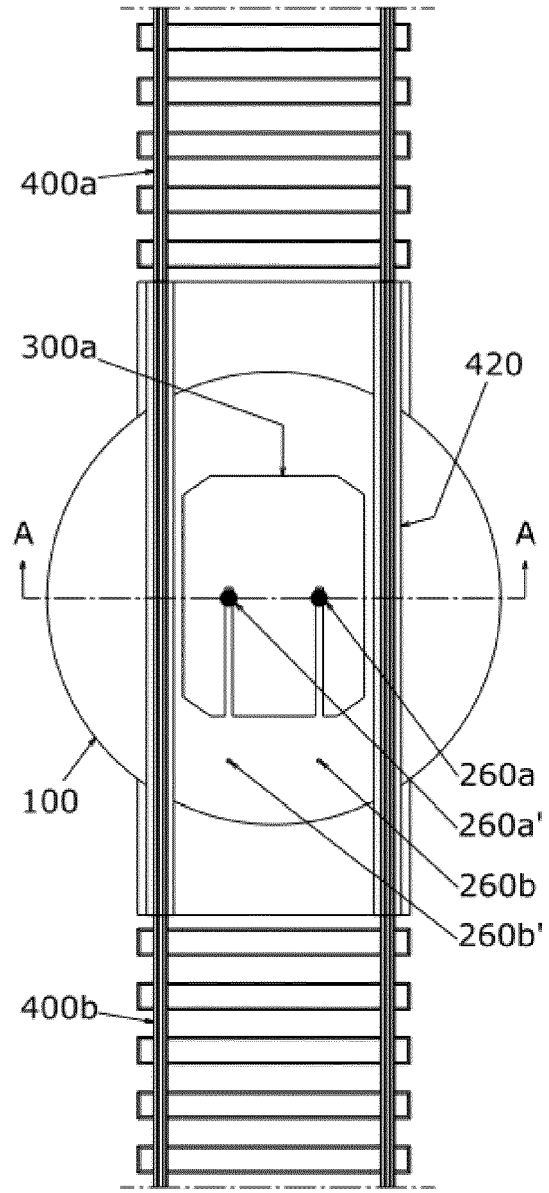
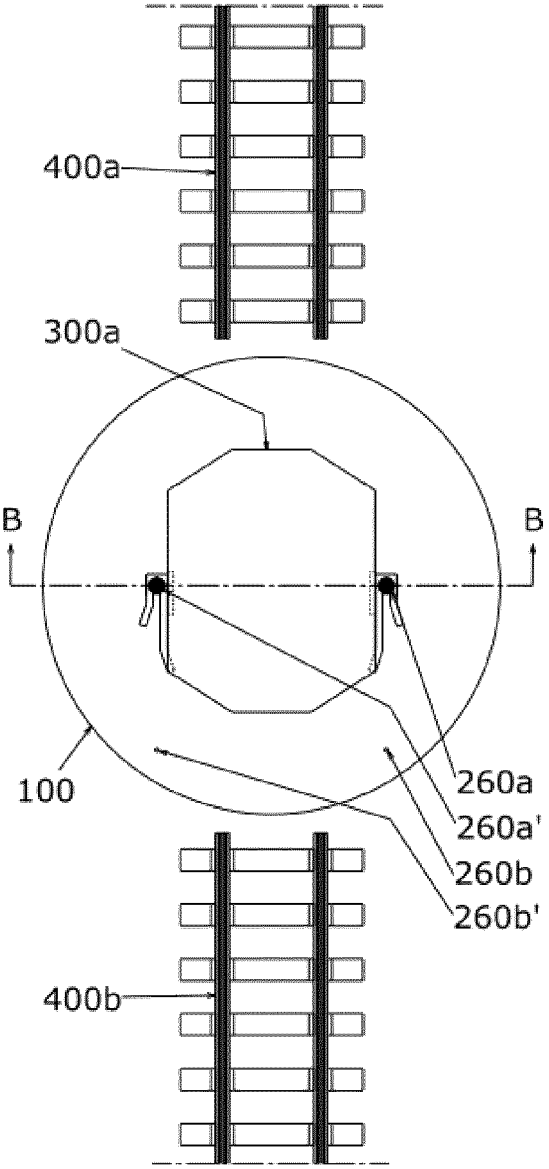
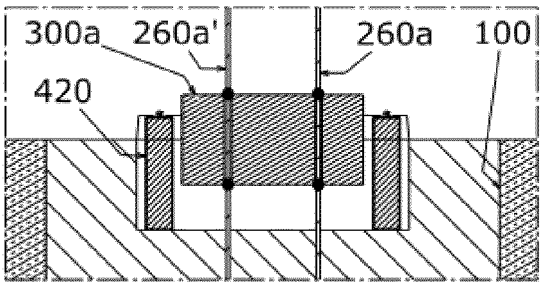


