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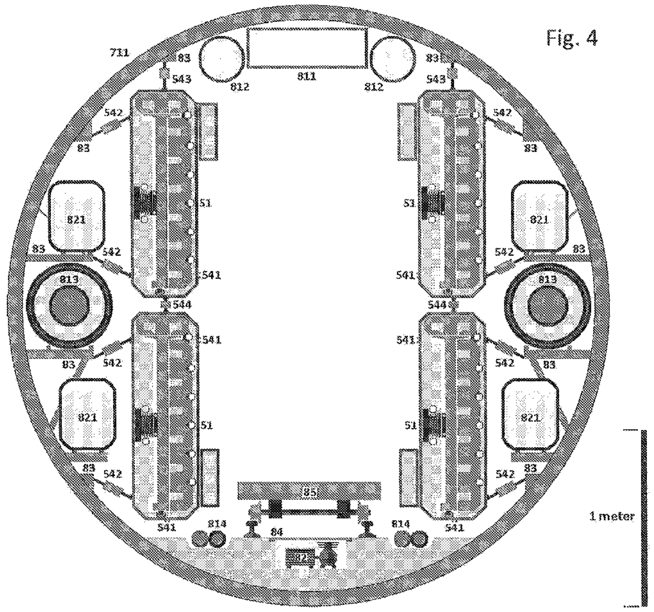

Fig. 4

(57) Abstract: The invention is in the field of a kinetic energy storage system. The system can be used to store huge amounts of energy, e.g. GWh's of energy. Such a system can be used to balance fluctuations in supply of energy at the one hand, such as due to more or less sun or wind energy being available, and fluctuations in consumption of energy at the other hand, such as between day and night.

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Kinetic energy storage system

FIELD OF THE INVENTION

The invention is in the field of a kinetic energy storage system. The system can be used to store huge amounts of energy, e.g. GWh's of energy. Such a system can be used to balance fluctuations in supply of energy at the one hand, such as due to more or less sun or wind energy being available, and fluctuations in consumption of energy at the other hand, such as between day and night.

BACKGROUND OF THE INVENTION

A slowly improving technology is the 'flywheel energy storage' (FES). It benefits in having basically no derating in its capacity over time, like other medium size energy storage solutions like batteries have, this makes its operational reliability predictable. It has a high full roundtrip efficiency by itself, unfortunately it may have more energy loss in self-discharge at average use, than by its power conversion loss. It also requires little or no rare materials, but measured capacity related, it requires some substantial amount of additional system material quantity. Also the capacity per unit does not reach industrial size unless multiple units would be combined. Considering some amount of maintenance per small unit, the energy loss, mostly by self-discharge, and material quantity per capacity, it doesn't seem to have a very optimal over all operational energy storage price.

WO 2015/047092 A1 recites a kinetic energy storage system comprising a mass body and energy conversion means arranged to convert electrical energy into kinetic energy of the mass body. The mass body comprises a one or more carriages, and the energy storage system further comprises a track in the form of a continuous loop supporting the one or more carriages in an operational velocity range. This energy storage system has not been put into practice yet.

The present invention therefore relates to an improved energy storage system, which overcome one or more of the above disadvantages, without jeopardizing functionality and advantages.

SUMMARY OF THE INVENTION

The present invention relates in a first aspect to a kinetic energy storage system (KES). Different to FES, 'kinetic energy storage' (KES) relies from a kinetic aspect more on high velocity than high mass, accomplished by using a type of mass guidance mechanism. It largely benefits as well along the existing industrial size storage technologies (PHES, CAES, Fuel) by its large scale unit size, where the systems cross section size relates to its energy density, but as well largely without the drawbacks of being landscape depended, such as mountain terrain (PHES) or underground caverns (CAES), only relied on placeability in a horizontally flat land- or under water surface, which makes this type of storage accessible for most countries. Its real life roundtrip efficiency, even including related self-discharge, it performs better than so far all existing industrial size storage technologies, having only batteries to perform better. Considering the fact that most countries should largely be able to benefit from this type technology, enabling ownership of industrial size storage capacity, by means of relatively few material per storage capacity, high true life roundtrip efficiency, relatively cheap in maintenance per storage capacity, an overall relatively little landscape or underwater obstruction by being placed underneath a soil, and therein also reducing some amount of failure hazard as well, concluding so far that this may be the number one in industrial size energy storage when it comes to: durability-, ecological- and recourses friendly-, and real life operational costs combined aspects.

The present invention is also subject of a priority application NL2021471. The application and the contents thereof are hereby incorporated by reference.

The present system performs better in terms of velocity of the kinetic mass, in relation to the choice of material and in structure, overall structural weight and material use per equal amount of energy capacity, price per amount energy storage capacity, and amount of self-discharge compared to e.g. a flywheel system.

The below are considerations as a guide for optimizing performance, but these are in no way limiting.

A challenge in any energy storage is to store as much energy as possible with the use of the least amount of mass and volume made at the lowest costs. For kinetic energy storage the amount of mass relative to the amount of energy storage (capacity) will be pursued most likely. Increasing e.g. flywheels energy density can be achieved only by using a mass material with a higher tensile strength. For example: using a mass with a higher mass-density will invoke more to its own tensile strength, causing the maximum rotating velocity to reduce, thereby reducing the storable energy, while still increasing its weight. A lightweight material also allows a higher rotation speed.

If, like in figure 1, two kinetic storage setups that both make use of a type of guidance system placed inside a housing 713, 'setup A' and the 'setup B', each having both the same properties, except setup B to have a cross section twice the size of setup A. The kinetic energy density, may become doubled in setup B where the orbits radius has doubled compared to setup A. The amount of energy density as a single factor relates directly to a radius of a system. The energy storage capacity of setup B is four times the capacity of setup A. In figure 1 each span 723 is numbered separately for each setup. Each of the ten spans shown are representing an equal span strength and equal span length. Because in both setups their guidance systems can both equally transfer an equal amount of centripetal force per same amount of circumferential length, therefore both setups requires to have an equal length interval between spans (as shown by the grey arrows, one for each setup). Because setup B has twice the circumferential length as setup A, the number of span attachment points doubles from four points to eight points. But because the diameter of setup B is twice that of setup A, each span in setup B can only reach from the guidance system to the centre point in the middle, where in setup A it reaches across the full diameter by only a single span each. When a system is made solid anchored into the ground, instead of intended to be mobile by means of span constructions across its full diameter, it may only need very short, or no span constructions at all. If a soil is able to withstand a certain amount of lateral force by means of placement depth or type of anchoring, it is able to catch the transferred guidance force per system length equally no matter the total circumferential length of the system.

An amount of storable energy does not relate to the amount of weight of the kinetic mass, but directly to the amount of applicable centripetal force. The consequence of making a kinetic mass lighter without reducing the kinetic energy is directly linked to a necessary increased mass velocity while maintaining the same amount of centripetal force to be transferred. Because weight can only by means of velocity contribute to the amount of storable amount of energy, than all of the remaining kinetic mass material can exclusively be aimed on being useful for: guidance, suspension and drive traction. Not only is there no necessity for any additional mass to carry with it, it becomes even more lucrative when the weight of an even already bare remaining rotor mass, or solid ring-shaped mass, to be called: ring for short, having no additional weight itself, may possibly be reduced even more. But thus will it become more difficult to apply the same amount force when less material is used. It sort of becomes harder to grab on to. Kinetic energy in such system could be stored in some type of magnetizable mass, largely consisting of most likely: iron, where the guidance system could be made using 'electrically manipulatable magnet structures', that may consist partially of permanent magnets, but probably for the most part, or even completely out of one or more electromagnets in different ways, at least in a stacked like fashion as shown by 441, 442 and 443 in figure 6. Because the amount of mass by itself is not directly proportional to the amount of energy storage, and the weight of the rings iron used as the remaining kinetic mass, already stripped from any other possible added weight, could be reduced even further, therefore the description: 'ring' or 'rotor system' seems more applicable than: 'kinetic mass'. Several more specific effects are shown in figure 2, where each example represents an equal scale, showing different effects of magnetic paths shown by black lines and their magnetic directions by arrows. Shown in example A is how a system implies to be the most electrical efficient by having the largest height per single magnetic path which also surrounds the thickest least electrical resistive coil wiring. To reduce the material use by means of reduction in the guidance system 41, like in shown at B, its winding can be made smaller, in this case narrowing the guidance system, reducing the quantity of its core material, as well as its wiring material, but causing an increase in power consumption because of the increase in electrical resistance. Still both A and B use the same initial amount of material and weight at their rings. Like mentioned, it's not the weight to be proportional to the kinetic energy storage capacity, but the combination of mass times velocity squared. Knowing that: stored energy, as well as amount of centripetal force are both proportional to mass times velocity squared, stored energy equals to centripetal force times radius, divided by two. To reduce the kinetic weight without reducing kinetic energy, the amount of centripetal force has to remain the same, by increasing its velocity. Thereby it becomes harder to grab on to the remaining mass while remaining the same amount of compensating guidance force. The force per amount of mass increases where not the force itself increases, but the mass does decrease. To sustain in amount of force, it is not the frontal magnetic surface area that has to increase. An certain electromagnet will always be able to apply a certain amount of magnetic force of about one hundred kilo Newton per square meter at a theoretically ideal two gap at the point of reaching saturation, as long as there are no obstructions along the magnetic path to over saturate, having the magnetic path to be compromised by narrowing its magnetic cross section at any point along it. The same amount of magnetic flux will also has to be transferred all the way at both ring and guidance system when their magnetic cross sections are equal along its mutual magnetic path. Each part of cross section along its path will only be able to reach a certain amount of flux before it will saturate. To transfer an equal amount of magnetic force between the frontal surface areas that the ring and the guidance system faces each other, but still be able to reduce the amount of core material, it is possible to repeat a number of magnetic paths over the vertical height, instead of transferring all magnetic flux through one single (bulky, very heavy) wide path. So its possibly cheaper to increase the number of magnetic paths into several smaller and narrower vertical stacked magnetic paths instead, by alternating the magnetic direction in each stack, as shown in figure 2.C. Therefore in C the total amount of core weight compared to A and B is about half, just by having a double magnetic path in C instead of a single path at A and B. Note that the core material in both ring 11 as well as the guidance system 41 have both been reduced, only the amount of conductor material for each magnetic path remains the same between B and C. But when the number of conductive wiring doubles, and the conductor thickness does not change, than the power consumption will double because of it. Note also that the magnetic flux limit count equal for both ring and guidance system. Where one can be narrowed, or has to be widened, equally so can, or will have the other. If they do not match, like shown at D, the narrowest will saturate over the other. In D it's the ring that saturates by being narrower than its own guidance system. In such case the rings iron core would always have a higher magnetic flux than its guidance system at equal electromagnetic power conditions until a point of saturation at some point in the magnetic path is reached, causing the transferable magnetic force between them to be limited by the magnetic path to be partial overloaded, and therefore obstructing the whole magnetic path as a chain around an electric conductive wiring. This is shown at D by the magnetic fields to even partial leave the rings iron core at the location where it is no longer capable to contain it. Not only saturation will cause a possible reduction in transferable force between guidance system and its ring, also the gap between the two will. As shown in E in comparison to the other samples, is that at the same magnetic flux, such as at the point of saturation, the amount of magnetic force will be opposite to gap clearance squared (besides that, also magnetic resistance plays a role). This will also risk that when the gap between the ring and its guidance system starts to increase even a little when its magnetic path already saturates, that it becomes almost impossible to stabilizing the horizontal position of the ring by maintaining a safe amount of gap clearance by means of increasing electrical power into the guidance system to avoid the systems most catastrophic scenario possible. A safe margin is highly recommended to avoid of having a magnetic path to become fully saturated at an already initially intended gap clearance, especially in case of imperfections in: ring orbit, magnetic feedback, or by means of external lateral forces to occur, such as at an earthquake. Some more structural error to avoid is what is shown in F, having two neighboring electrical wiring to have an equal current direction along through the guidance system. When a single coil causes two opposite magnetic pathways, like in C, D and E, the current direction seen in cross section fashion, it will automatically have the current direction to approach (the viewer) at one point, and continue to enter (away from the viewer) at the other point, making an electrical loop. When a chain of neighboring loops are placed in a stack of magnetic paths, all loops have to have the same equal non-opposing polarity, thereby will each magnetic path alternate each other neighboring path. But where a polarity of one loop opposes a neighboring loop, it will cause the electrical current direction to be the same as the neighboring magnetic paths, like shown in F, where the magnetic flux is added up from both loops to effectively create only one single magnetic path where two are intended, making it to become only half effective. See that the middle part in F does not show a magnetic crossing between the ring and its guidance system, and therefore does not transfer any substantial magnetic force at that point between them. The limit in magnetic flux remains the same, and therefore the force per equal amount of core cross section. When only half of the cross section is used effectively, than only half the intended force can be applied. Therefore this effect should be avoided, which luckily is very easy to be realized.

