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[54] **MAGNETICALLY SUSPENDED RAILWAY SYSTEM**

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[51] **Int. Cl.** **E01b 25/08**

[58] **Field of Search** ..... 104/23 FS, 96, 105, 130, 104/134, 148 MS, 148 SS, 148 LM

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[57] **ABSTRACT**

In the magnetically suspended railway system disclosed, magnetizable carriers suspended from under each side of a railroad car, support lift and traction magnets and side-to-side guide magnets which are electrically controlled to move along the underside and upright of an inverse-T shaped magnetizable rail mounted from the tops of stationary C-shaped rail supports. Slide surfaces on the rail supports, which are more closely spaced to the carriers than to the car bottom, hold up the train at the carriers in the absence of magnetic force. At switch areas where the rails diverge into two pairs, stationary lift magnets engage the carrier and guide the car along the desired direction. Interlaced non-touching fingers magnetically couple the carriers from one car to the other.

29 Claims, 7 Drawing Figures

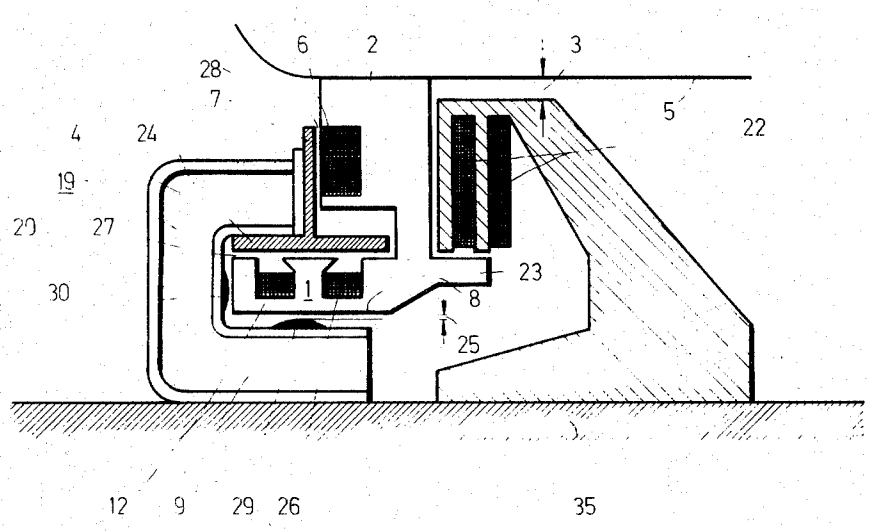
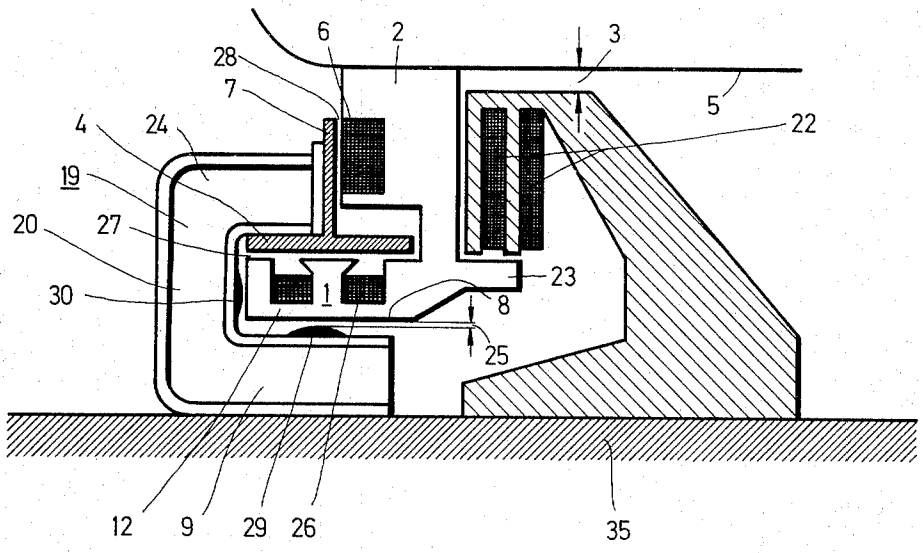


