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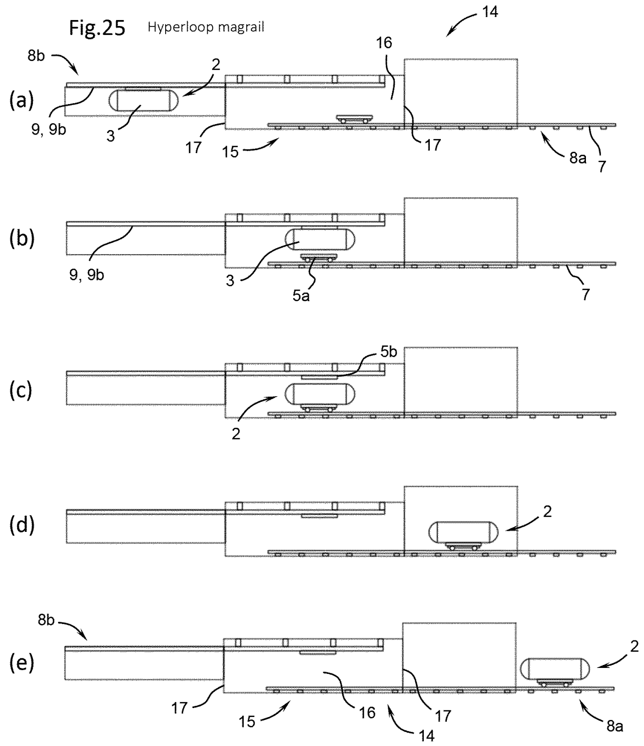
(54) INTEROPERABILITY SYSTEMS FOR RAILWAY INFRASTRUCTURES

(57) A railway system including at least two railway guide systems (8, 8a, 8b) interfacing at a system conversion station (14), at least one railway guide system comprising a magnetic levitation railway track (9) and the other railway guide system comprising one of a wheel railway track (7) and a magnetic levitation railway track (9), the system conversion station (14) comprising a bogie storage zone for storing one or more bogies adapted for locomotion on the first railway guide system and for storing bogies adapted for locomotion on the second railway guide system.

Fig.25 Hyperloop magrail



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Description

[0001] The present invention relates to an interoperable railway system enabling railway vehicle carriages to be transported on different railway guide systems including wheel railway tracks and magnetic levitation railway tracks and optionally also in vacuum tube railway guide systems.

[0002] Railway infrastructure in Europe and other continents includes a plurality of different systems and standards. Due to the different systems and standards, different railway guide systems may only be used with railway vehicles conforming to specific standards and that are isolated from railway networks having other standards and systems. The lack of interoperability between different railway network systems is a significant drawback in the fluidity of transporting goods and persons as well as increasing infrastructure costs. There would be a significant advantage in interconnecting various existing networks as well as enabling existing networks to be upgraded or to add on new railway networks with more advanced technologies. In view of the large park of existing railway vehicles, it would however be necessary to allow existing vehicles to continue operating on existing infrastructure.

[0003] In recent years there has been a development of new means of transport that could be an alternative or a complement to conventional rail. These are mainly magnetic railroads, vacuum railroads, and magnetic levitation railway systems interoperable with traditional rail infrastructure. Moreover, both in the European Union and in the United States, work has already begun to regulate new modes of transport. This approach is expected to make it possible to unify the standard for the vacuum tube railway and magnetic levitation railway systems. However, aspects of interoperability between systems are still a challenge.

[0004] In view of the foregoing, it is an object of this invention to provide a system that allows railway carriages to operate on different railway infrastructure networks including at least a wheel railway network and a magnetic levitation railway network that is interoperable in a cost effective and efficient manner, in particular allowing the transfer from one system to another system rapidly and efficiently, while allowing existing networks and infrastructure to continue to be utilized and new infrastructure to be added.

[0005] It is advantageous to further ensure interoperability with vacuum tube railway infrastructure systems.

[0006] It would be advantageous to provide a system that allows integration of an atmospheric pressure network to a vacuum tube network.

[0007] It would be advantageous to allow interoperability between networks of the same basic type, for instance wheel railway networks, that are of different gauges.

[0008] It would be advantageous to provide an interoperability system that may boost or replace existing propulsion systems.

[0009] Objects of the invention have been achieved by providing a modular railway vehicle according to claim 1.

[0010] Objects of the invention have been achieved by providing a railway system according to claim 10.

[0011] Disclosed herein is a modular railway vehicle comprising a carriage, one or more bogies and a corresponding one or more coupling mechanisms interconnecting the bogies to the carriage, the coupling mechanism comprising a bogie coupling interface fixed to the bogie and a carriage coupling interface fixed to the carriage, the bogie coupling interface being lockable and detachable to the carriage coupling interface allowing different bogies to be exchangeably attached to the carriage such that the modular railway vehicle may be adapted for circulation on railway guide systems of different types including at least a magnetic levitation railway track, the carriage being provided with at least one carriage coupling interface on a floor of the carriage and at least one carriage coupling interface on a roof of the carriage.

[0012] In an advantageous embodiment, the bogies are selected from a group including bogies with wheel track engaging members and bogies with magnetic levitation track engaging members.

[0013] In an advantageous embodiment, the track engaging members are connected to a base of the bogie via a suspension.

[0014] In an advantageous embodiment, the carriage comprises at least two carriage coupling interfaces positioned under the carriage floor.

[0015] In an advantageous embodiment, the carriage comprises at least two bogie coupling interfaces positioned on the carriage roof.

[0016] In an advantageous embodiment, the coupling mechanism includes a guide pin on one of the bogie or the carriage and a complementary guide cavity on the other of the bogie or carriage, the guide pin and cavity having a tapered or conical shape portion.

[0017] In an advantageous embodiment, the coupling mechanism includes pluggable electrical interconnections for establishing electrical contact between the carriage and the bogie for power and/or signal transmission.

[0018] In an advantageous embodiment, the vehicle comprises at least one propulsion system including a linear electric motor having a mover fixed to the modular railway vehicle for electromagnetic drive coupling to a stator mounted on a railway guide system.

[0019] In an advantageous embodiment, the mover comprises one or more permanent magnets, or an induction plate for coupling to an electromagnetic field generated in the stator.

[0020] Also disclosed herein is a railway system including at least two railway guide systems interfacing at a system conversion station, at least one railway guide system comprising a magnetic levitation railway track and the other railway guide system comprising one of a wheel railway track and a magnetic levitation railway track, the system conversion station comprising a bogie storage zone for storing one or more bogies adapted for locomotion on the first railway guide system and for storing bogies adapted for locomotion on the second railway guide system.

[0021] In an advantageous embodiment, the magnetic levitation railway track is a floor-mounted or an overhead magnetic levitation railway track.

[0022] In an advantageous embodiment, at least one of the railway guide systems is a magnetic levitation railway track in a vacuum tube .

[0023] In an advantageous embodiment, the system conversion station comprises an airlock with a chamber with sealing doors on either end of the chamber to allow a change in pressure from a first railway guide system to a second railway guide system.

[0024] The railway system may further including a plurality of modular railway vehicles according to the embodiments described above.

[0025] Further objects and advantageous features of the invention will be apparent from the claims, from the detailed description, and annexed drawings, in which:

Figures 1 to 4 illustrate schematically in cross-section, viewed in the direction of travel, different *per se* known railway systems including a magnetic levitation railway system in a vacuum tube (figure 4), a conventional wheel track railway system (figure 2), and a conventional wheel track railway system retrofitted with a magnetic levitation railway system for transporting both conventional wheel track railway vehicles and magnetic levitation railway vehicles along the same railway network (figures 1 and 3);

Figures 5 to 9 schematically illustrate in cross-section various *per se* known magnetic levitation and guide systems, figure 5 illustrating a floor-mounted magnetic levitation railway track with a centrally positioned magnetic propulsion system, figure 6 illustrating a floor-mounted combined magnetic propulsion and levitation system centrally arranged, figure 7 illustrates a roof-mounted magnetic levitation and lateral guide system, figure 8 illustrates an alternative roof-mounted levitation, guide and propulsion system, and figure 9 illustrates an " X " arranged lateral guide and propulsion system;

Figures 10 to 12 schematically illustrate in cross-section various *per se* known linear propulsion systems, figure 10 illustrating a permanent magnet linear synchronous motor in cross-section, figure 11 illustrating a linear induction motor in cross-section, and figure 12 illustrating an embodiment of a linear synchronous reluctance motor in cross-section;

Figures 13 to 20 schematically illustrate in simplified form various configurations of electrodynamic levitation components for the magnetic levitation rails, such magnetic levitation rails being *per se* known and having permanent magnets and/or electromagnets for generating a magnetic levitation force between a stator and mover during at least the linear displacement of the mover along the stator;

Figure 21 illustrates a schematic view in longitudinal cross-section of an embodiment of a floor-mounted bogie and coupling mechanism for coupling the bogie to a carriage of a railway vehicle;