Also other aspects may be considered in design and engineering to translate this technology into a successfully functional product. The use of proven technologies keeps costs low and predictable. Such as the proven use and construction of long distance pipeline connections like they are already used for transport of oil, and how they can be constructed, coupled, welded, anchored into the ground, elevated from the surface, or even placed under water. Despite maintaining a specific gap clearance between the ring and its suspension system itself is a very unstable process, this already has electronically proven to be very well manageable. The same type of electromagnetic force feedback is used in electromagnetic suspended globes. Secondly a similar solution counts for the guidance system, but with the difference of maintaining an horizontal force for means of compensating the rings centripetal force. What as well should add to the chance for success in engineering is the fact that all these individual aspects have proven themselves in real life situations in one way or another already, and should also be fairly well calculated and simulated into a single combined setup. Exceptions herein may be aspects of: the extreme high velocity of the ring, human maintenance performed to systems inside a long narrow pipe like structure, remaining just over one meter wide, the aspect for the safe use of high voltage enclosed electrical systems to be installed perhaps even in under water housing structures as well, the whole construction can only be an almost perfect donut-shape, demanding placement predetermination along its full perimeter completely on forehand to avoid any possible obstacle on its path, and therein also reduce- and solve unequal sinking into the soil, and avoid and counter unequal deformation of the internal ring systems from alternating vertical as well as lateral forces each along their full perimeters.

Thereby the present invention provides a solution to one or more of the above-mentioned problems.

Advantages of the present invention are detailed throughout the description.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates in a first aspect to a kinetic energy storage system according to claim 1.

In an exemplary embodiment of the present system the solid ring-shaped mass may comprise at least two connectable ring sections. As such the system can be constructed by sub-elements, which makes construction and handling much easier and lowers costs. Typically many ring sections are provided.

In an exemplary embodiment the present system may comprise at least two ring system modules, where each module comprises an internal system. As such the system can be constructed by sub-elements, which makes construction much easier and lowers costs. Typically many ring system modules are provided.

In an exemplary embodiment the present system may comprise a squirrel cage rotor construction adapted to accelerate and to decelerate the solid ring-shaped mass by means of interaction between a stator system, and the rotor comprising short circuit windings, preferably as an integral part of the solid ring-shaped mass wherein a combined same piece of iron core is part of both the solid-ring mass as well as of the rotor.

In an exemplary embodiment the present system may comprise a squirrel cage rotor construction adapted to accelerate and to decelerate the solid ring-shaped mass by means of interaction between a stator system, and the squirrel cage rotor construction comprising internal short circuit windings embedded in ferrite, mounted directly to the solid ring-shaped mass' surface.

In an exemplary embodiment the present system may comprise alternating magnetic polarity arranged permanent magnets mounted to the rings surface, adapted to accelerate and to decelerate the solid ring-shaped mass by means of interaction between the stator system and a permanent magnet rotor construction.

In an exemplary embodiment of the present system at least one ring system comprises a stator system, comprising along the perimeter sets of lengthwise arranged electromagnets, preferably adapted for creating artificially controllable sequential progressing electromagnetic fields to interact with any of the mentioned rotor systems to enable bi-directional exchange in mechanical force.

In an exemplary embodiment of the present system at least one ring system comprises a suspension system, preferably arranged in sections, preferably divided according the division of ring systems modules, adapted to provide suspension along an entire circumferential length inside an entire ring system, where each suspension system section comprises electrically manipulatable magnet constructions, comprising electromagnets, which can be in an optional combination with permanent magnets. Each section may comprise an individual active feedback controlled magnetic force for maintaining a specific gap clearance between the ring and the suspension system (at any given point). Note that ‘section’ here doesn’t mean ‘module’ or being detachable! A module can comprise multiple sections, or a section can be merged by multiple modules, or even equally divided 1:1.

In an exemplary embodiment of the present system at least one ring system may comprise a guidance system, such as at each ring system module, adapted to compensate a ring’s centripetal force by means of a divided setup along the entire circumferential length inside each entire ring system, preferably a sectional divided setup, where each guidance system section comprises electrically manipulatable magnet constructions, comprising electromagnets, in an optional combination with permanent magnets. Each section may comprise an individual active feedback controlled magnetic force for maintaining a specific gap clearance between the ring and the guidance system (at any given point).

In the present system the electrically manipulatable magnet constructions, comprising electromagnets, typically comprising 1-100% electromagnets (based on a total magnetic field strength), preferably 10-99.9% electromagnets, more preferably 30-99.8% electromagnets, even more preferably 50-99% electromagnets.

In an exemplary embodiment of the present system the guidance system may comprise individual controllable electrically manipulatable magnet constructions by being arranged over the vertical height within at least one section of the guidance system adapted to control ring torsion, such as by (individual) active feedback control.

In an exemplary embodiment of the present system a main facility housing construction may comprise internal mounting and support structures for the ring system for the subsequent assembly and disassembly of ring systems or modules.

In an exemplary embodiment of the present system a main facility housing construction may be anchored into the soil comprising external additional mounting constructions at some length interval along the perimeter of the main facility housing for capturing the centripetal forces throughout the main facility housing construction outward.

The main facility housing construction may be at a certain depth in the soil, such as >100m deep, preferably >500 m. At such depth the gravity force of the soil compensate the centripetal forces intrinsically.

In an exemplary embodiment of the present system a main facility housing construction may be anchored into the soil comprising external additional span constructions, by means of chains or cables at some length interval along the perimeter of the main facility housing for capturing the centripetal forces throughout the main facility housing construction outward towards some kind of firm anchor point (see e.g. figure 10).

In an exemplary embodiment of the present system a main facility housing construction may be anchored into the soil comprising external additional pile constructions by means of piles, such as by means of being pile-driven, at some length interval along the perimeter of the main facility housing for capturing the centripetal forces throughout the main facility housing construction outward (see e.g. figure 11).

In an exemplary embodiment of the present system a main facility housing construction may be placed elevated above the soil, comprising pillar constructions where the pillars are anchored into the soil at some length interval along the perimeter of the main facility housing to capture and transmit the centripetal forces throughout the main facility housing construction outward (see e.g. figure 12).

In an exemplary embodiment of the present system a main facility housing construction may be placed elevated above the soil, comprising pylon constructions where the pylons are anchored into the soil at some length interval along the perimeter of the main facility housing to capture and transmit the centripetal forces throughout the main facility housing construction outward (see e.g. figure 13).

In an exemplary embodiment the present system stores at least one hundred Mega Watt hour (MWh), preferably more than 1 GWh, more preferably more than 10 GWh, even more preferably more than 100 GWh, and/or peak power provision of more than ten Mega Watt peak (MWp), preferably more than 100 MWp, more preferably more than 1 GWp, even more preferably more than 10 GWp.

In an exemplary embodiment of the present system a solid ring-shaped mass comprises a mechanism, where each ring section comprising at least one screw mechanism coupled to a transfer axle to transfer a ring section gap spacing setting mechanically from one end of each section to the other end, to obtain a balanced gap spacing between every two up following ring sections (see e.g. figure 8).

The invention is further detailed by the accompanying figures and examples, which are exemplary and explanatory of nature and are not limiting the scope of the invention. To the person skilled in the art it may be clear that many variants, being obvious or not, may be conceivable falling within the scope of protection, defined by the present claims.

SUMMARY OF THE FIGURES

Figures 1-14 show exemplary details of the present system.

