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(54) **BUOYANT MARINE RAIL SYSTEM**

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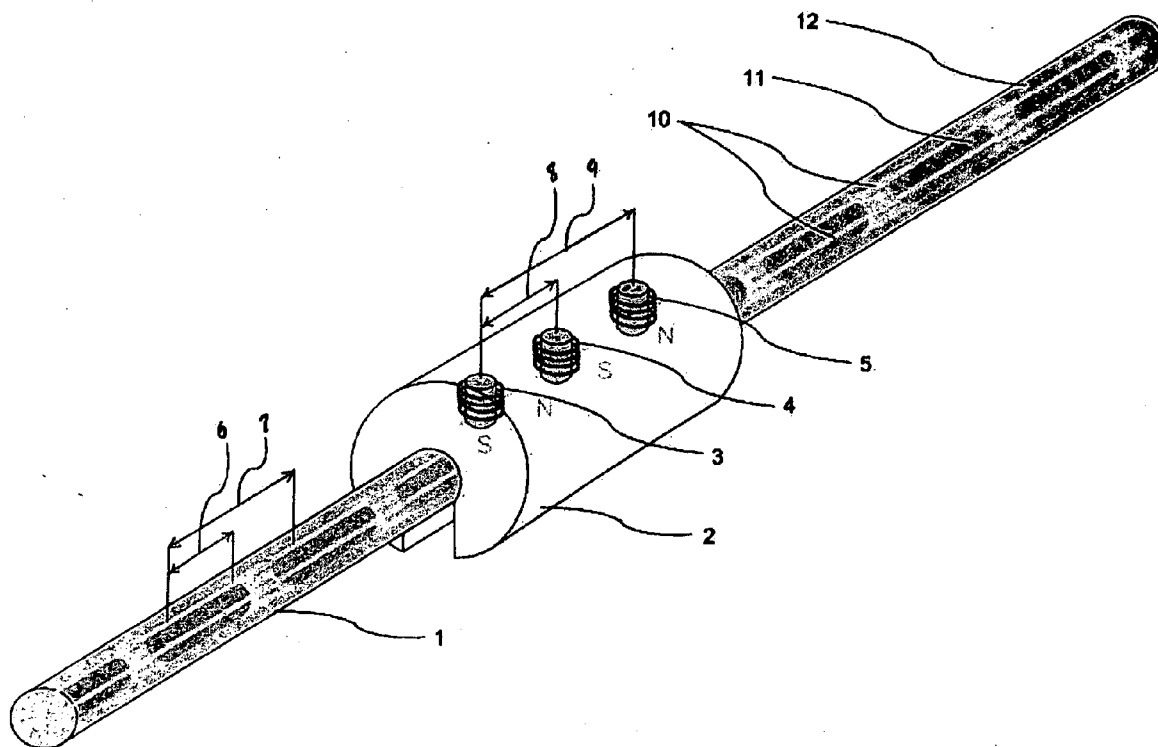
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(57) **ABSTRACT**
A rail system may include a rail buoyant in a fluid, and a vehicle buoyant in the fluid. The vehicle may be electromagnetically and/or mechanically coupled to the rail for movement along the rail.