Fig.1



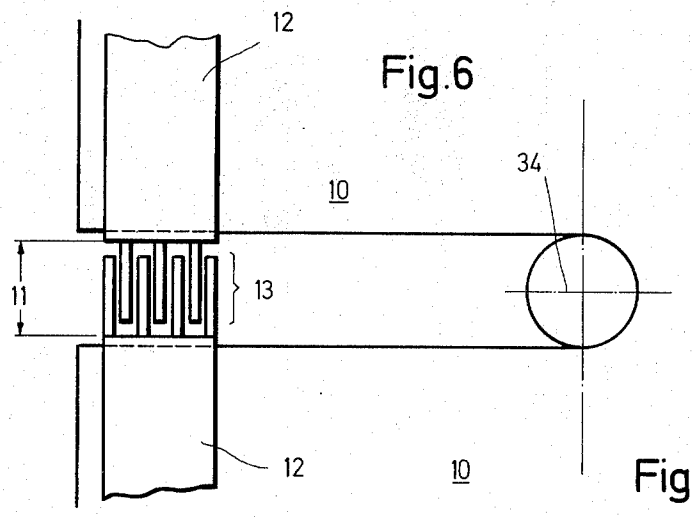
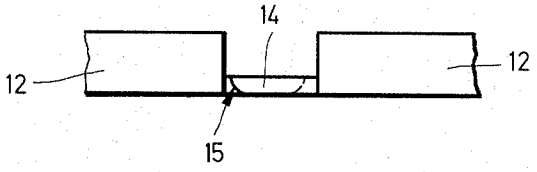


Fig.6

Fig.7



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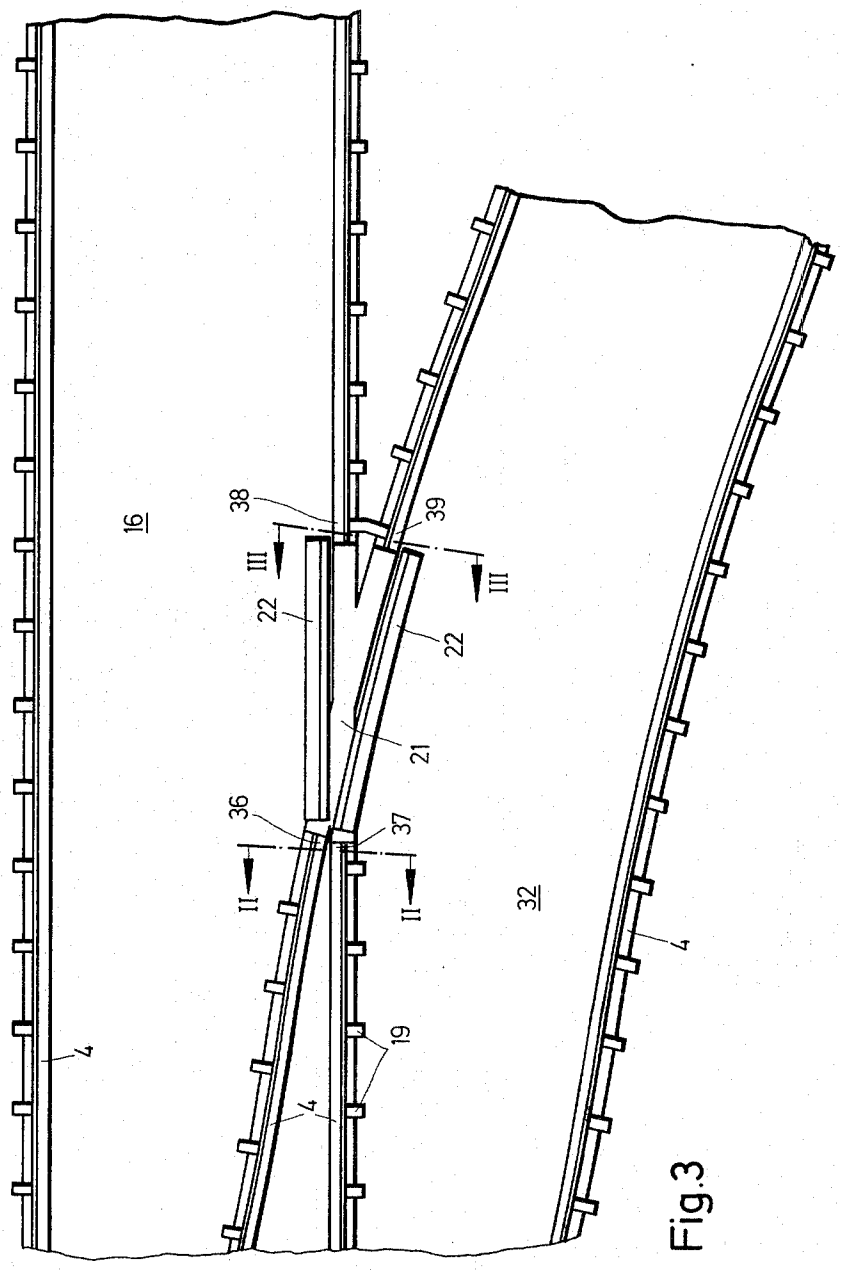

