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[54] **WATER TRANSPORTATION SYSTEM WITH
SHORE-BASED PROPULSION**
50 Claims, 41 Drawing Figs.

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[51] Int. Cl..... B63b 21/56
[50] Field of Search..... 114/0.5, 0.5
F, 231; 115/7, 8; 104/71, 72; 272/32

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ABSTRACT: A ferry water transportation system wherein a freely floating vessel is propelled across the water by an underwater cable. The cable is moved by a winch driven from a power source, and both the winch and power source are located on shore, or on a floating terminal at shoreside. The vessel is guided and kept on course by the cable system, and its speed and direction are controlled from the vessel or from shore, as desired. The vessel thus has no onboard propulsion machinery; so the internal hull volume may be filled with foamed material to make the vessel unsinkable.

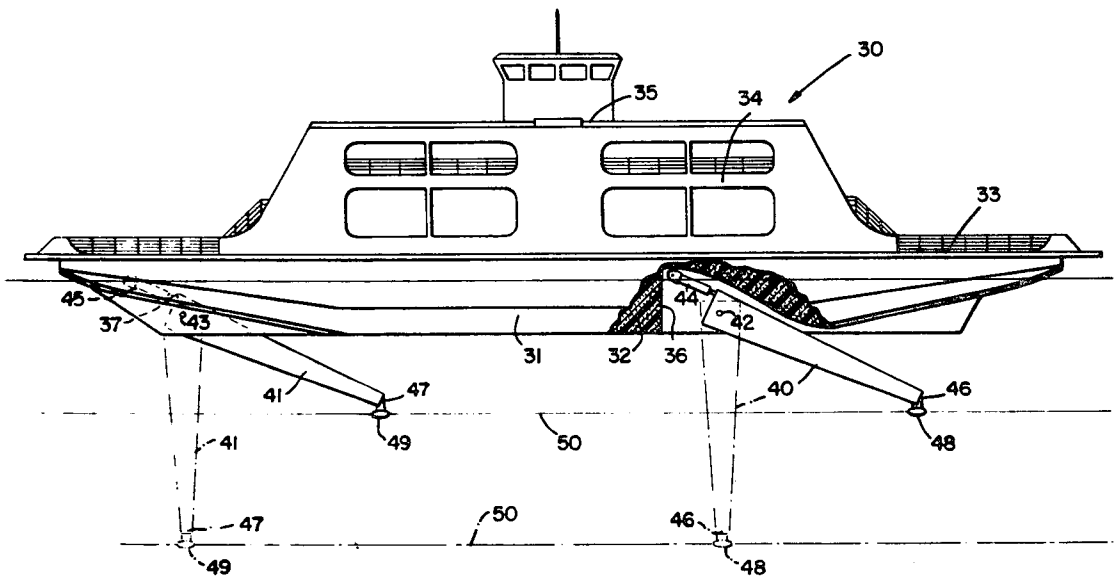


FIG-1

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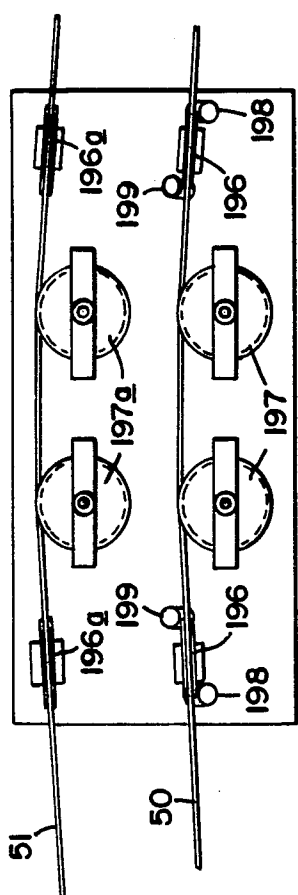