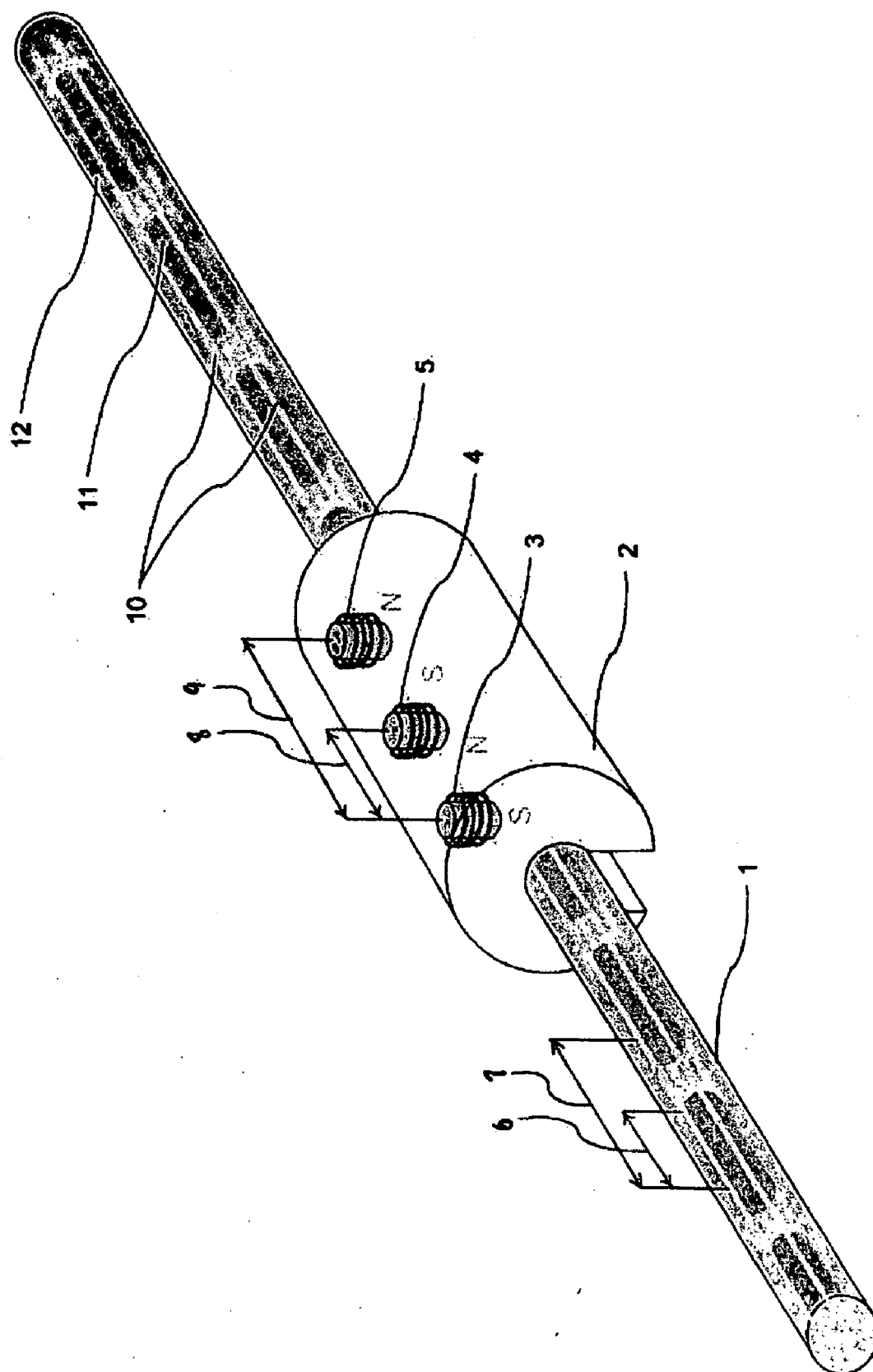


FIG. 1

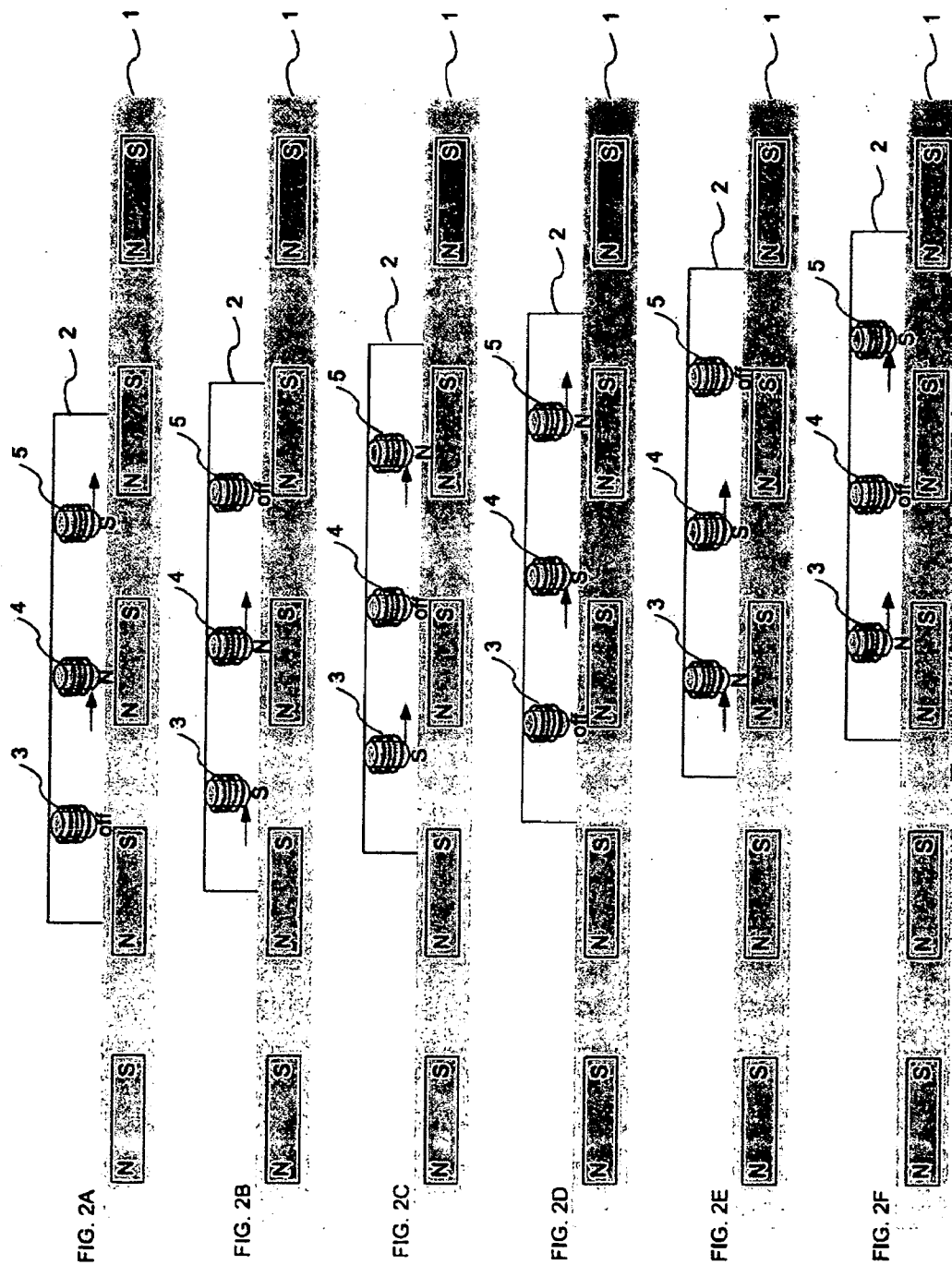


FIG. 2