Figure 22 illustrates a schematic view in longitudinal cross-section of an embodiment of a roof-mounted bogie and a coupling mechanism for coupling the bogie to a carriage of a railway vehicle;

Figure 23 is a simplified longitudinal cross-section of a railway vehicle according to an embodiment of the invention illustrating a carriage coupled to floor-mounted bogies;

Figure 24 is a view similar to figure 23 of the carriage coupled to roof-mounted bogies for overhead magnetic levitation and propulsion of the railway vehicle;

Figure 25 illustrates in a simplified cross-sectional manner a first embodiment of an interoperable railway system including a system conversion station allowing conversion from a vacuum tube railway system to a conventional wheel track railway system;

Figure 26 is a schematic top cross-sectional view of the system conversion station of figure 25 illustrating storage zones for bogies of the vacuum tube railway guide system and wheel track railway guide system;

Figure 27 is a view similar to figure 26 of a similar embodiment;

Figure 28 is a view similar to figure 25 of a system conversion station for conversion from a vacuum tube system to another vacuum tube system;

Figure 29 is a view similar to figure 28 of yet another embodiment for conversion from a floor-based magnetic levitation system to another floor-based magnetic levitation system;

Figure 30 is yet another embodiment illustrating a conversion station for conversion of a floor-based magnetic levitation system to an overhead magnetic levitation system;

Figures 31 and 32 are schematic simplified views in cross-section of a system conversion station airlock, figure 31 showing the airlock with a door in an opened position and figure 32 showing the airlock with a door in a closed position.

[0026] Referring to the figures, starting with figures 1 to 4, railway systems of different types are illustrated, each being *per se* known. In figure 2, a conventional wheel railway vehicle 2a is illustrated having a carriage fitting within an outer standard profile 30 on a railway guide system 8 formed of a wheel railway track 7. The wheel railway track 7 may be combined, or retrofitted if it already exists, with a magnetic levitation railway track 9 having magnetic levitation rails 22, and a propulsion system with a linear motor 10 having a stator 11 and a mover 12 mounted on the carriage 3 of the magnetic levitation railway vehicle 2b, as illustrated in figures 1 and 3. A railway system for implementation of magnetic levitation railway tracks in existing wheel track infrastructure is described for instance in publication WO 2020/038964. The magnetic levitation railway vehicle 2b may be configured to move along a magnetic levitation track 9 mounted in parallel to the wheel railway track 7 in order to use existing wheel track infrastructure, and may also be driven along a dedicated magnetic levitation railway track that may in addition be provided within a vacuum tube 13 as illustrated schematically in figure 4.

[0027] The conventional wheel railway vehicle may be an electric vehicle comprising a pantograph 31 that connects to a catenary, for instance overhead the railway system as is well known. The conventional railway vehicle 2a however may also be driven by autonomous power means such as a diesel engine onboard the locomotive.

[0028] Referring to figures 5 to 8, different magnetic levitation and propulsion systems for magnetic levitation railway vehicles 2b are schematically illustrated. The suspension system and linear motor may be separated, for instance as illustrated in the embodiments of figures 5 and 7 where the magnetic levitation rails 22 are separate from the linear motor 10 comprising a stator 11 mounted on the ground or roof of a tube and a mover 12 mounted on the railway vehicle 2b. The suspension system and linear motor may however be combined for both propulsion and magnetic levitation as is schematically illustrated in the embodiment of figure 6 or in the embodiment of figures 8 and 9, figure 8 illustrating a roof-mounted magnetic levitation system to which the carriage 3 is suspended, and in figure 9 the magnetic levitation propulsion system may be distributed around the carriage within a tube 13 of a vacuum tube railway system.

[0029] The linear motor 10 of the propulsion system may have various configurations. In a first example, the motor may for instance be in the form of a permanent magnet linear synchronous motor illustrated schematically in cross-section in figure 10 having a ferromagnetic back plate 33 coupled to permanent magnets 34 of alternating polarity forming part of the mover 12 that electromagnetically couples to the stator 11 comprising a ferromagnetic core 35 and electromagnet windings 36 wound thereon to provide the electromagnetic alternating field to drive the mover. A permanent magnet linear synchronous motor is a linear motor consisting of two parts moving relative to each other. The first comprises for instance three-phase windings, while the second is equipped with permanent magnet systems. When energized, the windings produce a magnetic field that interacts with the magnetic field from the permanent magnets. By appropriately controlling the frequency and voltage of the winding supply, the magnetic field starts to travel along with the motor, thus producing a synchronous relative motion of the stator with respect to the magnetic poles. Depending on the configuration, the winding can be stationary and placed in the track along the entire route (long-primary motor) or moving and placed on the vehicle (short-primary motor) and interacting with magnets on the stator.

[0030] Another example of a linear motor 10 is illustrated in figure 11 showing a linear induction motor, the cross-section showing a ferromagnetic back plate 33 that is mounted behind a conductive induction plate 37 such as an aluminium or copper plate that couples electromagnetically to a stator 11 comprising a ferromagnetic core 35 and windings 36 thereon. A linear induction motor is a linear motor consisting of two parts moving relative to each other. The first comprises for instance three-phase windings, while the second comprises a stack of aluminum plates laid on a ferromagnetic backplate. When energized, the windings produce a magnetic field. By appropriately controlling the frequency and supply voltage of the winding, the magnetic field starts to travel along the motor, thus creating asynchronous relative motion of the stator with respect to the magnetic poles. Depending on the configuration, the winding can be stationary and placed in the track along the entire route (long-primary motor) or moving and placed on the vehicle (short-primary motor).

[0031] Another example of a linear motor that may be used in magnetic levitation railway vehicles is illustrated in figure 12, showing a linear synchronous reluctance motor schematically in cross-section, comprising a ferromagnetic mover construction 38 coupling electromagnetically to a stator 11 comprising a ferromagnetic core 35 with windings 36 mounted thereon to generate the electromagnetic field coupling electromagnetically to the ferromagnetic mover construction 38 to generate the driving force in the direction of displacement of the vehicle. A linear synchronous reluctance motor is a linear motor consisting of two parts moving relative to each other. The first comprises for instance three-phase windings, while the powered winding produces a magnetic field that penetrates the ferromagnetic secondary. By appropriately controlling the frequency and supply voltage of the windings, the magnetic field begins to travel along the motor, thus producing synchronous relative motion of the stator to the magnetic poles. Depending on the configuration, the winding can be stationary and placed in the track along the entire route (long-primary motor), or it can be moving and placed on the vehicle (short-primary motor).

[0032] Referring now to figures 13 to 20, various examples shown schematically and in a simplified manner of magnetic railway tracks 9 comprising stationary levitation rails 22 and corresponding moving magnetic levitation pads 19 fixed to the railway vehicle.

[0033] Electromagnetic levitation systems (also called electromagnetic suspension systems) may be divided into two main categories applicable in high-speed magnetic transportation:

EDS (Fig. 13-15)

EDS - (electrodynamic suspension) magnetic suspension systems, whose principle of operation is based on electrodynamic interactions. In an electrodynamic suspension system, an element is the source of the magnetic field (e.g., permanent magnet or electromagnet) and a conducting piece (e.g., aluminum plate). During their relative motion, the moving magnetic field induces eddy currents in the conducting element, which, as they flow, interact with the forcing magnetic field. The result is a force acting on both parts that have two main components. A levitation or guiding force (repelling the two pieces from each other) and a magnetic braking force are created.

EMS (Fig. 15-18)

EMS - (electromagnetic suspension). Levitation and guidance systems of the electromagnetic suspension type used for instance in "maglev" railroads. The classical system is based on the magnetic force between an unpowered ferromagnetic element and a ferromagnetic element with a wound coil energized by an electric current. By appropriately energizing the winding of the electromagnet, an attractive force is created between the two elements as a result of a common flux flowing through them. These systems can be equipped with permanent magnets to increase the system's energy efficiency. A passive ferromagnetic element is mounted in the track in most maglev rail suspension systems, while the vehicle is equipped with electromagnets.

[0034] It is further known in theory to consider Superconducting suspensions (Fig. 19-20):
Superconducting levitation - a magnetic suspension system, which may be considered an exceptional type of electrodynamic suspension since superconductors may be regarded as perfect conductor materials. Typically the vehicle is equipped with superconductors that are cooled down to very low temperatures, while the track consists of permanent magnets. Similar to EDS during the motion, the moving magnetic field induces eddy currents in the superconductors, which, as they flow, interact with the forcing magnetic field. The result is a force acting on both elements that has two main components. However, because the superconductor has almost no resistance, only levitation force appears without the magnetic drag.

[0035] In figure 13, the magnetic levitation rail 22 is formed by or comprises a stationary conducting element, for instance an aluminium plate separated by an airgap from a moving magnetic levitation pad 19 on the railway vehicle that has a plurality of permanent magnets with a direction of polarity that changes, the arrangement in figure 13 corresponding to a Halbach array. Figure 14 shows a front view, namely in the direction of travel, and figure 15 showing a front view of an alternative variant with a V-shape rail 22 that provides both vertical and lateral guiding. The embodiments of figures 13 to 15 correspond to an electrodynamic levitation system.