Fig.3

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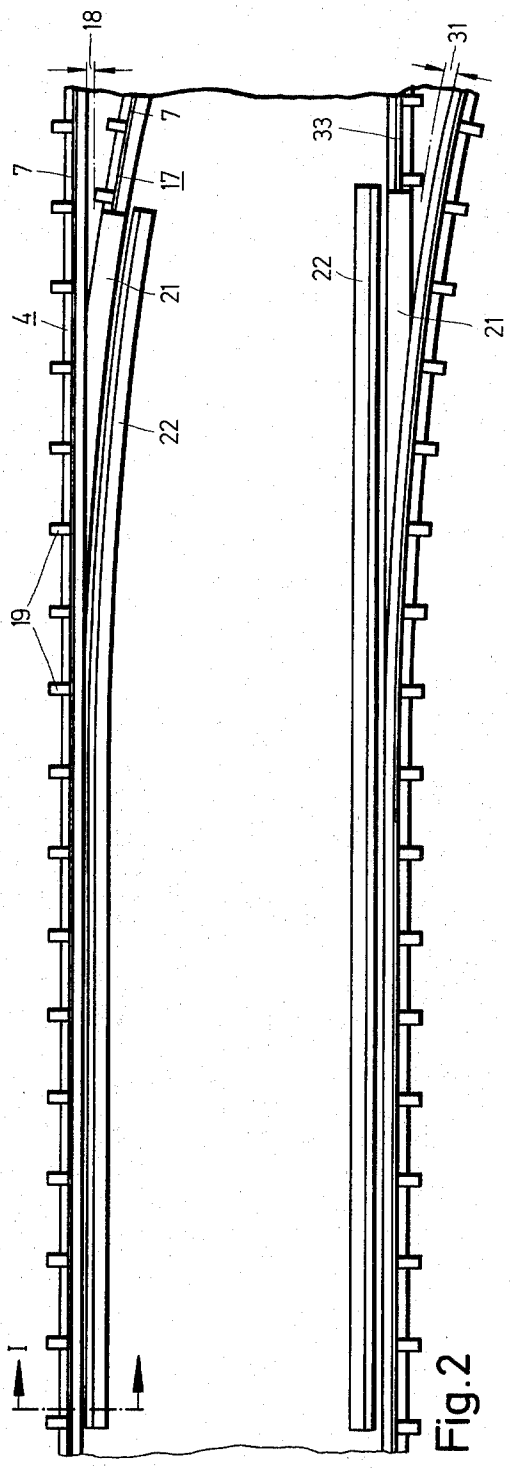