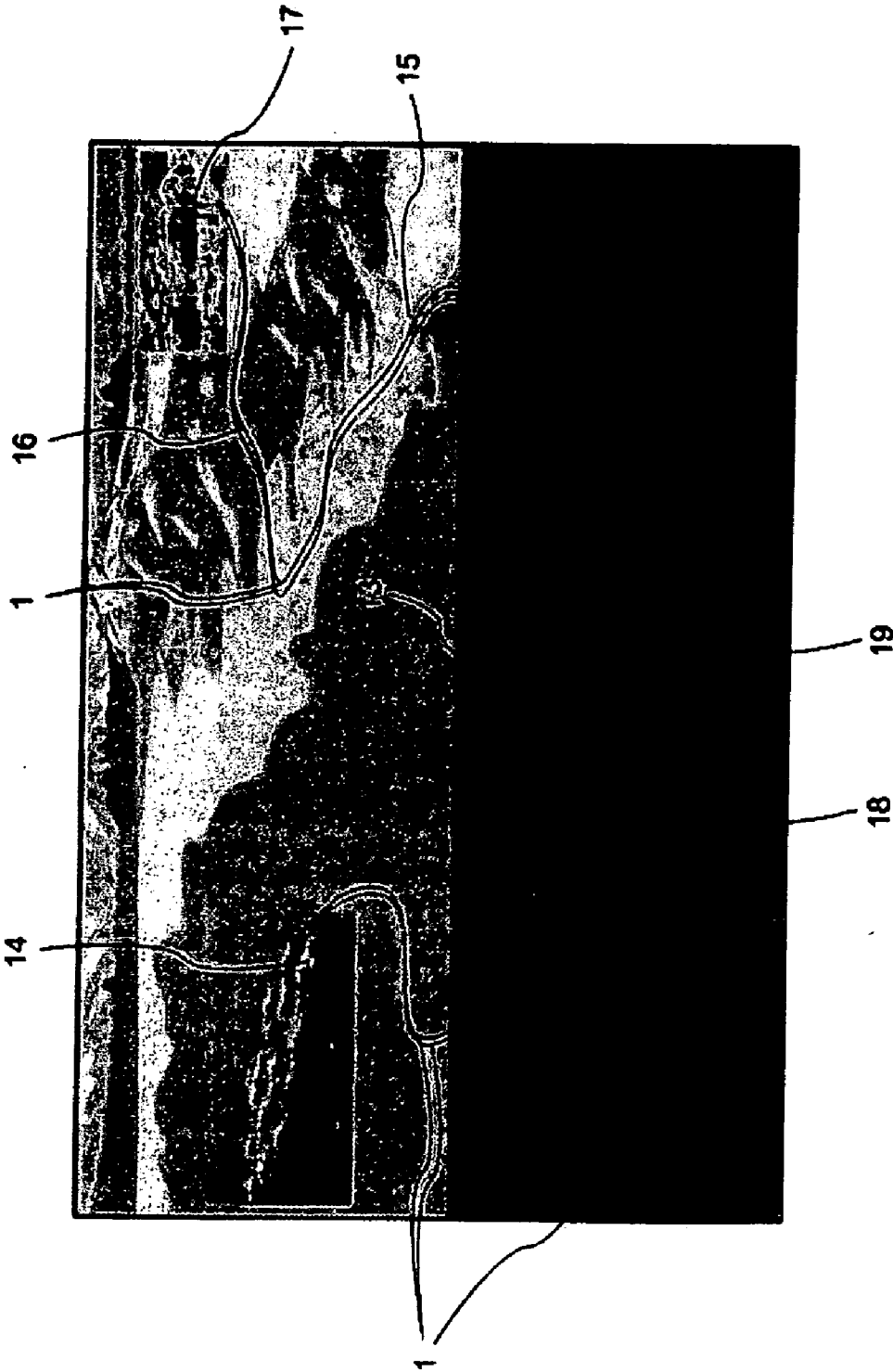


FIG. 3

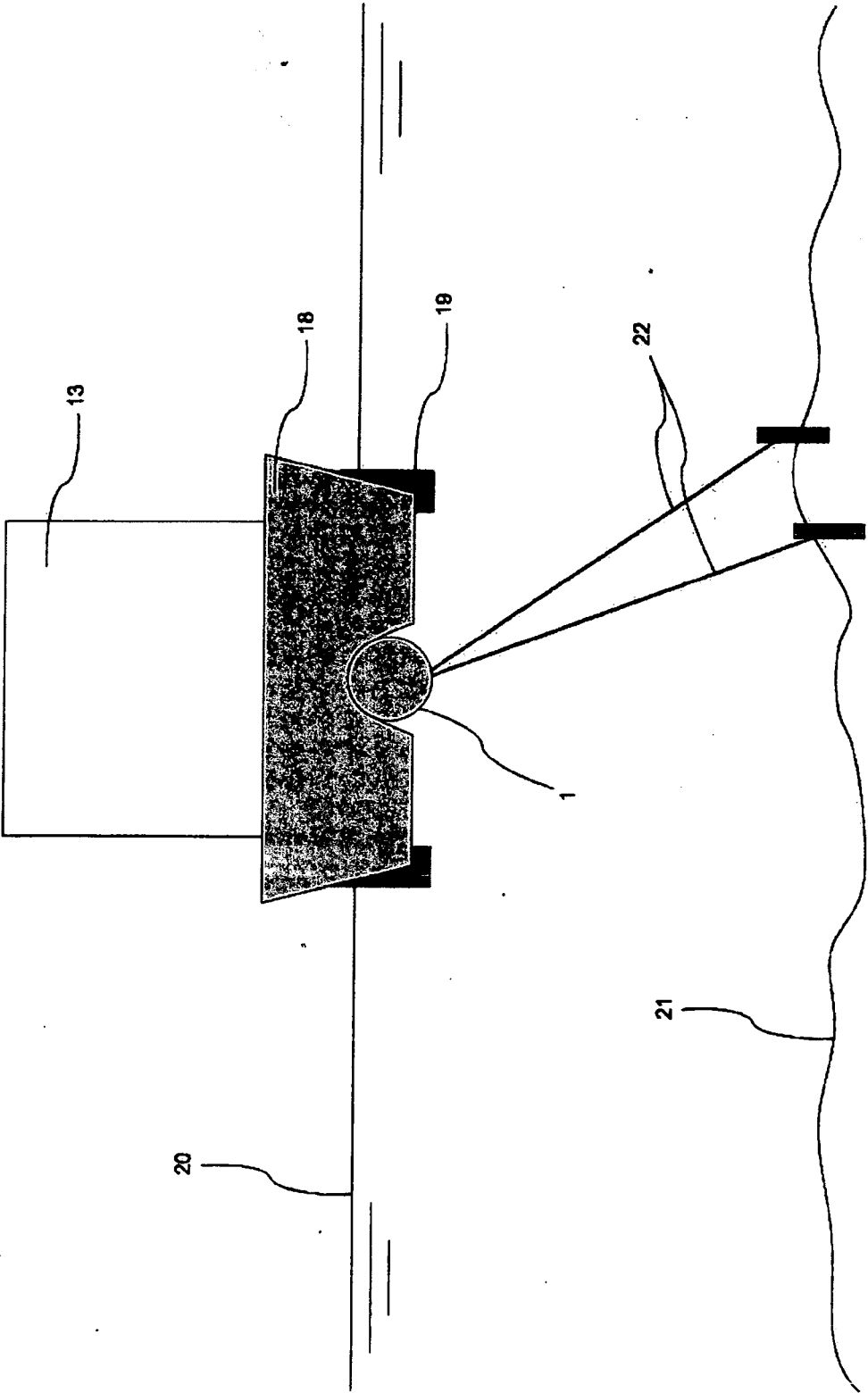


FIG. 4