FIG. 16B







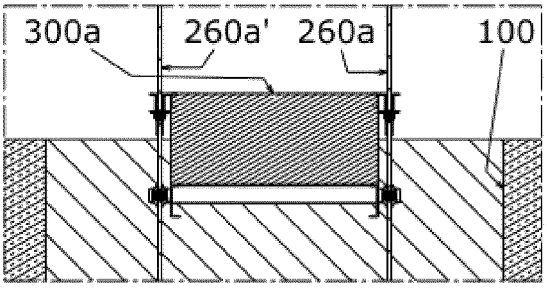


FIG. 17A

FIG. 17B

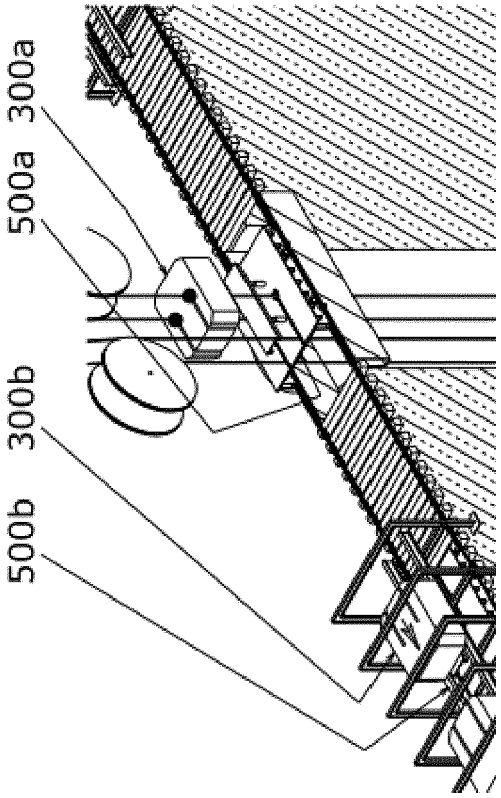


FIG. 18B

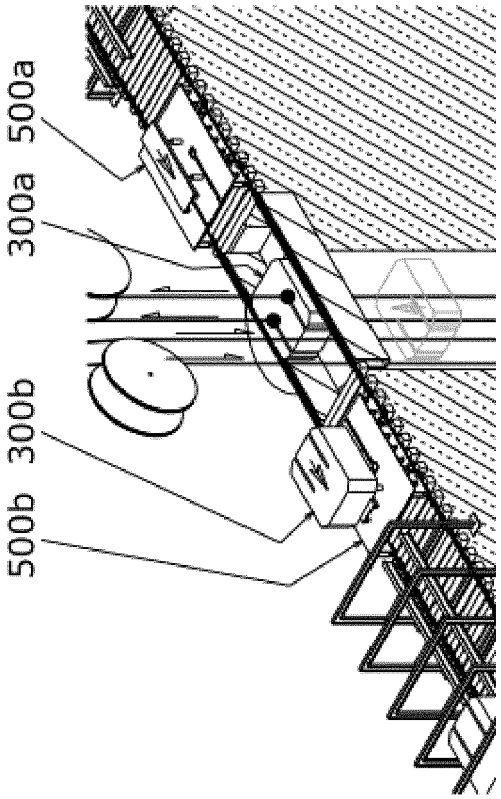


FIG. 18A

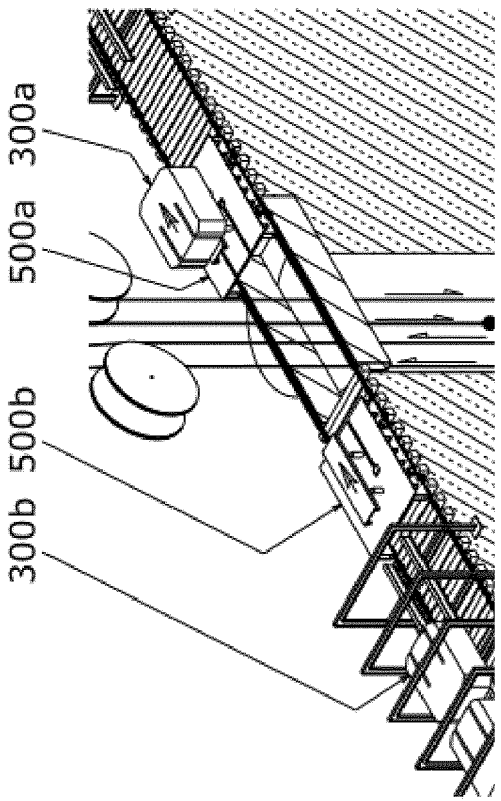


FIG. 18D

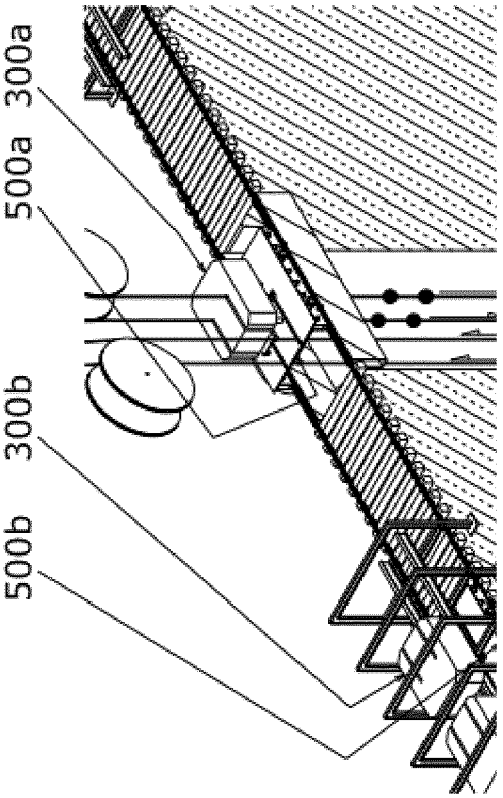


FIG. 18C

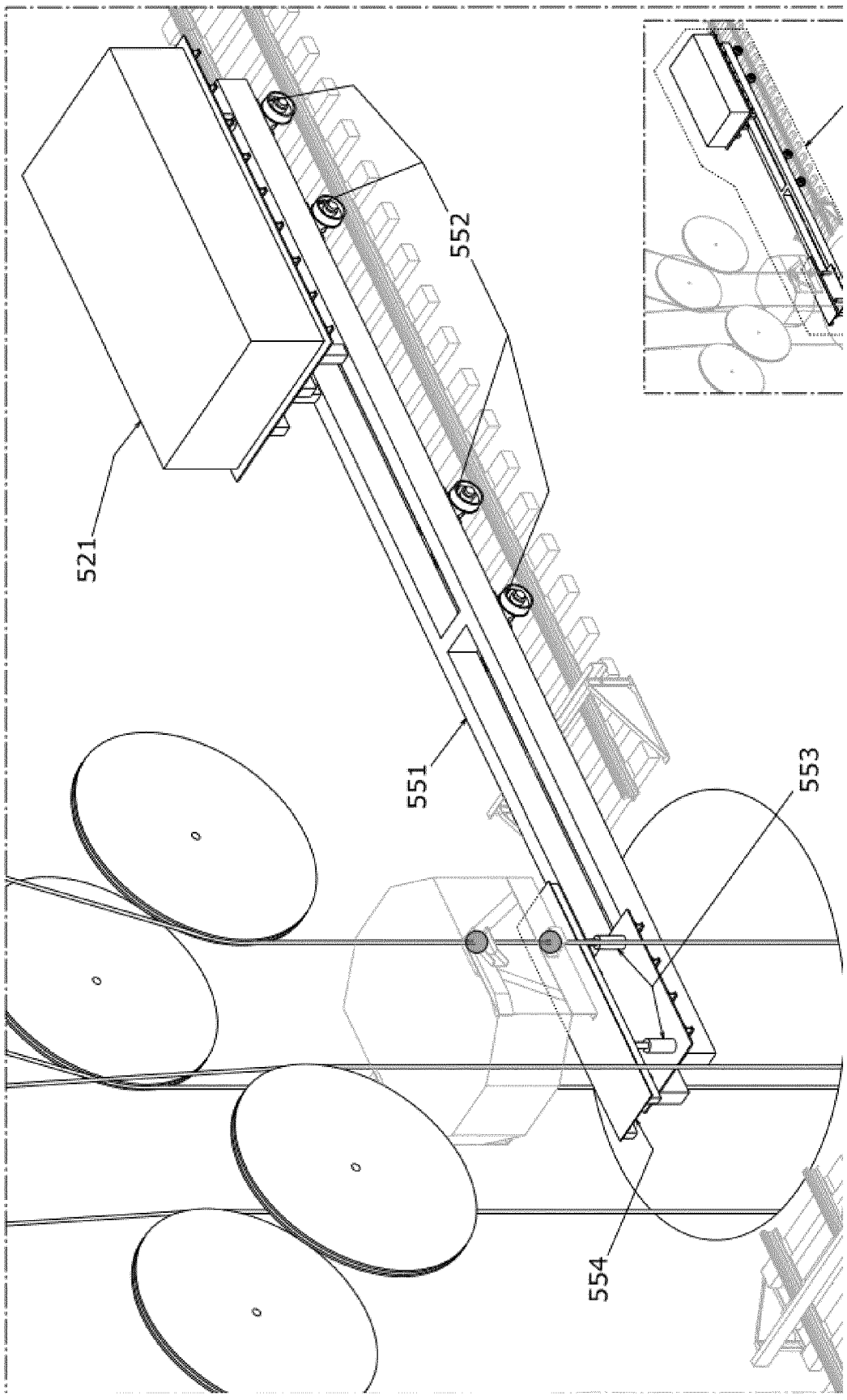


FIG. 19

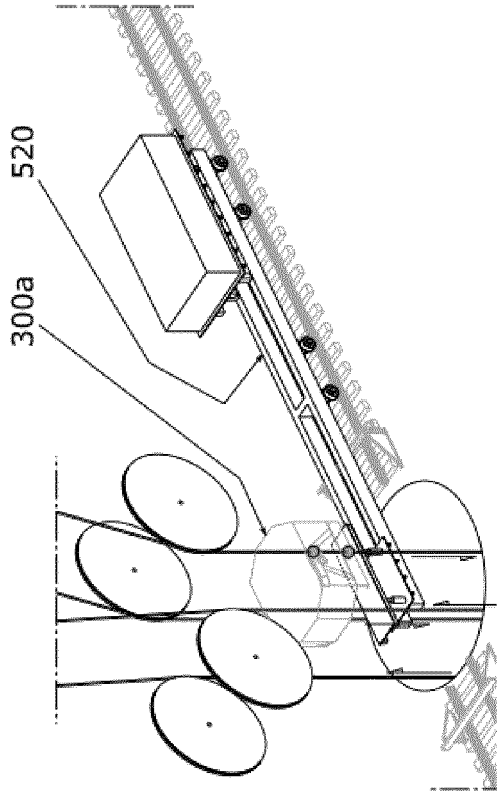


