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Goodnight et al.

[11] **3,861,321**

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[54] **TRANSPORTATION SYSTEM AND VEHICLES FOR THE SYSTEM**

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[52] **U.S. Cl.** ..... **104/148 MS**, 104/130, 104/105, 104/23 FS

[51] **Int. Cl.** **B61b 13/00**

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

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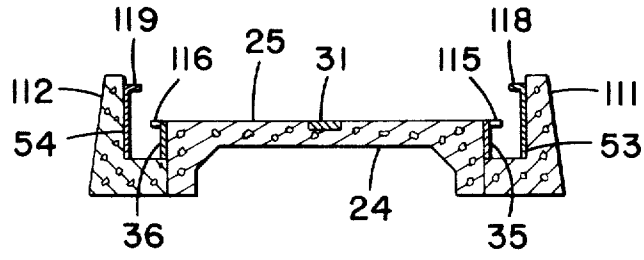
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Assistant Examiner—D. W. Keen
Attorney, Agent, or Firm—Walter J. Jagmin; James M. Cate; H. C. Goldwire

[57] **ABSTRACT**

A transportation system having a roadway and vehicles movable over the roadway, the vehicles being levitated over the roadway by air cushion or magnetic means and the vehicles and the roadway having cooperable magnetic means for maintaining the vehicles properly aligned relative to the roadway. A vehicle movable over a roadway provided with ferromagnetic side rails, the vehicle having selectively energizable electromagnet assemblies at its sides cooperable with the ferromagnetic side rails for maintaining the vehicle in proper longitudinal alignment with the roadway during its movement thereover.