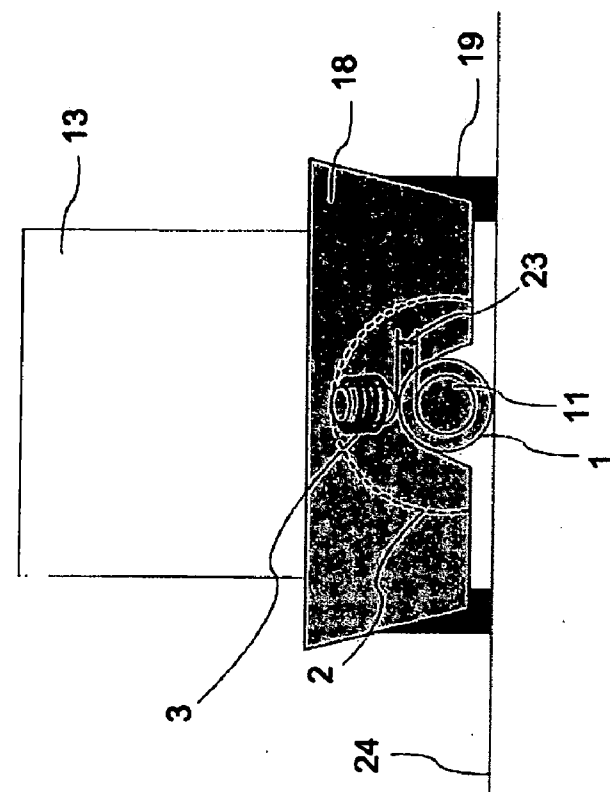


FIG. 5

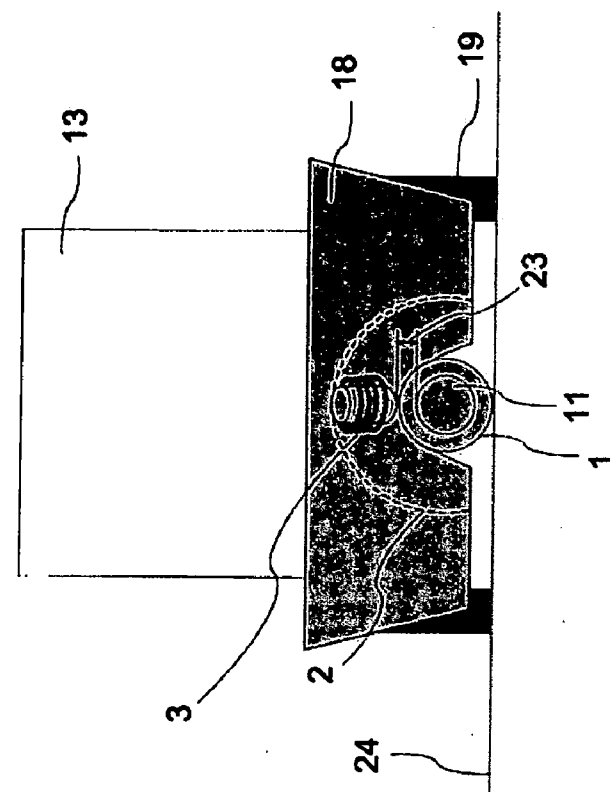


FIG. 6

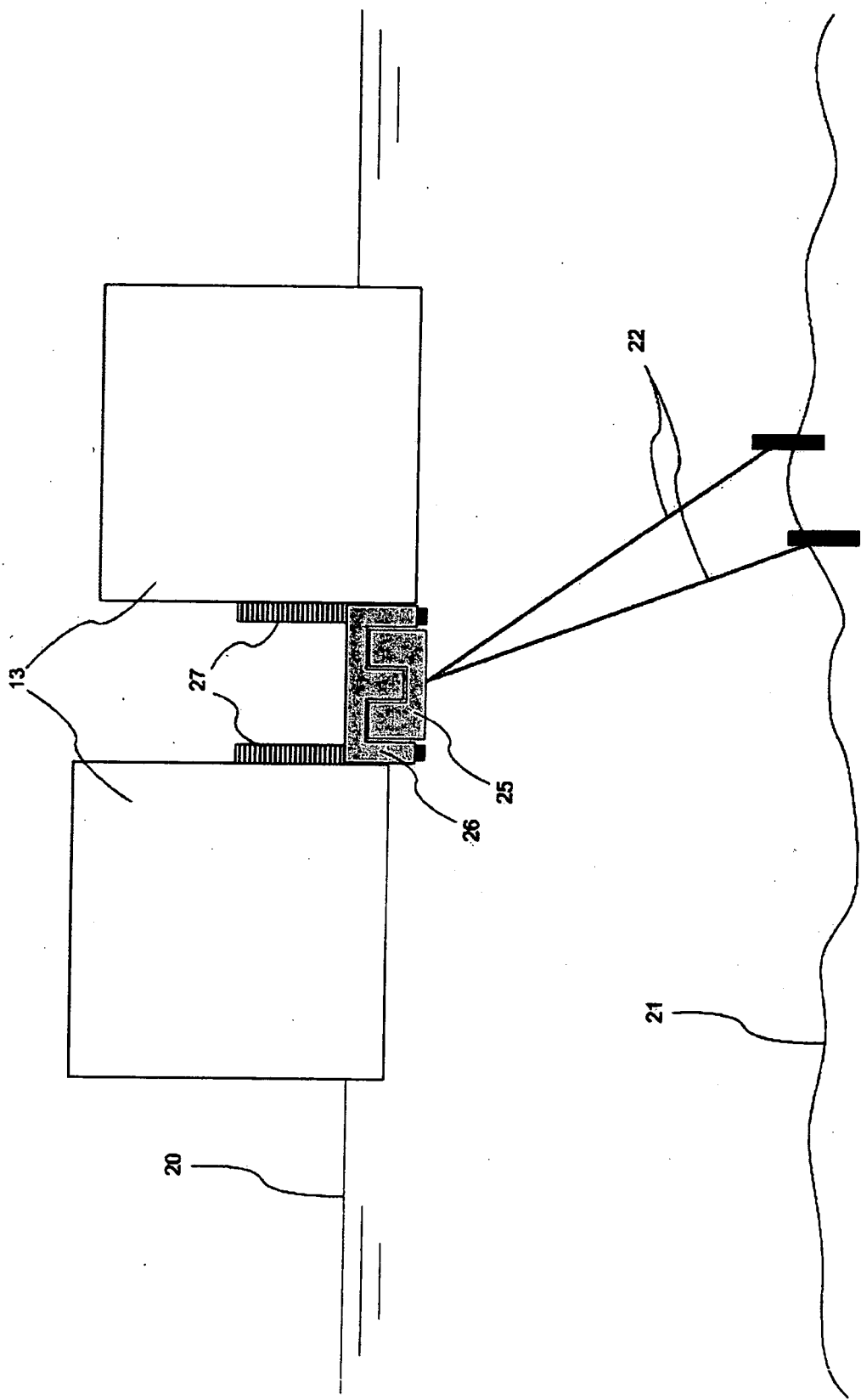


