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(54) **Articulated passenger rail vehicle with an intermediate car module**

(57) An articulated passenger rail vehicle has two cars (12A), each supported by two bogies, and an intermediate car module (14A) articulated to the two cars. The articulation axes of the intermediate car module are located between the rotation axes of the adjacent bogies. The distance between the two bogies of one of the cars is greater than the distance between the two nearest bogies of the two cars. The intermediate car module (14) is provided with a door opening (51) for boarding and alighting while the cars are kept free of door openings.

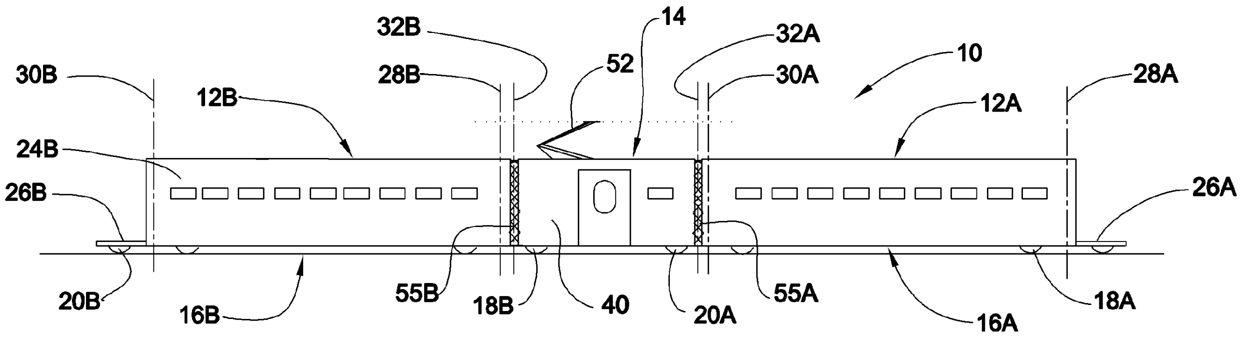

Fig.1

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Description

[0001] The present application is a divisional application from EP 04 797 951.3, the content of which is integrated herein by reference.

[0002] The invention relates to an articulated railway vehicle for passenger transportation, in particular a passenger rail vehicle, of the type comprising cars supported by a front bogie and a rear bogie.

[0003] In conventional passenger trains, the cars are articulated to one another at their ends. Considerable side swing is experienced at sidings, railroad switches and on arcuate tracks. This side swing is a compound relative motion between the cars, comprising lateral translation and rotation. The bellows allowing passage from one car to the next have to accommodate this relative motion, resulting in a complex, bulky and unwieldy construction, which restricts the available space for the passageway. The lateral acceleration is particularly noticeable when the train approaches a station and passengers gather in vestibules at the end of the car. The lateral translation movement between adjacent cars is perceived as particularly unpleasant, also from a visual point of view, since it imparts the sensation of an unstable and unsafe vehicle body.

[0004] As such, the location of the vestibule at the end of the car is not optimal. When boarding, space for passengers in the vestibules is limited. Luggage has to be carried through small doors. Little space is available for accommodating the bulkiest pieces of luggage near the doors. The passageways to the saloons are narrow, causing queues along the gangways. On the other hand, however, if the doors were located in the middle of the car, problems would arise because of the gap that would extend between the door and the platform when the platform is curved.

[0005] In figure 10, a conventional passenger train 200 running on a curved track 202 of constant radius R has been illustrated. The cars 204A, 204B are pivotally supported by front and rear four-wheel undercarriages or bogies 206A, 208A, 206B, 208B and articulated to one another at their ends via a coupling rod 210. Typically, the distance between the front and rear bogies is equal to the distance between the articulation axes of the cars divided by the square root of 2. For illustration purposes, the centerline 212 of the track 202 has been represented, as well as the outside envelope 214 of the train. The longitudinal vertical center plane 215A, 215B of each car body contains the vertical axes of rotation 216A, 216B, 218A, 218B of the undercarriages in relation to the car body and crosses the centerline 212 of the track in the immediate vicinity of the vertical axes of rotation.

[0006] At a station with curved platforms, the edge of the platform will be outside the envelope 214 and, at best, tangential to it. In the middle of the car, where the car is tangential to the envelope on the inner side of the curve, the external lateral side of the car is at a considerable distance from the envelope. This is the reason why doors and vestibules, which have to open on both sides to give access to both concave platforms 220 and convex platforms 222, cannot be located in the middle of the car, far from the undercarriages. Towards the ends of the cars, i.e. close to the undercarriages, the distance from the lateral side of the car to the envelope is more or less the same on both lateral sides. The doors are preferably located in this area, because the gap between the train 200 and the platform will be more or less the same for concave platforms 220 and convex platforms 222. However, in this area, the angle between the train and the envelope can be considerable. This means that the gap between the train and the platform is not constant, which makes it difficult to provide foldable doorsteps to bridge this gap. Moreover, passengers boarding and alighting can easily misjudge the width of the gap and may get injured if the gap is not properly bridged.

[0007] Another problem arises when the train passes through curves. As shown in figure 10, electrical current collectors 224 are used to connect the train to the catenary. The electrical collectors 224 have their heads extending perpendicularly to the longitudinal vertical center plane of the car, straight above the rotation axis of one of the undercarriages. The current collector head appears to be at an angle and not even centered in relation to the centerline 212 of the track. In such a configuration, it is very difficult to precisely control the preset pressure to be applied by the collector head on the catenary.

[0008] On the other hand, if the current collector were located midway between the two undercarriages of the car, where its head would be perpendicular to the centerline, the distance to the centerline would increase dramatically.

[0009] A tramway with two cars articulated to a central intercommunication passage is known from EP 0 121 503. Each car is supported by a distal bogie and a proximal bogie adjacent to the intercommunication passage. The intercommunication passage can pivot in relation to each car about an articulation axis, which is also the rotation axis of the corresponding adjacent bogie in relation to the car.

[0010] An articulated train is known from US 1 875 214, provided with central cars pivotally arranged between two bogies and end parts also pivotally mounted on the bogies, so that each bogie has two articulation axes, one for the adjacent central car and one for the adjacent end part. The central cars are designed exclusively for passenger transportation, while the end parts are designed to serve as driver's cab, entrance for the passengers, corridor and the like. Due to construction with two separate independent articulation axes on the bogies, considerable relative lateral movements of the end parts relative to the central cars may occur on curved tracks. All longitudinal forces have to be transferred from one car to the next via the bogies, which is usually not considered safe in case of a crash.

[0011] Various embodiments of a railway passenger vehicle with an articulated passageway between adjacent carriages are disclosed in US 3 030 897. The position of the passageway in a curve, and in particular its position relative to a centerline of a track of constant radius is not discussed.

[0012] Accordingly, there is a need for a rail vehicle of the general type having cars supported by two bogies, which is free from these drawbacks.

[0013] More specifically, there is a need for a rail vehicle of the general type having cars supported by two bogies, which limits the lateral acceleration in the boarding and alighting areas and increases comfort. Another object of the invention is to provide a rail vehicle, which reduces the gap between the door openings and the platform, both on concave and convex platforms.

[0014] According to a first aspect of the present invention, there is provided an articulated passenger rail vehicle provided with:

- a first car comprising a first car superstructure supported by a first bogie and a second bogie, wherein the first bogie rotates in relation to the first car superstructure about a first rotation axis and the second bogie rotates in relation to the first car superstructure about a second rotation axis ;
- a second car comprising a second car superstructure supported by a third bogie and a fourth bogie, wherein the third bogie rotates in relation to the second car superstructure about a third rotation axis and the fourth bogie rotates in relation to the second car superstructure about a fourth rotation axis and
- an intermediate car module articulated to the first car superstructure and to the second car superstructure so as to pivot about a first vertical articulation axis fixed in relation to the first car superstructure and about a second vertical articulation axis fixed in relation to the second car superstructure, wherein:
    - the first vertical articulation axis and second vertical articulation axis are spaced apart from and located between the second rotation axis and third rotation axis,
    - the distance between the second rotation axis and the third rotation axis is substantially smaller than the distance between the first rotation axis and the second rotation axis, and
    - the intermediate car module is provided with a door opening for boarding and alighting the vehicle and with a passageway between the door opening and the first car superstructure.