FIG-2

FIG-28

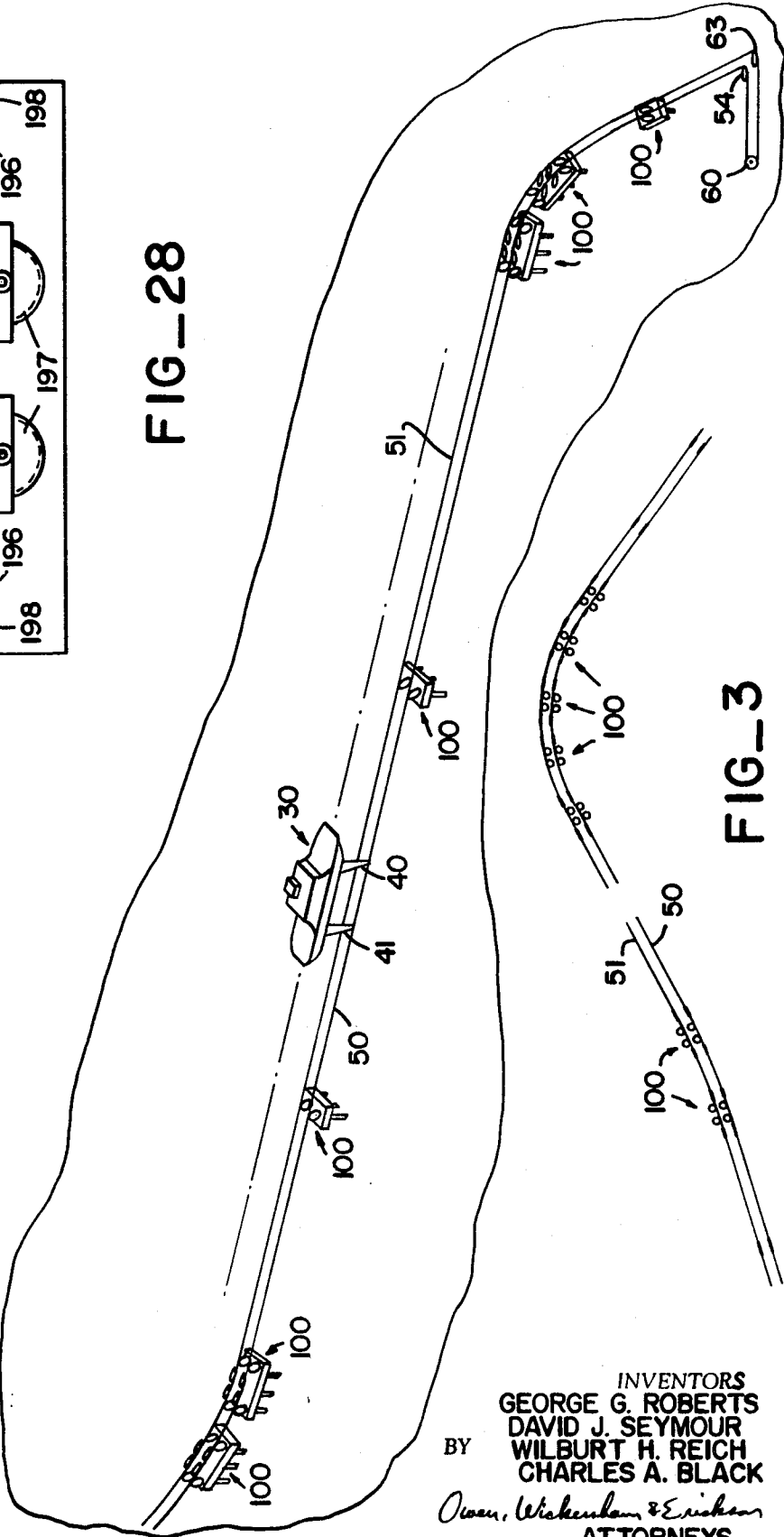


FIG-3

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FIG-5