FIG. 7

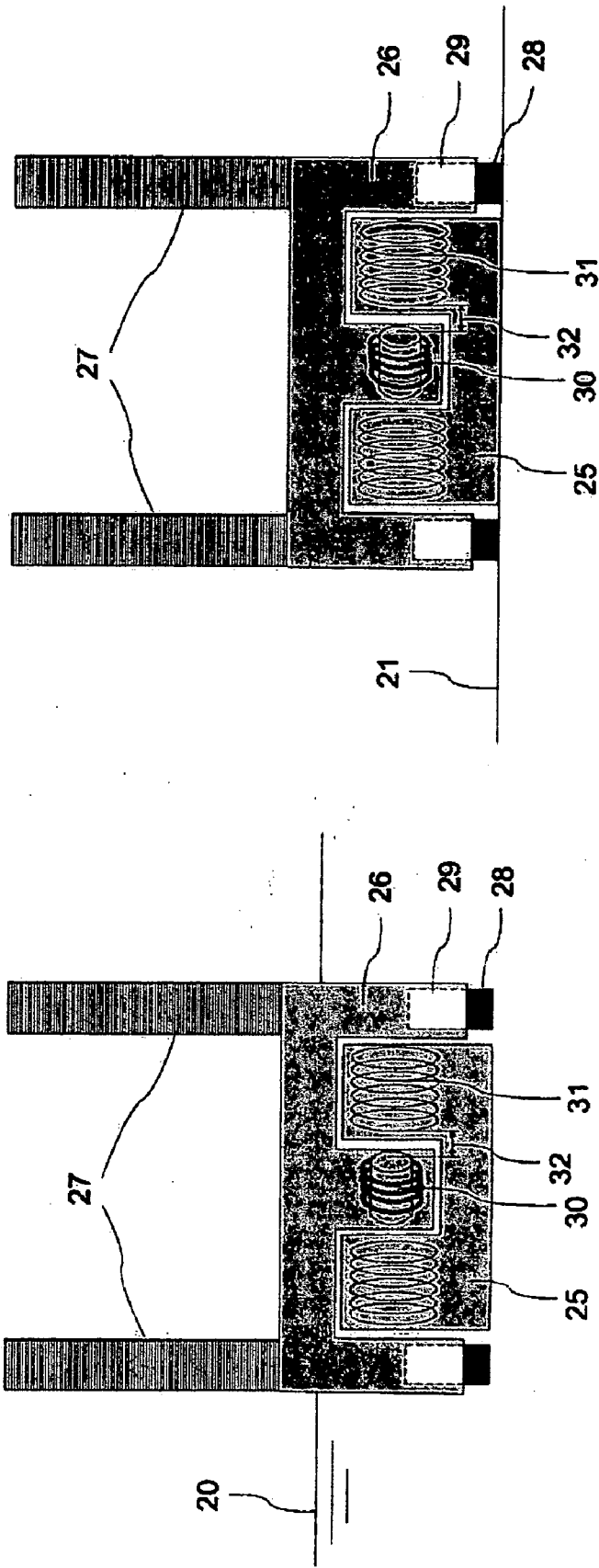
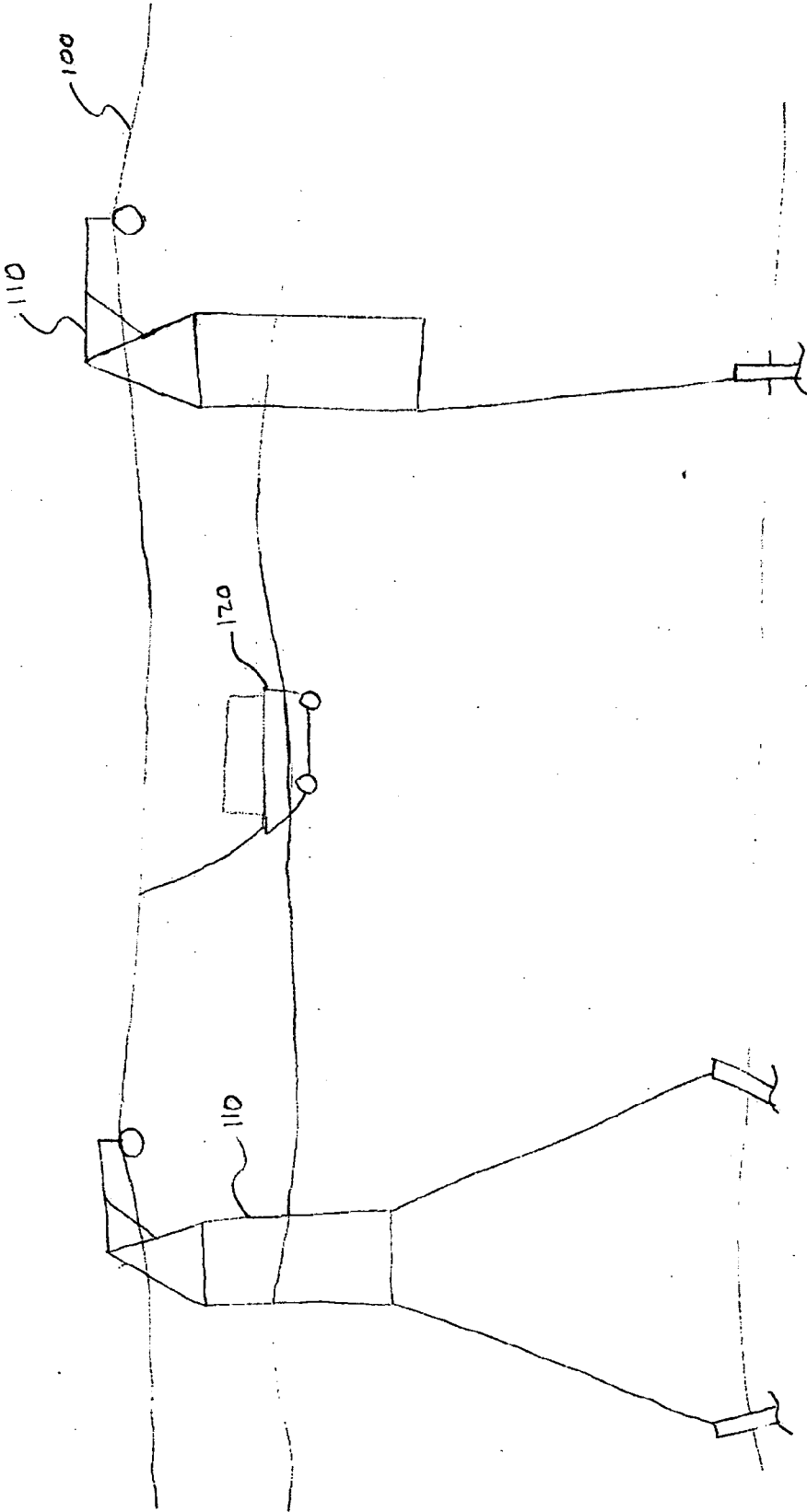