FIG. 20B

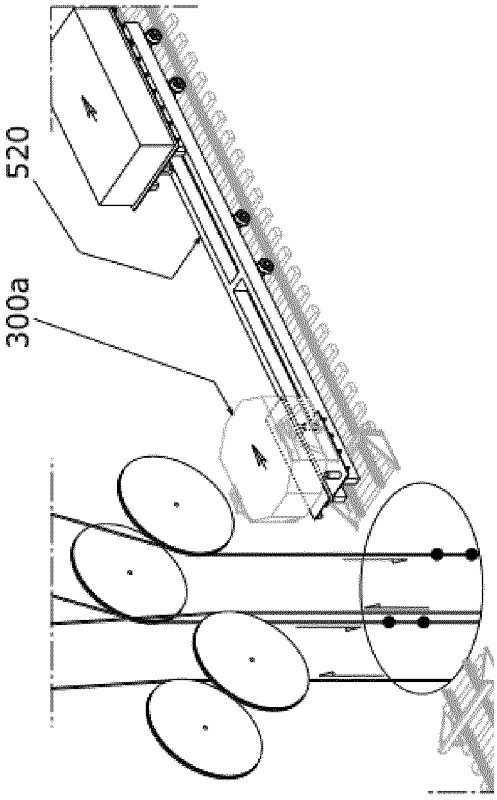


FIG. 20D

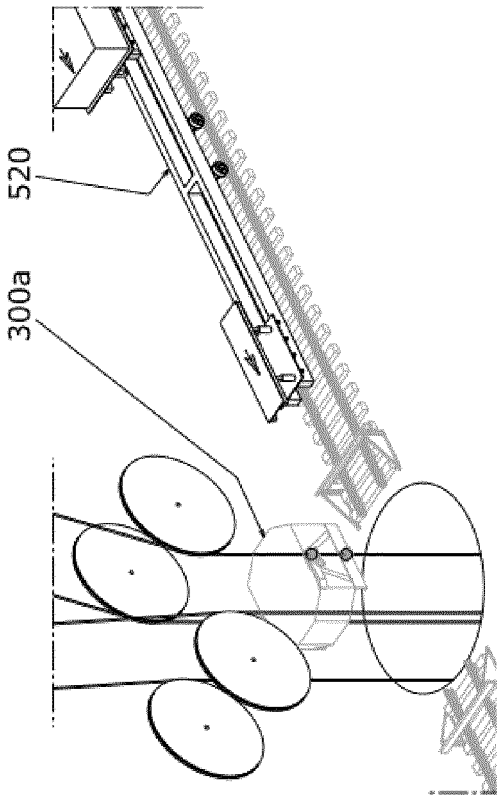


FIG. 20A

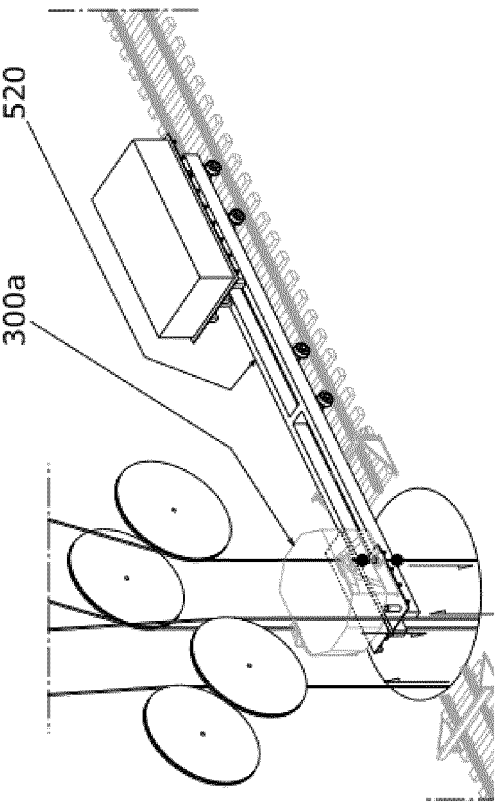


FIG. 20C

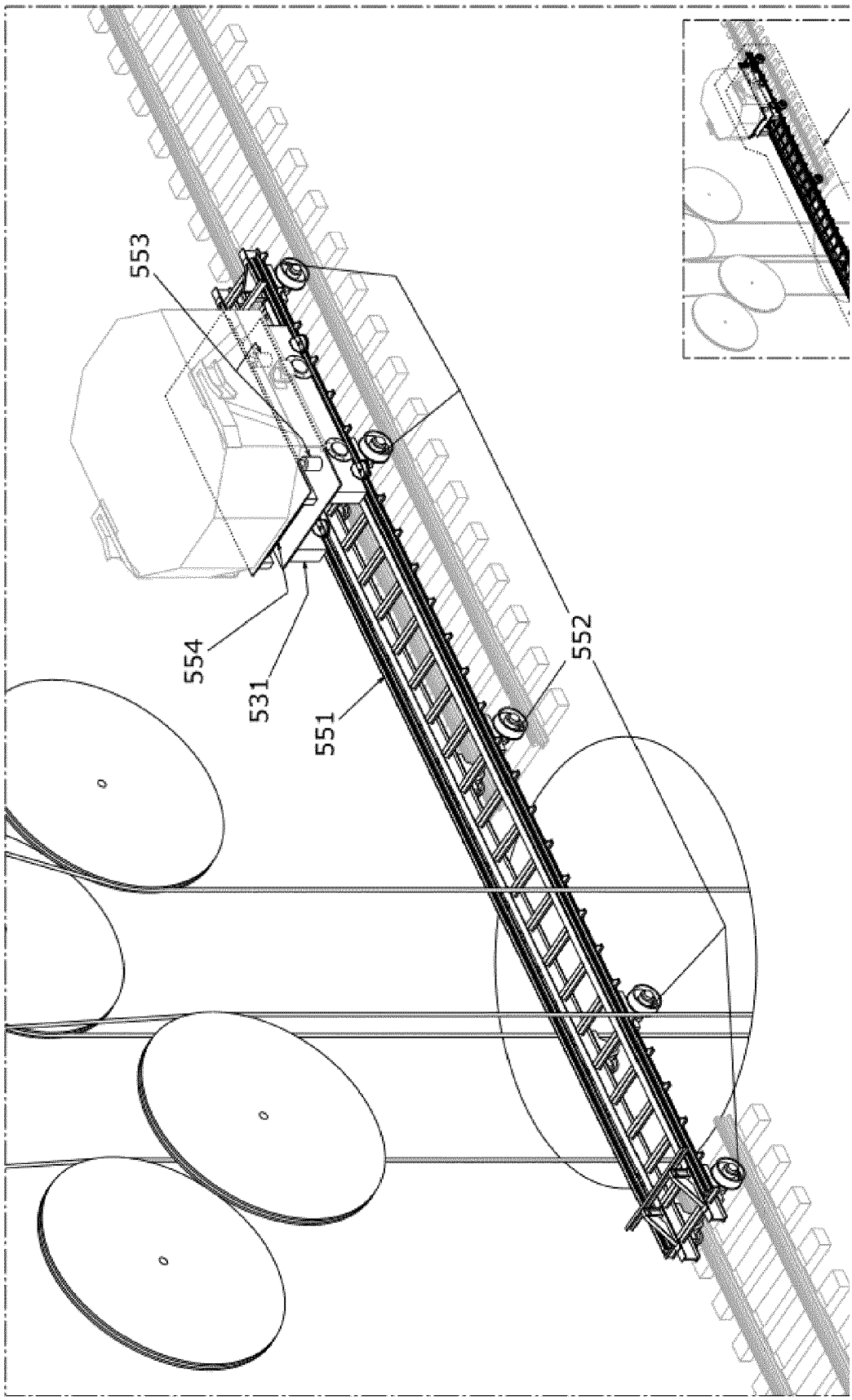


FIG. 21

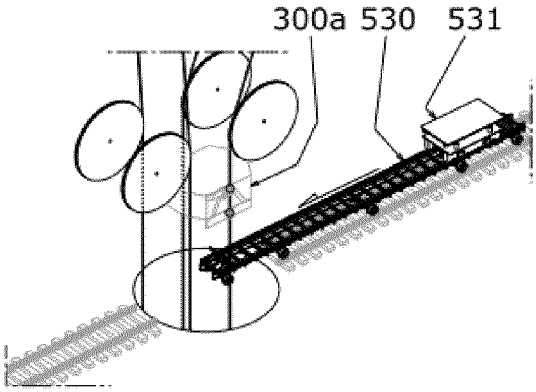


FIG. 22A

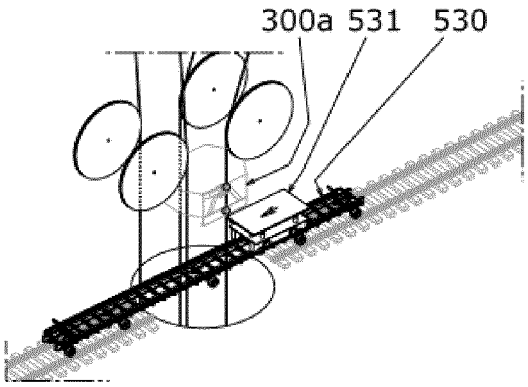


FIG. 22B

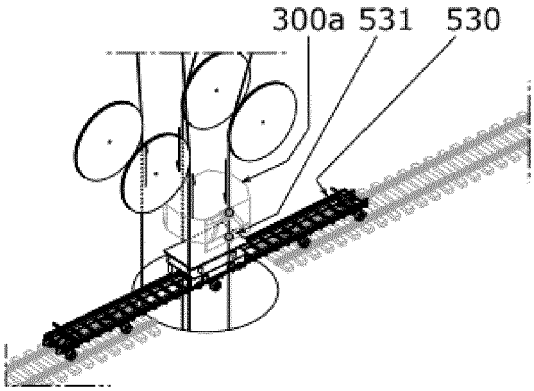