Fig.2

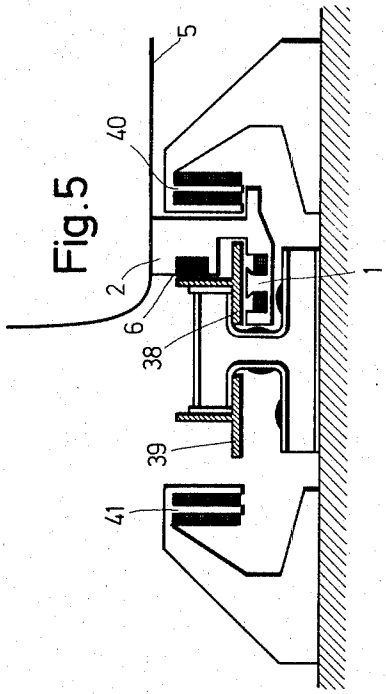

Fig.5

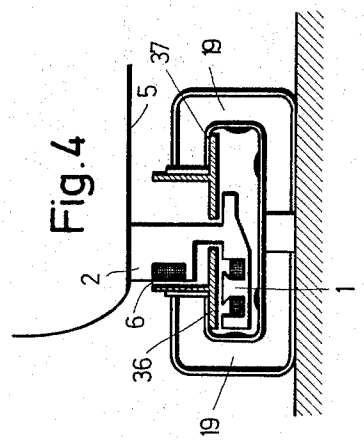

Fig.4

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MAGNETICALLY SUSPENDED RAILWAY SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to suspension railways, and particularly to railways wherein railway cars are suspended above the ground by strong magnetic fields.

In suspension railways supported by traction magnets, carrying magnets are generally mounted above the railway cars in order to keep them floating without other devices to be attached to the vehicle itself. Such a system requires head masts carrying supports for the rail-like armatures that serve as magnetic keepers or short circuits.

Omitting the masts so as to install the rail-like armatures at ground level, requires disposing the carrying magnets on the side of or below the car or vehicle. However, such a system is costly because separate pairs of rails are required to serve as carriers and guides. Such a system also fails to solve the problem of traversing switches where a pair of rails forks into two pairs of rails going in different directions or where two pairs of rails merge. As switch areas this is particularly a problem because there parts of the vehicle may not be magnetically floating. Moreover, such a system fails to take into account a power failure that disables the carrying magnets. Under such circumstances the vehicles can no longer be kept floating. Both the car and the rail may then be destroyed. This is a particular likelihood when the car is traveling at high speed.

It is an object of this invention to improve suspension railways. Another object of the invention is to improve railways where cars are supported against the force of gravity above a rail arrangement by means of carrying magnets disposed below the cars.

Another object of the invention is to eliminate the beforementioned disadvantages.

SUMMARY OF THE INVENTION

According to a feature of the invention these objects are obtained and the disadvantages of the prior art are obviated, by disposing carrying magnets below the vehicle so they are coupled to rail means and suspend the vehicle and move it forward, by securing guide magnets under the vehicle and coupling them to the rail means for transversely guiding the vehicle relative to the rail means, and by securing a carrier to the bottom of the vehicle and mounting the carrying magnet on the carrier. A plurality of running surfaces are then formed on the rail means opposite to the carrier.

According to another feature of the invention the guide magnets are also mounted on the carrier.

According to yet another feature of the invention the rail means includes a magnetizable structure forming an armature for both the carrying magnet and the guide magnet.

According to still another feature of the invention one carrier mounted on one side of the vehicle supports one carrying magnet so that it is magnetically coupled with one rail of the rail means and another carrier supports another carrying magnet so that it is coupled with another rail of said rail means.

According to still another feature of the invention the rails are interrupted at switch areas where the rail means diverge or converge, and slide rails for mechanically supporting the car are disposed in the switch area.

According to yet another feature of the invention the slide rails are disposed so that the carrying magnets slide on the slide rails. Preferably the slide rails are equipped with a slide coating.

According to still another feature of the invention stationary carrying magnets are disposed in the switch area and the carriers include auxiliary armatures for coupling magnetically to the stationary carrying magnets.

According to yet another feature of the invention the stationary carrying magnets are controlled so as to be energized along the travel direction in which the vehicle is to pass.

According to yet another feature of the invention the guide magnets are energized in accordance with the direction of travel as a switch is passed, and thereby assume control of the vehicle.

According to yet another feature of the invention the carrying magnets are disposed to jut out latterally and under the rail. The rails are preferably supported on C-shaped carriers.

According to yet another feature of the invention the distance between the sliding surfaces of the rail means and the carriers is less than the distance between the carriers and the bottom of the cars. In this manner the bottoms of the cars are protected from frictional engagement with the rail means in the absence of magnetic lifting forces.

According to yet another feature of the invention one railroad car following another is magnetically coupled to the other by means of magnetic extensions having non-touching interlacing fingers.