13 Claims, 13 Drawing Figures



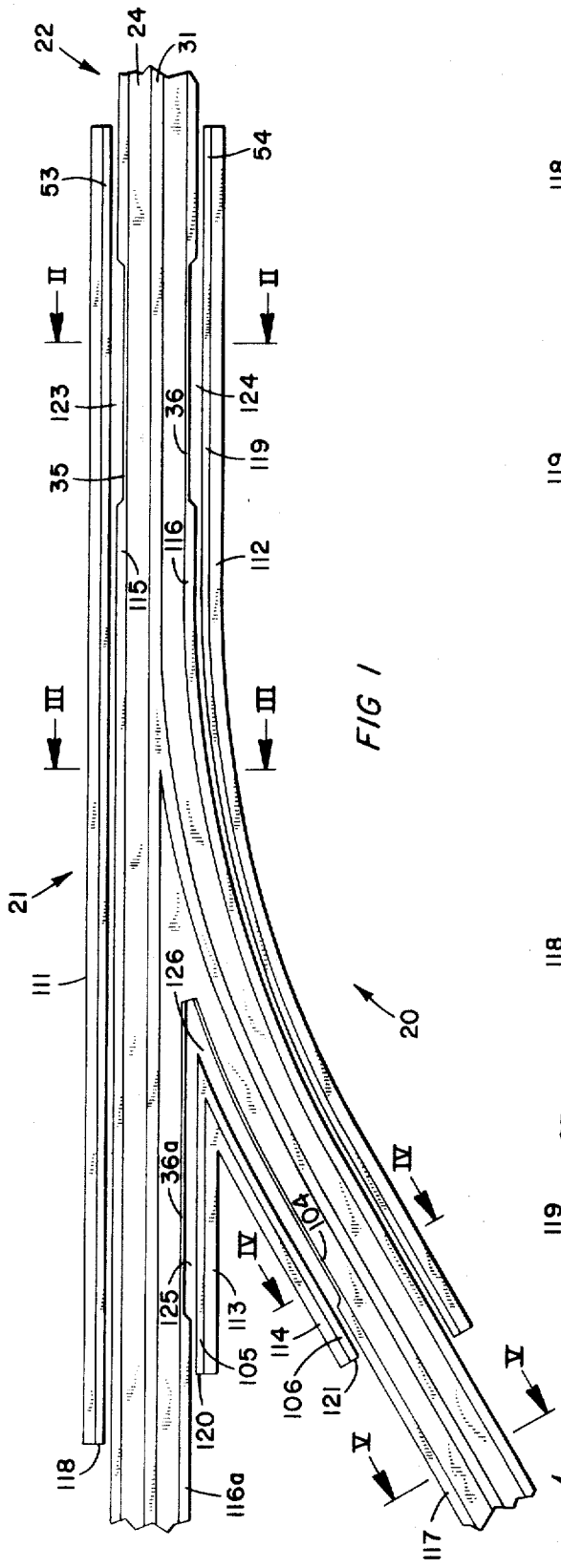


FIG 1

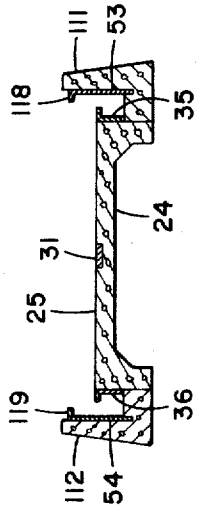


FIG 3

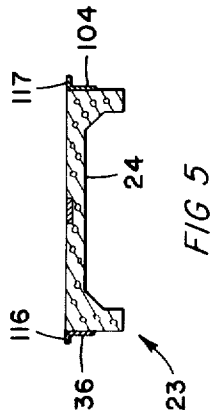


FIG 5

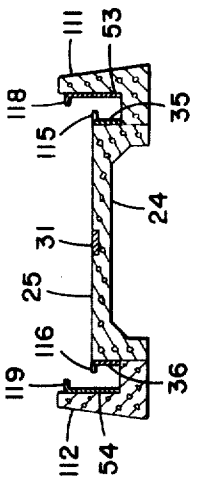


FIG 2

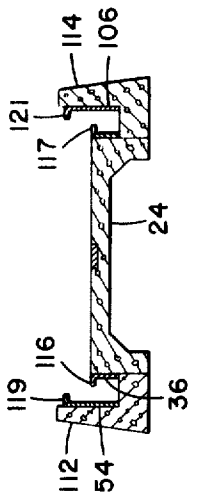


FIG 4

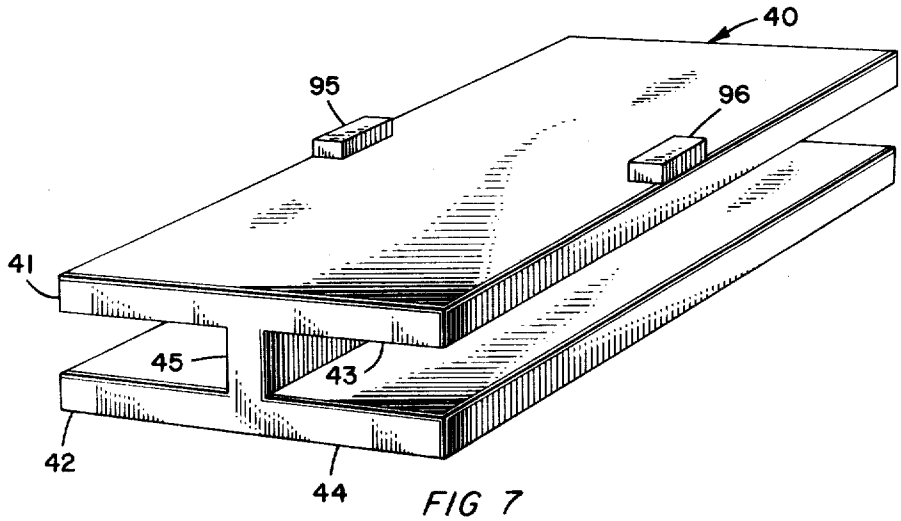


FIG 7

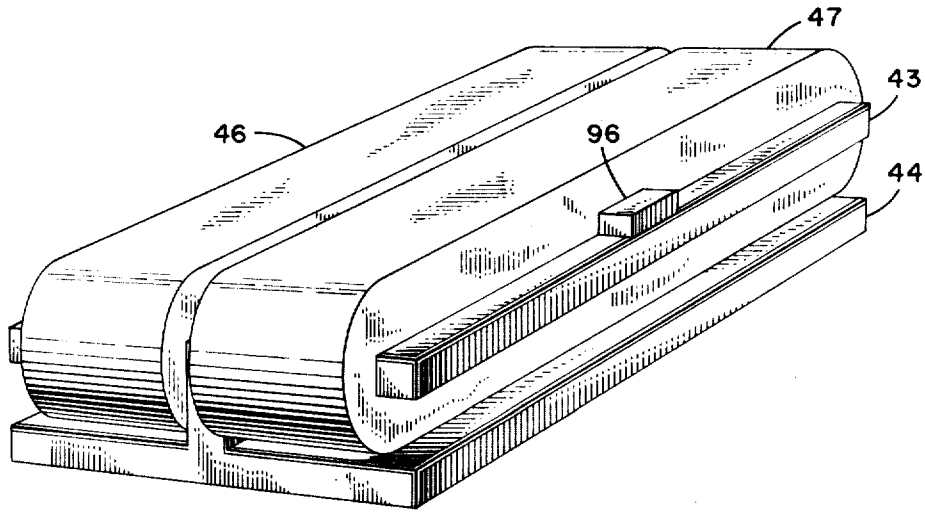


FIG 8

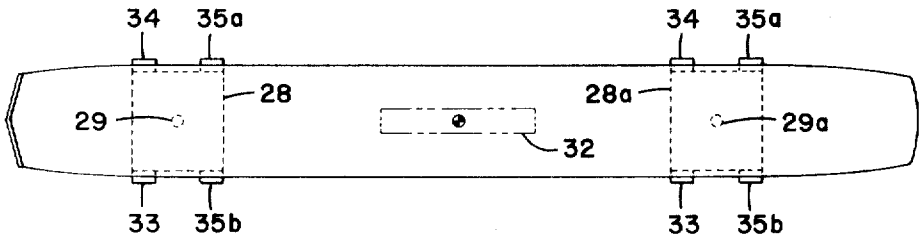


FIG 6