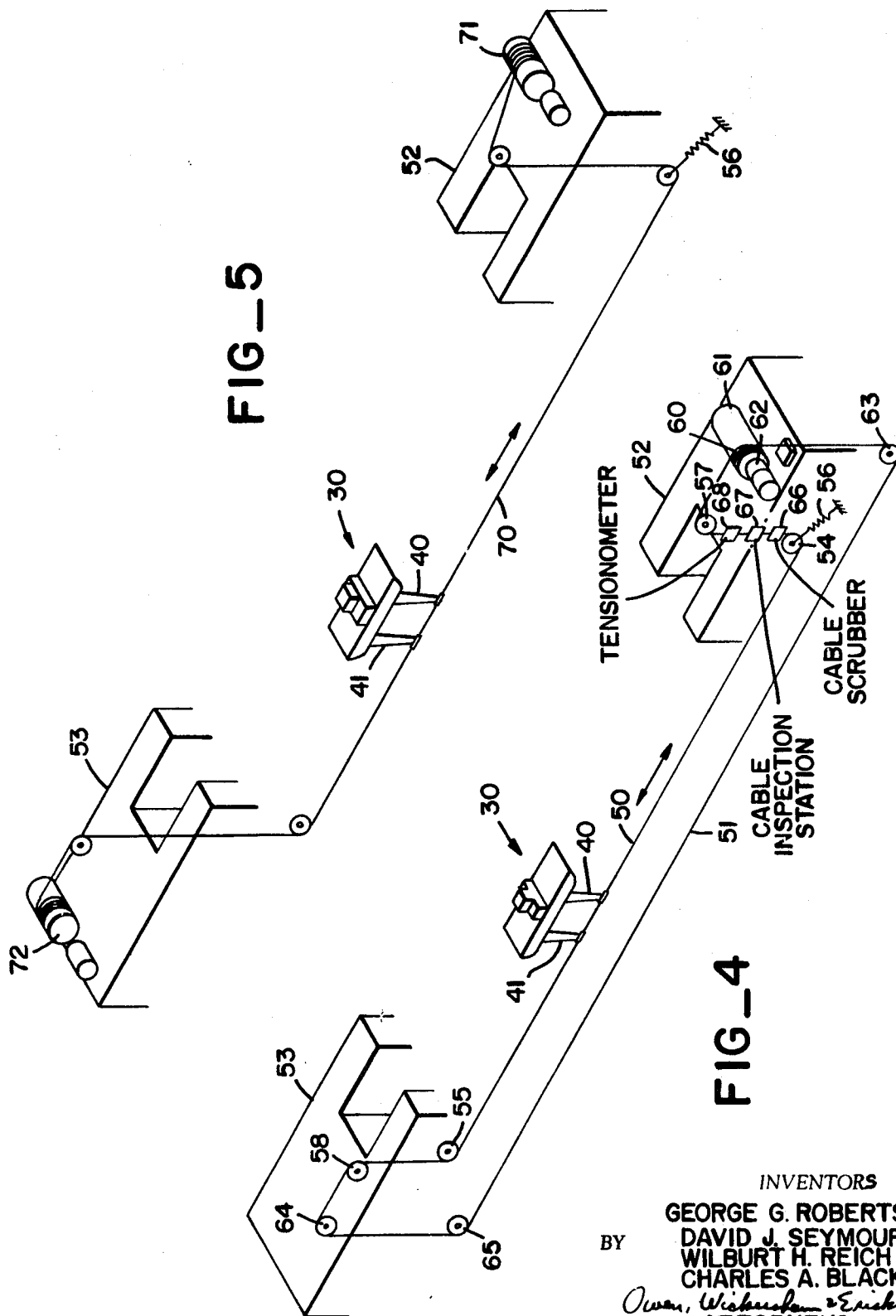
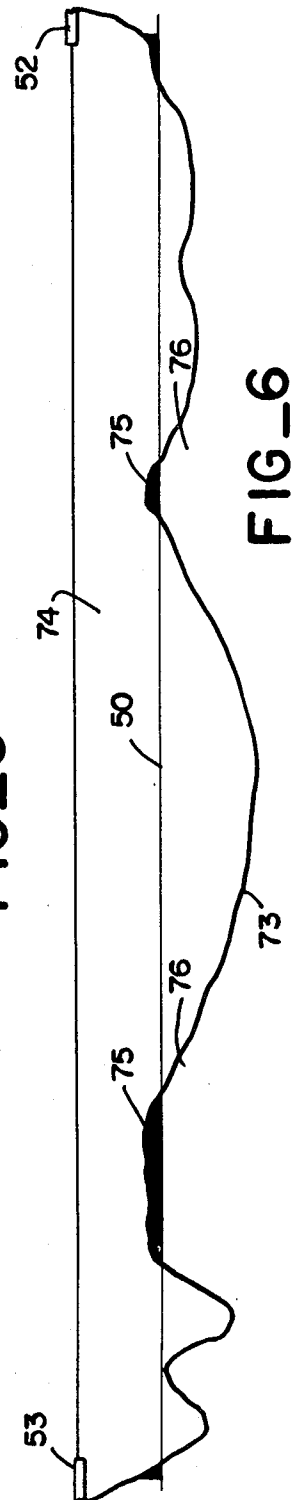
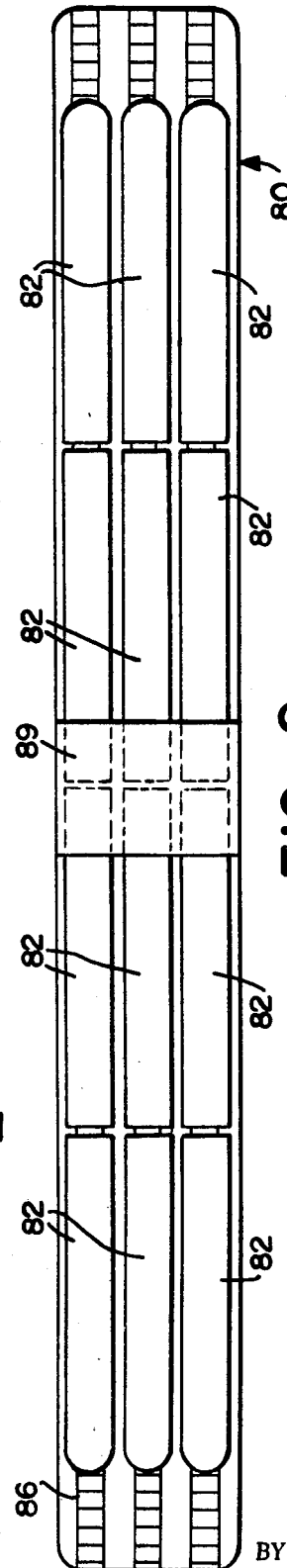