These and other features of the invention are pointed out in the claims. Other objects and advantages of the invention will become obvious from the following detailed description when read in light of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional drawing of a part of a system embodying features of the invention, and showing in detail the essential parts of one side of the vehicle and the accompanying rail arrangement as the vehicle enters the switch area at the section I—I of FIG. 2;

FIG. 2 is a top view of the rail arrangement in the switch area where a vehicle is about to be switched;

FIG. 3 illustrates a top view of a rail arrangement in a switch area at the end of a diverging pair of rails;

FIG. 4 is a section at II—II of FIG. 3 of the system in FIG. 1, again showing the bottom of one side of the vehicle coupled to one rail as it comes out of the switching area;

FIG. 5 is a sectional view illustrating the vehicle of FIG. 1 as it comes out of the switching area at the section III—III of FIG. 3;

FIG. 6 is a top view of two railroad cars forming a part of the system embodying features of the invention and the means for magnetically coupling the car in the system embodying features of this invention; and

FIG. 7 is a side elevation of the structure in FIG. 6.

DESCRIPTION OF PREFERRED EMBODIMENTS

In FIG. 1 a carrying magnet 1 projects from a carrier 2 at the bottom 5 of an otherwise not disclosed vehicle. The latter is driven by a known linear motor arrangement, also not shown. Another carrier 2 which is an identical mirror image of the carrier shown is located

on the other side of the vehicle. The carrying magnet **1** which juts out laterally from the carrier **2** includes a pole plate **12** having electric windings **26** embedded therein. The magnet **1** extends over the entire length of the vehicle. It may be divided into various magnet sections if necessary or desired. Spaced above the magnet **1**, across an air gap **27**, a rail **7** serves as an armature for the carrying magnet **1**. A rail carrier **19** located on a rail bed **35** supports the rail **4**. The rail carrier **19** is C-shaped and composed of a foot **9**, a center portion **20**, and a head **24**.

When the carrying magnet **1** is energized electrically by means of the windings **26** a magnetic field develops between it and the rail **4**. The magnetic field keeps the vehicle floating by means of the carrying magnet **1** and the carrier **2**. In this process the air gap **27** decreases as the energizing current in the windings **26** increases.

To compensate for unevenness in the structure of the guide rail **4**, as well as to balance out deflections of the vehicle such as may be caused by wind gusts, a guide magnet **6**, fastened to the carrier **2** and separated from a longitudinal rib **7** of the rail **4** by another air gap **28**, serves as the carrier's armature.

Depending upon the electrical energization of the guide magnet **6** and another guide magnet which forms a mirror image of the guide magnet **6** on the other side of the vehicle, the unevenness or the deflections or other disturbances can be equalized. Thus the moving parts of the vehicle can be prevented from striking the fixed rail arrangement. Known control and regulating equipment, such as that used for many other control and regulating applications, are used for this purpose.

During the vehicle's operation the asymmetries may become so great that the control and regulating process could be insufficient to prevent the moving parts of the vehicle from striking the fixed rail arrangement. The same can occur if the magnetic field in the carrying magnet collapses. For such eventualities the rail carrier **19** which supports the rail along its entire line at regular intervals, such as every 2 meters, supports running surfaces **29** and **30** in the foot **9** and the center portion **20**. The corresponding parts of the vehicle, namely the magnet **1** can glide on the running surfaces **29** and **30** under these circumstances. If necessary the surfaces **29** and **30** can bring the vehicle to a standstill by converting the vehicle's kinetic energy into frictional heat. In this regard contact between the bottom **5** of the vehicle and the uppermost part of the rail arrangement is prevented by keeping the distance **3** between the bottom of the vehicle and the rail arrangement greater than the distance **25** between the lower surface of the magnet **1** and the running surface **29**. Thus sliding of the magnet **1** on the surface **29** prevents mutual contact between the vehicle and the rail.

FIGS. **2** and **3** illustrate the manner in which the vehicle of FIG. **1** switches over from the rails of one track to a side track or from a through rail to a tongue rail. As shown in FIG. **2** an open section forms a gap **18** between a through rail **16** and a tongue **17**. The gap **18** must be sufficiently wide so as not to interfere with the beforementioned lateral motions emanating from the vehicle so that the carriers **2** and their associated parts **1, 6** and **23** can travel through. As also shown in FIG. **2**, a similar gap **31** is located on the side of the tongue rail opposite the gap **18**. The gap **31** permits free passage of the corresponding parts when the vehicle is to travel on the curved track **32**.