[0015] Thanks to the intermediate car module articulated on both the first and second car bodies, swinging between the car bodies is significantly reduced. The bellows between the intermediate car module and the car bodies do not need to accommodate large displacements, and can have a simple structure, which leaves more room for passageways. The articulation axes of the intermediate car module are fixed in relation to the car superstructure, so that the passengers do not see, or otherwise experience, any lateral translation movement of the intermediate car module in relation to the car superstructure. For the same reason, the car superstructures and the intermediate car modules form a continuous articulated body, which in case of a crash will deform in a predictable manner to absorb the impact energy.

[0016] The articulation axes of the intermediate car module are located between the second and third rotation axes, which ensures smooth running of the vehicle in curves. The side movement of the intermediate car module with respect to the centerline of the railway is very limited in curves. Therefore, the gap between the door opening of the intermediate car module and the platform will be substantially identical for concave and convex platforms.

[0017] According to a preferred embodiment of the invention, the first car superstructure and the second car superstructure comprise passenger compartments or saloons, while the intermediate car module is used as a vestibule for the first car and/or second car. No further doors are necessary for accessing the cars so that it is possible to design one or both of the car bodies without door openings. The superstructure of the cars is thus greatly simplified.

[0018] Preferably, the intermediate car module is provided with a luggage storage area. Boarding the train is facilitated by the large dedicated vestibule. Passengers entering or leaving the cars are not hampered by luggage.

[0019] The intermediate car module is preferably provided with a toilet compartment and/or any piece of equipment that generates noise and vibration or, more generally, any piece of equipment that is not necessary in the passenger saloons, e.g. a bistro area or vending machines. A partition with an automatic door can also be located between the passenger compartment and the articulation axis to further isolate the passenger compartment from the equipment generating noise or vibration. This construction also offers excellent modularity and exchangeability. At least part of the intermediate car module can also be used as entertainment or play area.

[0020] According to a further embodiment of the invention, the intermediate car module is further provided with an electric current collector. This takes advantage of the fact that the longitudinal vertical center plane of the intermediate car module hardly moves sideways with respect to the center line of the track in curves so that good contact is ensured between the electric current collector, e.g. a pantograph or the like, and the catenary. Moreover, the current collector, which generates noise and vibration, is kept apart from the passenger compartments. For the same reason, the intermediate car module is further provided with an electric brake.

[0021] Advantageously, the vehicle is further provided with a first deformable airtight connection between the first car superstructure and the intermediate car module, and a second deformable airtight connection between the intermediate car module and the second car superstructure.

[0022] Preferably, the second bogie and the third bogie extend at least partially below the intermediate car module.

[0023] According to one embodiment, longitudinal forces transmitted from the first car to the second car are transmitted via the intermediate car module. Alternatively, forces could also be transferred, for instance, via one or more connecting rods directly connecting the first car to the second car.

[0024] Preferably, the intermediate car module is supported only by the first car superstructure and the second car superstructure. Alternatively, the intermediate car module could also be partly supported by the adjacent bogies. However, care should be taken to the fact that the latter solution involves vertical movements between the intermediate car module and the adjacent cars, which may not be desired.

[0025] According to one embodiment, the first, second, third and fourth rear bogies are four-wheel bogies. The bogies may be motorized.

[0026] Advantageously, the intermediate car module comprises a movable plate, which can be moved between a higher position which is flush with the floor level of the first car superstructure and a lower position for moving wheelchairs and/or trolleys from and to the floor level.

[0027] Advantageously, the door-to-platform distance can be optimized when the distances between the first, second, third and fourth rotation axis and the first and second articulation axis are such that when the vehicle runs on a curved track of constant radius, a longitudinal vertical plane containing the first and second vertical articulation axes is tangential to the centerline of the curved track, irrespective of said radius. This condition is met for the bogies provided with two wheel sets with a wheel base W, when the distance *D* between the second rotation axis and the first articulation axis, the distance *Z* between the first and second vertical articulation axes and the distance *S* between the first and second rotation axis are such that :

$$Z^2 + W^2 = 4D \cdot (D + S).$$

[0028] According to a second embodiment of the invention, each of the bogies is provided with one pair of wheels, wherein the distance *D* between the second rotation axis and the first articulation axis, the distance *Z* between the first and second vertical articulation axes and the distance *S* between the first and second rotation axis are such that:

$$Z^2 = 4D \cdot (D + S).$$

[0029] The distance ($S + 2D$) is approximately equal to the length of the car superstructures. Advantageously 15 *meters* $\leq S + 2D \leq$ 25 *meters*.

[0030] Advantageously, $2.5 \leq \frac{(S + 2D)}{Z} \leq 5$. The length of the intermediate car module is substantially less than the length of the cars.

[0031] Preferably, $Z + 2D \leq \frac{S}{2}$. The distance between the nearest bogies of two adjacent cars is less than half the distance between the two bogies of the same car.

[0032] According to one embodiment, the first and second rotation axes are fixed in relation to the first car superstructure, and the third and fourth rotation axes are fixed in relation to the second car superstructure.

[0033] Advantageously, the first and second articulation axes are fixed in relation to the intermediate car module.

[0034] Advantageously, the intermediate car module is supported only by the first and second car superstructures. No additional bogie is required for supporting the intermediate car module. Alternatively, the intermediate car module can also be at least partly supported by the bogies.

[0035] The intermediate car module is the preferred location for the overhead electric current collectors and/or the door openings for boarding and alighting the vehicle. Preferably, the first car superstructure and the second car superstructure comprise passenger compartments or saloons and are not provided with door openings for boarding and alighting from the vehicle.

[0036] In a preferred embodiment, the vehicle is further provided with a first bellows between the first car superstructure and the intermediate car module, and a second bellows between the intermediate car module and the second car superstructure. The second bogie extends at least partially below the first bellows and the third bogie extends at least partially below the second bellows.

[0037] More generally, the second and third bogies preferably extend at least partially below the intermediate car module. This configuration leaves more space for large bogies, e.g. bogies with a large wheel-base *W*, in particular when the articulation axis is close to the rotation axis of the bogie, i.e. when *D* is small.

[0038] Preferably, longitudinal forces transmitted from the first car to the second car are transmitted through the intermediate car module.

[0039] The invention applies primarily to intercity rail vehicles, high-speed trains included. It can, however, also be implemented in tramway vehicles and, more generally, in any type of passenger rail vehicle.

[0040] Other advantages and features of the invention will become more clearly apparent from the following description of specific embodiments of the invention given as non-restrictive examples only and represented in the accompanying drawings in which:

- figure 1 is a side view of a railway vehicle according to a first embodiment of the invention, including two cars connected by an intermediate car module;
- figure 2 is a sectional top view of the railway vehicle of figure 1;
- figure 3 is a schematic side view of the vehicle of figure 1, without body structure;
- figure 4 illustrates a schematic view of the intermediate car module of figure 1 during a mounting process;
- figure 5 illustrates a detail of a movable floor of the intermediate car module, in a low position;
- figure 6 illustrates the movable floor of figure 5 in a high position;
- figure 7 is a side view of a railway vehicle according to a second embodiment of the invention;
- figure 8 is a schematic view of an articulated railway vehicle of the invention in a curve; and
- figure 9 is a geometric illustration of the parameters used for optimizing the position of the rotation axes of the vehicle of figure 8;
- figure 10 is a schematic view of a conventional articulated rail vehicle of the prior art in a curve.

[0041] With reference to figures 1 to 4, an articulated passenger rail vehicle 10, in this example an intercity rail vehicle, is provided with passenger cars 12A, 12B and intermediate suspended modules 14.