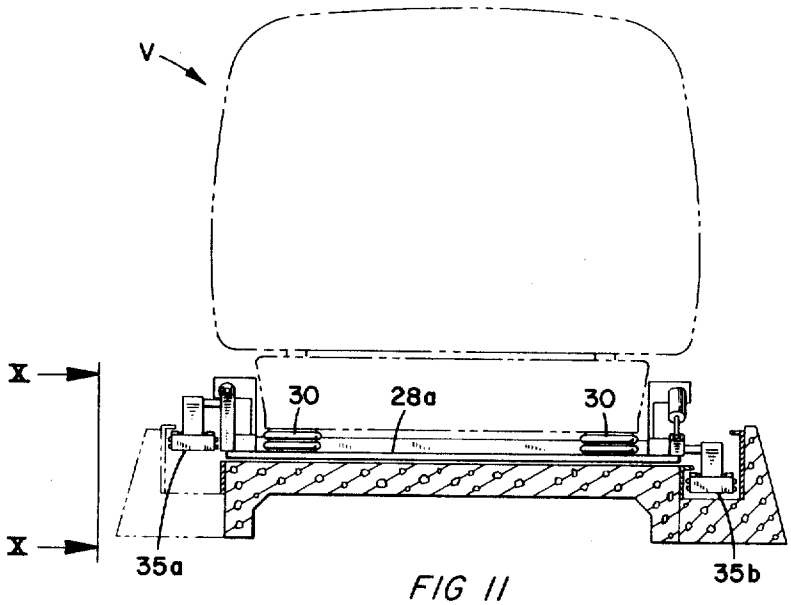


FIG 11

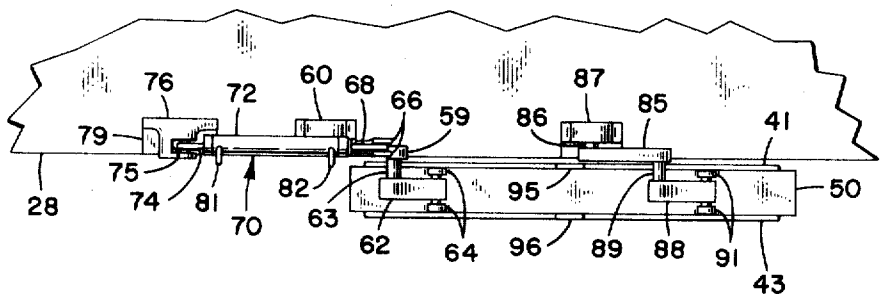


FIG 9

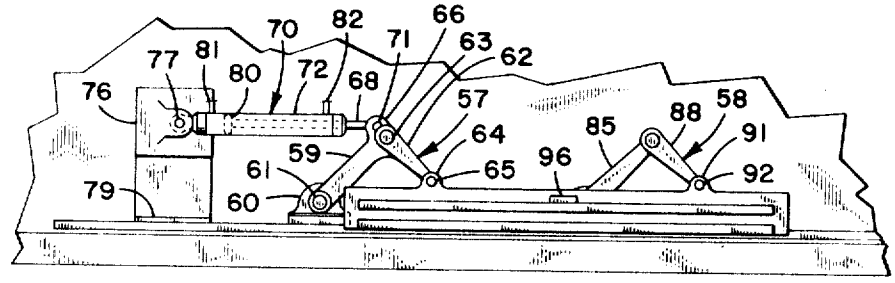


FIG 10

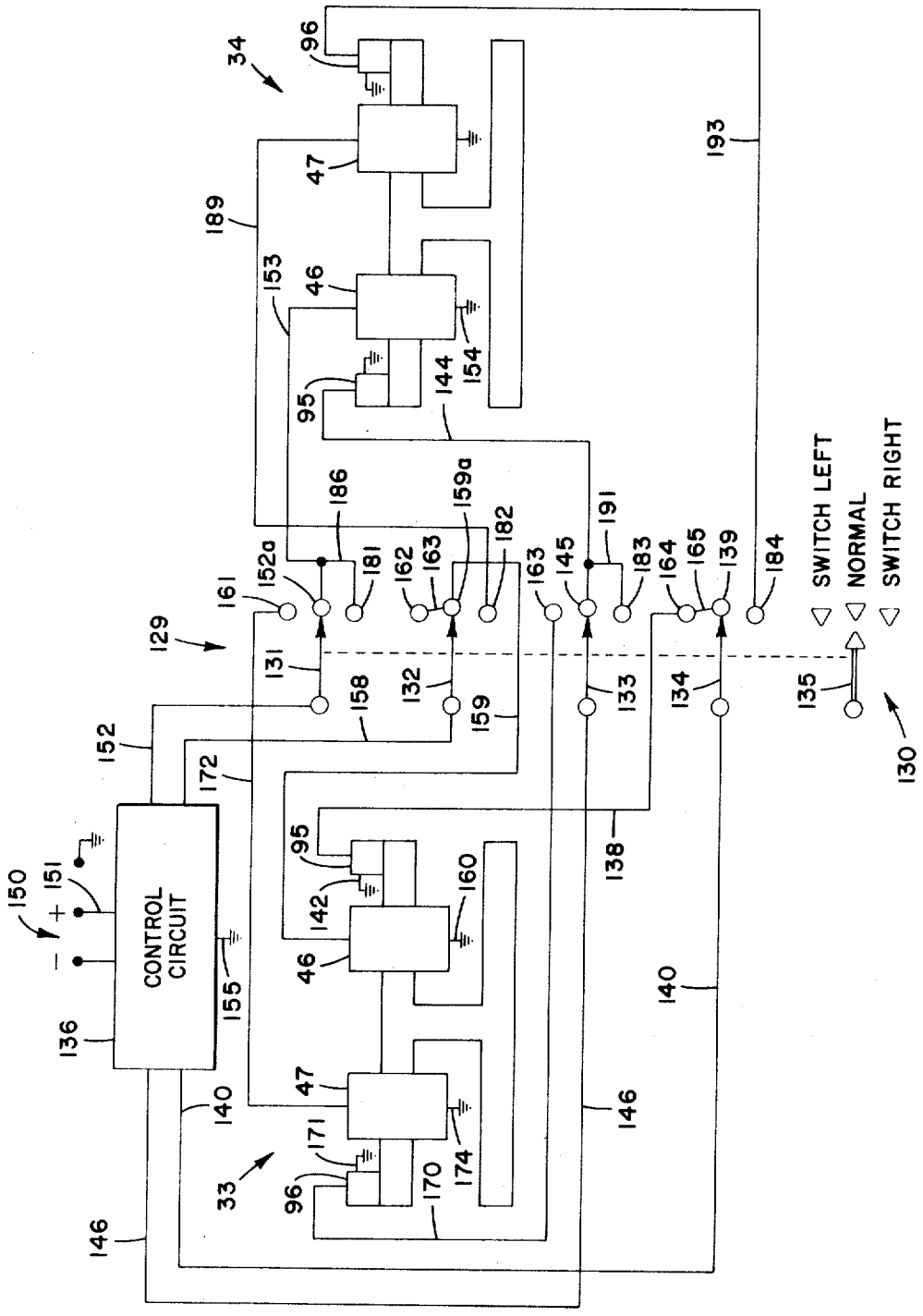


FIG 12

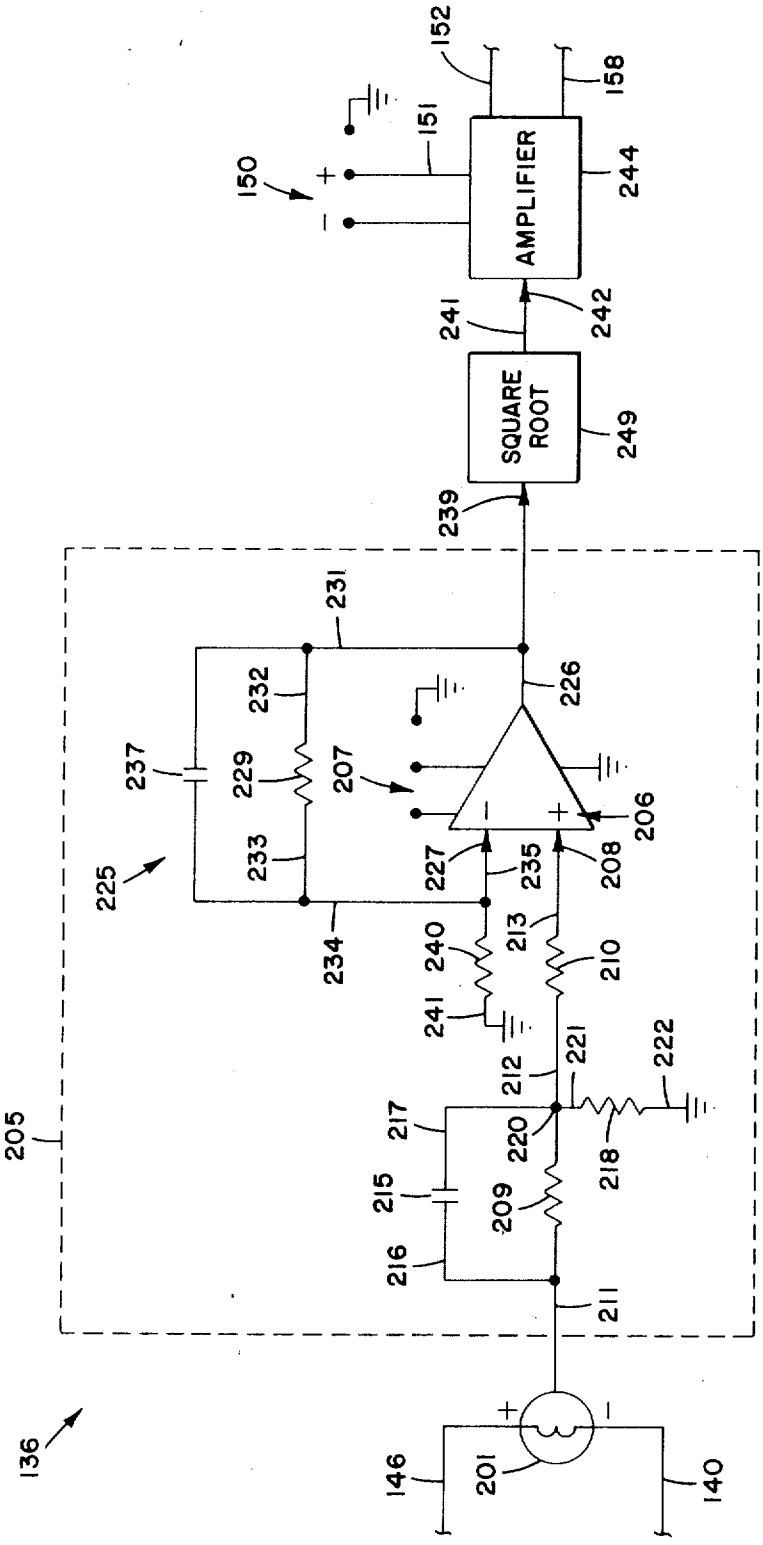

AMPLIFIER
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FIG 13

TRANSPORTATION SYSTEM AND VEHICLES FOR THE SYSTEM

This invention relates to transportation systems and vehicles usable in such transportation systems.