The magnetic circuit is interrupted by a very wide longitudinal air space when the carrying magnet **1** travels across the gap **18**. This makes it impossible for the vehicle to continue floating magnetically. The vehicle thus touches down on the running surfaces **29** of the feet **9** and slides along them. The sliding continues until the magnet is again cooperating with the corresponding portion of the rail **4** as it runs on the tongue **33** during straightaway travel or on the tongue **17** during travel around a bend.

This process of passing a switch can be improved by a through slide rail **21** attached to the feet **9** of the rail carriers **19**. The spacings between the rail carriers **19** are shorter in the area of the switch and particularly at the location of the slide rail **21** than along the remaining portions of the line. This makes it possible more readily to absorb the great mechanical stresses which occur here more frequently. The slide rail **21** assures a more shock-free gliding action than the running surfaces **29**. To reduce the friction against these parts the latter are, according to one embodiment of the invention, provided with special slip or glide coatings composed of materials such as polyamides, polyurethanes, and fluorhydrogen-polymers. According to another embodiment of the invention, the sliding surfaces are lubricated in the more conventional manner.

Such an arrangement is roughly comparable to the path of the flange of the usual flange wheel used in conventional railroads over a filler piece or fairing at the switch point in crossings and switches for the purpose of shock attenuation. Such an arrangement is simple but not free of wear. In the suspension railway described above this would be the only place during operation of the vehicle that the vehicle does not glide forward while it is being floated magnetically.

According to another embodiment of the invention considerable improvement results from replacing the glide guides or slide guides in the area of the switches by a magnetic floating guide which corresponds, in the regular case, to a reversal of the normal guide described above and used in straightaway travel. For this purpose a stationary carrying magnet **22** of appropriate length is fastened along the line in the switch area. A cooperating auxiliary iron armature **23** is attached to the vehicle. The coil of the stationary magnet **22** is electrically energized either continually or only when a vehicle approaches. In any event the vehicle is kept floating in the switch areas where the through rail **4** is interrupted. This is done by the the carrying magnet **22** and the auxiliary armature **23**. This avoids the vehicle's running over the surfaces **29** or the slide rail **21**.

According to another embodiment of the invention the slide rails **21** are also provided with the auxiliary armature **23** to take care of emergencies such as failure of the magnetic energization.

The vehicle may be guided through the switches either solely or only partly by the guide magnet **6** following through longitudinal rib **7** to the left for straightforward travel and to the right for a right turn. The direction is selected by increasing or decreasing the energization of the guide magnet **6** located on the left or on the right below the vehicle bottom **5**. This means it is controlled from the train. This contrasts with the control heretofore practiced with switch mechanism located off the train on the ground. The guidance of the vehicle may even be programmed into the vehicle. This programming may cause the vehicle to turn off the

through track on the basis of so-called target departure. On the other hand it may be said to respond to an emergency in the vehicle as a so-called emergency departure.

The passage of a vehicle through a switch area may be followed by studying FIGS. **1, 4** and **5** successively. In the position of the vehicle corresponding to FIG. **1,** the stationary carrying magnet or lifting magnet **22** operates together with the carrying magnet **1.** When the vehicle travels to the right the carrying magnet **22** assumes the responsibility for keeping the left side of the vehicle floating to the extent that the carrying magnet **1** is unable to or is not adequately able to be held in suspension by the parts of the rail **4** which serve as the armature for the magnet **1.** In the position shown in FIG. **4,** that is in the section II—II FIG. **3,** the vehicle is already in the process of leaving the switch area. On the left side it is carried only by a rail portion **36.** A rail portion **37** which is provided for straightforward travel remains out of action. In the position shown in FIG. **5,** which is a section III—III of FIG. **3,** a rail portion **38** now carries the vehicle while a rail portion **39,** provided for straightforward travel, remains out of action. At the same time the effect emanating from the fixed carrying magnet **40** also ends at this position. The other fixed carrying magnet would have been functional only during straight away travel. The arrangement according to the invention obviates the switch setting time which would otherwise be required. Under these circumstances two vehicles traveling immediately behind one another can be separated. This can be done even if they have traveled up to the switch as a unit.

The system according to the invention does not require moving parts. Thus it is basically no longer necessary to limit the arc radius of the switch. As a result the switch can be traversed at full traveling speed. This enables a train leaving the line to slow down after it has passed the switch. Thus a train leaving a line need not interfere with the flow of traffic in the line.