DETAILED DESCRIPTION OF THE FIGURES

For the convenience of the reader sub numbering of generic elements is used. In the figures:

1 Ring
11 Ring, cross section
110 Ring, partial display of midsection or around the rotor area, cross section
111 Ring head, cross section
112 Ring foot or balancing weight (counter balancing the heads weight), cross section
113 Embedded rotor, cross section
114 Embedded short circuit windings, cross section
115 Ferrite rotor, cross section
116 Ferrite rotor short circuit windings, cross section
117 Permanent magnet rotor, cross section
12 Ring side view
120 Ring side view, partial display located at ring sequence balancing mechanism, outside view
1200 Ring side view, partial display located at ring sequence balancing mechanism, open cross section
121 Ring head, side view
122 Ring balancing weight, side view
123 Embedded rotor, side view
124 Embedded short circuit windings, side view
125 Ferrite rotor, side view
126 Ferrite rotor short circuit windings, side view
127 Permanent magnet rotor, side view
2 Stator
21 Stator, cross section
22 Stator surface area, frontal view
23 Stator, top view
24 Stator winding
25 Stator cooling
3 Suspension system
31 Suspension system, cross section
32 Suspension system surface area, bottom view, surface facing ring head
33 Suspension system, top view
34 Suspension system, side view
35 Suspension system electrical inductor winding
4 Guidance system
41 Guidance system, cross section
42 Guidance system surface area, frontal view

421 Guidance system magnetic (iron) surface area, frontal view
43 Guidance system, back view
441 Guidance system electrical inductor winding (upper)
442 Guidance system electrical inductor winding (middle)
443 Guidance system electrical inductor winding (lower)
45 Guidance system cooling
451 Guidance system cooling heat filler/heat conductor
5 Ring system
51 Ring system, cross section
52 Ring system, side view
53 Ring system, top view
54 Ring system housing
541 Ring system housing support slot structure
542 Ring system housing horizontal support strut
543 Ring system housing vertical support strut
544 Ring system housing through-piece coupling strut
55 Ring system filler material
56 Ring system support wheel
57 Electronics box
6 Gaps
61 Ring to Ring coupling gap (shows before sections are being connected into each other)
611 Ring to Ring thermal expansion gap (in vacuum)
6110 Ring to Ring gap sequence balancing mechanism (figure 8)
6111 Ring to Ring gap sequence balancing mechanism male screw, side view
6112 Ring to Ring gap sequence balancing mechanism male screw, head end view
6113 Ring to Ring gap sequence balancing mechanism receptive screw nut, side view
6114 Ring to Ring gap sequence balancing mechanism receptive screw nut, head end view
6115 Ring to Ring gap sequence balancing mechanism sliding connection wrench, side view
6116 Ring to Ring gap sequence balancing mechanism sliding connection wrench, head end view
6117 Ring to Ring gap sequence balancing mechanism pass through axle, side view
612 Ring rotor to Stator gap (in vacuum)
613 Ring to Suspension system actively maintained gap (in vacuum)

614 Ring to Guidance system actively maintained gap (in vacuum)
622 Stator to Stator thermal expansion gap
633 Suspension system to Suspension system thermal expansion gap
644 Guidance system to Guidance system thermal expansion gap
7 Main facility
71 Main facility housing (tube, pipe or tunnel construction)
711 Main facility housing, cross section
712 Main facility housing, side view
713 Main facility housing, top view
721 Main facility span construction, cross section
722 Main facility span construction, side view
723 Main facility span construction, top view
731 Main facility pile construction, cross section
732 Main facility pile construction, side view
733 Main facility pile construction, top view
741 Main facility pillar construction, cross section
742 Main facility pillar construction, side view
743 Main facility pillar construction, top view
751 Main facility pylon construction, cross section
752 Main facility pylon construction, side view
753 Main facility pylon construction, top view
761 Main facility, housing for: heat transfer equipment, transformers, etc. and personal entrance, top view
762 Main facility maintenance and operator room, top view
763 Main facility straight pipe/tunnel for catastrophic ring failure, top view
764 Main facility catastrophic ring failure damper buffer, top view
8 Additional equipment
81 Pipes and cables
811 Air duct
812 Pipes for cooling
813 Main high Voltage cables
814 Local distribution low Voltage cables
82 Pumps, compressors and such
821 Emergency water supply for cooling at a catastrophic failure
83 Wall support structure
84 Maintenance floor and equipment hatch
85 Maintenance train

Figure 1 shows the effect of using the amount of full across span material when an energy storage system using a guidance system would be made mobile. When due to using a same type of guidance system in two different sized setups their guidance forces in both setups would be equal between them, the distance between attachment points is equal too when also each span would be equally strong. But due to their different sizes, the amount of span construction material quadruples when the guidance force remains the same between them, but the orbit in setup B is twice as shallow as in setup A, it will allow its rings velocity to increase by having its kinetic energy per equal amount of mass to be doubled. If both setups have the same height, then setup B will be using twice the amount of ring mass due to its double sized orbit length. The energy storage capacity would then be four times the amount of setup A.

Figure 2 shows six different effects of magnetic force interaction between a guidance system 41 and its ring 11. At A the guidance system is most bulky having the widest magnetic cross section, as well as using the most conductive wire material. At B the wire thickness is reduced, what will cause an increase in electrical power demand per equal magnetic force. At C the complete amount of core material is about halved by having two magnetic paths instead of one at the same vertical height. Because the number of wiring is doubled, so will the power consumption per equal amount of magnetic force. D shows what happens if the rings width would not match with the core cross section of the guidance system. At E the magnetic force per magnetic excitation is reduced by having an increased gap clearance. F shows the effect of having two neighboring electric wires to be in counter polarity causing both wire current directions to line up instead of countering each other creating a single magnetic path where two are intended to be, becoming only half as effective.

Figure 3 shows the effect of having imperfect placement of the ring system. Such when the ring can experience free fall when the ring system forms from a certain point curved downward. This critical amount of vertical curvature can be calculated using the variables shown in this figure.

Figure 4 shows a possible cross section impression of the facility housing showing all main attributes inside it. In this case using four ring systems. Ring systems can be placed subsequently by using connectable support struts. A facility can be made in different sizes allowing a different number or a different ring system size. This figure does not show by which means the facility is placed or mounted or anchored in-, on top- or above ground or water.

Figure 5 shows more specific how a ring system support strut mechanism could be applied and used. Note that struts 542 holding a ring system at the inside bend inside the facility has to withstand a span force, where struts 542 for the outer bend has to withstand a compressing force. All other vertical struts 543 and 544 has to withstand span forces only. All struts are drawn the same, but may be different in real life for enabling different force directions between them, and may have to reach different distances. A support strut will most likely be a mechanical screw based solution, adjustable perhaps by a small electromotor or just by hand or both.

Figure 6 shows different aspects and system of- and inside a ring system. With on top in the middle a ring system cross section 51 of all main elements inside it. To the right it aligns at equal height a part of the back side of a guidance system 43 using tree vertically stacked independent induction wirings, where two ends of a coupled ring system sections meet each other, showing a gap 644 between them that shows here by the gap between two guidance system sections. Aligned below it, a similar part at between two sections but seen from the inside outward 42, showing the magnetic surface that faces the ring. To its left shows an small part aligning with the orbital outer side part of the ring 12 showing inner parts of in this case a ferrite type rotor. Left to the ring does lineup to the frontal view of the stator 22. Directly below it the top down view of the same stator part 23. Directly above the ring 12 shows the suspension system by side view perspective 34. Left to it aligns with its cross section view 31 twice. Above them the top 33 and bottom view 32 of the same part of suspension system, also displayed at the point where two sections meet having a gap 633 between them.

Figure 7 shows three different ring parts using different rotor layouts. To the left: having the rotor and its short circuit windings to be completely embedded inside the ring, making the ring and the rotor to share the same part of core. Hereby the ring can be considered to be rotor itself, because a specific part of the core is used for being both rotor as well as it is used as being a part of the magnetic guidable kinetic mass. At the middle: a ferrite based rotor containing short circuit wiring. At the right: a rotor using permanent magnets for a synchronous type of propulsion. The upper part of the figure shows the each ring setup shown sideways towards rotor surface. In the lower part each rotor on or in each ring is shown by cross section (each ring here is not shown in full height).

Figure 8 shows an example of a ring gap clearance 611 balancing mechanism 6110 to make ring gap clearances to be 95% to 99% the same compared between two consecutively ring gap clearances. This is to avoid having an aggravating ring gap clearance unbalance. To be completely being balanced by individual stator section fore alone, saving energy by having the stator hereby to apply only relatively small individual balancing forces instead.

Figure 9 shows a clear top view of a complete energy storage facility including possible maintenance and storage rooms and the straight safety tunnel, showing the tunnel or pipe diameter in one scale perspective, and the circumferential size of the facility in a different scale measure. It also shows how housing for heat transfer equipment, transformers, etc. and personal entrance 761 could be placed on top of the facility tunnel or pipe 713 when this pipe or tunnel is at a certain depth underground to attain enough lateral anchoring force by its surrounding soil, but when the facility is placed more shallow it 761 can also be placed next to it inside the circumferential outline of the facility (not shown in this figure). Its interval in intermediate spacing could differ (like the figure seems to suggest), as long as the facilities internal systems are enabled to be powered from a medium high Voltage out of a power supply from it every few kilometers or so.

Figure 10 shows in three different perspectives the main facility housing attached to a type of span construction (in this case displayed by chains) for anchoring into the soil at a certain points somewhere more towards the virtual centre point of the facility structure. This can be used in case the facility housing may not be placed sturdy enough by placing in soft soil, or to shallow underneath the surface, of too highly elevated above the ground to capture the lateral force through the elevation providing structure alone, what could be the case by using a pylon structure (75x), like it is shown in figure 13.

Figure 11 shows in three different perspectives the main facility housing anchored by a type of (pile-driven) pile setup. In this figure the piles are placed at the outer perimeter of the facility pushing the facility against its lateral force. This technique can also be applied at the inner perimeter such as in combination with the span construction (72x), as shown in figure 10.

Figure 12 shows in three different perspectives the main facility housing placed on top of a pillar construction. In this figure each pillar construction uses two pillars, any other number of pillars could be used as well, such as where obstacles underneath it are to be avoided. When this type of construction is not build to elevate the facility relatively low above ground level, it may do fine by having the pillars being firm enough into the soil to capture enough lateral force without additional span constructions.

Figure 13 shows in three different perspectives the main facility housing placed elevated on top of some type of pylon support structure. This type of elevation support can be used for more higher elevation above ground level, but as well under water crossing deeper water as well, most likely when especially only relatively small parts of the facilities perimeter has to be elevated this way. This type of construction may well be capable of having the facility elevated to a certain height, but to compensate the lateral force too, an additional span construction may even be always required in combination hereof.