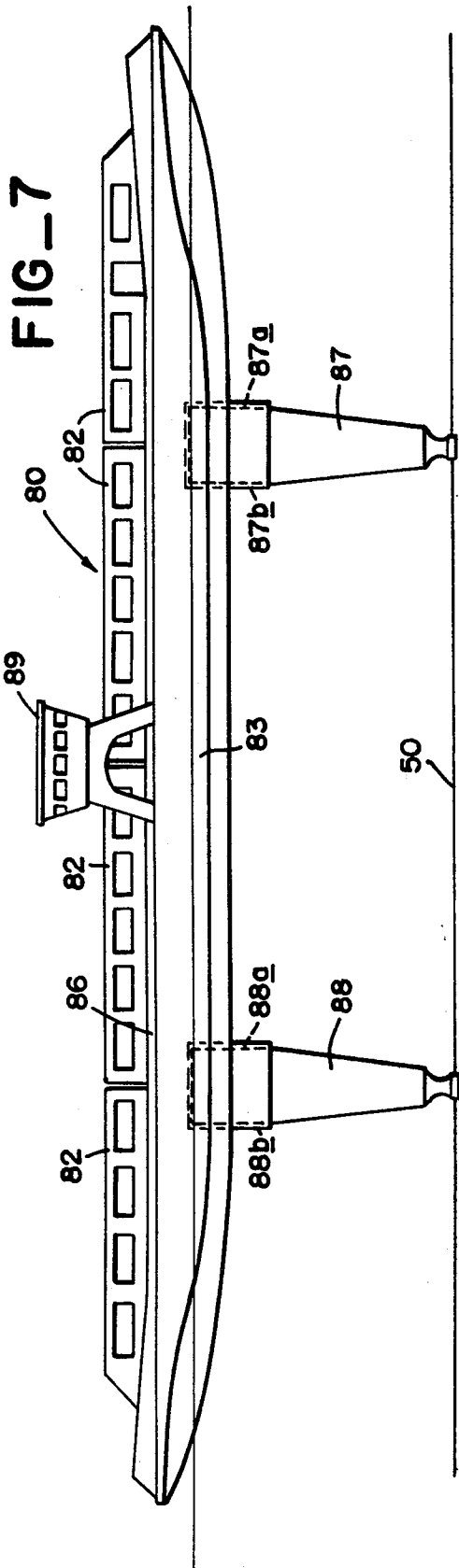
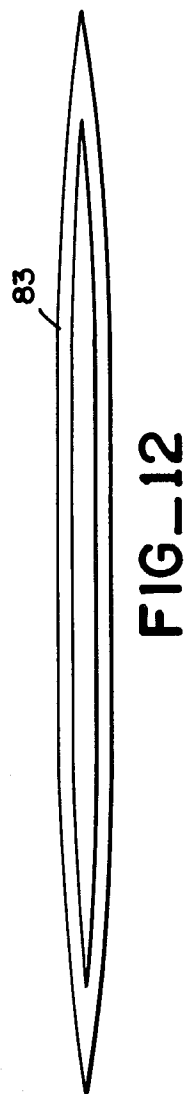