[0036] In the embodiments of figures 16 to 18, an electromagnetic levitation type of system is shown for the magnetic levitation railway track 22 and magnetic levitation pad 19. In this embodiment, a stationary ferromagnetic beam forms the magnetic levitation rail 22 which in this case would for instance be roof-mounted such as in the embodiments of figures 7 and 8 that couples electromagnetically to a moving ferromagnetic element with electromagnet that forms the magnetic levitation pad 19 coupled to the railway vehicle 2b. Figure 17 illustrates schematically a front view of the magnetic levitation rai of figure 16 and figure 18 shows an alternative front view, namely in the direction of travel going into the plane of the paper.

[0037] Figure 19 shows yet another schematic illustration of a railway guide system with a magnetic levitation railway track having moving superconductors that couple electromagnetically to a stationary track made of permanent magnets, the stationary track forming the magnetic levitation rail 22 and the moving superconductors forming the magnetic levitation pad 19 mounted to the railway vehicle 2.

[0038] Referring to figures 21 to 24, the modular transport vehicle 2 enables interoperability between conventional wheel railway, magnetic levitation railway, and vacuum tube railway system solutions. The railway system according to an aspect of this invention comprises a modular railway vehicle 2 comprising a carriage 3 with a chassis 4 including bogies 5 removably fixable to the carriage 3. The carriage 3 comprises a compartment for the transport of goods or persons and equipment of the vehicle. The carriage may further comprise inter-carriage linking members (not shown) to link together a plurality of carriages on the railway track, one or more of the carriages providing the propulsion force to drive the linked railway vehicles. In systems with the possibility of linking the carriages together, as is typically found in wheel track railway systems, when converting from one railway system to another, the carriages may be unlinked prior to conversion and relinked after conversion from one railway guide system to another railway guide system.

[0039] In an advantageous embodiment the carriage 3 may form a universal air-tight passenger or cargo compartment to which any propulsion and levitation module can be attached and detached easily.

[0040] The modular railway vehicle 2 comprises a coupling mechanism 6 for coupling the bogie 5 to the carriage 3. The coupling mechanism comprises a bogie coupling interface 39 and a carriage coupling interface 40 that mate and lock together when the bogie is coupled to the carriage. The railway vehicle comprises bottom bogies 5a coupled detachably to floor-mounted carriage coupling interfaces 40a. The railway vehicle may advantageously further comprise one or more roof-mounted carriage coupling interfaces 40b for coupling to overhead bogies that are guided by an overhead railway guide system 8b.

[0041] The bottom bogies 5a may be provided with wheels configured for a conventional wheel track railway, or with magnetic levitation pads 19 for a magnetic levitation railway track 9, or may comprise magnetic levitation pads and in addition wheels that serve to support the railway vehicle at slow speeds and at stop. The latter arrangement allows magnetic levitation suspension systems based on electrodynamic principles to be used whereby the wheels disengage from the railway track once a velocity that is sufficient to generate the electromagnetic force to lift the carriage off the magnetic levitation track and form an airgap therebetween is reached. The bogie 5 may further comprise a suspension 32 that interconnects the coupling interface 39 to the bogie base connected to the track engaging members 19, 25.

[0042] The bogie coupling interface 39 is releasably fixable to the complementary carriage coupling interface 40. The coupling mechanism may include a guide pin 20 and complementary guide cavity 21 that may for instance have tapered or conical shapes to locate the bogie coupling interface 39 to the complementary carriage coupling interface 40 during coupling, a locking system such as pins, clamps and other type of locking mechanisms being used to lock the coupling mechanism once the bogie is coupled to the carriage. A pluggable electrical interconnection may also be provided on the coupling mechanism to allow electrical interconnection between the bogie and carriage, for instance for power and signal transmission, for instance for sensors and any motor components provided on the bogie.

[0043] One example of a positioning and locking mechanism that will connect the vehicle carriage to the bogie may be based on a *per se* well-known spindle-holder joint used for instance in CNC machine tools. The tapered socket may for instance be mounted on the carriage coupling interface 40 and the conical plug mounted to the bogie coupling interface 39. There is at least one locking mechanism per bogie.

[0044] The coupling mechanism 6 may be equipped with various *per se* known mechanical locking mechanisms that may be activated manually, hydraulically, pneumatically or electrically and that securely lock the interfaces together such as with hooks, rotating locks with or without threads, clamps, latches, wedges, and bolts.

[0045] The railway system may thus be provided with various bottom and top bogies of different sizes and standards and different rail track engaging members adapted for the railway network in use, and allowing transition from one railway network to another railway network with a different rail track system by changing bottom and/or top bogies at a conversion station 14.

[0046] The overhead railway guide system may be used only in a system conversion station 14 as illustrated in figure 29 allowing the modular railway vehicle 2 to transition from a first railway guide system 8 to a second different railway guide system 8', the overhead bogie allowing the carriage to be suspended from the roof to allow the bottom bogies to be removed and replaced with the bogies for the second railway guide system 8'. In this particular embodiment, the roof-mounted bogies thus only serve for the transition from one system to the other within the system conversion station 14.

[0047] The roof-mounted bogies may be used for a magnetic levitation railway track with an overhead railway guide system 8b driven for instance with magnetic levitation systems as schematically illustrated in figures 7 and 8. In such case, the roof-mounted bogie 5b comprises a linear motor mover and magnetic levitation pads for propulsing and guiding the modular railway vehicle 2 along the overhead railway track 9b.

[0048] Figure 25 illustrates a modular railway vehicle 2 that travels on an overhead railway guide system 8b of a first railway network connected via a system conversion station 14 to a second railway network with a ground railway guide system 8a, in particular a wheel railway track 7. In the conversion station 14, the roof-mounted bogie 5b is unlocked and decoupled from the carriage 3 and the carriage is coupled and locked to a floor-mounted bogie 5a. The railway vehicle may then continue travel along the wheel railway track.

[0049] The system conversion station may further comprise bogie storage zones 18 to park bogies that have been uncoupled from the modular railway vehicle when transitioning from one system to another or that are in waiting for a modular transport vehicle arriving from another railway guide system network. Overhead bogies 5b and ground bogies 5a may be parked in a bogie storage zone 18 of the conversion station as schematically illustrated in figures 26 and 27.

[0050] In the embodiment illustrated in figure 28, the modular railway vehicle 2 arrives in the system conversion station from an overhead magnetic levitation railway track 9b and is coupled to a bottom bogie 5a in the conversion station 14 and recoupled to another bogie 5b of a second overhead magnetic levitation railway track 9b that may be of another system standard.

[0051] In the embodiment illustrated in figure 29, the modular railway vehicle 2 arrives in the system conversion station from a ground magnetic levitation railway track 9a and is coupled to an overhead bogie 5b in the conversion station 14 and recoupled to another bogie 5a of a second ground magnetic levitation railway track 9a that may be of another system standard.

[0052] In the embodiment illustrated in figure 30, the modular railway vehicle 2 arrives in the system conversion station from a ground magnetic levitation railway track 9a and is coupled in the conversion station 14 to an overhead bogie 5b of an overhead magnetic levitation railway track 9b.

[0053] The modular railway vehicle provided with bogie coupling mechanisms on both the bottom side and roof side thus allows multiple conversions between different railway guide systems in a rapid and convenient manner.

[0054] When moving from a railway system such as a vacuum tube system operating at an underpressure, to a railway system operating at atmospheric pressure or at a different underpressure, the system conversion station 14 may be provided with an airlock 15 comprising a chamber with doors 17 on either end thereof, in particular that sealingly engage a frame 42 around the entry or exit of the chamber 16. The airlock allows the modular railway vehicle to transition from one pressure zone to another pressure zone.

[0055] In relation to the examples of figures 25 and 28-30, a procedure going from the second railway network to the first railway network may of course also be performed with the inverse order to those described above.

Examples of Configurations and Operation sequences:

Magnetic levitation railway on conventional wheel track railway infrastructure with shunting locomotive having no service propulsion on the magnetic levitation railway vehicle

[0056]

1. Magnetic levitation railway vehicle (MRV) arrives at the last available magnetic levitation railway infrastructure segment. It may be the end of the linear on the main or branch line or sidetrack.
2. The linear motor segment power supply turns off.
3. MRV lifts the levitation pads and, if available, also the linear motor mover. The magnetic levitation railway vehicle opens the coupling mechanism and engages the parking brake.
4. Shunting vehicle couples with the magnetic levitation railway vehicle.
5. After confirmation of successful coupling (also applies to mover and levitation pad lift), the magnetic levitation railway vehicle releases the parking brake.
6. The trainset formed by the shunting vehicle and magnetic levitation railway vehicle starts operating as a conventional trainset.