[0042] Each of the passenger cars is provided with a car superstructure 16A, 16B supported by two bogies 18A, 20A, 18B, 20B. Each car superstructure is formed of a frame 22A, 22B that supports a single-hull body structure 24A, 24B. In this embodiment, the frame 22A, 22B partly protrudes from the body structure at both longitudinal ends of the car. The bogies are located below the longitudinal protrusions 26A, 26B of the frame. The bogies 18A, 20A, 18B, 20B are preferably four-wheel bogies which are allowed to rotate in relation to the corresponding frame about a rotation axis 28A, 30A, 28B, 30B, e.g. by means of a kingpin and/or connecting rods as is well known in the art. The connection may allow some lateral relative motion between the vehicle superstructure and the bogie as well as rotation about horizontal lateral and/or longitudinal axes. A secondary suspension (not shown) is also provided between the bogies and the superstructure as is well known in the art.

[0043] The distance between rotation axes 28A, 30A of the two bogies of a passenger car 12A is substantially greater than the distance between the rotation axes 30A, 28B of the two closest bogies of successive passenger cars 12A, 12B. For instance, the distance between the adjacent bogies of two successive cars can be 4 to 8 meters, or less, while typically the span between the two bogies of a passenger car will be 17 meters or more. The location of the rotation and articulation will be discussed hereinafter with reference to figures 8 and 9.

[0044] The bogies 20A, 18B extend at least partly below the intermediate car module 14 which is directly supported by the longitudinal protrusions of the frames of the two adjacent cars so as to pivot about two vertical articulation axes 32A, 32B. The distance between the two articulation axes 32A, 32B of the intermediate car module is smaller than the distance between the axes of rotation 30A, 28B of the adjacent bogies. The intermediate car module 14 has a single-hull body 40 reinforced so as to transfer the longitudinal forces from one car to the next. More specifically, the connection between the body structure of the intermediate car module and the frame of each adjacent car is realized by means of a lower knuckle joint 42A, 42B, as shown schematically in figure 4. Further guidance can be provided by an upper knuckle joint 44A, 44B comprising an upper pin 46A, 46B cooperating with a foldaway knuckle 48A, 48B hinged to the body structure of the adjacent car. This construction makes it possible to easily assemble and disassemble the intermediate cars, e.g. to give good access to the cars for maintenance or refurbishing. Of course, other types of articulated connections or swivel couplings can be used between the intermediate car module and the adjacent cars.

[0045] The intermediate car module is provided on each lateral side with a door 50 for closing a large door opening 51. One or more electric current collectors 52 and/or one or more electrical brakes (not shown) are fixed to the roof of the intermediate car module. The intermediate car module can be equipped with one or more toilet compartments and/or luggage storage areas.

[0046] The intervals between the car superstructures and the intermediate car module are bridged by deformable airtight connections in the form of bellows 55A, 55B. The bellows can have a simplified structure and a large passageway opening, since the relative rotation angle between the intermediate car module and the car superstructures is about half the relative rotation angle between two cars in a conventional train. Preferably, inflatable chamber bellows are used, as known, for example, from US4539912. The knuckle joints 42A, 42B, 48A, 48B are preferably arranged such that the vertical articulation axes 32A, 32B are located within the space surrounded by the bellows 55A, 55B or very close to the bellows.

[0047] The intermediate car module 14 forms a vestibule 56 for boarding and alighting the train, and a passageway 58 from one passenger car to the next. The passenger cars themselves do not have to include boarding doors and vestibules, which may leave more space for passenger seats 60. An interior partition with a sliding door can be provided at each end of each passenger car, to isolate the saloons or compartments from the adjacent intermediate car module.

[0048] Figures 5 and 6 depict the floor of the intermediate car module and will now be described in more detail. A central movable platform 70 is located laterally between the two door openings 51A, 51B, and two ramps 72A, 72B join the central platform to stationary sills 74A, 74B located at each end of the intermediate car module. The sills are flush with the floor level of the adjacent vehicle bodies. The ramps 72A, 72B are hinged to the edges of the sills 74A, 74B and have a free end extending below or above the central platform 70. The central platform 70 is guided so as to move vertically between a low position shown in figure 5 and a high position shown in figure 6. An electric motor (not shown) is coupled to a worm drive (not shown) to move the central platform 70 and the ramps 72A, 72B between the low and high positions. Alternatively, any other type of motor or source of mechanical work, e.g. a hydraulic ram or an air cylinder can be used. In the high position, the platform and the ramps are flush with the sills and the floors of the adjacent cars. When the train is in motion, the platform is in the high position. The platform is lowered at stations to allow wheelchairs and/or trolleys to board and alight the train and/or to facilitate boarding of physically challenged individuals. To keep the slope of the ramps reasonably level, the sills should be preferably located as far as possible from the central platform and take advantage of the full length of the intermediate car module.

[0049] With reference to figure 7, an articulated passenger rail vehicle 10 according to a second embodiment of the invention is shown. The passenger vehicle according to the second embodiment of the invention, in this example an intercity rail vehicle, is of similar constitution to that of the first embodiment: the same reference numbers have been taken to designate identical or similar elements.

[0050] The vehicle is provided with passenger cars 12A, 12B and intermediate suspended modules 14. Each of the passenger cars is provided with a car superstructure 16A, 16B formed of a single-hull body structure 24A, 24B extending between two ring-shaped support modules 100A, 102A, 100B, 102B, each supported by two bogies 18A, 20A, 18B, 20B. The bogies 18A, 20A, 18B, 20B are preferably four-wheel bogies which are allowed to rotate in relation to the corresponding support module 100A, 102A, 100B, 102B about a rotation axis 28A, 30A, 28B, 30B, e.g. by means of a kingpin and/or connecting rods as is well known in the art. The ring-shaped modules 102A, 100B, are rigidly connected to the adjacent single-hull body structure 24A, 24B at one end and are connected to the intermediate suspended module 14 via an articulated connection at the other end. Each articulated connection has a vertical axis of articulation 32A, 32B, which is offset with respect to the axis of rotation 30A, 30B of the adjacent bogie. Bellows located between the intermediate car module and the ring-shaped support modules allow communication between the cars. Preferably, the axis of rotation of the articulated connection is located within the space defined by the bellows, i.e. between the ring-shaped support module and the intermediate car module, such that when the car pivots with respect to the intermediate module, the side movements are minimized.

[0051] The intermediate module is identical to the intermediate module of the first embodiment.

[0052] The ring-shaped support module imparts modularity to the train and can also be used to connect the single-hull car superstructure to a driver's cab module 110. To increase modularity, the driver's cab module can be chosen out of a range of interchangeable driver's cab modules having different shapes and/or different technical specifications. The connection between the driver's cab module and the support module is preferably rigid, even though an articulated driver's cab is also possible, as disclosed e.g. in US 2001/0052305. Alternatively, the driver's cab 110 can be connected to an intermediate module 114 to offer another door, and/or a room to accommodate bicycles. Advantageously, this intermediate module can also be used as additional crash zone.

[0053] If the passenger car is to be connected to a conventional passenger car or a conventional locomotive, an end module 112 can be rigidly connected to the ring-shaped support module. The length of the end module is about half the length of the intermediate car module and is preferably such that, if two end modules 112A, 112B are connected to one another, the resulting distance between the two support modules on both sides of the end modules would be the same as the distance between two support modules on both sides of an intermediate module 14.

[0054] The geometrical configuration of the cars and bogies of the first and second embodiments will now be described in relation to figures 8 and 9. In these figures, the vehicle has been represented on a curved track 150 of constant curvature. For illustration purposes, the centerline 152 of the track 150 has been represented, as well as the outside envelope 154 of the train. The longitudinal vertical center plane 156A, 156B of each car superstructure contains the vertical axes of rotation 28A, 30A, 28B, 30B of the undercarriages in relation to the car superstructure and crosses the centerline 152 of the track in the immediate vicinity of the vertical axes of rotation. The vertical center plane 158 of the intermediate module contains the vertical articulation axes 32A and 32B. In figure 9, the following parameters have been illustrated:

S is the distance between the first rotation axis and the second rotation axis
Z is the distance between the first articulation axis and the second articulation axis
D is the distance between the second rotation axis and the first articulation axis
R is the radius of curvature of the track centerline
X is the distance between the longitudinal center plane of the intermediate car module and center of curvature of the track
W is the distance between the front and rear wheel axle of the bogies
e is the distance between the first or second rotation axis and the centerline of the track.
a is the distance between the first articulation axis and the centerline of the track.
i is the distance between the longitudinal center plane of the first car and the centerline of the track.