Figure 14 shows how the head ends of a solid ring-shaped mass 12 are able to fit into each other. In a real build setup, additional measures are required to prevent the head ends not only to slide vertical, but sideways as well. Also detachment should be prevented once the ring sections are connected.

The figures are further detailed in the description and examples below.

EXAMPLES

As long as the price for permanent magnets, even without any energy costs, cannot compete with the cheaper solution of electromagnets, and also due the need for a variable magnetic force, proportional to the centripetal force that also has to feedback a specific maintained gap clearance, or position of the ring towards both guidance system and the suspension system at any given point, electromagnets are required to be used at least in one form or another. Figure 6 shows the basic construction setup of both its suspension systems electromagnetic structure 3x as well as its guidance systems electromagnetic structure 4xx. To allow the suspension system to be segmented into sections, like it is shown by 32 and 33, it will be required to have at least one complete inductor surrounding a centre core, like shown at 31, creating two magnetic paths, based on the principle as shown in figure 2.C. The ring head as displayed at 111 seems to be too flat. If the ring can be made between 3 and 10 cm wide, the height of a single magnetic path around a single piece of inductor wiring 35 that itself can be between 1 and 3 cm would end up to be between 7 and 23 cm high. To allow the guidance system to be made into sections as well, like it is shown by 42 and 43, it will also be required to contain completely formed inductors like it is partially shown in figure 6 having this guidance system to have tree fully formed individual inductors: 441, 442 and 443. Each fully formed inductor magnet will consist of two magnetic paths each. So each inductor can be responsible for a height between 14 and 46 cm within the total height of a guidance system. For example, if a single inductor wire through a single magnetic path would form a square of 1 cm, the power consumption (P) per magnetic path (n) per meter of system length (L) could then be 112 Watt/meter/path. If this amount of inductor wiring would be applied in the example as shown in figure 4, it would have three inductor wires per ring system, creating six magnetic paths in each of the four ring systems. Some 12.3% of the saturation current may be required at the suspension system.

Electromagnets can be used to guide and suspend the rotating ring. After guidance and suspension, a third active electromagnetic based system can be used to accelerate and decelerate the ring, to add and remove its kinetic energy, charging and discharging the energy storage system by changing the rings velocity. This can be achieved using artificially made 'actively controllable sequential electromagnetic fields' produced by the 'stator' 2 of the system, made by electromagnets placed side by side 22, facing a 'rotor structure' 115 and 125 which will be attached to the ring 1, facing each other along the entire perimeter length for each ring system. The produced sequential electromagnetic field will be picked up by the rotor structure of the ring, applying torque. This so called 'rotor structure' can be constructed mainly based on two different types, of solutions by means of magnetic composition: A rotor structure made by permanent magnets 117 and 127 attached to the ring facing towards the stator, making the ring to always try to catch up exactly with the displacement of the sequential magnetic field without slip when charging the system. Without empowering the electromagnets, the rings permanent magnets will keep on inducing an alternating magnetic field in the stators electromagnets, proportional in Voltage and frequency to the rings velocity. Discharging can easy be achieved by transferring the induced alternating Voltage into a load producing current which first can be rectified even by passive rectifiers (like using diodes only). Or by a rotor structure made by the use of short circuit windings 114, 116, 124 and 126 incased directly into the rings own iron core, sharing the same core material 113 and 123, or by some ferrite based material 115 and 125, to construct a squirrel cage rotor setup like shown in figure 7, which forms a circumferential shallow curved linear like structure. Similar to the operation of a squirrel cage induction motor (see also: en.wikipedia.org/wiki/Induction_motor). This type of rotor structure will also try to catch up speed toward the displacement of the actively applied sequential magnetic field, but in this case it does have slip in proportion to the amount of torque being exchanged between the stator system and the ring through its rotor structure. Without empowering the electromagnets, this type of rotor structure does not create any magnetic field, so it will not induce any alternating magnetic field in the stators electromagnets. For this type of rotor structure, the stator is required to induce its own sequential electromagnetic field for transfer of torque into, as well as out from the ring by small changes in sequence frequency in relation to the rings velocity. This difference also translates directly to the amount of slip. When the ring accelerates, the impedance of the stator electromagnets behaves almost resistive. When the stator is empowered, but its sequence follows the rings velocity without slip, the impedance of the stators electromagnets behaves inductive. When the ring decelerates, the impedance of the stators electromagnets behaves almost counter resistive, where AC Voltage and AC Current almost opposes each other, shifted in phase almost 180° declaring necessity of a specific calculated active sequential stator excitation also for recuperating electric power out of stored kinetic energy when a type of squirrel cage rotor is used. Each rotor structures are able to exchange torque between the ring and the stator system, changing the rings velocity enabling it to apply acceleration as well as deceleration.

A main reason for the design of a guidance based energy storage system is to use less- as well as cheaper material per amount of storable kinetic energy. With the use of a guidance system the tensile force in the ring can be reduced to zero, by centripetal force to be transferred by magnetic force. Ring systems 5 per energy storage facility 71 will most likely be between one and ten (like four in figure 4). An amount of recoverable electrical energy per commercial facility will roughly be between 2 and 1000 GWh. This makes the calculated max. ring velocity to be in a range between 690 and 4,116 m/s.

Despite having the energy stored kinetically using a contact free suspended rotating ring, completely surrounded by almost vacuum, even with the ring in total to have no head sides that would result in some parachute like effect. It may experience drag from the large ring surface area that passes facing the large surface area of all the static parts that includes all direct facing surface area surrounding the ring, such as: the drive stator, the suspension system, the guidance system, and even the passive static surface underneath the ring. This drag independently translates to a power loss or self-discharge, proportional to the air pressure of the vacuum, the rings total amount of outer surface area, the rings velocity squared and divided by the gap clearance between the ring and its static surrounding. Estimated is the optimal gap clearance between the ring and the active systems to be in a range of one millimeter. Estimated is the velocity to be between 690 and 4,116 m/s depending to the circumferential ring size. Estimated could be the vacuum pressure to be more or less one Pascal to perform optimal. From a systems self-discharge perspective any lower pressure is desired, but this requires more pumping power and pumping installation capacity and price as well. On the other hand a higher pressure may also be desired for ring cooling purposes. When energy storage transfer takes place by applying torque by the stator onto or from the rotor, it will accumulate heat buildup when its completely surrounded by vacuum. This heat can partially be released by heat radiation, but at the same time as well by extremely low pressure, high velocity air convection. To reach an optimum performance based on vacuum air pressure, an optimization according the amount of: velocity, energy transfer, pumping power and ring temperature has to be considered to be an integral actively maintained and adjustable part of the energy storage process, mainly depending on its ring temperature.

To prevent damage at bringing a ring to a complete standstill, and to reduce the required energy to accomplish it, it is possible to add small wheels 56 in the floor of the vacuum housing, so the ring is allowed to be carefully dropped from the suspension system even when it still moves slowly when the system itself does not generate enough recoverable power out of the kinetic movement from its own stator to energize its own suspension system.

To attain an effective safely functioning artificially gap clearance feedback loop, for each suspension system 613 as well as each guidance system 614, it may require more than one system to observe the exact clearance between each of them and the ring at any given point and at any given time.

CLAIMS

1. An energy storage system comprising
a main facility housing construction (7), founded into soil firmly by being placed firmly attached to a soil,
comprising at least one ring system (5),
each ring system (5), comprising an enclosed ring system housing (54) for providing vacuum, at least one
electromechanical part, the part comprising an exchanger for exchanging electrical power into
mechanical energy and vice versa, comprising,
a solid ring-shaped mass (1),
a stator system (2), comprising along the perimeter sets of lengthwise arranged electromagnets, adapted for transferring electromechanical linear propulsion towards and from
the solid ring-shaped mass,
a suspension system (3) comprising electrically manipulatable magnet constructions, comprising electromagnets, adapted for transferring of electromechanical vertical force towards the
solid ring-shaped mass and for countering its gravitational force, and
a guidance system (4), comprising electrically manipulatable magnet constructions, comprising electromagnets, adapted for transferring of electromechanical horizontal force towards the
solid ring-shaped mass and for countering its centripetal force.

2. The system according to claim 1, where the solid ring-shaped mass comprises at least two connectable ring sections.

3. The system according to claim 1 or 2, comprising at least two ring system modules, where each module comprises an internal system.

4. The system according to any of claims 1-3, comprising a squirrel cage rotor construction adapted to accelerate and to decelerate the solid ring-shaped mass by means of interaction between a stator system, and the rotor comprising short circuit windings, preferably as an integral part of the solid ring-shaped mass wherein a combined same piece of iron core is part of both the solid-ring mass and the rotor.

5. The system according to any of claims 1-3, comprising a squirrel cage rotor construction adapted to accelerate and to

decelerate the solid ring-shaped mass by means of interaction between a stator system, and the squirrel cage rotor construction comprising internal short circuit windings embedded in ferrite, mounted directly to the solid ring-shaped mass' surface.

6. The system according to any of claims 1-3, comprising alternating magnetic polarity arranged permanent magnets mounted to the rings surface, adapted to accelerate and to decelerate the solid ring-shaped mass by means of interaction between the stator system and a permanent magnet rotor construction.

7. The system according to any of claims 1-6, where at least one ring system comprises a stator system, adapted for creating artificially controllable sequential progressing electromagnetic fields to interact with any of the mentioned rotor systems to enable bi-directional exchange in mechanical force.

8. The system according to any of claims 1-7, where at least one ring system comprises a suspension system, arranged in sections, divided according the division of ring systems modules, adapted to provide suspension along an entire circumferential length inside an entire ring system, where each suspension system section comprises electrically manipulatable magnet constructions, comprising electromagnets.

9. The system according to any of claims 1-8, where at least one ring system comprises a guidance system adapted to compensate a ring's centripetal force by means of a divided setup along the entire circumferential length inside each entire ring system, in a sectional divided setup, where each guidance system section comprises electrically manipulatable magnet constructions, comprising electromagnets.

10. The system according to claim 9, in which the guidance system comprises individual controllable electrically manipulatable magnet constructions by being arranged over the vertical height within at least one section of the guidance system adapted to control ring tilting, such as by feedback control.

11. The system according to any of claims 1-10, where a main facility housing construction comprises internal mounting and support structures for the ring system for the subsequent assembly and disassembly of ring systems.

12. The system according to any of claims 1-11, where a main facility housing construction is anchored into the soil comprising external additional mounting constructions at some length

interval along the perimeter of the main facility housing for capturing the centripetal forces throughout the main facility housing construction outward.