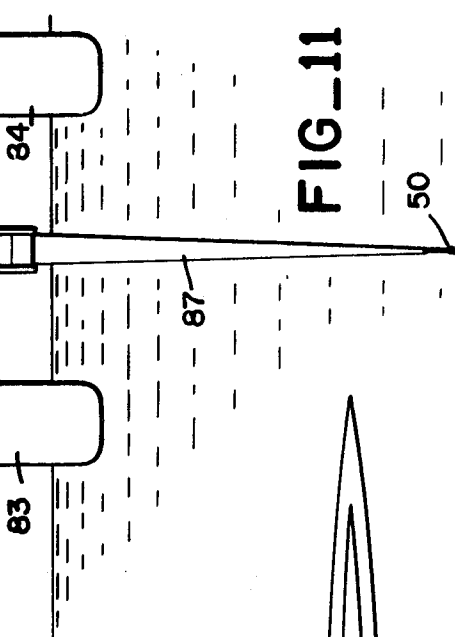
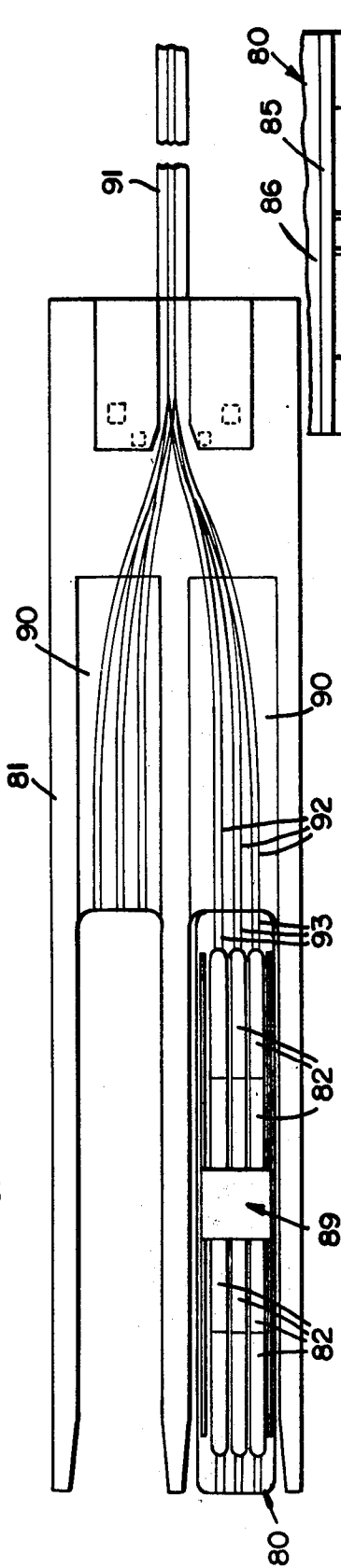
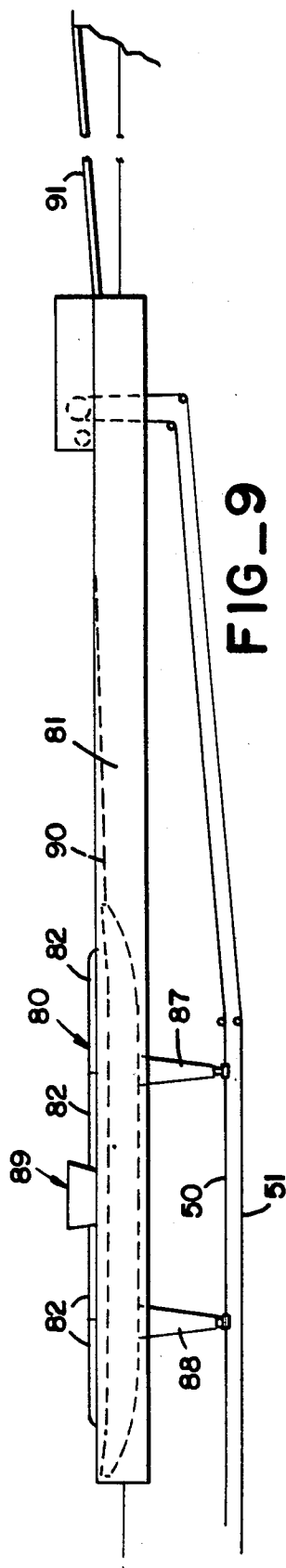