[0055] Considering the different right triangles, the geometrical relations are given with a very good approximation by the following equations:

$$\text{(I)} \qquad (R-i)^2 + \left(\frac{S}{2}\right)^2 = (R-e)^2$$

$$\text{(II)} \qquad (R-i)^2 + \left(\frac{S}{2}+D\right)^2 = (R-e+a)^2$$

$$\text{(III)} \qquad (R-e+a)^2 = \left(\frac{Z}{2}\right)^2 + X^2$$

$$\text{(IV)} \qquad (R-e)^2 + \left(\frac{W}{2}\right)^2 = R^2$$

[0056] Combining the above equations so that the two variables *e* and *i* disappear, it follows:

$$\text{(V)} \qquad \left(\frac{S}{2}\right)^2 - \left(\frac{S}{2}+D\right)^2 + \left(\frac{W}{2}\right)^2 = R^2 - X^2 - \left(\frac{Z}{2}\right)^2 .$$

[0057] Now, if the longitudinal vertical center plane of the intermediate car module is to be tangential to the centerline of the track, then:

$$\text{(VI)} \qquad X = R .$$

[0058] It follows from (V) and (VI) that:

$$\text{(VII)} \quad \left(\frac{S}{2}\right)^2 - \left(\frac{S}{2}+D\right)^2 + \left(\frac{W}{2}\right)^2 - \left(\frac{Z}{2}\right)^2 = 0;$$

and finally:

$$\text{(VIII)} \quad W^2 + Z^2 = (S + 2D)^2 - S^2 = 4D \cdot (D + S).$$

[0059] The equation (VIII) is independent from the radius *R*. For bogies with one set of wheels, the equations are still valid, with the additional condition *W* = 0.

[0060] When the rotation axes of the bogies and the articulation axes of the car bodies meet the requirement of equation (VIII), the longitudinal center plane of the intermediate car module is tangential to the track centerline on any track of constant radius of curvature, as shown in figure 9. The tangent point is located halfway between the articulation axes. Accordingly, if the intermediate car module is arranged as vestibule for boarding, the door opening should also be located halfway between the articulation axes, i.e. be more or less equidistant to the two articulation axes. For the same reason, if the intermediate car module is arranged with current collectors, the current collector head in the extended position should preferably be halfway between the articulation axes.

[0061] The parameters *S*, *D*, *W* and *Z* can be chosen quite freely in the range defined by equation (VIII). It should be noted however that *D* should be strictly above 0 and that in practice *Z* should be above 2.5 to allow the intermediate car module to be used as a vestibule and/ or as a support for an electric current collector. According to one preferred embodiment, the distance S is chosen such that:

$$\text{(IX)} \quad S = \frac{S + 2D + Z}{2}\sqrt{2}.$$

[0062] This equation is similar to the optimization rule used for conventional trains, where the distance *S* is equal to the length of the car superstructure divided by the square root of 2. When this condition is fulfilled, the vehicle construction can be optimized both for vehicles equipped with the intermediate module and for vehicles equipped with two end modules as shown in figure 8, without changing the distance between the axes of rotation of the two adjacent bogies of two adjacent cars.

[0063] In table I below, the distance *W* has been arbitrarily fixed at 2.5 meters, and *S*+*2D*+*Z* has been varied, while *S* is determined by equation (IX).

Table I (all distances in meters)

S+2D+Z	***W***	***S***	***Z***	***S+2D***	***D***
25.000	2.500	17.678	6.125	18.875	0.599
24.000	2.500	16.971	5.870	18.130	0.580
23.000	2.500	16.263	5.614	17.386	0.561
22.000	2.500	15.556	5.358	16.642	0.543
21.000	2.500	14.849	5.101	15.899	0.525
20.000	2.500	14.142	4.844	15.156	0.507

[0064] However, the additional condition of equation (IX) is not compulsory. In table II, the distance S has been varied from $S = \frac{S + 2D + Z}{4}\sqrt{2}$ to $S = 1.25\frac{S + 2D + Z}{2}\sqrt{2}$, while (*S*+*2D*+*Z*) and *W* are fixed.

Table II (all distances in meters)

S+2D+Z	***W***	***S***	***Z***	***S+2D***	***D***
25.000	2.500	8.839	10.813	14.188	2.674
25.000	2.500	13.258	8.859	16.141	1.441
25.000	2.500	17.678	6.125	18.875	0.599
25.000	2.500	22.097	2.609	22.391	0.147

[0065] The value *W* depends on the type of bogie, as shown in table III, in which *W*=0 describes a two-wheel bogie.

Table III (all distances in meters)

S+2D+Z	*W*	*S*	*Z*	*S+2D*	*D*
25.000	0.000	17.678	6.250	18.750	0.536
25.000	1.250	17.678	6.219	18.781	0.552
25.000	1.875	17.678	6.180	18.820	0.571
25.000	2.500	17.678	6.125	18.875	0.599
25.000	3.125	17.678	6.055	18.945	0.634

[0066] When comparing the configuration of figure 8 to the configuration of the previously discussed prior art vehicle illustrated in figure 10, it becomes apparent that the envelope of the vehicle of the invention on the external side of the curve is minimized.

[0067] Of course, on tracks with a variable radius of curvature, the longitudinal center plane may not be exactly tangential to the track centerline. The gap between the longitudinal center plane and the centerline of the track is, however, insignificant. The angle between the longitudinal center plane and the centerline of the track is also negligible.

[0068] While preferred embodiments of the invention have been described, it is to be understood by those skilled in the art that the invention is naturally not limited to these embodiments. Many variations are possible:

[0069] The connection between the intermediate car module and the adjacent cars can be of any type that allows relative vertical rotation and transmits longitudinal forces. Some degree of rotation about a horizontal longitudinal axis of the vehicle may be allowed. For instance, a single lower spherical joint could be used, or a pair of lateral connection rods articulated on both sides of the frame of the passenger car.

[0070] The platform 70 can be replaced by any type of suitable lifting device, e.g. a lifting device as described in WO99/48458.

[0071] The passenger cars may or may not be provided with door openings for boarding and alighting.

[0072] In the present application, the term bogie is used in a very generic way, to designate any type of wheel assembly.

[0073] The bogies can have one or several pairs of wheels. The wheels should be allowed to pivot about a vertical axis with respect to the car superstructures, e.g. together with a frame of the bogie or individually. The bogies can be provided with or without a bogie frame. It can be provided with separate axles for each wheel. One or several axles or wheels can be driven.

[0074] The intermediate car module can be equipped with predefined crush-zones, avoiding the door sections. These crush zones can advantageously supplement or replace crush zones in more frequently occupied areas like the passenger compartments. Similarly, crush zones can be provided on the end modules.

[0075] In the text of the application, there is no substantial difference between the terms articulation axis and rotation axis. The pivotal connection between the bogies and the car frames may have more than one degree of freedom of rotation, i.e. more than one axis of rotation, to allow articulation on a non-even track. Spherical bearing connections are also encompassed by the invention. The same applies to the pivotal connections between the intermediate car module and the adjacent cars. Moreover, the rotation axis of the bogies in relation to the car frame need not be fixed.

[0076] The invention also applies to double-decker rail vehicles, in which case it may be advantageous to provide one or more flights of stairs and/or an elevator for access to the upper and/or lower levels at least partially within the intermediate car module.