13. The system according to any of claims 1-12, where a main facility housing construction is anchored into the soil comprising external additional span constructions, by means of chains or cables at some length interval along the perimeter of the main facility housing for capturing the centripetal forces throughout the main facility housing construction outward towards an anchor point.

14. The system according to any of claims 1-13, where a main facility housing construction is anchored into the soil comprising external additional pile constructions by means of piles at some length interval along the perimeter of the main facility housing for capturing the centripetal forces throughout the main facility housing construction outward.

15. The system according to any of claims 1-14, where a main facility housing construction is placed elevated above the soil, comprising pillar constructions where the pillars are anchored into the soil at some length interval along the perimeter of the main facility housing to capture and transmit the centripetal forces throughout the main facility housing construction outward.

16. The system according to any of claims 1-15, where a main facility housing construction is placed elevated above the soil, comprising pylon constructions where the pylons are anchored into the soil at some length interval along the perimeter of the main facility housing to capture and transmit the centripetal forces throughout the main facility housing construction outward.

17. The system according to any of claims 1-16, for storing at least one hundred Mega Watt hour (MWh), and/or peak power provision of more than ten Mega Watt peak (MWp).

18. The system according to any of claims 1-17, where a solid ring-shaped mass comprises a mechanism, where each ring section comprising at least one screw mechanism coupled to a transfer axle to transfer a ring section gap spacing setting mechanically from one end of each section to the other end, to obtain a balanced gap spacing between every two up following ring sections.

Fig. 1

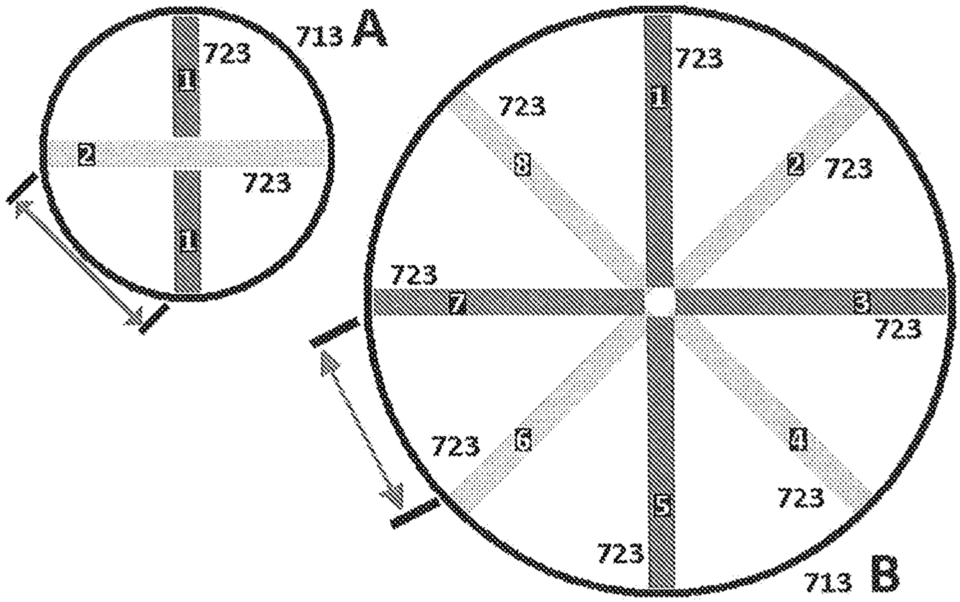
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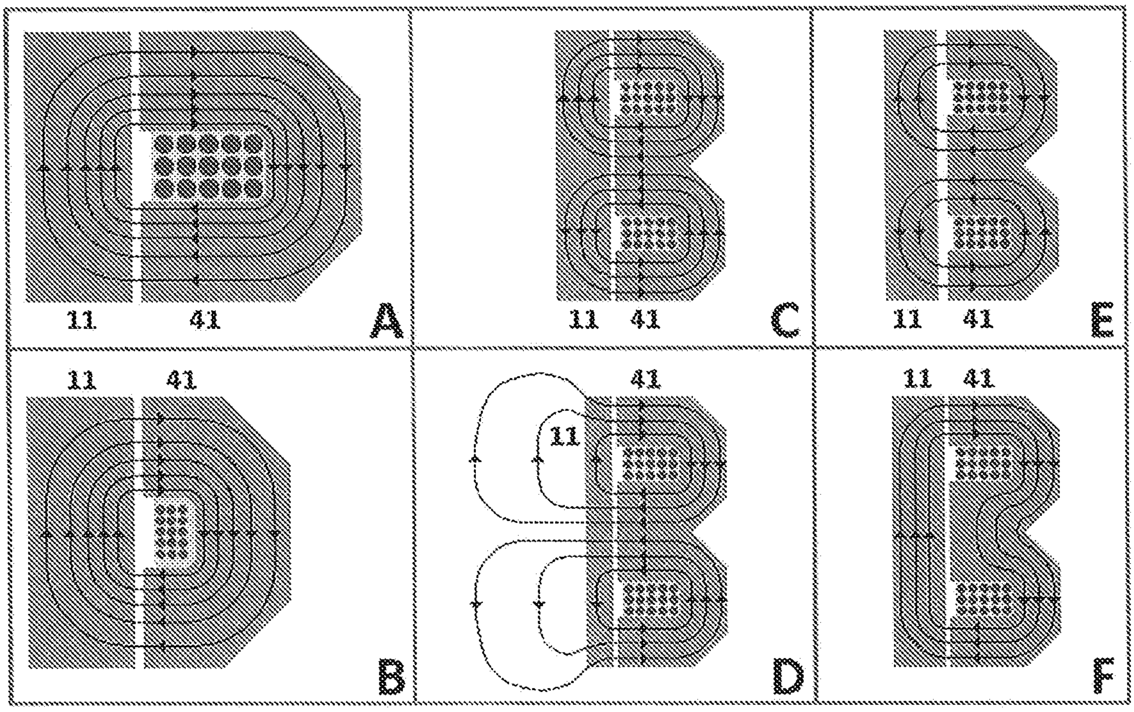
Fig. 2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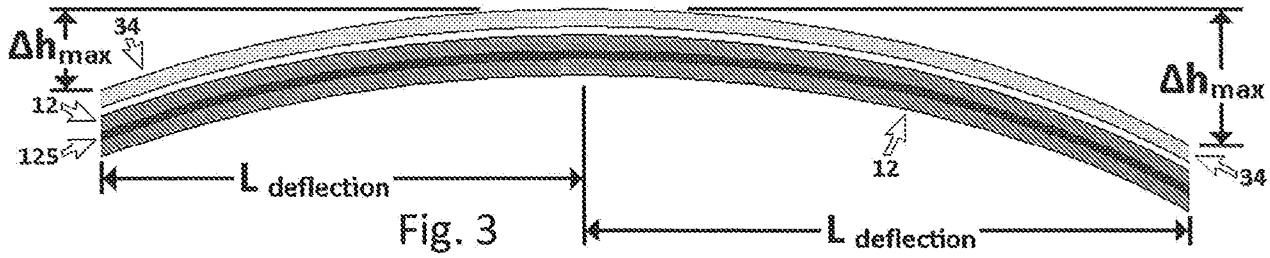
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Fig. 3

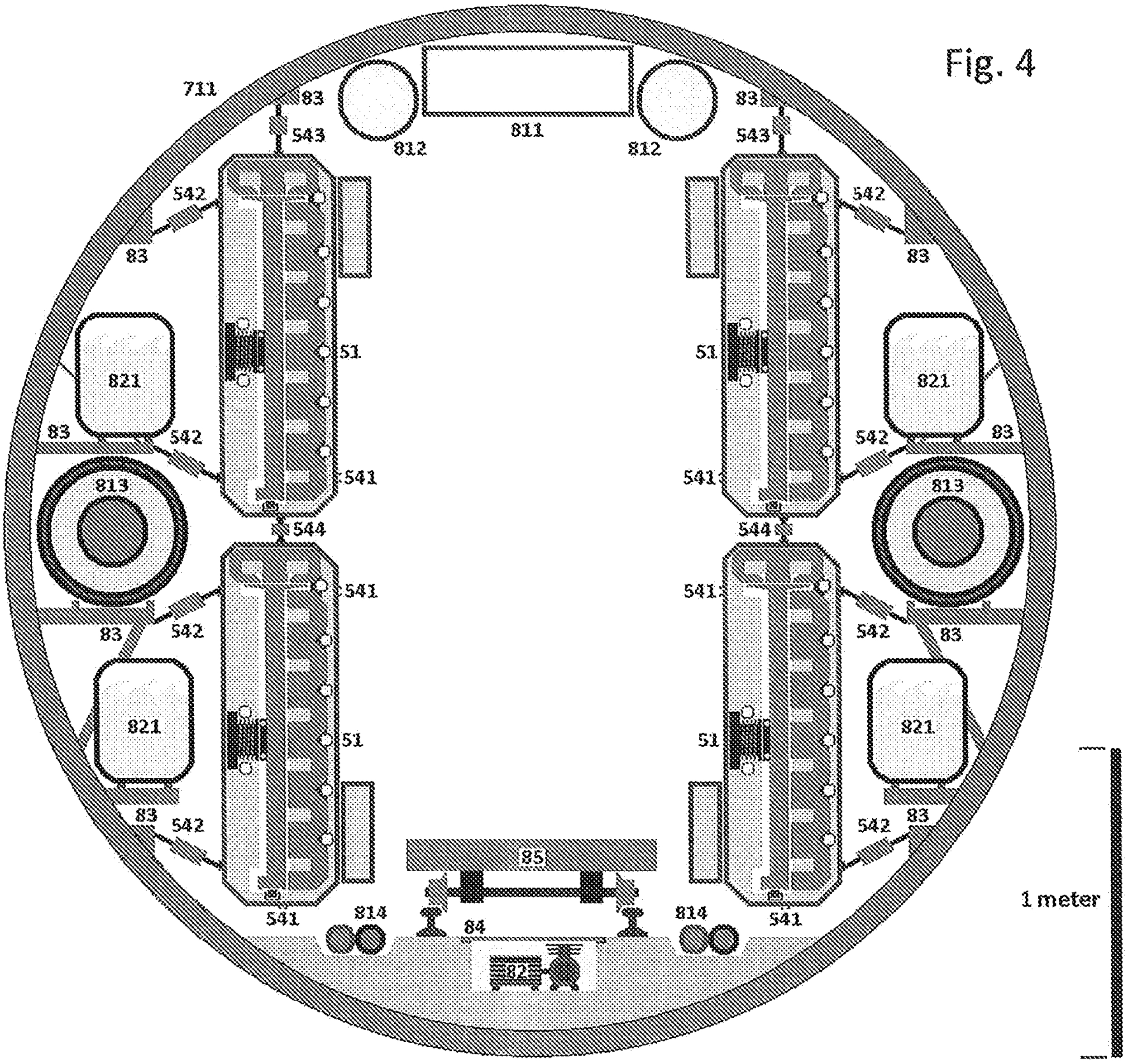
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Fig. 4