FIG. 9

FIG. 8



FIG. 11



BUOYANT MARINE RAIL SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This U.S. non-provisional application claims priority under 35 USC §119 to U.S. Provisional Application No. 60/666,588 filed Mar. 31, 2005, the content of which is incorporated herein in its entirety by reference.

BACKGROUND

[0002] A linear motor is analogous to a conventional rotary electric motor that has been sliced open and rolled out flat. In a linear motor, a magnetic field generated by either the rotor or stator is used to produce linear motion.

[0003] Many concepts for one type of linear motor technology called a linear induction motor (LIM) have been proposed over the years for ground transportation systems. High-speed trains propelled, not by their wheels, but by a LIM have been built and tested to achieve speeds of 250 mph. In another familiar example, the MAGLEV Train system operates at speeds over 300 mph and has no wheels at all, pulling itself along the unpowered track by magnetic induction fields. In addition to high-speed trains, many applications of linear motor technologies can be found in low-speed logistics transport systems. For example, transport systems found in hospitals, factories, and warehouses typically consist of a powered conveyor (stator) that generates magnetic fields in synchrony (synchronous linear motor) with the fields in the track to produce motion in its conveying carts. Although such applications of linear motor technology are generally thought to provide acceptable performance, they are not without shortcomings.

[0004] Linear motor technology works best when the gap between the motor poles and the reaction rail is small. To this end, conventional LIMs are tethered to massive guideways that are braced to the ground or ground-based elevated structures for the purpose of reducing vibration in the track, which leads to variation in the gap. A linear synchronous motor (LSM), which is another type of induction motor for propulsion, uses a similar guideway structure. Precise gap tolerance between the rotor and the stator elements is achieved during linear motor operation by reducing the vertical forces of the vehicle in motion on the braced track. Even in current marine applications, such as amusement rides and ferries (for example), including vehicles that ride on the water's surface and vehicles that penetrate it to go below the surface, existing LIMs and LSMs are supported by guideway structures on the ground beneath the water.

[0005] The guideway structure needed to minimize the gap for linear motor transport systems limits its usefulness to a predetermined and fixed path. In addition, the guideway structure is expensive in terms of both its construction and maintenance costs.

SUMMARY

[0006] According to an example, non-limiting embodiment, a rail system may include a rail buoyant in a fluid and a vehicle buoyant in the fluid. The vehicle may be electromagnetically coupled to the rail for movement along the rail.

[0007] According to another example, non-limiting embodiment, a rail may include a substrate. A plurality of

spaced apart electromagnetic elements may be imbedded in the substrate. The substrate may be fabricated from a material with a density sufficient to give the rail buoyancy in a fluid.

[0008] According to another example, non-limiting embodiment a conveying system may include a buoyant guide. A buoyant vehicle may be coupled to the floating guide. The buoyant guide and the buoyant vehicle may cooperate to convey the buoyant vehicle.

[0009] The above and other features of the invention including various and novel details of construction and combinations of parts will now be more particularly described with references to the accompanying drawings. It will be understood that the particular rail system embodying the invention is shown by way of illustration only and not as a limitation of the invention. The principles and features of this invention may be employed in varied and numerous embodiments without departing from the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] **FIG. 1** is a schematic perspective view of a linear motor according to an example, non-limiting embodiment of the invention.

[0011] **FIGS. 2A-2F** illustrate an example firing sequence that may be suitably implemented in the linear motor shown in **FIG. 1**.

[0012] **FIG. 3** illustrates an operational scenario of a rail system according to an example, non-limiting embodiment of the invention.

[0013] **FIG. 4** is a front view of the rail system shown in **FIG. 3**.

[0014] **FIG. 5** is a schematic cross-sectional view of the rail system shown in **FIG. 3**, while in a buoyant condition.

[0015] **FIG. 6** is a schematic cross-sectional view of the rail system shown in **FIG. 3**, while on land.

[0016] **FIG. 7** is a front view of a rail system according to another example, non-limiting embodiment of the invention.

[0017] **FIG. 8** is a schematic cross-sectional view of the rail system shown in **FIG. 7**, while in a buoyant condition.

[0018] **FIG. 9** is a schematic cross-sectional view of the rail system shown in **FIG. 7**, while on land.

[0019] **FIG. 10** is a schematic perspective view of a rail system according to another example, non-limiting embodiment of the invention.

[0020] **FIG. 11** is a schematic perspective view of a rail system according to another example, non-limiting embodiment of the invention.