[0057] If there are more magnetic levitation railway vehicles, the points 1-3 apply to multiple magnetic levitation railway vehicles, and the procedure in the points 4-5 is extended:

4. Shunting vehicle couples with the first magnetic levitation railway vehicle.
5. After confirmation of successful coupling (also applies to mover and levitation pad lift), the first magnetic levitation railway vehicle releases the parking brake.
6. The trainset couples with the second vehicle, and the procedure is repeated until the last magnetic levitation railway vehicle is in the platoon.
7. Trainset including the whole platoon starts operating as a conventional trainset.

No shunting vehicle; service propulsion on the magnetic levitation railway vehicle

[0058]

1. Magnetic levitation railway vehicle (MRV) arrives at the last available magnetic levitation railway infrastructure segment. It may be the end of the linear on the main or branch line or sidetrack. The magnetic levitation railway vehicle engages the parking brake.
2. The linear motor segment power supply turns off.
3. MRV lifts the levitation pads and, if available, also the linear motor mover.
4. MRV turns on the service propulsion and starts the operation if the traffic management system allows it.

[0059] There are two variants with the magnetic levitation railway vehicle platoon. If the magnetic levitation railway vehicles should operate independently, the procedure is similar to the above. All the segments which the platoon occupies should be switched off. Then, all service propulsions are controlled according to the virtual coupling system.

Magnetic levitation railway on conventional wheel track railway infrastructure table further comments

[0060]

- If the magnetic levitation railway vehicle for service propulsion needs the catenary, then after the parking brake is engaged, the pantograph is lifted, the grounding slider is put down to the rail (to close the circuit) and catenary power supply is switched on.
- There is also a possibility where the magnetic levitation railway vehicle with service propulsion does not stop, only slows down.

Conventional wheel track railway on magnetic levitation railway infrastructure

[0061] *Fully electrified line with catenary*

1. When the conventional wheel track railway train approaches the magnetic levitation railway infrastructure, the system checks whether the linear motor segments are unpowered and no magnetic levitation railway vehicle occupies the closest linear mo-

tor segments.

2. If the system check allows, the conventional wheel track railway trainset can safely enter the magnetic levitation railway infrastructure. If there is an obstacle, the conventional wheel track railway trainset engages brakes and stops before entering the linear motor segments.

Magnetic levitation railway infrastructure not equipped with the catenary

[0062] In such a case, the electric multiple units cannot enter the magnetic levitation railway infrastructure (unless they are equipped with a magnetic levitation railway booster system). Only diesel-powered and hybrid units can operate on non-catenary magnetic levitation railway infrastructure.

1. When the hybrid or diesel conventional wheel track railway train approaches the magnetic levitation railway infrastructure, the system checks whether the linear motor segments are unpowered and no magnetic levitation railway vehicle occupies the closest linear motor segments.
2. If the system check allows, the conventional wheel track railway trainset can safely enter the magnetic levitation railway infrastructure. If there is an obstacle, the conventional wheel track railway trainset engages brakes and stops before entering the linear motor segments.

Magnetic railway booster case

[0063] A wheel-supported vehicle equipped with a magnetic railway booster (MRB) can enter magnetic levitation railway infrastructure.

1. The vehicle with MRB approaches the magnetic levitation railway infrastructure. The system checks whether the linear motor segments are unpowered and no magnetic levitation railway vehicle occupies the closest linear motor segments.
2. The vehicle slows down to ca. 20-30 kph and enters the inactive linear motor segment.
3. Induced current in the stator allows the linear motor controller to detect the vehicle speed and set the synchronous current frequency.
4. Once the vehicle and the electromagnetic field are synchronized, the vehicle with MRB can accelerate to the given operational speed.

Magnetic levitation railway- magnetic levitation railway interoperability

[0064] The propulsion and guidance modules are exchanged in a specified system conversion station. For the current considerations, let the M1 refer to the magnetic levitation railway system in the first configuration and M2 refer to the second magnetic levitation railway configuration.

1. The vehicle operates in the M1 configuration.
2. It stops in a specified area as it approaches the system conversion station.
3. The M1 bogie is detached from the carriage - the coupling mechanism is released.
4. The carriage is lifted and moved to the M2 area. M1 bogie is moved to station storage.
5. The carriage is lowered on the M2 bogie, then coupled via the coupling mechanism.
6. After the automatic safety check, the vehicle in the M2 configuration leaves the interface station and continues the movement on the M2 infrastructure.

Vacuum tube railway system - vacuum tube railway system interoperability

[0065] The propulsion and guidance modules are exchanged in a specified system conversion station integrated with an airlock. For the current considerations, let H1 refer to the vacuum tube railway system in the first configuration and H2 refer to the second vacuum tube railway system configuration.

1. The vehicle operates in the H1 configuration. The Airlock doors are open from the H1 side.
2. It stops in a specified area as it approaches the system conversion station.
3. The airlock doors H1 are closed and latched, and the bogie is detached from the carriage- the coupling mechanism is released.
4. Airlock pressure changes to H2 conditions.
5. The carriage is moved away from the H1 bogie and moved to the H2 area. H1 bogie is moved to station storage.
6. The carriage is attached to the H2 bogie, then coupled via the coupling mechanism.
7. After the automatic safety and pressure check, the airlock doors are released and open, vehicle in the H2 configuration leaves the system conversion station and continues the movement on the H2 infrastructure.

[0066] The airlock can be fitted into the system in two options - it includes the system conversion station or not. In case where the system conversion station is inside the airlock, all bogie exchanging subsystems are also pressurized, however, then the pressurization or depressurization can be done simultaneously with the bogie exchange which saves time and increases overall system capacity. On the other hand, the system conversion station outside the airlock is less costly in infrastructure costs for there is no need to pressurize it, but it increases the transition time between two environments.

List of references

[0067] Railway system

Railway vehicle

wheel railway vehicle 2a, magnetic levitation railway vehicle 2b
modular railway vehicle 2
Carriage 3
Outer profile 30
Chassis
Bogie 5 (roof-mounted bogie 5a, floor-mounted bogie 5b)

Track engaging members
Wheel track engaging member/ wheel 25
Magnetic levitation track engaging member / pad 19
Suspension 32

Coupling mechanism (bogie to carriage coupling mechanism) 6

Bogie coupling interface 39
Carriage coupling interface 40
Guide pin 20
Guide cavity 21
Locking mechanism

Railway guide system 8

wheel railway track 7
magnetic levitation railway track 9
magnetic levitation rail 22

Propulsion system
linear motor 10

stator 11

ferromagnetic core 35
coil 36

mover 12

ferromagnetic back plate 33
ferromagnetic mover construction 38
permanent magnets 34
induction plate 37

pantograph 31

Vacuum tube 13
System conversion station 14

Airlock 15

Chamber 16
Door 17

Bogie storage zone 18

Claims

1. A modular railway vehicle (2) comprising a carriage (3), one or more bogies (5, 5a, 5b), and a corresponding one or more coupling mechanisms (6) interconnecting the bogies to the carriage, the coupling mechanism comprising a bogie coupling interface (39) fixed to the bogie and a carriage coupling interface (40, 40a, 40b) fixed to the carriage, the bogie coupling interface being lockable and detachable to the carriage coupling interface allowing different bogies to be exchangeably attached to the carriage such that the modular railway vehicle may be adapted for circulation on railway guide systems (8, 8a, 8b) of different types including at least a magnetic levitation railway track (9), the carriage being provided with at least one carriage coupling interface (40a) on a floor of the carriage and at least one carriage coupling interface (40b) on a roof of the carriage.

2. The modular railway vehicle according to the preceding claim wherein the bogies are selected from a group including bogies with wheel track engaging members (25) and bogies with magnetic levitation track engaging members (19).

3. The modular railway vehicle according to the preceding claim wherein the track engaging members (19) are connected to a base of the bogie via a suspension (32).

4. The modular railway vehicle according to any preceding claim wherein the carriage comprises at least two carriage coupling interfaces (40a) under the carriage floor.

5. The modular railway vehicle according to any preceding claim wherein the carriage comprises at least two bogie coupling interfaces (40b) on the carriage roof.

6. The modular railway vehicle according to any preceding claim wherein the coupling mechanism includes a guide pin (20) on one of the bogie or the carriage and a complementary guide cavity (21) on the other of the bogie or carriage, the guide pin and cavity having a tapered or conical shape portion.

7. The modular railway vehicle according to any preceding claim wherein the coupling mechanism includes pluggable electrical interconnections for establishing electrical contact between the carriage

and the bogie for power and/or signal transmission.

8. The modular railway vehicle according to any preceding claim comprising at least one propulsion system including a linear electric motor (10) having a mover (12) fixed to the modular railway vehicle (2) for electromagnetic drive coupling to a stator (11) mounted on a railway guide system (8).

9. The modular railway vehicle according to the preceding claim wherein the mover (12) comprises one or more permanent magnets (34), or an induction plate (26) for coupling to an electromagnetic field generated in the stator (11).