The above advantage also applies for vehicles entering a line. This can also be done at full speed. It is necessary therefore to take the flow of traffic into consideration only to the extent that vehicles are required to keep the necessary distance between each other.

When several vehicles or cars are coupled to form a single unit such as a train, then according to another embodiment of the invention, the through-carrying magnets are provided with interruptions as shown in FIG. **6.** These interruptions are distributed over the length of the train at the ends of the vehicles **10.** The vehicles **10** are shown only in part to the left of a pivot point **34.** The purposes of the interruptions is to allow the train to negotiate curves.

Such interruption might endanger continuous floating. This is so because in curves the interruptions **11** between the pole plates **12** of the carrying magnet would coincide with the feet **9.** At larger curve radiuses and under some circumstances even during straightforward travel, the interruptions may produce hard shocks to the vehicles **10.** As shown in FIG. **6,** this is avoided by providing the ends of the pole plates **12** of the carrying magnets **1** with teeth **13** which resemble those of expansion joints on bridges and which mesh. Thus for all practical purposes a closed back surface for the neighboring pole plates **12** is created in the area of the interruptions **11.**

In order to avoid protruding edges the ends **15** of the teeth **14** are rounded off as shown in FIG. **7.**

The teeth assure a virtually closed magnetic path even when the train negotiates curves and when the vehicles **10** are mutually pivoted about the pivot point **34.** This results in a constant magnetic field. Therefore, the vehicles are floated in a quite and steady manner.

In FIG. **5,** the other fixed magnet **41** which would have become functional for straight travel is substantially the mirror image of the magnet **40.**

It should be noted that electrical control circuits are mounted on the vehicle or car, or cars **10** of FIGS. **1, 4, 5,** and **6** for controlling the magnets **1** and **6.** Similar control circuits for the magnets **22, 40** and **41** are mounted according to one embodiment of the invention, on the cars or vehicles. According to another embodiment of the invention the controls for magnets **22, 40** and **41** are mounted off the vehicle. Where vehicle mounted, these controls may be coupled from the train to a stationary energizing source.

While embodiments of the invention have been described in detail it will be obvious to those skilled in the art that the invention may be embodied otherwise without departing from its spirit and scope.

What is claimed is:

1. A suspension railway system, comprising a vehicle, rail means located under the vehicle, carrying magnet means disposed below the vehicle and coupled to said rail means for suspending the vehicle and moving the vehicle forward, guide magnet means secured under said vehicle and coupled to said rail means for transversely guiding the vehicle relative to said rail means, carrier means secured to the bottom of said vehicle and mounting said carrying magnet means, said rail means including at least one magnetic structure forming an armature for both said carrying magnet and said guide magnet means, said carrier means projecting said carrying magnet means below the armature, said armature being disposed between said carrying magnet means and the bottom of the vehicle, and a plurality of running surfaces on said rail means and opposite said carrier means for mechanically supporting said vehicle during the absence of suspension, said rail means including a switch area at which said armature is interrupted, said rail means further including slide means in the switch area for mechanically supporting the vehicle during the absence of suspension.

2. A system as in claim **1,** wherein said carrier and said slide means are located relative to each other so that when said vehicle passes through the switch area said carrier is disposed opposite said slide means.

3. A system as in claim **1,** wherein said slide means include a coating of slipping material.

4. A system as in claim **1,** wherein said rail means includes stationary magnet means along said rail means in the switch area, said carrier including a magnetizable portion opposing said stationary magnet means for forming an armature for said stationary magnet means when said carrier passes through said switch area.

5. A system as in claim **4,** wherein said rail means forks in two directions at said switch area and wherein said stationary magnet means includes a first electromagnetic portion extending in one of the directions and a second electromagnetic portion extending in the other direction, and wherein control means energize only the electromagnetic portion extending in the direction in which the vehicle is intended to pass.

6. A system as in claim 1, wherein controller means energize said guide magnet and said carrying magnet means, and wherein said controller means energize said guide magnet means in accordance with the direction the vehicle is to follow when passing through the switch area.

7. A system as in claim 1, wherein the armature is longitudinal and said rail means forms a second longitudinal armature coupled to said carrier magnet means and said guide magnet means, said armatures being located during operation of the vehicle on respective sides of the vehicle, said second armature being coupled to both said carrying magnet means and said guide magnet means, said carrier means projecting said carrying magnet means below said second armature, said second armature being disposed between said magnet means and the bottom of the vehicle.