DESCRIPTION OF EXAMPLE, NON-LIMITING EMBODIMENTS

[0021] In example, non-limiting embodiments of the invention shown in **FIGS. 1-10**, the rail system includes a buoyant rail (or track) **1 & 25**; its component junctions (not shown), unions (not shown), and tethers **22**; and complementary buoyant vehicles **2, 18, & 26** that ride the track **1 & 25**. In a first example embodiment, which is depicted in

FIGS. 1-6, the track **1** has a round cross-sectional profile. In a second example embodiment, which is depicted in **FIGS. 7-9**, the track **25** has a u-shaped profile.

[0022] I. A Track, Round in Cross-Section—**FIGS. 1-6**:

[0023] A buoyant track **1** includes a substrate **12** imbedded with electromagnet elements, such as permanent magnets **11**, for example. The substrate **12** may be fabricated from a plastic material and/or a composite material. The cross-sectional profile of the track **1** is round with symmetry about its axis as shown in **FIG. 1**. In this way, the track **1** may function properly even if one portion of the track is twisted relative to another. The diameter of the profile is not much greater than the diameter of the imbedded magnets **11** so as to minimize the gap **23** (see **FIGS. 5 & 6**) between the track **1** and rail-riding vehicle **2 & 18**. The track **1** may include internal reinforcing fibers **10**, which are not necessarily symmetrical about the axis of the track **1**. The reinforcing fibers **10** run the length of the track **1** and resist the external tensioning forces applied to the track **1**, which would otherwise cause it to stretch.

[0024] The substrate **12** may be fabricated from a material that is buoyant in water. The density of the substrate **12** material is sufficiently lower than that of water to compensate for the weight of electromagnetic elements (such as the magnets **11**, for example) and reinforcing elements (such as the reinforcing fibers **10**, for example) imbedded within it. The track **1** may also include spacers (not shown) provided between the electromagnetic elements. The spacers (not shown) and the magnets **11** may be fixed to the reinforcing fibers **10** to provide a sub-assembly that may have a cylindrical shape. The material of the substrate **12** may then be provided on the cylindrical sub-assembly by conventional extrusion techniques.

[0025] The magnets **11** imbedded within the track **1** are held in position relative to one another by the spacers **10**, which are also imbedded in the substrate **12**. In an alternate embodiment, the spacers **10** may be modified to accommodate coils, solenoids and/or conductive plates that function similarly. In the disclosed example embodiments, the track **1** is a passive element to the extent that it is un-powered. Here, the internal elements of the track **1** act as reaction plates for the overall synchronous motor system. In alternative embodiments, powered primary electromagnets and/or powered coils (for example) for a LIM system may be included in the track **1**.

[0026] The rail-riding vehicles **2** complement the buoyant track **1** in a geometric fashion in two ways. First the cross-sectional geometry of the vehicle hull **18**, which is that portion of the rail-riding vehicle **2** in potential contact with the water when in the marine environment, corresponds to the cross-sectional geometry of the track **1**. Second, the positioning of the primary coils **3, 4, & 5** (see **FIGS. 1 & 2**) is such that at least one of the coils **3, 4, & 5** is suitably positioned with respect to one of the reaction elements **11** in the track **1** to generate a propulsion force when energized by a control device. The rail system is balanced to achieve hydrodynamic efficiency in the hull and track mounting geometry, while also achieving maximum electromagnetic efficiency in the primary and secondary coil mounting geometry.

[0027] In this example embodiment, the hull **18** includes a cavity that is round in cross section. Positioning of the

cavity is such that the gap between the track **1** and the hull **18** does not vary significantly as the system transitions from operating in water as shown in **FIGS. 4 & 5** to operating on land as shown in **FIG. 6**.

[0028] The primary coils **3, 4, & 5** of the linear synchronous motor shown in **FIG. 1** are spaced apart in such a way that electrical switching among them yields propulsion force. For example, if the length **6** of an imbedded magnet is l and the length **7** from the front of one magnet to the front of the next is $2l$, then the length **8** between primary coils **3 & 4** is $1.25l$ and the length **9** between primary coils **3 & 5** is $2.5l$ to allow generation of a propulsion force at every step down the track **1**. Such geometries are well understood in this art.

[0029] To ride on the track **1**, a rail-riding vehicle energizes each of its solenoids at timings to develop forces of attraction and repulsion. A solenoid firing sequence may be implemented with either AC (by controlling the frequency) or DC (by switching the current) power. The firing sequence may be used to propel the rail-riding vehicle **2** along the track **1**. An example firing sequence is depicted in **FIGS. 2A-2F**.

[0030] An example, non-limiting operational concept for the buoyant marine rail system is depicted in **FIG. 3**. Here, standard shipping containers **13**, which are commonly referred to as Twenty-Foot-Equivalent units (TEUs), are transported by the rail system from a base at sea **14**, across the beach **15**, over terrain **16**, and all the way into the field base ashore **17**. In this illustration, the rail-riding vehicle **2 & 18** resembles a barge with wheels **19**.

[0031] Given that the buoyant track **1** is statically neutral without need for a guideway structure (which is typical of conventional linear motors), it is mobile and can be moved into position on demand. At the interface between the water and the land, commonly known as the beach **15**, the support for the weight of the track **1** is transitioned from the water to the ground as shown in **FIG. 3**. The track **1** is sufficiently stiff to permit relatively little distortion in the beach **15** region, as well as in the water or on land.

[0032] **FIG. 4** depicts a front view demonstrating how the system is tethered **22** to the land **21** beneath the water. In this example embodiment, the track **1** floats on the surface **20** of the water. However, the invention is not limited in this regard so long as the track **1** is buoyant. Tethering **22** is common for vessels such as semi-submersible oil rigs that operate in a relatively fixed position in ocean waters. It will be appreciated that a track tethered **22** to the ocean floor **21** will be buoyed by the water and does not need additional supporting structure. Rather, the tether **22** keeps the track **1** from floating away, much like the brake on a LIM roller coaster keeps it from rolling away down the track.

[0033] The rail-riding vehicles **2 & 18** include wheels **19** that are positioned such that the track **1** is in the same relative position with regard to the underside of the vehicle **2 & 18** when the vehicle **2 & 18** is on land **24** or in the water **20**. **FIG. 5** shows the system in water **20** and **FIG. 6** shows the same system on dry land **24**.