An object of this invention is to provide a new and improved transportation system and a new and improved vehicle usable in the transportation system.

Some transporation systems have roadways over which vehicles are levitated, as by air cushion or magnetic repulsion means, and are propelled over the roadway by suitable drive means, such as linear induction motors. In such systems it is necessary that the vehicles and the roadway be provided with cooperable guide means for maintaining the vehicles in proper lateral alignment relative to the roadway. Such guide means should preferably operate with a minimum expenditure of energy and a minimum restraint or drag on the forward movement of the vehicle and provide forces tending to move the vehicle back into proper alignment which vary not only with the degree of displacement of the vehicle from proper alignment, but also with the rate of such displacement in order to prevent excessive lateral displacement of the vehicle relative to the vehicle. Such guide means should also permit switching of the vehicle from one section or main line of the roadway to another or branch line thereof.

Accordingly, it is an object of this invention to provide a new and improved system having a roadway and vehicles movable thereover wherein the roadway and the vehicles are provided with cooperable guide means for maintaining the vehicles in properly aligned relationship with the roadway.

Another object is to provide a new and improved transportation system wherein the guide means is energized only at the times the vehicle tends to move out or is out of proper transverse or lateral alignment with the roadway.

Still another object is to provide a transportation system provided with a roadway having a planar top surface and side ferromagnetic guide rails along the sides of the roadway, and a vehicle having electromagnet means which are cooperable with the guide rails and are energized when the vehicle tends to move out of alignment with the roadway to provided electromagnetic forces between the magnet and the guide rails to maintain in proper longitudinal alignment with the roadway.

Still another object is to provide a transportation system wherein the roadway may have a main section and branch sections extending angularly from the main section and wherein the electromagnetic means are individually movable between lower operative positions in alignment with the guide rails and upper inoperative positions wherein they are positioned above the roadway to permit movement of the vehicle from one section of the roadway to another.

An important object is to provide a new and improved vehicle movable over a roadway having ferromagnetic guide rails along its side wherein the vehicle has selectively energizable electromagnetic means cooperable with the guide rails for holding the vehicle in properly aligned relationship relative to the roadway.

Another object is to provide a vehicle, of the type described, having control means for controlling energization of the electromagnetic means to cause them to be energized only when the vehicle tends to move out of proper relationship to the roadway.

Still another object is to provide a vehicle, of the type described, wherein the control means varies the energization of the electromagnetic means not only in accordance with the degree of displacement of the vehicle from proper relationship with the roadway but also in accordance with the rate of displacement to whereby the degree of displacement of the vehicle is minimized even under conditions of imposition of sudden extreme transverse forces on the vehicle.

Additional objects and advantages of the invention will be readily apparent from the reading of the following description of transportation systems constructed in accordance with the invention and reference to the accompanying drawings thereof, wherein:

FIG. **1** is a top fragmentary view of a roadway of the vehicle system embodying the invention;

FIGS. **2, 3, 4** and **5** are sectional views taken on lines **2—2, 3—3, 4—4** and **5—5**, respectively, of FIG. **1**;

FIG. **6** is a top schemtaic view of a vehicle of the transportation system embodying the invention;

FIG. **7** is a perspective view of a core of an electromagnetic assembly of the vehicle;

FIG. **8** is a perspective view of an electromagnetic assembly of the vehicle embodying the invention;

FIG. **9** is a fragmentary top view showing the means by which the electromagnetic assembly of the vehicle is movable vertically between operative and inoperative positions;

FIG. **10** is a side view of the assembly illustrated in FIG. **9**;

FIG. **11** is a partly schematic vertical sectional view showing a vehicle of the transportation system on the roadway thereof;

FIG. **12** is a block view illustrating the control means for a pair of electromagnetic assemblies of the vehicle; and,

FIG. **13** is a partly schematic view of the control circuit of the vehicle.

Referring now to the drawing, the transportation system **20** includes a roadway **21** which may have a main section **22** and one or more branch sections **23.** The roadway may be formed of concrete bed **24** having a top planar surface **25** over which vehicles V may move. The vehicles during movement are levitated above the planar surface **25** of the roadway by any suitable means, such as by compressed air which is forced into the downwardly opening air cushion pans **28** and **28a** which are secured to the vehicle body by suitable pivot means **29** and **29a**. The compressed air is transmitted to the downwardly opening pans through suitable flexible conduits **30** in a well known manner. The exact means by which the vehicles are levitated over the roadway, not being a part of this invention and being well known, will not be described further.

The vehicles may be propelled over the roadway by any suitable drive means such as a linear induction motor having primaries **31** embedded in the roadway and secondaries **32** connected to the vehicles.

Each vehicle is guided and stabilized during its high velocity movement over the roadway by guide means which include electromagnet assemblies **33, 34, 35*a*** and **35*b*** which are mounted at the four corners of each lift pan and which cooperate with the ferromagnetic side rails **35** and **36** which are rigidly secured to the roadway bed **24** at its sides.

Each of the electromagnet assemblies includes a core **40,** substantially I-shaped in cross section, which may

be formed of laminated steel or iron. The core has top and bottom inner horizontal sections **41** and **42**, top and bottom outer horizontal sections **43** and **44** and a central vertical connector section **45**. An inner coil **46** is disposed about the top inner section **41** and an outer coil **47** is disposed about the top outer core section **43**.

Each electrogmagnet assembly includes a suitable rectangular housing **50** in which the electrogmagnet formed by the cores and coils are disposed. The inner portions of the sections **41** and **42** extend outwardly of the inner side of the housing while the outer portions of the outer sections **43** and **44** extend outwardly of the opposite outer side of the housing for a purpose to be described below. It will be apparent that when the coil **46** is energized with direct current, the inner horizontal portions **41** and **42** and the connector portion **45** of the core have a magnetic flux induced therein and constitute a horseshoe magnet. For example, the top portion **41** constitutes the south pole of the magnet and the bottom portion **42** constitutes the north pole of the magnet. As a result, the electromagnet assembly, when the coil **46** is energized, is attracted to a ferromagnetic side rail which its horizontal portions **41** and **42** face. Similarly, when the coil **47** is energized, the top and bottom outer portions **43** and **44** constitute the south and nother poles and the electromagnet assembly will be attracted toward an adjacent outer ferromagnetic rail such as the rails **53, 54, 105** and **106**. The outer rails are disposed at locations of shunting or switching of a vehicle from the main track section to a side or branch section **23** as will be explained below.

Each of the magnet assemblies **50** is mounted on an air pan, such as the air pan **28**, by means of cranks **57** and **58**, FIGS. **9** and **10**. The crank **57** has an arm **59** which is pivotally mounted at its lower end to a bracket **60** for pivotal movement about a shaft **61**. The bracket **60** may be secured to the top surface of the air pan by any suitable means, such as bolts, welding or the like.

The other arm **62** of the crank **57** is rigidly secured at its upper end to the upper end of the arm **59** by a pin **63**. The lower end of the crank arm **62** is pivotally secured to the housing **50** by means of the lugs **64** which extend upwardly from the upper end of the top surface of the housing **50** and a shaft **65**.