10. A railway system including at least two railway guide systems (8, 8a, 8b) interfacing at a system conversion station (14), at least one railway guide system comprising a magnetic levitation railway track (9) and the other railway guide system comprising one of a wheel railway track (7) and a magnetic levitation railway track (9), the system conversion station (14) comprising a bogie storage zone for storing one or more bogies adapted for locomotion on the first railway guide system and for storing bogies adapted for locomotion on the second railway guide system.

11. The railway system according to the preceding claim wherein the magnetic levitation railway track (9) is a floor-mounted or an overhead magnetic levitation railway track.

12. The railway system according to any preceding claim wherein at least one of the railway guide systems is a magnetic levitation railway track (9) in a vacuum tube (13).

13. The railway system according to the preceding claim wherein the system conversion station (14) comprises an airlock (15) with a chamber (16) with sealing doors (17) on either end of the chamber to allow a change in pressure from a first railway guide system to a second railway guide system.

14. The railway system according to any preceding claim 10-13 further including a plurality of modular railway vehicles according to any preceding claim 1-9.

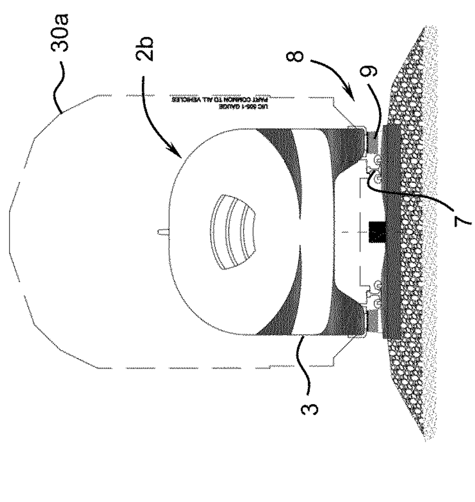


Fig.1 Magrail

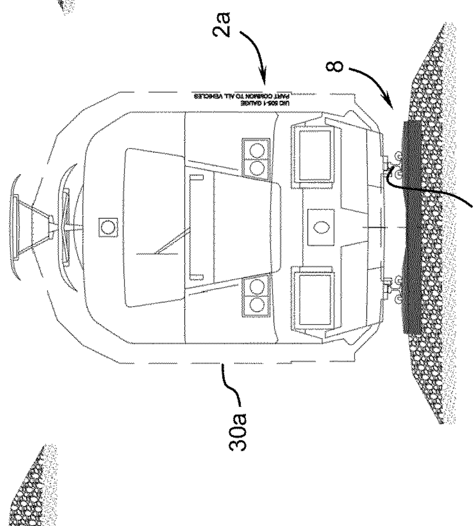


Fig.2 Conventional railway

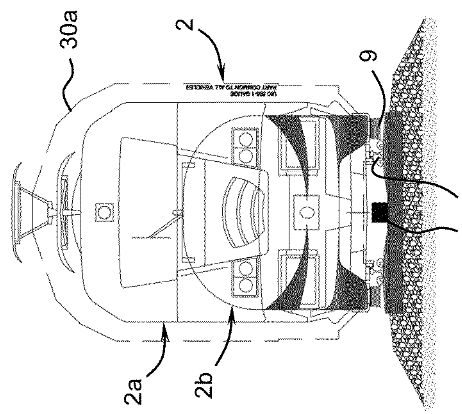


Fig.3 Magrail + conventional railway

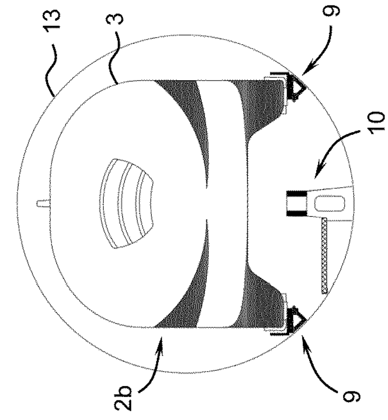


Fig.4 Hyperrail

Fig.5 Hyperloop, system 1

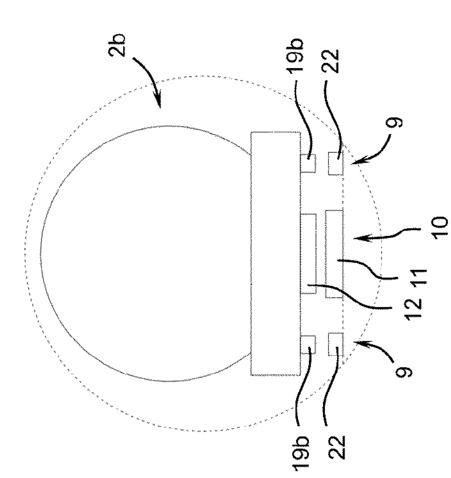


Fig.6

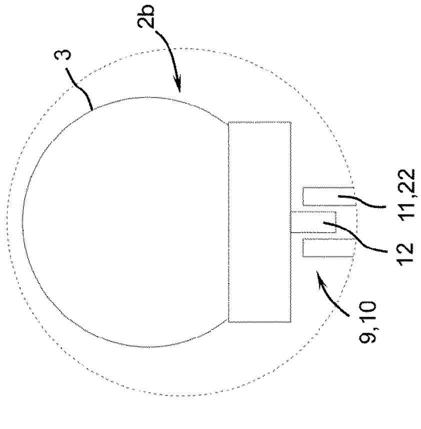


Fig.7

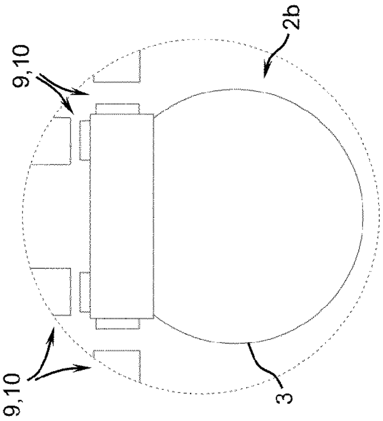


Fig.8

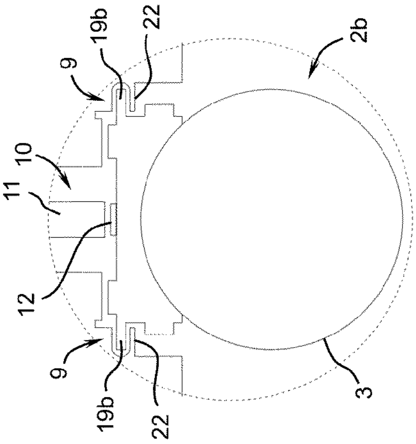


Fig.9

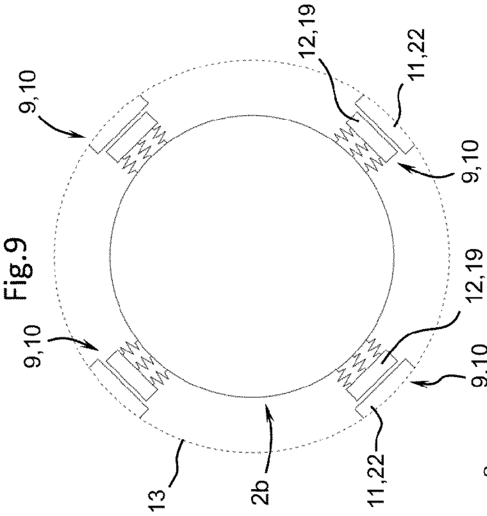


Fig.12 Linear synchronous reluctance motor – cross section

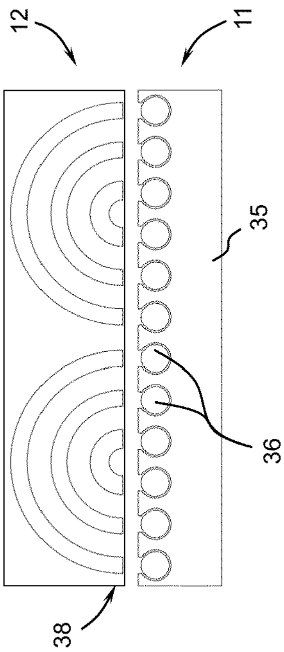


Fig.11 Linear induction motor – cross section

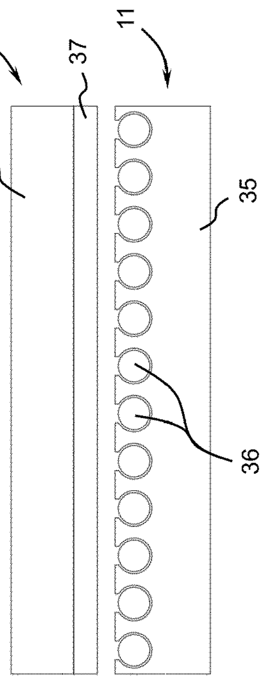
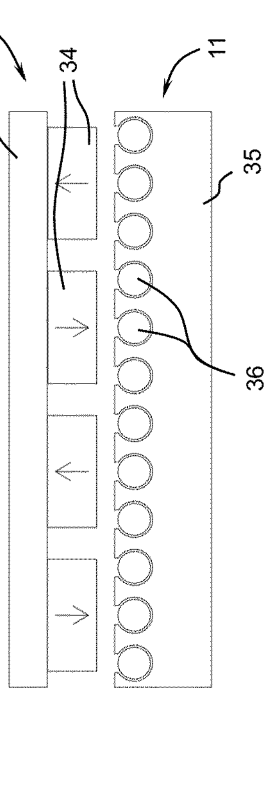