Fig. 5

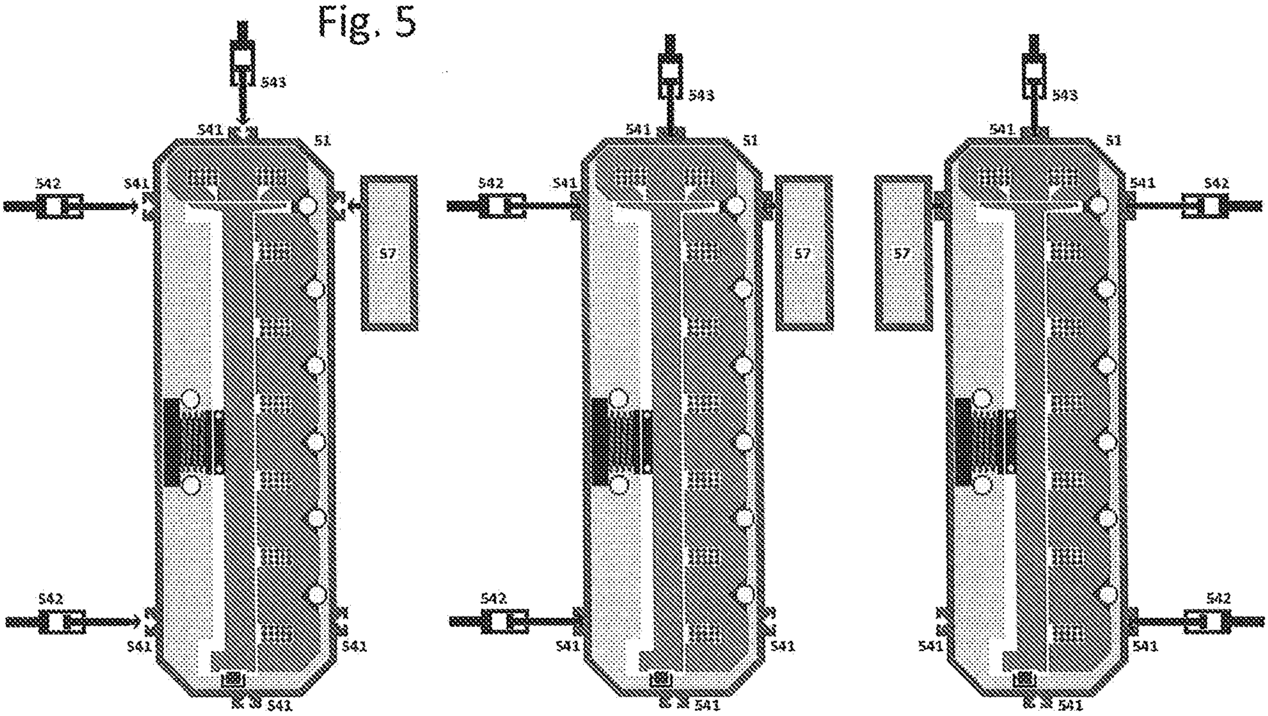
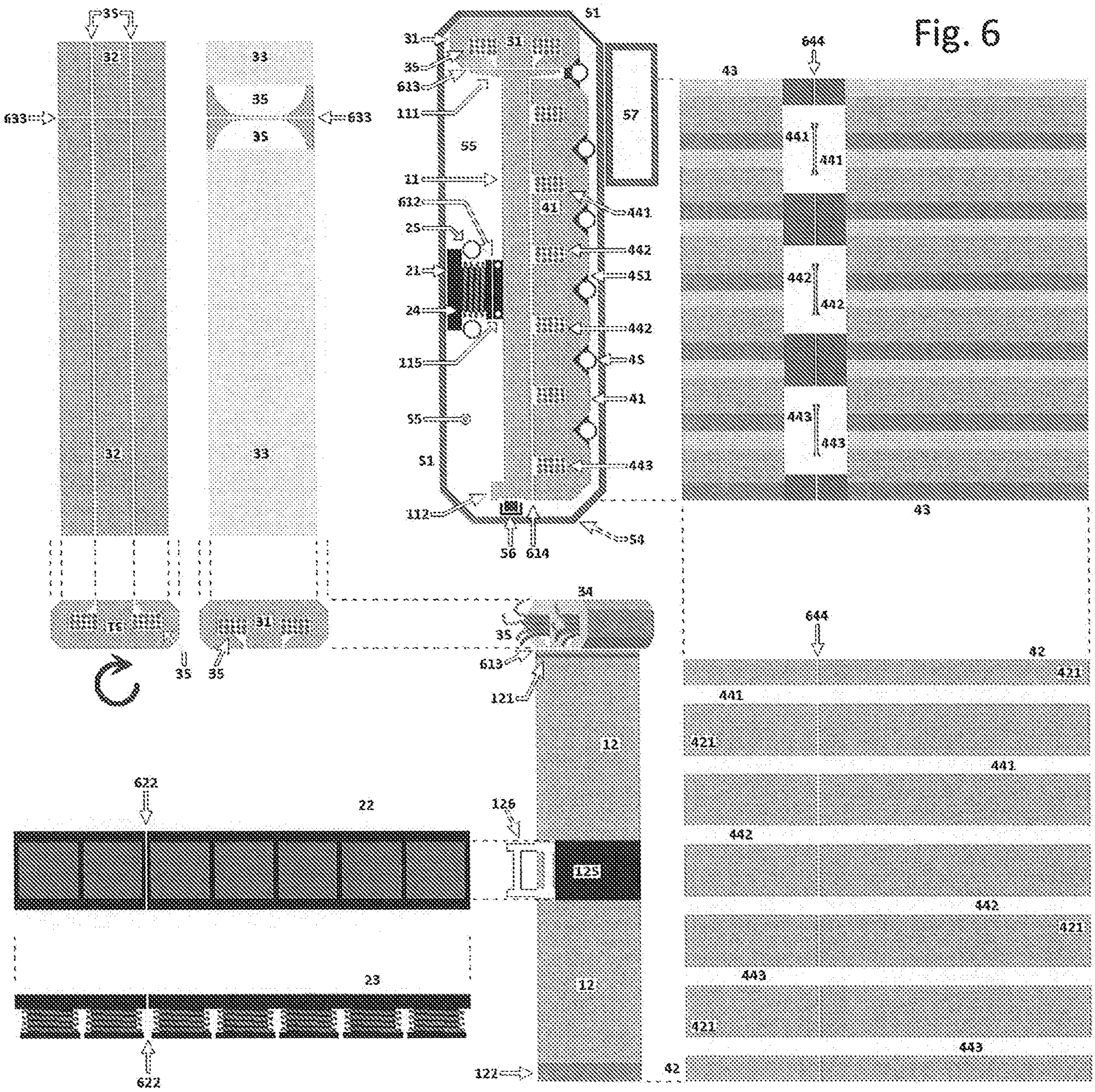


Fig. 6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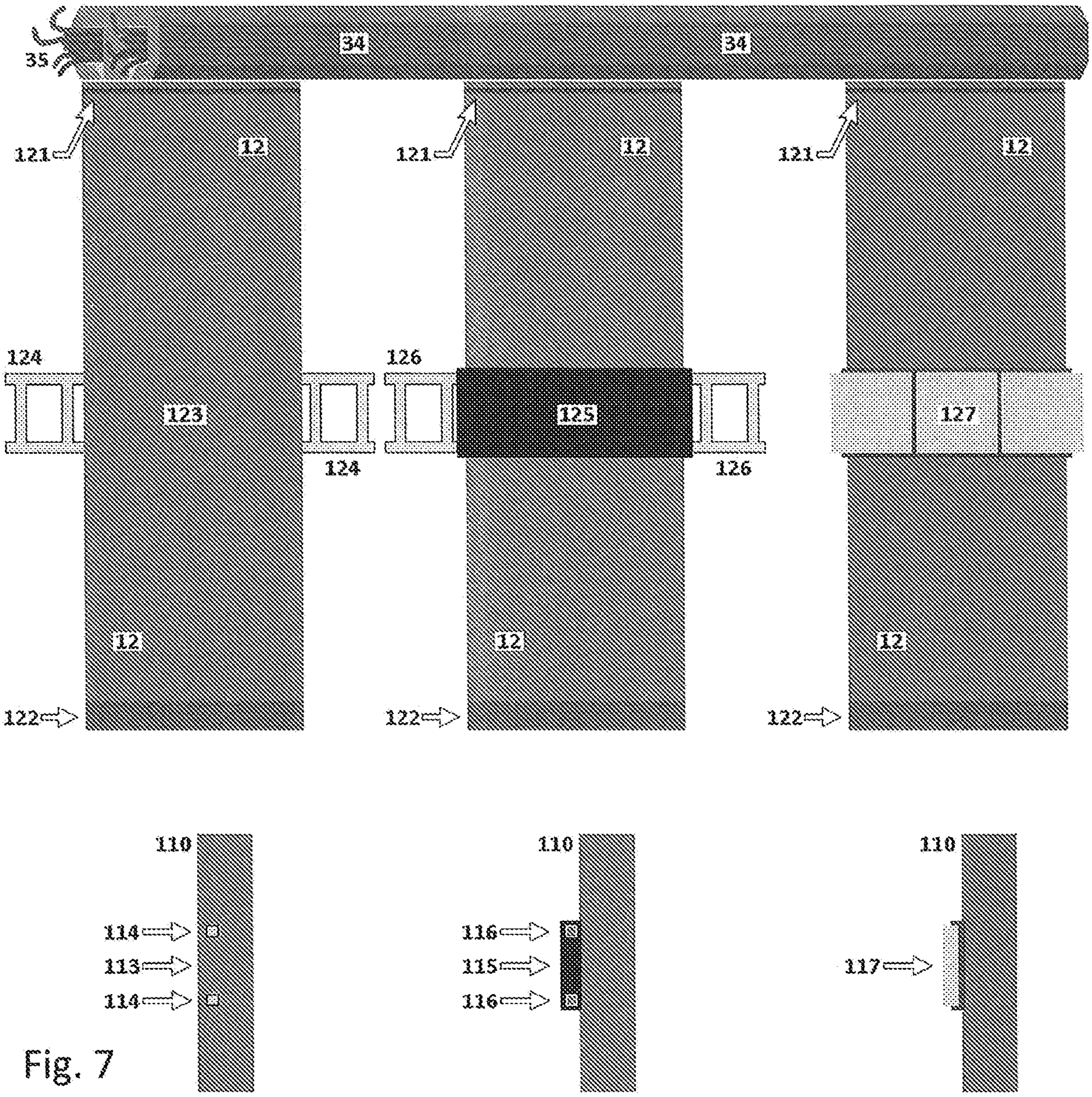
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Fig. 7