[0034] The gap **23** between the magnet **11** in the track **1** and the primary coil **3** in the rail-riding vehicle **2 & 18** is at least as thick as the substrate **12** provided on the magnet **11**.

[0035] In this example embodiment, the rail riding vehicle 2 and the hull 18 are fixed together as an integral unit. In an alternative embodiment, as shown in FIG. 10 (for example), the rail riding vehicle 2 and the hull 18 may be physically different (and buoyant) structures that are coupled together via a rope 40 (or other coupling mechanism). In this way, the rail riding vehicle 2 may serve as a tractor with the separate hull 18 (and cargo) being towed behind the rail riding vehicle 2.

[0036] II. A Track, U-Shaped in Cross-Section—FIGS. 7-9:

[0037] The following example, non-limiting embodiment is somewhat similar to the previous embodiment. However, as will be discussed in the following paragraphs, there are some notable differences including the shape of the track 25, the corresponding shape of the rail-riding vehicle 26, the TEU racks 27, and implications of a transverse orientation for imbedded coils 31 in the track 25 and corresponding transversely oriented primary coils 30 in the rail-riding vehicle 26.

[0038] With reference to FIG. 7 this example embodiment may include a track 25 that has a u-shaped profile, a complementary e-shaped rail-riding vehicle 26, and mounting racks 27 for transporting two independently floating containers 13 at a time.

[0039] By allowing shipping containers 13 of various load-out weights to float independently at different drafts as shown in FIG. 7, the rail-riding vehicles 26 may reduce forces that twist the track 1. However, the containers 13 (or TEUs) remain coupled to the rail-riding vehicles 26 in the horizontal plane for transport along the track 25.

[0040] With reference to FIGS. 8 and 9, the transverse arrangement of the coils in both the track 25 (passive coils 31) and the rail-riding vehicles 26 (primary switching coils 30) permits utilization of magnetic fields emanating from both ends of the primary coils 30. This yields increased power density over the example, non-limiting embodiment presented in FIGS. 1-6 and the ability to carry more payload.

[0041] In the example, non-limiting embodiment depicted in FIGS. 7-9, the transverse arrangement of the coils 30 & 31 reduces the dependence of gap tolerance on the dynamics associated with the marine environment. That is, buoyancy motions in the vertical direction caused by waves (for example) may have a reduced impact on the horizontal distance across the gap 32 between primary switching coils 30 on the rail-riding vehicles 26 and the passive coils 31 imbedded in the track 25.

[0042] The linear motor according to example, non-limiting embodiments of the present invention provides (for example) improved flexibility, cost, and mobility to linear motor technology. The disclosed buoyant marine rail system provides a novel mode of transporting various logistics payloads to or from a base at sea, across the beach, over land, and to a base on land. In its most elemental form, the disclosed buoyant marine rail system may substitute for steering mechanisms needed to steer self-propelled vehicles. Moreover, example, non-limiting embodiments of the present invention introduce a novel approach to levitation of the various components of a LIM or LSM via relative

buoyancy while in the marine environment, which reduces (and may altogether eliminate) the need for a guideway structure.

[0043] Various and novel details of construction and combinations of parts have been described with reference to the accompanying drawings. It will be understood that the particular buoyant marine rail system embodying the invention is shown by way of illustration only and not as a limitation of the invention. The principles and features of this invention may be employed in varied and numerous embodiments without departing from the scope of the invention.

[0044] For example, in the disclosed embodiments, the rail is passive (or unpowered) and the vehicle is active (or powered). In alternative embodiments, the rail may be active and the vehicle may be inactive. Also, as shown in FIG. 11 (for example) the track (in the form of a guide wire) may be directly buoyed by the water, suspended above the fluid by buoyed supports that are tethered to the land beneath the fluid, or resting on the ground beneath the fluid. In any case, the track may also be coupled to buoyant vehicles. Consider FIG. 11, for example. Here, a guide 100 is suspended above water by buoyed supports that are tethered to the land beneath the water. The guide 100 may be translated relative to the buoyed supports 110 to convey the floating vehicles 120 as desired. This embodiment may be somewhat functionally similar to a conventional ski lift.

What is claimed is:

1. A rail system comprising:

a rail buoyant in a fluid; and

a vehicle buoyant in the fluid;

the vehicle electromagnetically coupled to the rail for movement along the rail.

2. The rail system according to claim 1, further comprising:

electromagnetic reaction elements imbedded in the rail; and

primary coils provided on the vehicle.

3. The rail system according to claim 2, wherein the electromagnetic reaction elements are magnets.

4. The rail system according to claim 1, wherein the rail has an arcuate cross sectional shape.

5. The rail system according to claim 4, wherein the rail has a circular cross sectional shape.

6. The rail system according to claim 5, wherein the vehicle has a hull with a shape corresponding to the shape of the rail.

7. The rail system according to claim 1, wherein the rail has a U-shaped cross sectional profile.

8. The rail system according to claim 7, wherein the vehicle has a hull with a shape corresponding to the shape of the rail.

9. The rail system according to claim 1, further comprising:

wheels provided on the vehicle to support the vehicle on land.

10. The rail system according to claim 1, wherein the rail is flexible and has a repeating geometry along the length of the rail.

11. The rail system according to claim 1, wherein the vehicle is self-propelled along the rail.

12. A rail comprising:

a substrate; and

a plurality of spaced apart electromagnetic elements imbedded in the substrate;

wherein the substrate is fabricated from a material with a density sufficient to give the rail buoyancy in a fluid.

13. The rail according to claim 12, wherein the electromagnetic elements are electromagnetic reaction elements.

14. The rail according to claim 13, wherein the electromagnetic reaction elements are magnets.

15. The rail according to claim 13, wherein the electromagnetic reaction elements are coils.

16. The rail according to claim 12, further comprising:

a reinforcing member imbedded in the substrate.

17. The rail according to claim 16, wherein the reinforcing member is a plurality of fibers extending along the length of the rail.

18. The rail according to claim 12, further comprising:

spacers interposed between the electromagnetic elements.

19. The rail according to claim 12, further comprising:

a tether securing the rail to land underneath a body of water.

20. A conveying system comprising:

a buoyant guide; and

a buoyant vehicle coupled to the floating guide;

wherein the buoyant guide and the buoyant vehicle cooperate to convey the buoyant vehicle.

* * * * *