Fig.10 Permanent magnet linear synchronous motor – cross section



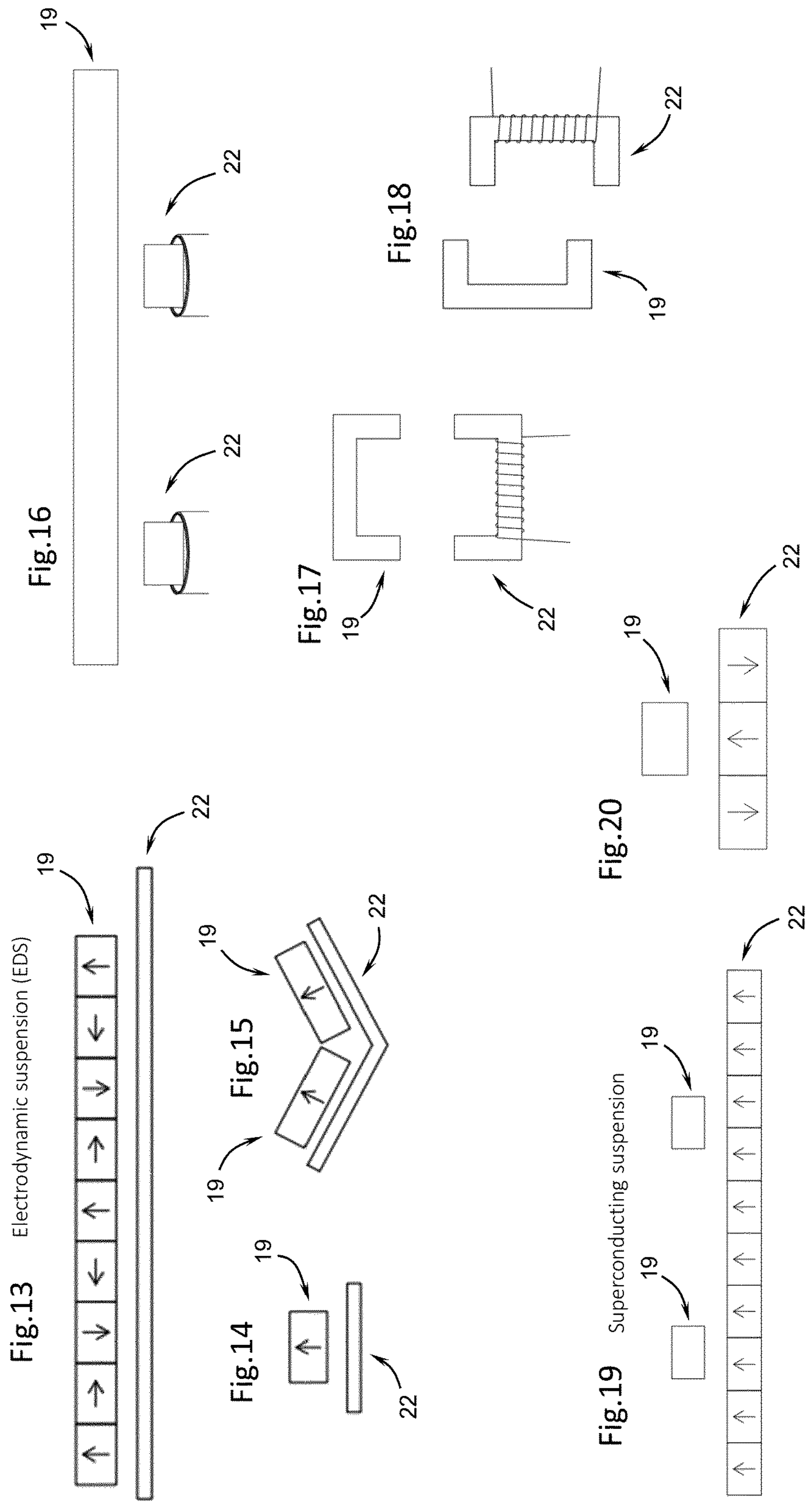


Fig.13
Electrodynamic suspension (EDS)
Fig.14
Fig.15
Fig.16
Fig.17
Fig.18
Fig.19
Superconducting suspension
Fig.20
19
22

Fig.21 Locking mechanism – joint bottom bogie-to-car

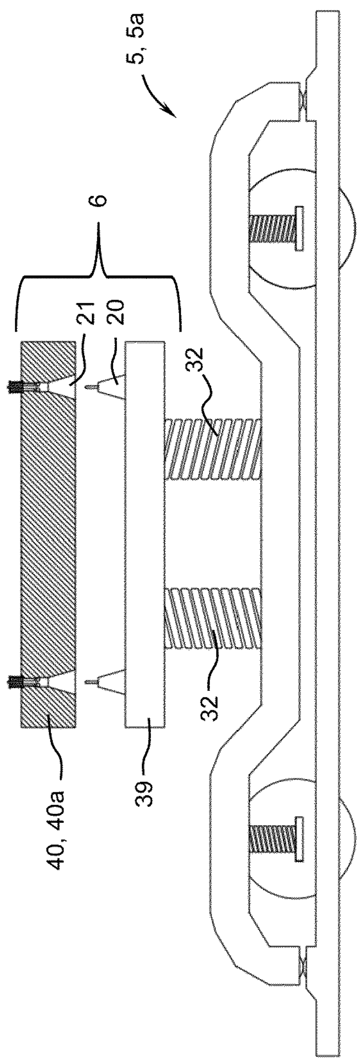
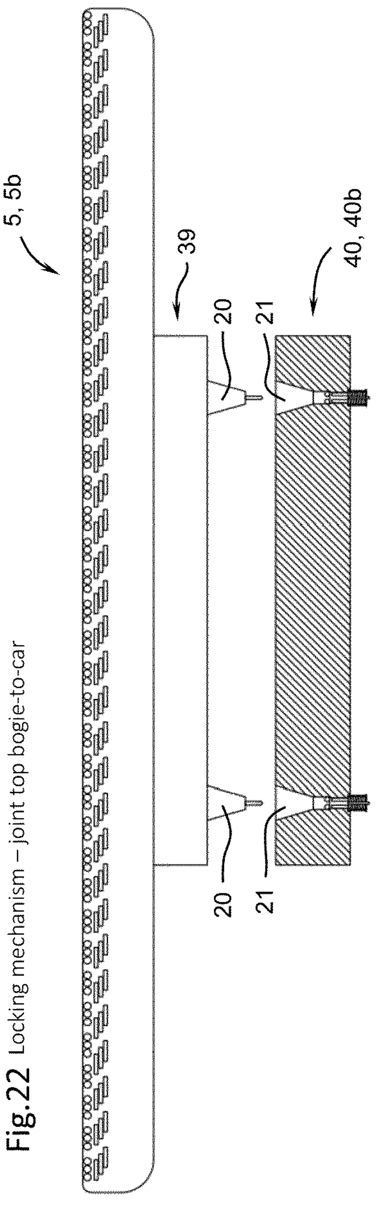