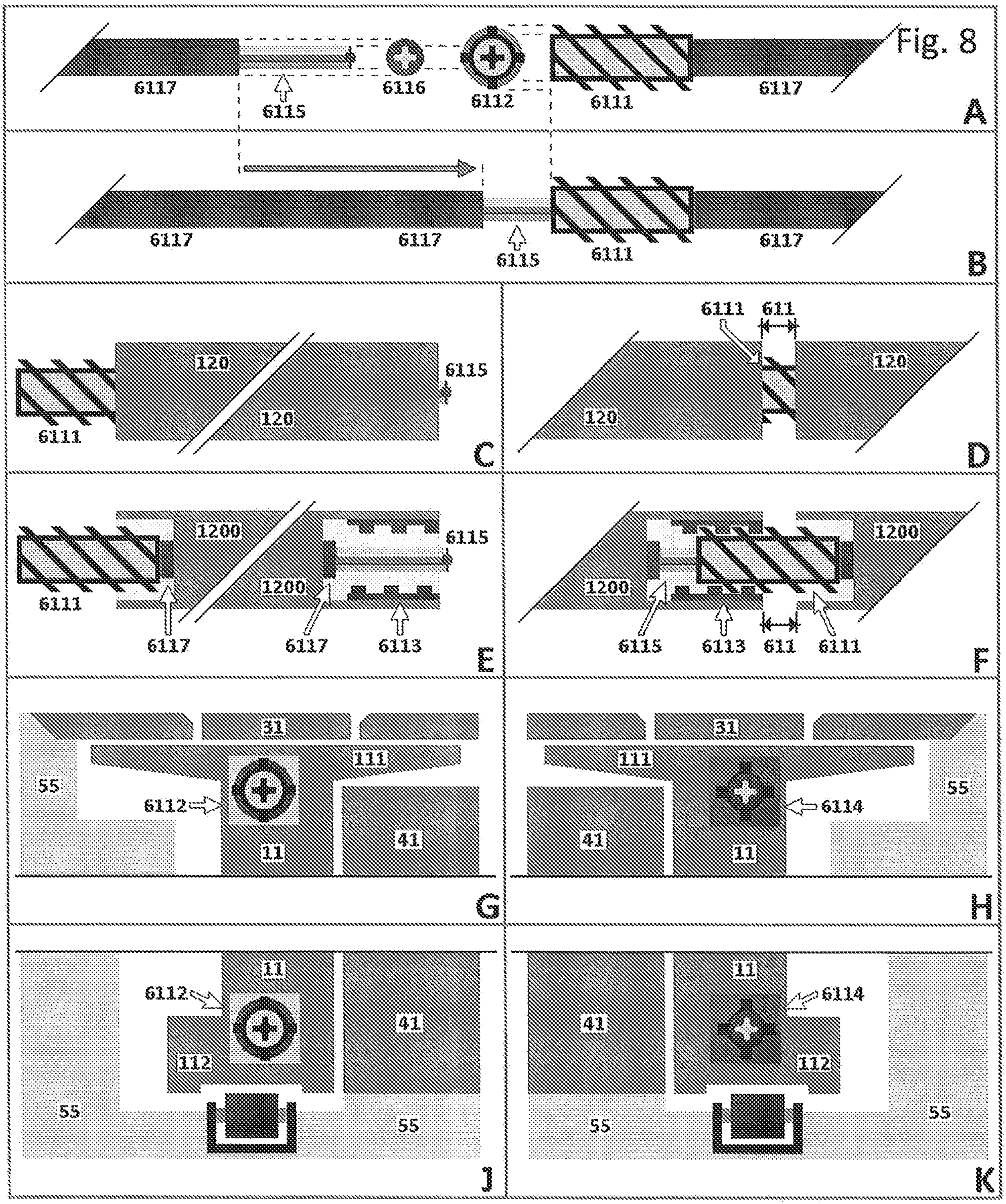
Fig. 8
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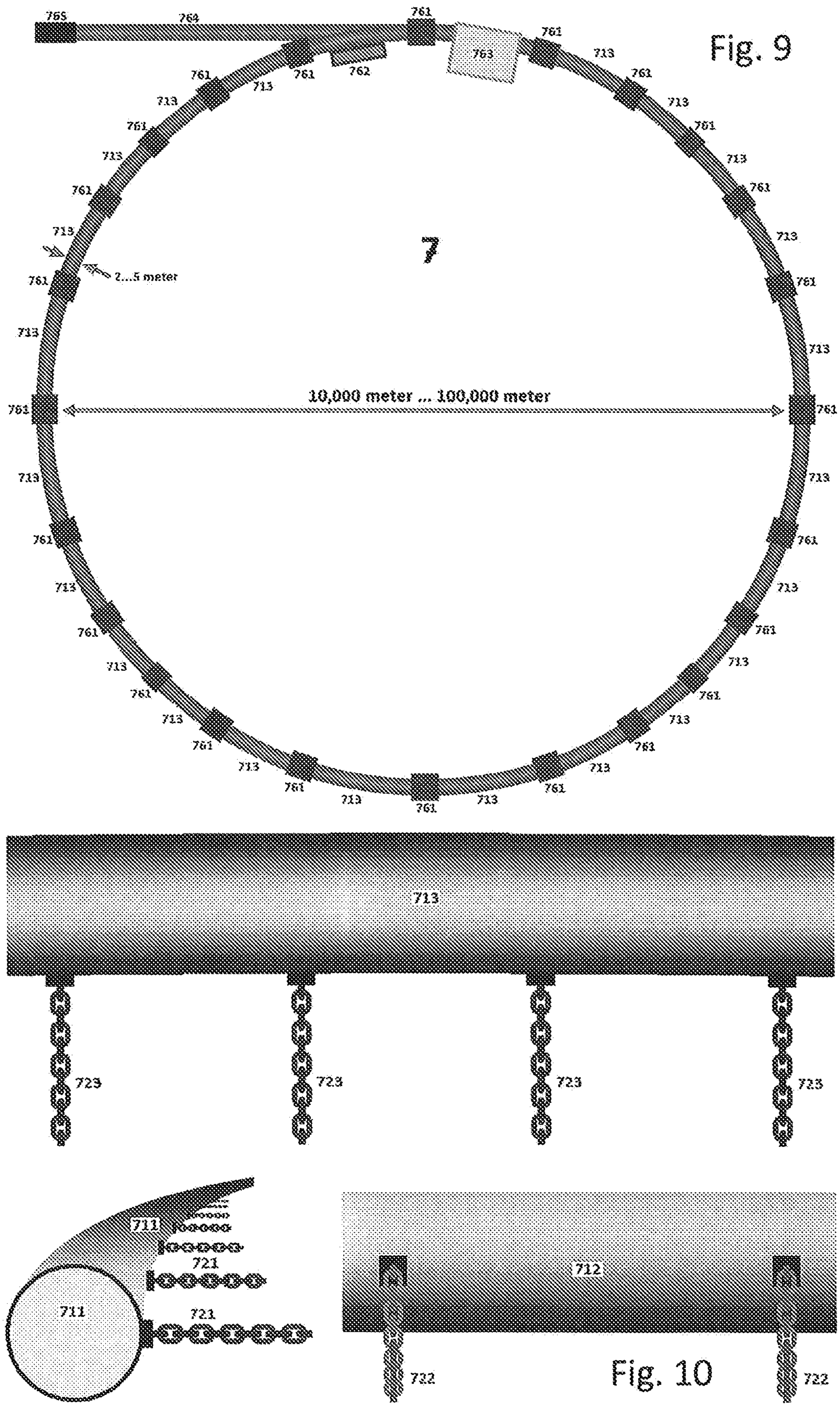
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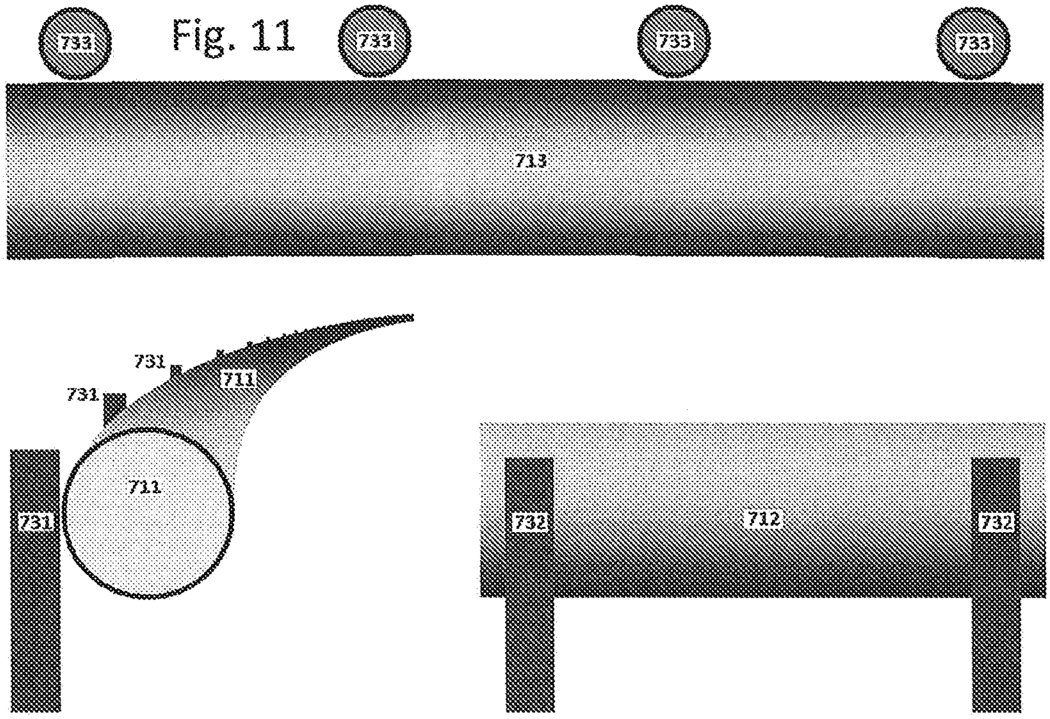
Fig. 9