Claims

1. An articulated passenger rail vehicle, provided with:

- a first car (12A) comprising a first car superstructure (16A) supported by a first bogie (18A) and a second bogie (20A), wherein the first bogie (18A) rotates in relation to the first car superstructure (16A) about a first rotation axis (28A) and the second bogie (20A) rotates in relation to the first car superstructure (16A) about a second rotation axis (30A);
- a second car (12B) comprising a second car superstructure (16B) supported by a third bogie (18B) and a fourth bogie (20B), wherein the third bogie (18B) rotates in relation to the second car superstructure (16B) about a third rotation axis (28B) and the fourth bogie (20B) rotates in relation to the second car superstructure (16B)

about a fourth rotation axis (30B); and
- an intermediate car module (14A) articulated to the first car superstructure (16A) and to the second car superstructure (16B) so as to pivot about a first vertical articulation axis (32A) fixed in relation to the first car superstructure and about a second vertical articulation axis (32B) fixed in relation to the second car superstructure,

characterized in that:

- the first vertical articulation axis (32A) and second articulation axis (32B) are spaced apart from and located between the second rotation axis (30A) and third rotation axis (28B),
- the distance between the second rotation axis (30A) and the third rotation axis (28B) is substantially smaller than the distance between the first rotation axis (28A) and the second rotation axis (30A), and
- the intermediate car module (14) is provided with a door opening (51) for boarding and alighting the vehicle and with a passageway (58) between the door opening and the first car superstructure (16A).

2. The articulated passenger rail vehicle of claim 1, wherein the distances between the first, second, third and fourth rotation axis and the first and second articulation axis are such that when the vehicle runs on a curved track of constant radius, a longitudinal vertical plane containing the first and second vertical articulation axes is tangential to the centerline of the curved track irrespective of said radius.

3. The articulated passenger rail vehicle of claim 2, wherein each of the bogies is provided with two wheel sets with a wheel base *W* and wherein the distance *D* between the second rotation axis and the first articulation axis, the distance *Z* between the first and second vertical articulation axes and the distance S between the first and second rotation axis are such that :

$$Z^2 + W^2 = 4D \cdot (D + S).$$

4. The articulated rail vehicle of any one of the preceding claims, wherein the first and second rotation axes (28A, 30A) are fixed in relation to the first car superstructure (16A), and the third and fourth rotation axes (28B, 30B) are fixed in relation to the second car superstructure (16B).

5. The articulated rail vehicle of any one of the preceding claims, wherein the first and second articulation axes (32A, 32B) are fixed in relation to the intermediate car module.

6. The articulated passenger rail vehicle of any one of the preceding claims, wherein the first car superstructure (16A) is not provided with door openings for boarding and alighting the vehicle.

7. The articulated passenger rail vehicle of claim 6, wherein the second car superstructure (16B) is not provided with door openings for boarding and alighting the vehicle.

8. The articulated passenger rail vehicle of any one of the preceding claims, wherein the passageway (58) allows passage between the first car superstructure (16A) and the second car superstructure (16B) through the intermediate car module (56).

9. The articulated passenger rail vehicle of any one of the preceding claims, wherein the first car superstructure (16A) and the second car superstructure (16B) comprise passenger compartments or saloons.

10. The articulated passenger rail vehicle of any one of the preceding claims, wherein the intermediate car module (14) is provided with a luggage storage area.

11. The articulated passenger rail vehicle of any one of the preceding claims, wherein the intermediate car module (14) is provided with a toilet compartment and or an electric current collector (52) and or an electric brake.

12. The articulated passenger rail vehicle of any one of the preceding claims, further provided with a first deformable airtight connection (55A) between the first car superstructure and the intermediate car module, and a second deformable airtight connection (55B) between the intermediate car module (14) and the second car superstructure

(16B).

13. The articulated passenger rail vehicle of any one of the preceding claims, wherein the second bogie (20A) and the third bogie (18B) extend at least partially below the intermediate car module (14).

14. The articulated passenger rail vehicle of any one of the preceding claims, wherein longitudinal forces transmitted from the first car to the second car are transmitted through by the intermediate car module (14).

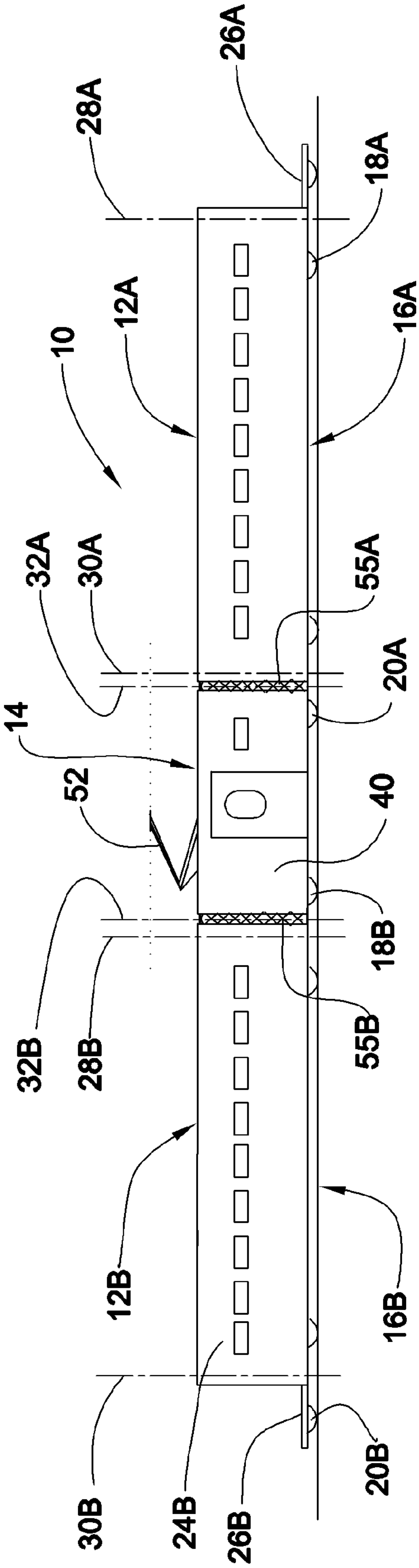
15. The articulated passenger rail vehicle of any one of the preceding claims, wherein the intermediate car module (14) is supported only by the first car superstructure (16A) and the second car superstructure (16B).

16. The articulated passenger rail vehicle of any one of the preceding claims, wherein the intermediate car module (14) comprises a lifting device which can be moved between a higher position which is flush with a floor level of the first car superstructure (16A) and a lower position for facilitating boarding.

17. The articulated passenger rail vehicle of any one of the preceding claims, wherein the vehicle is a double-deck rail vehicle with a lower level and an upper level, and the intermediate car module is provided with stairs to access the upper level.

18. The articulated passenger rail vehicle of any one of the preceding claims, wherein the first car superstructure (16A) comprises:

- a first ring-shaped support module (100A), supported by the first bogie (18A) and rotating in relation to the first bogie (18A) about the first rotation axis (28A);
- a second ring-shaped support module (102A), supported by the second bogie (20A) and rotating in relation to the second bogie (20A) about the second rotation axis (30A); and
- a single-hull body structure (24A) that extends between and is rigidly connected to the first ring-shaped support module (100A) and the second ring-shaped support module (102A).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18A
12A
10
16A
32A
30A
55A
20A
14
52
40
18B
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55B
12B
16B
30B
24B
26B
20B