Fig.22 Locking mechanism – joint top bogie-to-car



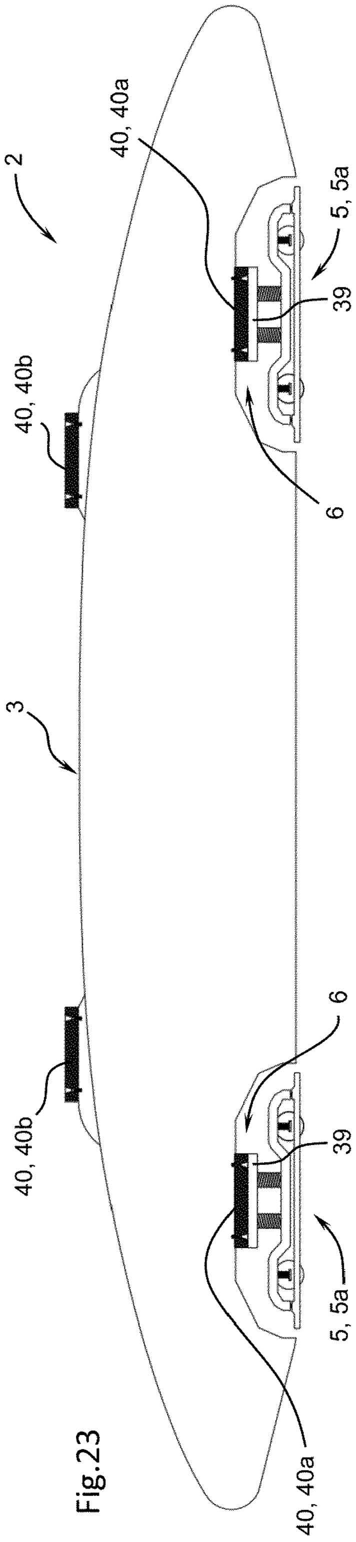

2
40, 40a
5, 5a
39
40, 40b
6
3
6
39
40, 40b
5, 5a
40, 40a

Fig.23

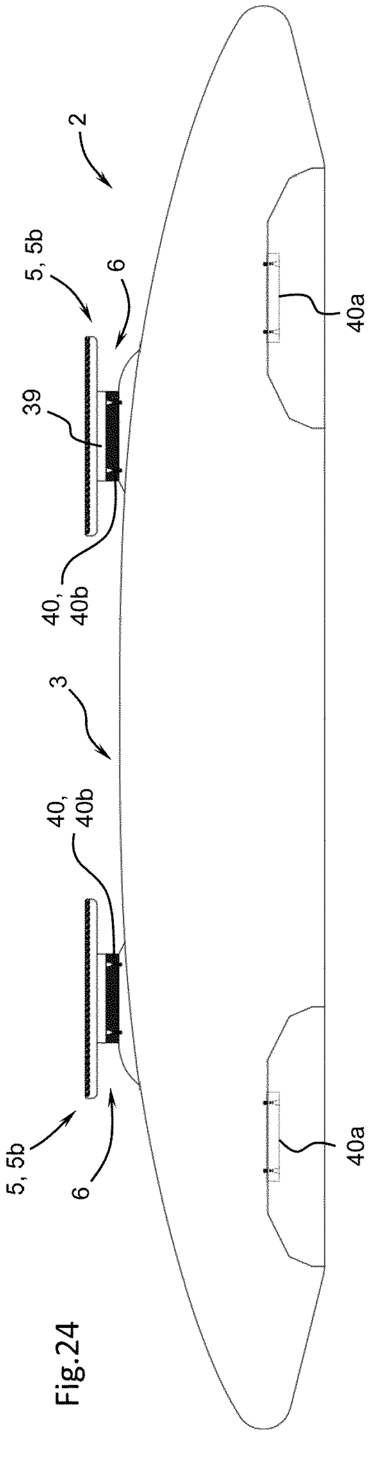

2
5, 5b
6
39
40a
40,
40b
3
40,
40b
5, 5b
6
40a

Fig.24

Fig.25 Hyperloop magrail

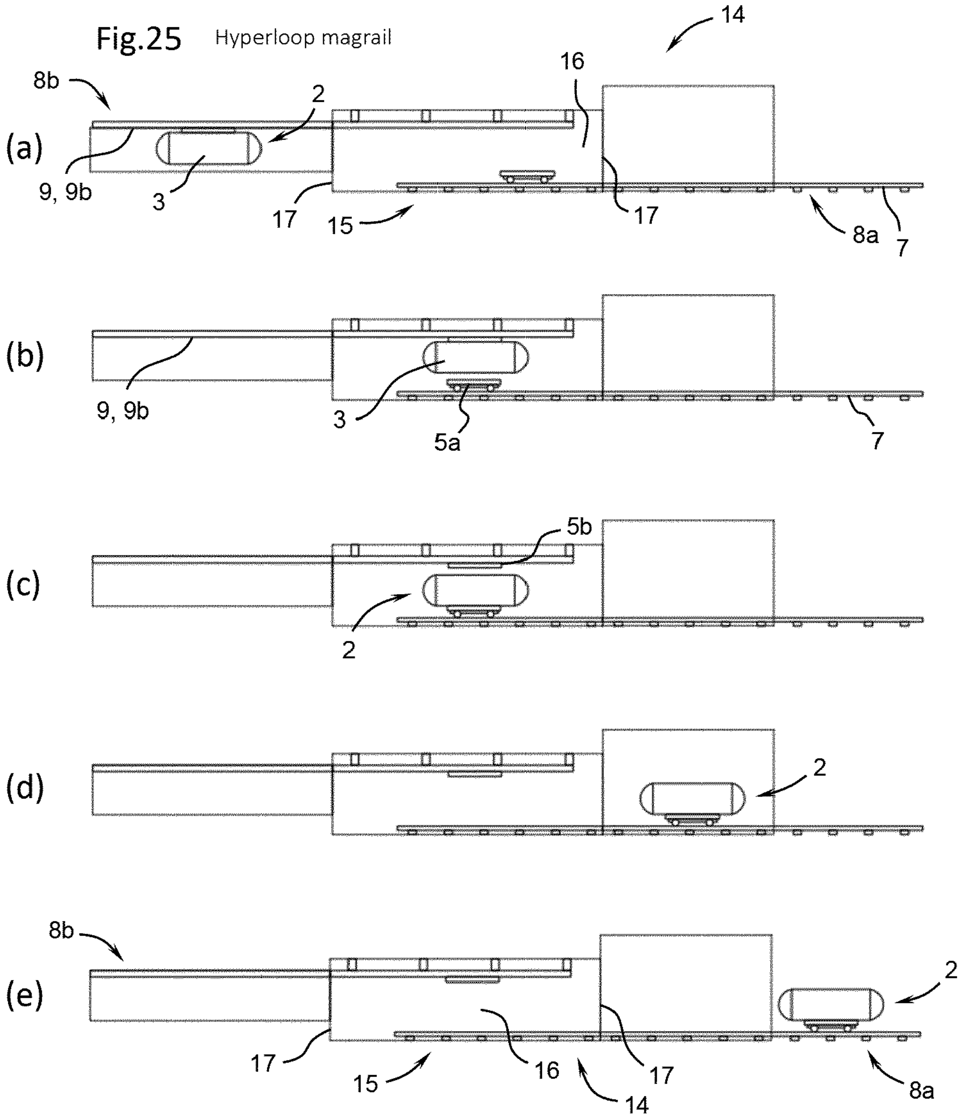


Fig.26

Interface station with bogies depot when changing Hyperloop to magrail systems

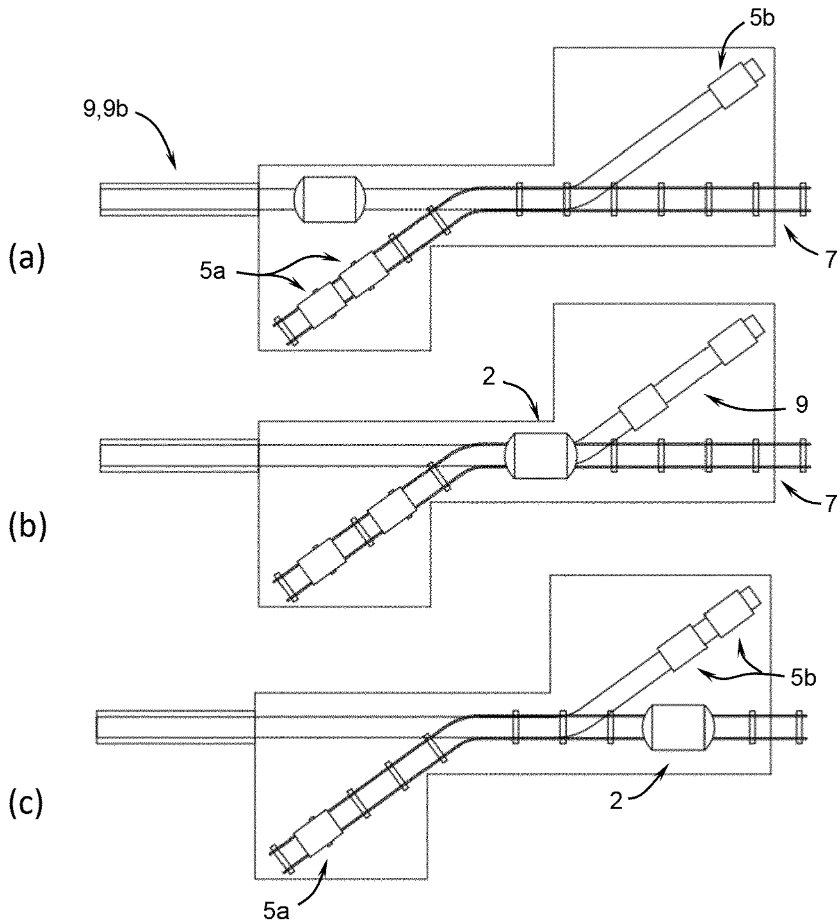
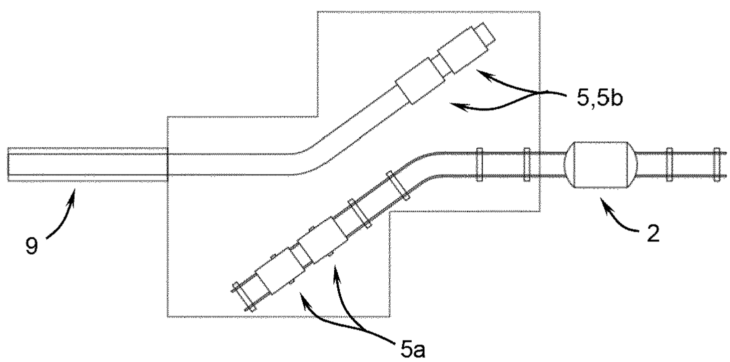