FIG. 22C

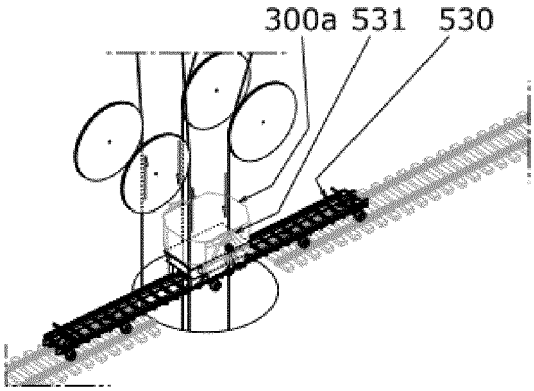


FIG. 22D

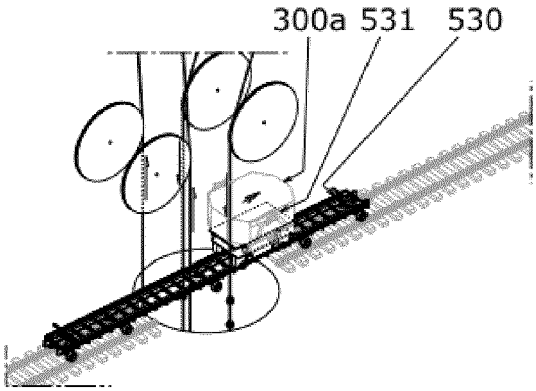


FIG. 22E

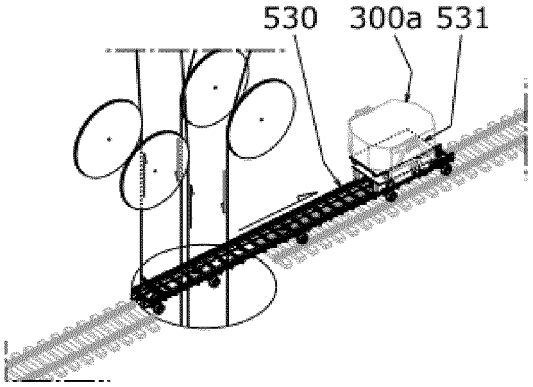


FIG. 22F

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EUROPEAN SEARCH REPORT

Application Number
EP 21 38 3022

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	SU 1 016 253 A1 (BOROVLEV VLADIMIR [SU]) 7 May 1983 (1983-05-07) * the whole document *	1-15	INV. B66B11/00 B66B17/00
A	US 2006/289240 A1 (SAKITA MASAMI [US]) 28 December 2006 (2006-12-28) * abstract * * figures 1,3,6 *	1-15	
A	CN 110 997 543 A (INVENTIO AG) 10 April 2020 (2020-04-10) * abstract; figures 1,2,6 *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			B66B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	16 May 2022	Nelis, Yves

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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16-05-2022

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
SU 1016253 A1	07-05-1983	NONE	
US 2006289240 A1	28-12-2006	NONE	
CN 110997543 A	10-04-2020	AU 2018317641 A1	05-03-2020
		AU 2018319105 A1	05-03-2020
		CN 110997543 A	10-04-2020
		CN 110997544 A	10-04-2020
		EP 3668810 A1	24-06-2020
		EP 3681835 A1	22-07-2020
		SG 11202000750V A	27-02-2020
		SG 11202000756U A	27-02-2020
		US 2020180911 A1	11-06-2020
		US 2020231410 A1	23-07-2020
		WO 2019034381 A1	21-02-2019
		WO 2019034405 A1	21-02-2019

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82