Fig.1

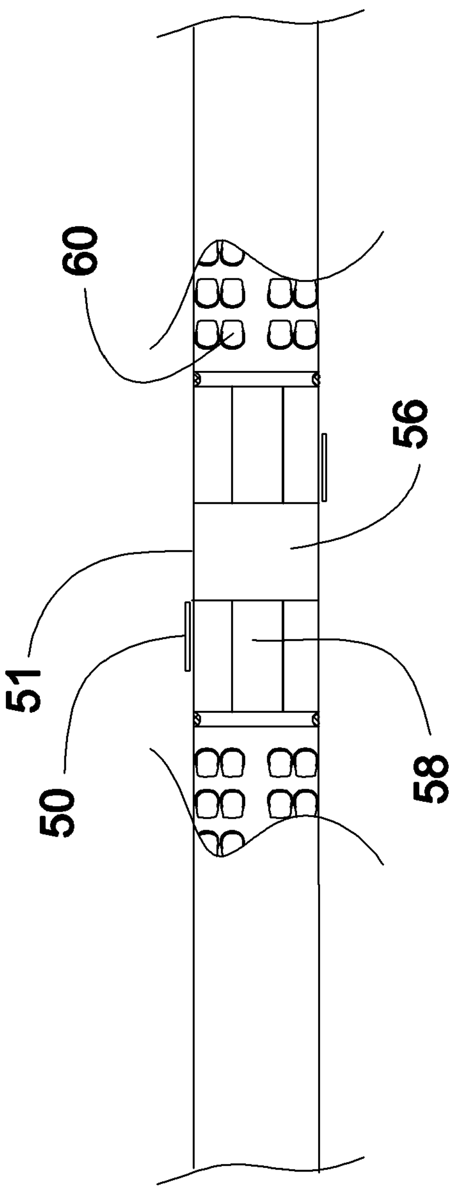
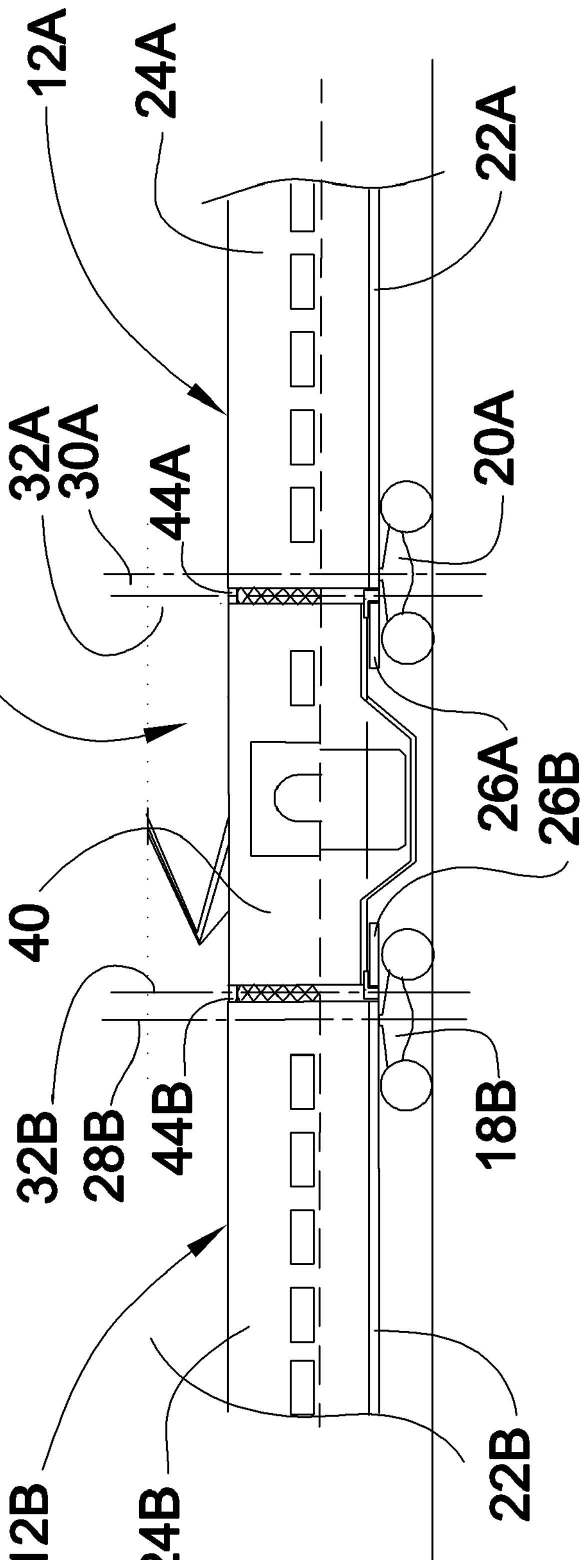


Fig.2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24A
22A
20A
32A
30A
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14
26A
26B
40
32B
28B
44B
18B
12B
24B
22B

Fig.3

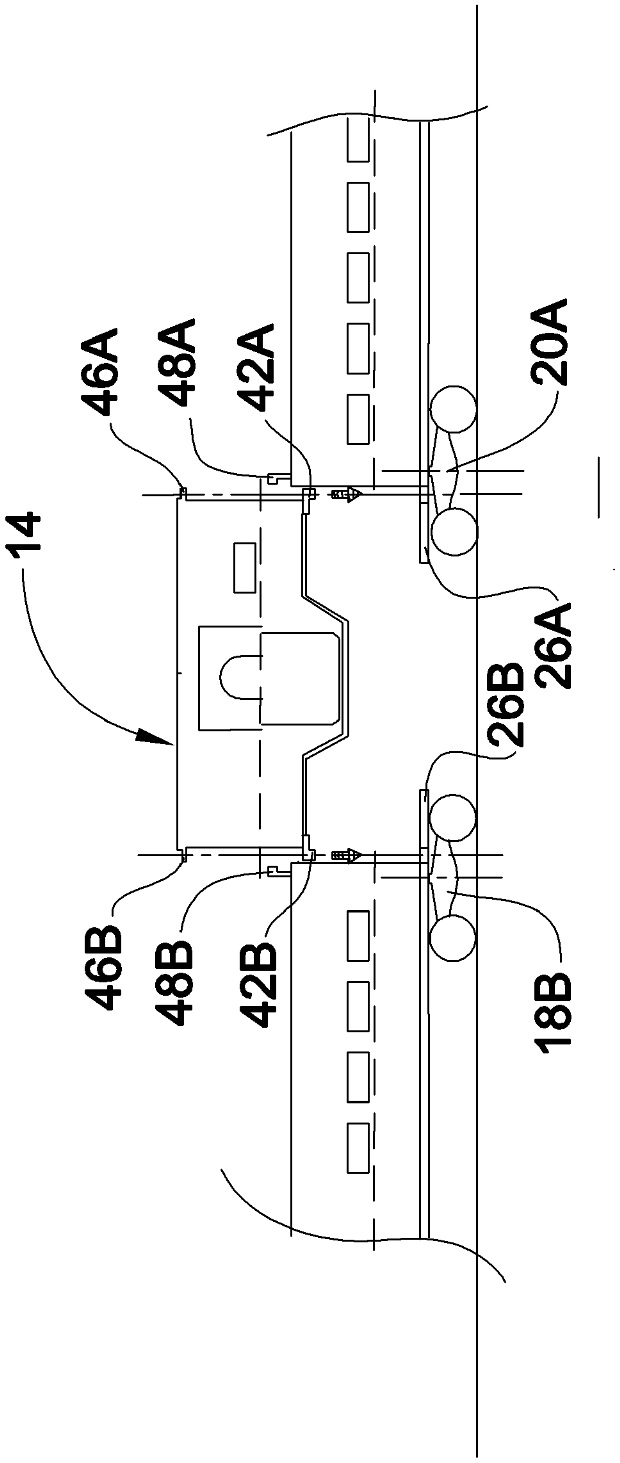
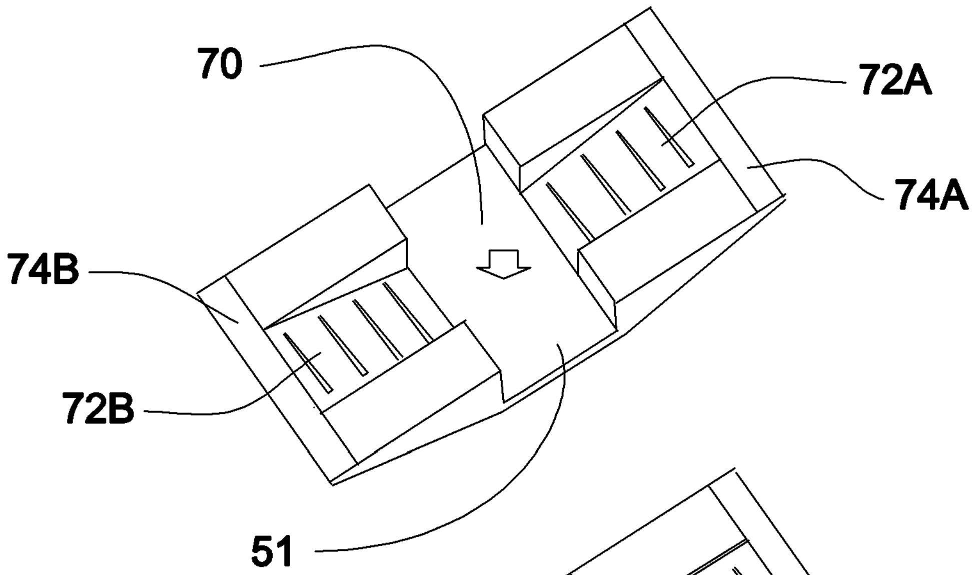