Fig.27

Interface station with bogies depot when changing Hyperloop to magrail systems



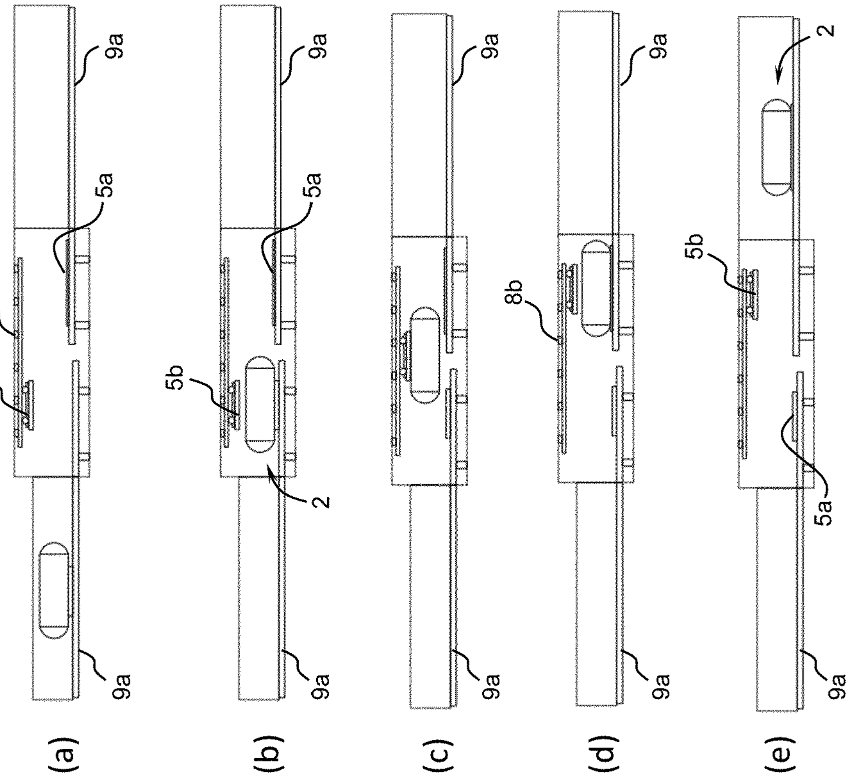


Fig.29

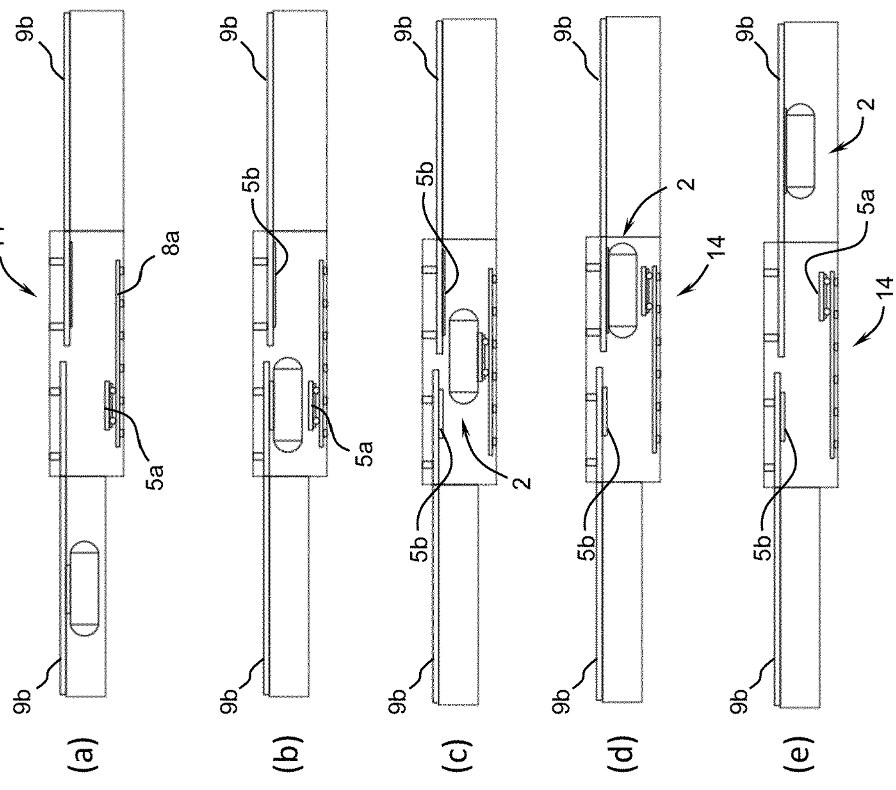


Fig.28

Fig.30

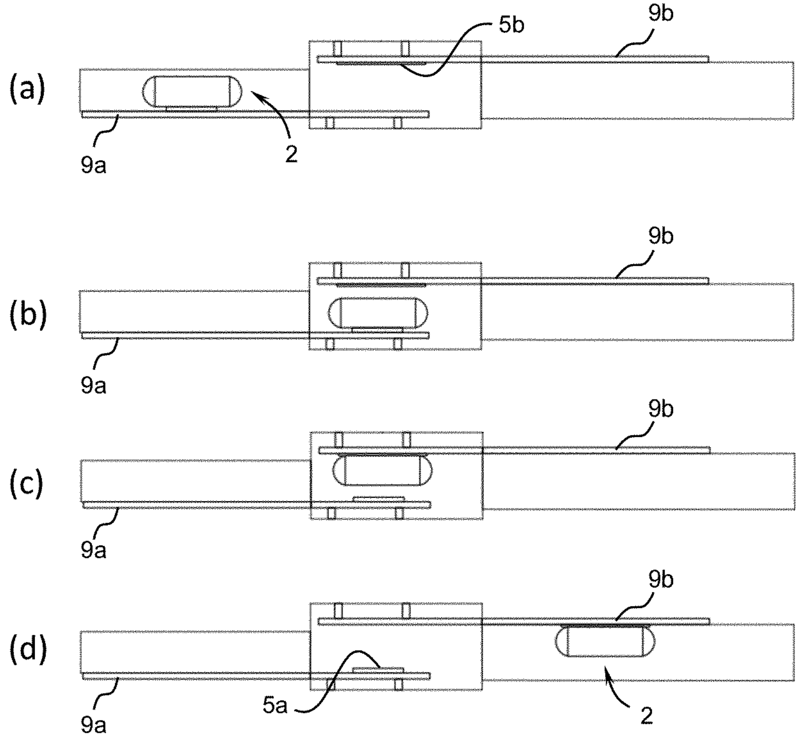


Fig. 31 Airlock in open position (airlock doors with sliders dotted)

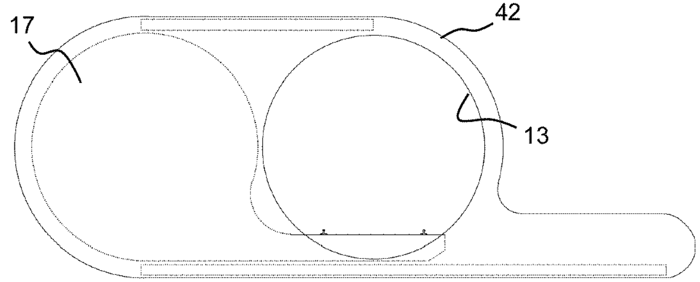
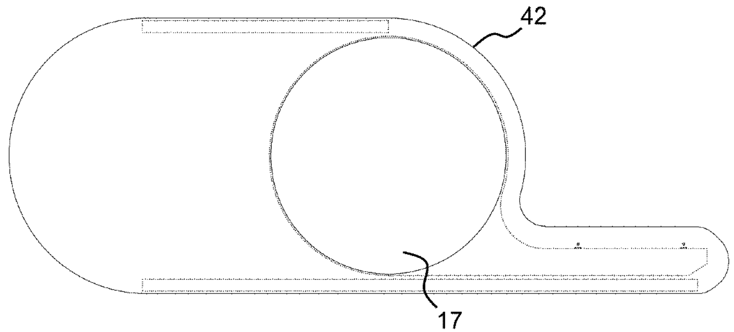


Fig. 32 Airlock in closed position (airlock doors with sliders dotted)



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Application Number
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	25 August 2022	Crama, Yves

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