Fig. 10

Fig. 11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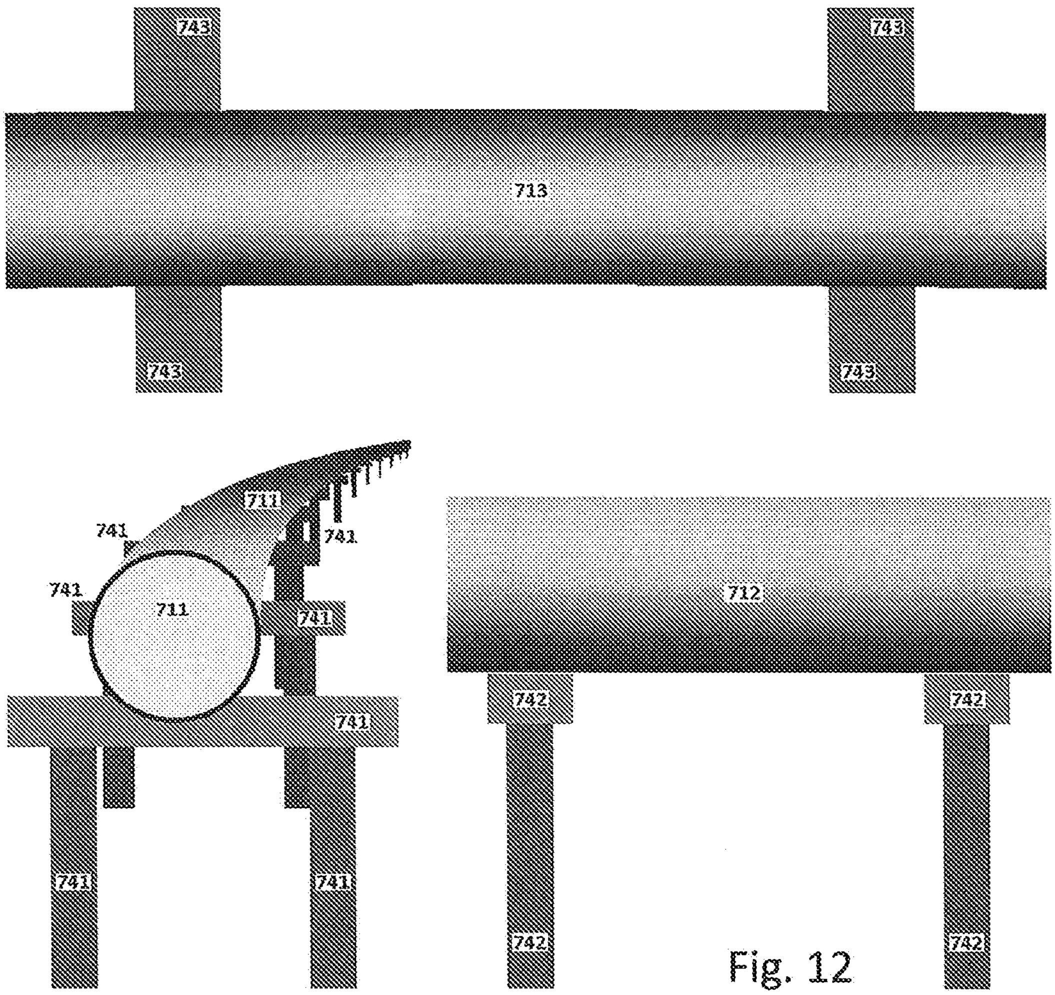
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Fig. 12

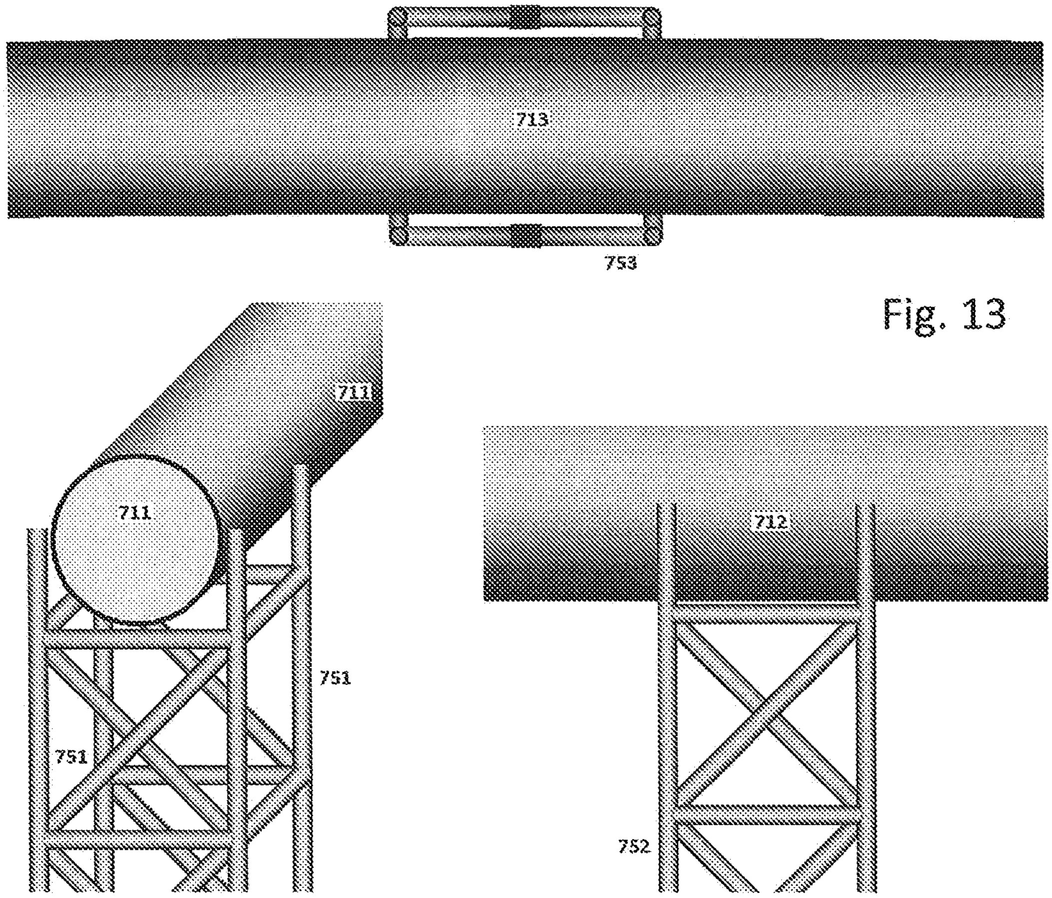
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Fig. 13

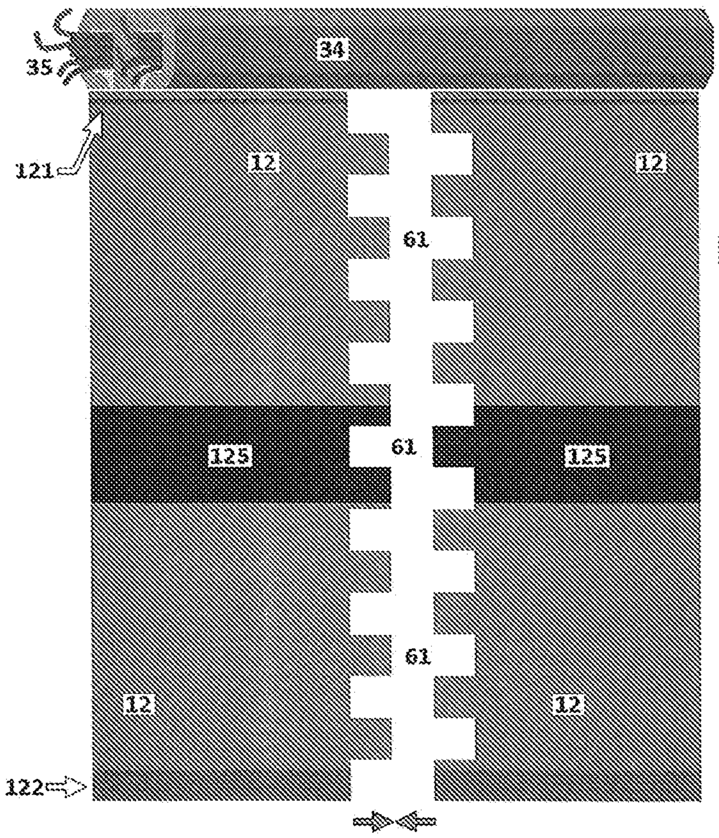
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Fig. 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2019/050512

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03G3/00 H02K41/02 H02K7/18
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F03G H02K B61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 2015/047092 A1 (STICHTING ENERGIE [NL]) 2 April 2015 (2015-04-02) page 2, lines 16-20; figures 1-3 page 3, lines 17-22 page 4, lines 9-18 page 5, lines 19-29 -----	1-18
A	US 4 148 260 A (MINOVITCH MICHAEL A) 10 April 1979 (1979-04-10) abstract; figure 3 -----	1
A	US 2018/058244 A1 (GOODWIN ROBERT LOVEJOY [US]) 1 March 2018 (2018-03-01) abstract; figure 24 -----	1
A	EP 2 574 785 A2 (BOEING CO [US]) 3 April 2013 (2013-04-03) paragraphs [0030], [0031]; figure 1 -----	1
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 November 2019	28/11/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	de Martino, Marcello

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2018/166946 A1 (WALSH RAYMOND JAMES [US]) 14 June 2018 (2018-06-14) paragraph [0022]; figure 8 -----	1
A	US 2003/192449 A1 (FISKE ORLO JAMES [US] ET AL) 16 October 2003 (2003-10-16) paragraph [0051]; figures 9a,9b -----	1

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL2019/050512

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
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US 2018058244	A1	01-03-2018	NONE			
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