Fig.4

Fig.5



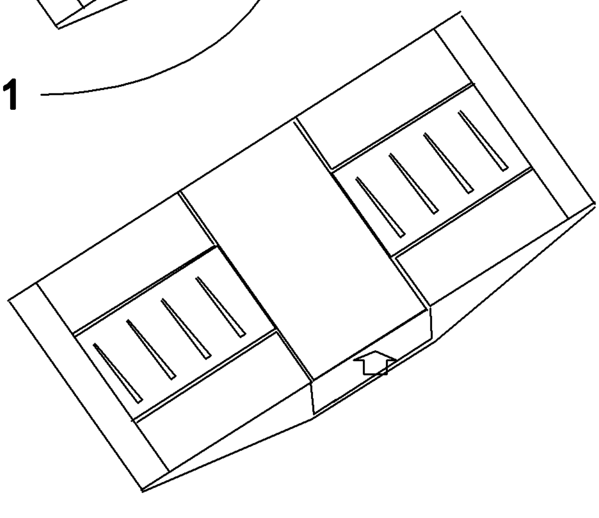
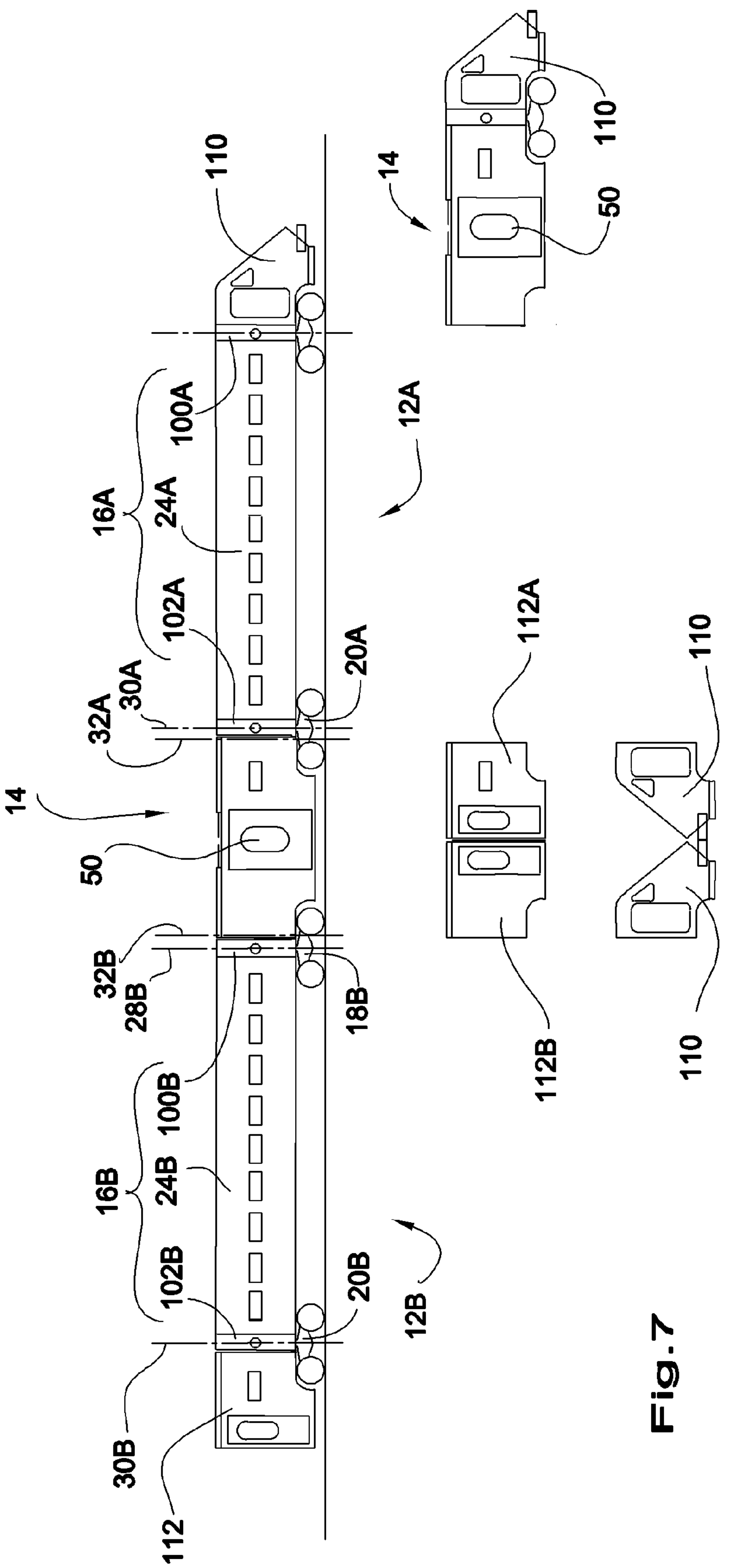


Fig.6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30A
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18B
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112B
110
110