8. A system as in claim 7, wherein carrying magnet means includes a first portion and a second portion, said carrier means projecting said first portion under said first armature and said second portion under said second armature.

9. A system as in claim 8, wherein said carrier means project under said armatures and hold respective portions of said carrying magnet means above said carrier means projecting under said armatures.

10. A system as in claim 8, wherein said carrying magnet means project laterally away from the center of said vehicle.

11. A system as in claim 8, wherein the distance between said carrier means and said slide means is smaller than the distance between said rail means and the bottom of the vehicle.

12. A system as in claim 8, wherein said rail means includes stationary magnet means having two portions each extending along said rail means in the switch area adjacent the interrupted portions of said armatures, said portions of said carrier means including a magnetizable part opposite each of said portions of said stationary magnet means for forming an armature for said portions of said stationary magnet means when said carrier means passes through the switch area.

13. A system as in claim 12, wherein said rail means forks at two directions at said switch area, and wherein said portions of said stationary magnet means each include a first electromagnetic part extending in one of the directions and a second electromagnetic part extending in the other direction, and wherein control means energize only the electromagnetic parts extending in the direction in which the vehicle is intended to pass.

14. A system as in claim 8, wherein controller means energize said guide magnet means and said carrying magnet means and wherein said controller means energize said guide magnet means in accordance with the direction the vehicle is to follow when passing through the switch area.

15. A system as in claim 8, wherein said rail means include two sets of support means, each of said support means having a foot portion, a central portion, and a head portion, each of said head portion supporting said armatures, said running surfaces being formed at the foot portions.

16. A system as in claim 8, wherein said rail means include armature supports and said running surfaces form part of said armature supports.

17. A system as in claim 8, wherein said running surfaces are formed from materials shaped as domes.

18. A system as in claim 8, wherein said first portion and said second portion extend longitudinally along the vehicle, said first portion and said second portion being respectively divided into a plurality of sections, said carrier means having a plurality of carriers, a plurality of said carriers each carrying one of said sections of said first portion and projecting said sections of said first portion under the first armature, a plurality of said carriers each carrying a section of said second portion and projecting the sections of said second portion under the second armature, said first plurality of carriers being longitudinally spaced under one side of the vehicle and said second plurality of carriers being longitudinally spaced under the other side of the vehicle.

19. A system as in claim 8, wherein said guide magnet means includes a first portion and a second portion, said carrier means positioning said first portion of said guide magnet means alongside said first armature and said carrier means positioning said second portion of said guide magnet means adjacent said second armature.

20. A system as in claim 19, wherein said first portion and said second portion extend longitudinally along the vehicle, said first portion and said second portion being respectively divided into a plurality of sections, said carrier means having a plurality of carriers, a plurality of said carriers each carrying one of said sections of said first portion and projecting said sections of said first portion under the first armature, a plurality of said carriers each carrying a section of said second portion and projecting the sections of said second portion under the second armature, said first plurality of carriers being longitudinally spaced under one side of the vehicle and said second plurality of carriers being longitudinally spaced under the other side of the vehicle.

21. A system as in claim 20, wherein each of said portion of said guide magnet means is divided into longitudinally spaced sections and each of said carriers carries one of said sections.

22. A system as in claim 7, wherein said carrier means project under said armatures between said magnetic means and said running surfaces.

23. A system as in claim 7, wherein said carrying magnet means project laterally outward away from the center of said vehicle.

24. A system as in claim 1, wherein said carrier means projects under said carrying magnet means.

25. A system as in claim 1, wherein said carrying magnet means project laterally outward away from the center of said vehicle.

26. A system as in claim 1, wherein the distance between said carrier means and said slide means is smaller than the distance between said rail means and the bottom of the vehicle.

27. A system as in claim 1, wherein said rail means includes C-shaped support means for said armature, said support means having a foot portion, a central portion and a head portion, said armature being supported by said head portion and said running surfaces being formed at the foot portion.

28. A system as in claim 1, wherein said rail means include armature supports and said running surfaces form part of said armature supports.

29. A system as in claim 1, wherein said running surfaces are formed from materials shaped as domes.

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