The crank arm **59** at its upper end is provided with a pair of upstanding lugs **66** between which extends the outer end of the piston rod **68** of a hydraulic or pneumatic ram **70** and is pivotally connected thereto by a pin or a shaft **71**. The cylinder **72** of the hydraulic ram, at its end opposite remote from the crank **57**, is provided with a lug **74** which extends into the slot **75** of a bracket **76** and is pivotally secured thereto by pivot pin or shaft **77**. The bracket **76** is provided at its lower end with a foot **79** which rests on the top surface of the air pan and is secured thereto in any suitable manner. The piston rod **68** extends from the piston **80** of the ram which is reciprocable in the cylinder **72**.

The piston moves to extend the piston rod **68** when fluid under pressure is admitted to its inlet **81** while fluid is allowed to exhaust from its other end through the fitting **82**. Conversely, the piston rod is moved to its retracted position when fluid under pressure is admitted into the cylinder through the fitting **82** and allowed to exhaust from the fitting **81**.

The crank **58** includes an arm **85** which is pivotally connected at its lower end to the air pan by a shaft **86** which is rotatably secured to a pillow block **87** mounted on the air pan. The other arm **88** of the crank **58** is rigidly secured to the top end of the arm **85** by a pin or rod **89**. The lower end of the crank arm **88** extends between a pair of upstanding lugs **91** of the housing and is pivotably secured thereto by a shaft or pivot pin **92**. The various connections of the cranks to the air pan and to the housing permit vertical movement of the housing relative to the air pan from a lower operative position such as that in which is disposed the magnet assembly **36** as seen in FIG. **11**, and an upper inoperative position, such as that in which is disposed the electromagnet assembly **35**, as seen in FIG. **11**.

Each of the electromagnet assemblies also includes inner and outer sensors **95** and **96** which may be mounted on the core as illustrated in FIG. **7**, or on the housing **50**, for sensing the air gap or distance between the electromagnetic assembly and its adjacent inner or outer guide rail of the roadway and providing voltages which vary in accordance with the air gap or distance between the electromagnetic assemblies and the side and outer rails of the roadway as will be explained in greater detail below.

Referring now to FIGS. **1** through **5** of the drawings, the roadway **21** in addition to the side ferromagnetic guide rails **35** and **36**, at location of juncture of a branch section **23** of the roadway with the main section **22**, is provided with the outer guide rails **53** and **54**. The guide rail **53** extends along one side of the roadbed parallel to and spaced from the side guide rail **35**. The guide rail **54** extends parallel to and spaced from the guide rail **36** which extends along one side of the main section and then curves to become one side guide rail of the branch section **23** of the roadway. A side guide rail **36a** extends from the juncture of the main section **23** and a guide rail **104** extends along the other side of the roadbed of the branch section **23**. Outer guide rails **105** and **106** extend from the juncture of the branch section with the main section of the roadbed parallel to and spaced from the side rails **36a** and **104** at the location of the branch section **23**.

The outer guide rails **53, 54, 105** and **106** may be secured to outer concrete side walls **111, 112, 113** and **114**, respectively.

The rails **35, 36, 36*a*** and **104** are provided with outwardly extending horizontal top flanges **115, 116, 116*a*** and **117**, respectively, while the outer guide rails **53, 54, 105** and **106** are provided with inwardly extending flanges **118, 119, 120** and **121**, respectively.

The top flange **115** of the guide rail **35** has a notch **123** to permit upward movement of the right side electromagnet assemblies **34** and **35*a*** to a position above the roadway in the event the vehicle is to move from the main section of the roadway onto its branch section **23**. Similarly, the top flange **116** of the side guide rail **36** has a section removed, or a notch **124**, to permit upward movement of the left side electromagnet assemblies **33** and **35*b*** to a position above the roadway in event the vehicle is to continue to move along the main section **22** of the roadway and not be shunted or switched onto the branch section **23**. The guide rail **116*a*** similarly has a section removed, as at **125**, to permit downward movement of the left side electromagnet assemblies **33** and **35*b*** downwardly to operative position relative to the guide rail **36*a*** as the vehicle moves past the juncture of the branch section of the roadway with the main section. Similarly, the flange **117** of guide rail **104** of the branch section **23** of the roadway has the

portion removed, as at **126**, to permit downward movement of the right side electromagnetic assemblies **34** and **35***a* into operative relation with the guide rail **104** as the vehicle moves from the main section of the roadway onto its branch section.

It will be apparent that as a vehicle V moves to the left along the main section **112** of the roadway and approaches its juncture with the branch section, if the vehicle is to continue moving to the left on the main section of the roadway, the left electromagnetic assemblies **33** and **35***b* are moved upwardly, as by causing compressed air to be introduced into the cylinders of their pneumatic rams **70** through the fittings **82** while the opposite fittings **81** are vented at the time the electromagnet assemblies on each air pan move into alignment with the gap or notch **124** in the top flange **16** of the guide rail **36.** As a result, the left side assemblies **33** and **35***b* are now in inoperative position above the roadway. Only the right side assemblies **34** and **35***a* are now operative. The inner coil **46** of each assembly **34** and **35***a* is energized if the vehicle tends to move transversely to the right relative to the roadway and the outer coils **47** of the assemblies **34** and **35***a* are energized if the vehicle tends to move transversely to the left relative to the roadway. After the electromagnetic assemblies **34** and **35***a* move past the location of juncture of the branch section of the roadway with its main section, the left side assemblies **33** and **35***b* are lowered through the notch **125** to operative relationship with the guide rail **36***a* and the inner coils of the right side assemblies and the inner coils of the left side assemblies will now be energized as required to maintain the vehicle in proper transverse relationship to the main section of the roadway as the vehicle moves past the juncture of the branch section with the main section.

Conversely, if the vehicle moving on the main section is to move, or be shunted or switched, onto the branch section **23,** the right side electromagnetic assemblies **34** and **35***a* are moved upwardly as they move into alignment with the notch **123** of the top flange **115.** The inner and outer coils of the left side assemblies **33** and **35***b* are then operative to maintain the vehicle in proper position on the roadway and to guide it onto the branch section **23.** As the vehicle moves onto the branch section, the right side ferromagnetic assemblies are lowered as they move into alignment with the notch **126** in the flange **117** and thereafter only the inner coils of the right and left side ferromagnetic assemblies are operative to guide the vehicle along the branch section **23.**

Due to the location of the ferromagnetic assemblies at the four corners of the air pans or support means **28** and **28**a of the vehicle, the radius of turning movement of the vehicle may be made relatively small so that the roadway may curve as required either along the main section or at the locations of the junctures of branch sections with the main section.