Fig.7

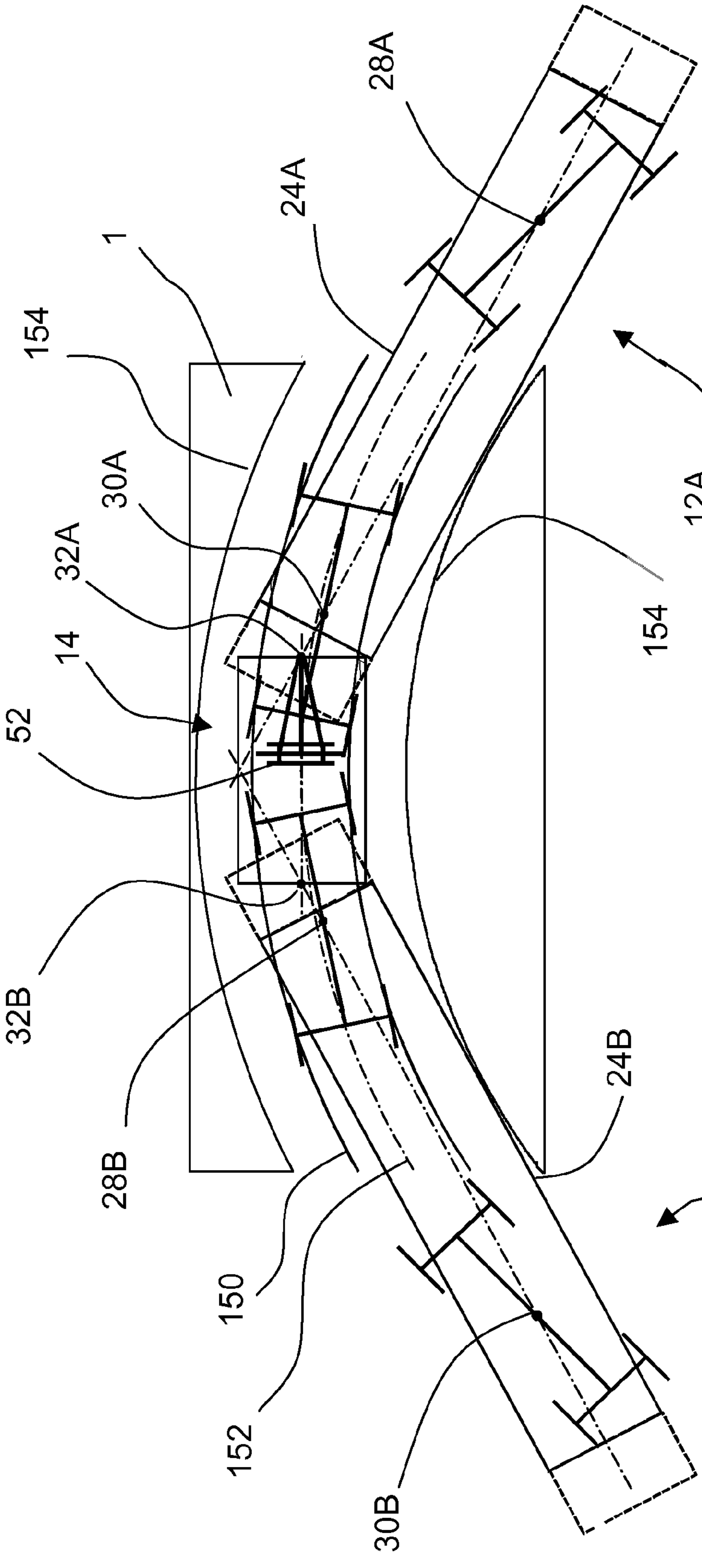

Fig.8

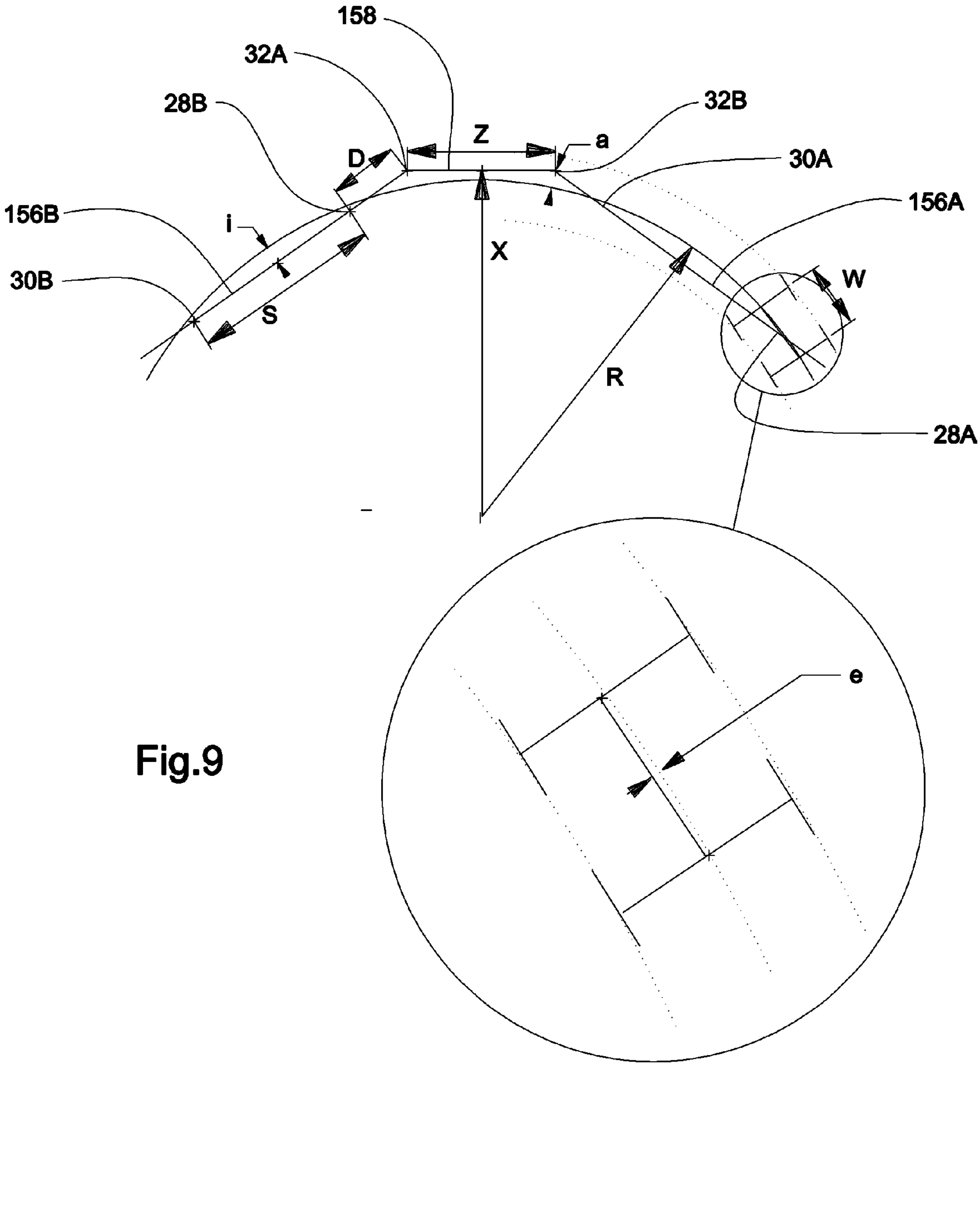

Fig.9

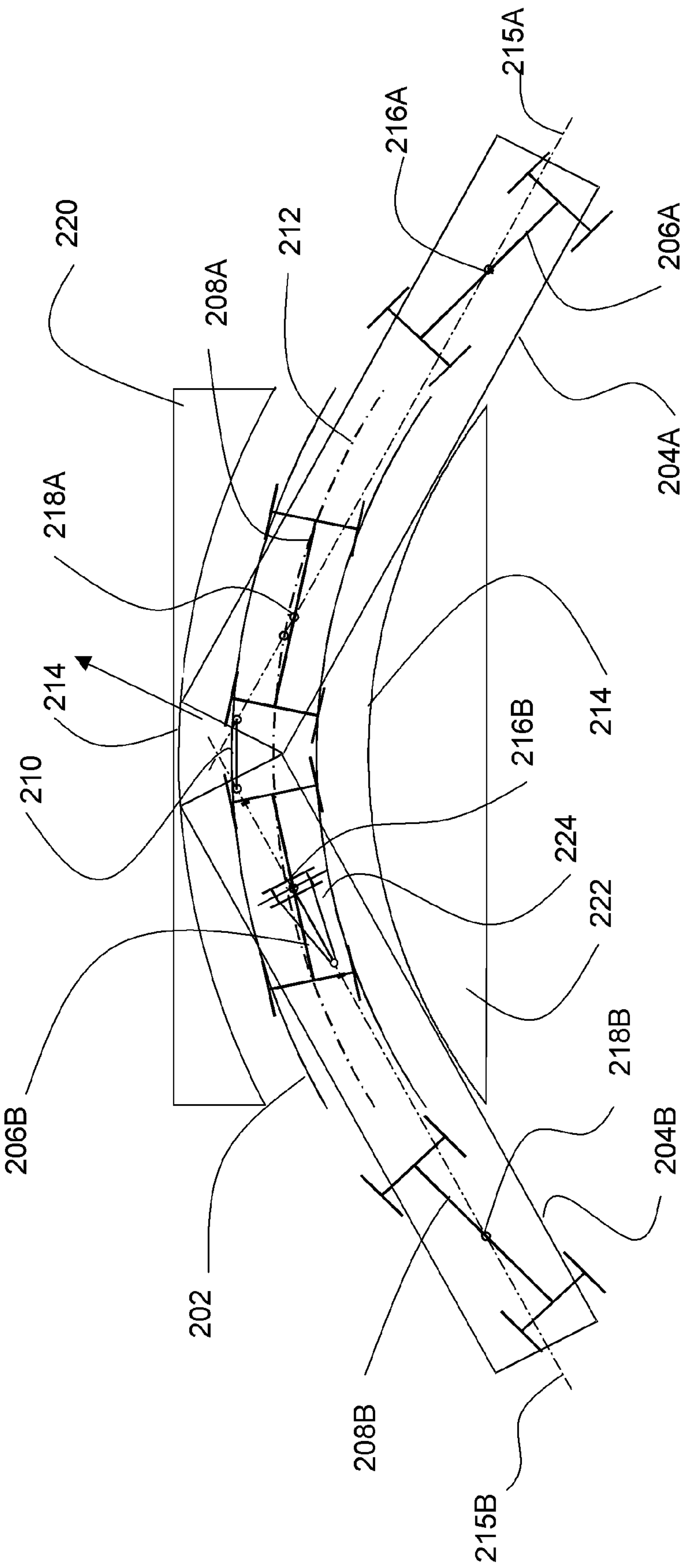

Fig.10

PRIOR ART

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EUROPEAN SEARCH REPORT

Application Number
EP 12 19 8272

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