Referring now to FIG. **12** of the drawings, the control means **129** for controlling operation of each pair of transversely aligned electromagnetic assemblies such as the left and right electromagnetic assemblies, **33** and **34,** includes a switch **130** having four movable contacts **131, 132, 133** and **134** and an operator and indicator handle **135.** The switch **130** controls the operation of the inner and outer coils of the two transversely aligned magnet assemblies **33** and **34** and of the air gap sensors **95** and **96** thereof. The air gap sensors may be of any suitable type such as the commerically available Kaman Sciences KD-2300-10CU-Multi-VIT transducer. Each air gap sensors provides an output voltage which varies in accordance with the air gap between the sensor and its adjacent ferromagnetic rail.

When the vehicle V is travelling along a straight section of the roadway, the switch contacts are in the positions illustrated in FIG. **12** and the inner air gap sensors **95** of the two magnetic assemblies are in operative condition, their outputs being transmitted to a control circuit **136** which controls the energization of the inner coils **46** of the two magnetic assemblies. One side of the output circuit of the sensor **95** of the electromagnetic assembly **33** is now connected to the control circuit **136** through a conductor **138,** the stationary contact **164** of the switch, a conductor **165,** the movable contact **134,** and the conductor **140.** The opposite side of the output circuit of the sensor **95** is connected to the control circuit through a conductor **142,** ground, and the conductor **155.** At this time the output of the sensor **95** of the right side assembly **34** is also transmitted to the control circuit **136** through a conductor **144,** the stationary contact **145** of the switch, the movable contact **133** and a conductor **146.** The control circuit **135,** as will be explained below, selectively energizes the inner coils **46** of the two electromagnetic assemblies **33** and **34** depending on the magnitudes of the output of the control signals of the two inner gap sensors **95** of the two assemblies, If, for example, a vehicle V moving along the main section of the roadway is properly positioned relative to the roadway, the outputs of the two inner sensors **95** of the electromagnetic assemblies **33** and **34** are equal. If the vehicle tends to move to the right, the output of the sensor **95** of the assembly **34** will tend to increase as its distance from the ferromagnetic side rail **35** tends to increase, while the output signal of the sensor **95** of the assembly **33** will tend to decrease as the gap between it and the side ferromagnetic guide rail **36** tends to decrease. The control circuit **136** will now cause the inner coil **46** of the right side electromagnetic assembly **34** to be energized with direct current which will vary as will be explained below with the rate of lateral movement of the sensors **95** of the left and right side assemblies away and towards, respectively, the side rails **35** and **36** and also with the distances between the sensor and the side rails. The control circuit will then connect the coil **46** of the assembly **34** across an input circuit of direct current **150,** one side of the coil **46** of the assembly **34** then being connected to one side of the direct current power input circuit through a conductor **151,** the control circuit **136,** a conductor **152,** the movable contact **131,** the stationary contact **152**a of the switch and the conductor **153.** The other side of the coil **46** of the assembly **34** is connected to the other side of the power input circuit through the conductor **154** and ground. The inner coil **46** of the left side magnetic assembly **33** will of course remain de-energized.

Conversely when the vehicle at the location of the electromagnetic assemblies **33** and **34** tends to move to the left, the inner sensor **95** of the right side assembly **34** tends to approach the guard rail **35** while the sensor **95** of the left side assembly **33** tends to move away from the side rail **36.** As a result, the control circuit **136** will now energize the inner coil **46** of the left side electromagnetic assembly **33** while leaving the inner coil of the opposite right side assembly **34** de-energized, the

coil **46** of the assembly **33** being connectible to the input circuit **150** through the control circuit **136**, a conductor **158**, the contacts **132** and **159***a* of the switch, the conductors **159** and **160**, and ground. The force of a magnetic attraction between the magnetic assembly **33** and the side rail will now tend to move the vehicle back toward the right to maintain it in proper relationship to the roadway.

If the vehicle which is moving to the left, as seen in FIG. **5**, is to be switched or shunted onto the branch section **23** when each pair of transversely aligned magnetic assemblies, such as the pair **33** and **34**, move into alignment with the gaps **124** and **123** in the flanges **116** and **115**, respectively, the right side assembly is moved upwardly, as explained above, above the side rail **35** and the roadbed. Simultaneously, the switch contacts are moved upwardly to positions wherein the contact **131** engages a stationary contact **161**, the contact **132** engages a stationary contact **162**, the contact **133** engages a stationary contact **162**, the contact **133** engages the contact **163**, and the contact **134** engages the contact **164**. The sensors **95** and **96** of the right side assembly **34** are now in inoperative condition disconnected from the control circuit **136**. The sensor **95** of the left side assembly **33** will now remain in operative condition since the contact **134** is now in engagement with the contact **164**. The inner coil **46** of the assembly **33** will also remain connected to the control circuit **136** since the stationary contact **162** is connected to the contact **159***a* by the conductor **163**.

One side of the outer gap sensor **96** of the assembly **33** is now connected to the control circuit **136** through the conductor **170**, a stationary contact **163** and the movable contact **133** of the switch, and the conductor **146** while its other side is connected to the control circuit through the conductor **171**, ground and the conductor **155**. One side of the outer coil **47** of the left side assembly **33** is now connected to one side of the power input circuit **150** through a conductor **172**, the contacts **161** and **131** of the switch and the conductor **152**. The opposite side of the outer coil **47** of the assembly **33** is connected to the other side of the power input circuit through a conductor **174**, ground and the conductor **155**.

The left side electromagnetic assembly **33** will then cooperate with the side rails **35** and **54** to guide the vehicle from the main section of the roadway to its branch section **23**, its outer coil **47** being energized to provide a magnetic attraction force between the assembly **33** and the guide rail **54** if the vehicle tends to move to the right from its proper transverse position relative to the roadway and the coil **46** being energized if the vehicle tends to move to the left from its proper position to provide a magnetic attraction force between the assembly **33** and the guide rail **36**.

As the vehicle moves onto the branch section **23** of the roadway and the right side assembly **34** moves into alignment with the gap **126** of the flange **117**, the assembly **34** is moved downwardly and contacts of the switch **130** are moved back to the position illustrated in FIG. **12** so that the assemblies **33** and **34** will now cooperate with the side rails **36** and **104** to guide the vehicle as it moves over the branch section **23**.

Conversely, if the vehicle is to continue to move on the main section **22** of the roadway past the juncture thereof with the branch section **23**, as the left side magnetic assembly **33** moves into alignment with the notch **124**, it is moved upwardly, as explained above, and the movable contacts **131-134** of the switch **130** are moved downwardly to engage the stationary contacts **181**, **182**, **183** and **184**, respectively, thereof. Such movement of the contacts **131–134** now prevents energization of both coils **46** and **47** of the left side assembly **33** and also disconnects its sensors **95** and **96** from the control circuit **136**. Movement of the contact **131** into engagement with the contact **181** now permits the energization of the inner coil **46** of the assembly **34**, the contact **131** now connecting one side of the coil **46** of the assembly **34** to the conductor **152** through the conductors **153** and **186**. Simultaneously one side of the outer coil **47** of the assembly **34** is connected to the conductor **158** through the conductor **189**, the contacts **182** and **132** of the switch.

The sensor **95** of the assembly **34** will now be connected to the control circuit **136** by the conductors **144** and **191**, the switch contacts **183** and **133**, and the conductor **146** and the sensor **96** of this assembly will be connected to the control circuit through the conductor **193**, the contacts **184** and **134** and the conductor **140**.

The right side electromagnetic assembly **34** will therefore now cooperate with the rails **35** and **53** to guide movement of the vehicle over the roadway past the juncture therewith of the roadway branch section **23**. When the left side magnetic assembly **33** moves into position past the Juncture of the roadway's branch and main sections, it is lowered through the notch **125** of the flange **116***a* of the side rail **36***a* and the switch contacts are moved again to the position illustrated in FIG. **12** and the inner coils **46** of the assemblies will now cooperate with the rails **35** and **36***a* to guide continued movement of the vehicle over the portion of the main section of the roadway to the left of its juncture with the branch section **23**.

The control circuit **136**, as illustrated in FIG. **13**, includes a summer **201** which sums the opposite polarity voltages which are supplied thereto by each particular pair of the air gap sensors which are connected to the conductors **140** and **146** at a particular time.

A compensation circuit **205** is provided to produce an output signal which varies not only with the distances or air gaps between the air gap sensors and their associated guide rails but also with the rate of change of such distances. The compensation circuit **205** includes a differential amplifier **206** having a power input circuit **207** and an input terminal **208** to which the output of the summer **201** is transmitted through a pair of resistances **209** and **210** connected in series between the summer and the amplifier input terminal **208** by the conductors **211**, **212**, and **213**. A capacitor **215** is connected across the resistance **209**, one side thereof being connected to the conductor **211** by a conductor **216** and its other side being connected to the conductor **212** by a conductor **217**. One side of a resistance **218** is connected to the common connection **220** of capacitor **215** and the resistances **209** and **210** by a conductor **221** and its other side is connected to ground through a conductor **222**.

The amplifier **206** has a feedback network **225** which serves as a filter to decrease noise or spurious frequencies connected between its output terminal or conductor **226** and its input terminal **227** which includes a resistance **229** connected between the conductor **226** and the input terminal **227** by the conductors **231**, **232**, **234** and **235**. A capacitor **237** is connected across the

output and input terminals **226** and **227** of the amplifier, and also across the resistance **229**, by the conductors **231** and **234**. The second input terminal **227** of the differential amplifier **206** is also connected to ground through the conductor **235**, a resistance **240** and a conductor **241**.

The resistance **209** is substantially greater than the resistances **210** and **218** so that if the output of the summer is, for example, a positive voltage of a given value and is constant, since the resistances **209** and **218** act as a voltage divider network, the voltage at the common junction **220** of the resistances **209** and **210** will now be smaller than the output voltage of the summer **201**. If the vehicle is being displaced laterally at a rapid rate, the output voltage will be transmitted directly through the capacitor **215** to the common connection **220** so that the input voltage at the input terminal **208** will now be greater for given instant air gap distances between the sensors **95** and their associated guide rails than that which would ordinarily be present at the common connection **220** at such distances if the sensors were not moving rapidly. As a result, the output of the differential amplifier will be greater for a given air gap between these sensors and their associated guide rails if the vehicle is being displaced at a lower rate or indeed if the air gap distances were constant as when the vehicle is slightly displaced laterally relative to the guide rails. This latter condition could occur in event of a constant side wind load on the vehicle. The output of the differential amplifier is transmitted to an input terminal **239** of a square root circuit **240** whose output voltage varies as the square root of the signal or input voltage transmitted to its input terminal **239**. The output of the square root circuit **240** is transmitted through a conductor **241** to the input terminal **242** of a push-pull amplifier **244**, which may be of any suitable commercially available type, such as a Westamp amplifier Model No. A653-286-BXX. The square root circuit is employed because the magnetic force produced by each coil varies as the square of the value of the current flowing therethrough.

Assuming now that the vehicle is on the main section **22** of the roadway and is in properly aligned position on the roadway, the outputs of the air gap sensors **95** of the left and right magnetic assemblies **33** and **34** which are being transmitted to the opposite sides of the summer **201** are equal. As a result, the output of the summer **201** is zero and the push-pull amplifier **244** is not energized and therefore neither of the coils **46** of the assemblies **33** and **34** is energized. The capacitor **215** of the compensating circuit is now in discharged condition, its opposite sides having the same potential since any charge on the capacitor **215** has been discharged to ground through the discharge resistance **218**.

If the vehicle should now tend to move or be displaced very slowly to the left relative to the roadway, the voltage output of the air gap sensor **95** of the right side assembly **34** will decrease as it approaches the side rail **35** while the voltage output of the air gap sensor **95** of the left side assembly will increase as the gap between it and the side rail **36** increases. The summer **201** will now provide a signal of slowly increasing voltage of one polarity, for example, negative. As a result the capacitor **215** will not be effective and the rate of change of the control voltage now being supplied to the input terminal **208** of the differential amplifier will also be slow and will vary with the distances between the sensors and the side rails. The voltage signal produced by the summer **201** and transmitted to the push-pull amplifier **244** will now cause the amplifier **244** to transmit a direct current through the conductor **158** to the coil **46** of the left side assembly so that the force of magnetic attraction between left side electromagnetic assembly and the rail **36** will now tend to move the left side assembly, and therefore the vehicle, to the right back towards properly aligned relationship with the roadway. At such time, of course, the output of the summer **201** would decrease to zero. No current is transmitted to the conductor **152**, and therefore to the coil **46** of the right side assembly, when current is supplied to the conductor **158**.

If the rate of lateral displacement of the vehicle to the left is great, the capacitor **215** will of course transmit a pulse of relatively high voltage to the common connection **220**, greater than that which would be present at the common connection **220** for a given displacement of the air gap sensors **95** relative to the guide rails **35** and **36** under static conditions of displacement. As a result, the energization of the coil **46** of the left side assembly **34** is relatively great and the force of magnetic attraction thereof with the guide rail **36** will be great and will arrest such movement of the vehicle and move it back to its proper position on the roadway.

It will be apparent that if the vehicle tends to move to the right relative to the roadway, the sensor **95** of the assembly **33** will approach the rail **36** while the sensor of the right side assembly will move away from the rail **35**. As a result, the voltage input to the conductor **40** will be smaller than the voltage input to the conductor **146** and a direct current of negative polarity produced by the summer, which varies in accordance with the degree and rate of displacement of the vehicle will cause the amplifier **244** to energize the coil **46** of the right side assembly **34**, through the conductor **152**, and move the vehicle back to the left.

It will now be apparent that each transversely aligned pair of electromagnetic assemblies, such as the pairs of assemblies **33** and **34** and **35*a*** and **35*b***, is provided with a separate control means **130** and that the electromagnetic assemblies of each such pair cooperate to exert lateral forces on the vehicle when the vehicle is displayed from proper position relative to the roadway to move the vehicle back to proper position.

It will further be seen that since the coils of the electromagnetic assemblies are energized only when the vehicle tends to move out of proper position relative to the roadway, minimum amounts of energy are expended and the "drag" or force tending to oppose forward movement of the vehicle, due to eddy currents induced in the ferromagnetic rails is minimized.

While a particular embodiment of the invention has been illustrated and described, various changes in structure may be made within the scope of the appended claims without departing from the spirit of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. A transportation system including: roadway comprising of a bed over which vehicles are movable longitudinally in levitated position and a pair of magnetic side guide rails extending longitudinally along opposite sides of the roadway; and a vehicle movable over the roadway, said vehicle having electromagnetic means at each side thereof aligned transversely and cooperable

with adjacent side rails thereof and selectively energizable when the vehicle tends to move out of proper alignment with the roadway for maintaining the vehicle in properly aligned transverse relationship over the roadway, each said electromagnetic means when energized being attracted to an adjacent guide rail or said roadway; sensor means operatively associated with each of said electromagnetic means and a guide rail adjacent said electromagnetic means for providing control signals which vary in accordance with the distance of the electromagnetic means from the adjacent side rail; and control means responsive to said control signals for controlling energization of said electromagnetic means to cause said electromagnetic means to exert lateral forces on said vehicle when said vehicle tends to move out of properly aligned transverse relationship to said roadway to cause said vehicle to maintain a properly aligned relationship with the roadway, said control means including means for varying the degree of energization of said electromagnetic means in accordance with the rate of change of said control signals.

2. The system of claim **1,** and means operatively associated with each of said electromagnetic means for selectively moving said electromagnetic means out of operative relationship with said side rail and above said roadway to permit movement of a vehicle from one section of the roadway to another section extending angularly relative to said one section.

3. The system of claim **2,** wherein said vehicle is provided with a pair of longitudinally spaced support means rotatable about vertical axes, said electromagnetic means being mounted on said support means.

4. The system of claim **3,** wherein each of said support means has a pair of front and a pair of rear transversely aligned electromagnetic means.

5. A transportation system including: roadway comprising of a bed over which vehicles are movable longitudinally in levitated position and a pair of magnetic side guide rails extending longitudinally along opposite sides of the roadway; and a vehicle movable over the roadway, said vehicle having electromagnetic means at each side thereof aligned transversely and cooperable with adjacent side rails thereof and selectively energizable when the vehicle tends to move out of proper alignment with the roadway for maintaining the vehicle in properly aligned transverse relationship over the roadway, said roadway including at least one outer guide rail extending parallel to and spaced outwardly of one of said guide rails, one of said electromagnetic means being movable between said outer guide rail and said one of said guide rails and comprising a pair of coils selectively energizable for providing magnetic forces selectively attracting said electromagnetic means to said outer guide rail and said one of said guide rails.

6. The transportation system of claim **5,** wherein one of said electromagnetic means includes a core having a pari of inner horizontal spaced portions extending inwardly toward said one of said guide rails and a pair of outer horizontal spaced portions extending outwardly toward said outer guide rail and a vertical connecting portion connecting said pairs of portions; one of said coils being positioned about one of said inner portions and the other of said coils being positioned about one of said outer portions.

7. In a vehicle over a longitudinal roadway having parallel longitudinal ferromagnetic guide rails along opposite sides thereof; a guides means comprising a pair of transversely aligned and spaced electromagnetic means mounted on said vehicle movable in spaced relationship to and cooperable with said guide rails for exerting transverse forces on said vehicle when said vehicle tends to move out of proper alignment with said roadway for holding said vehicle in proper transverse alignment relative to the roadway; sensor means operatively associated with each of said electromagnetic means for providing a signal which varies in accordance with the distance between each electromagnetic means and an adjacent guide rail of a roadway; and control means responsive to said control signals for varying energization of each of said electromagnetic means to vary the force with which each electromagnetic means is attracted to its adjacent side rail when the vehicle is displaced from a predetermined relationship relative to the roadway, said control means including means for varying the degree of energization of said electromagnetic means in accordance with the rate of change of said control signals.

8. The guide means of claim **7,** and means operatively associated with each of said electromagnetic means for selectively moving said electromagnetic means out of operative relationship with said side rail and above said roadway to permit movement of a vehicle from one section of the roadway to another section extending angularly relative to said one section.

9. In a vehicle movable over a longitudinal roadway having parallel longitudinal ferromagnetic guide rails along opposite sides thereof; a guide means comprising a pair of transversely aligned and spaced electromagnetic means mounted on said vehicle movable in spaced relationship to and cooperable with said guide rails for exerting transverse forces on said vehicle when said vehicle tends to move out of proper alignment with said roadway for holding said vehicle in proper transverse alignment relative to the roadway; said roadway including at least one outer guide rail extending parallel to and spaced outwardly of one of said guide rails, one of said electromagnetic means being movable between said outer guide rail and said one of said guide rails and comprising a pair of coils selectively energizable for providing magnetic forces selectively attracting said electromagnetic means to said outer guide rail and said one of said guide rails.

10. A transportation system including: roadway comprising of a bed over which vehicles are movable longitudinally in levitated position and a pair of magnetic side guide rails extending longitudinally along opposite sides of the roadway; and a vehicle movable over the roadway, said vehicle having electromagnetic means at each side thereof aligned transversely and cooperable with adjacent side rails thereof and selectively energizable when the vehicle tends to move out of proper alignment with the roadway for maintaining the vehicle in properly aligned transverse relationship over the roadway, each said electromagnetic means when energized being attracted to an adjacent guide rail of said roadway; sensor means operatively associated with each of said electromagnetic means and a guide rail adjacent said electromagnetic means for providing control signals which vary in accordance with the distance of the electromagnetic means from the adjacent side rail; control means responsive to said control signals for

controlling energization of said electromagnetic means to cause said electromagnetic means to exert lateral forces on said vehicle when said vehicle tends to move out of properly aligned transverse relationship to said roadway to cause said vehicle to maintain a properly aligned relationship with the roadway; and means operatively associated with each of said electromagnetic means for selectively moving said electromagnetic means out of operative relationship with said side rail and above said roadway to permit movement of a vehicle from one section of the roadway to another section extending angularly relative to said one section.

11. The system of claim **10,** wherein said vehicle is provided with a pair of longitudinally spaced support means rotatable about vertical axes, said electromagnetic means being mountd on said support means.

12. The system of claim **11,** wherein each of said support means has a pair of front and a pair of rear transversely aligned electromagnetic means.

13. In a vehicle movable over a longitudinal roadway having parallel longitudinal ferromagnetic guide rails along opposite sides thereof; a guide means comprising a pair of transversely aligned and spaced electromagnetic means mounted on said vehicle movable in spaced relationship to and cooperable with said guide rails for exerting transverse forces on said vehicle when said vehicle tends to move out of proper alignment with said roadway for holding said vehicle in proper transverse alignment relative to the roadway; sensor means operatively associated with each of said electromagnetic means for providing a signal which varies in accordance with the distance between each electromagnetic means and an adjacent guide rail of a roadway; and control means responsive to said control signals for varying energization of each of said electromagnetic means to vary the force with which each electromagnetic means is attracted to its adjacent side rail when the vehicle is displaced from a predetermined relationship relative to the roadway, and means operatively associated with each of said electromagnetic means for selectively moving said electromagnetic means out of operative relationship with said side rail and above said roadway to permit movement of a vehicle from one section of the roadway to another section extending angularly relative to said one section.

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