FIG-4

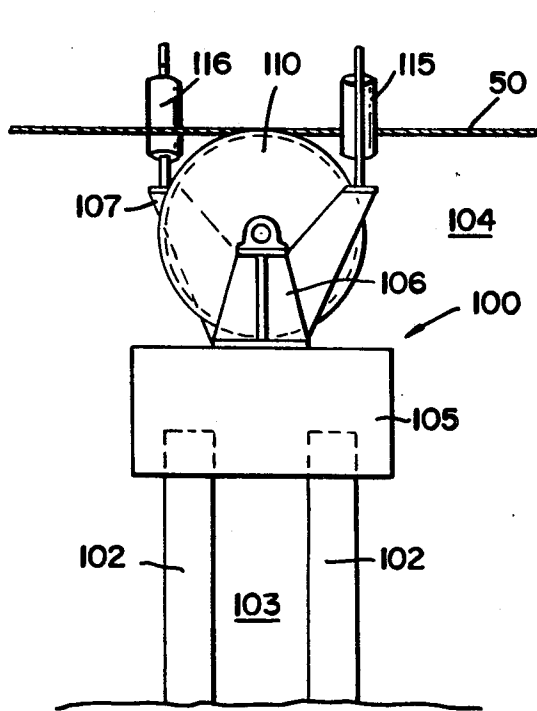
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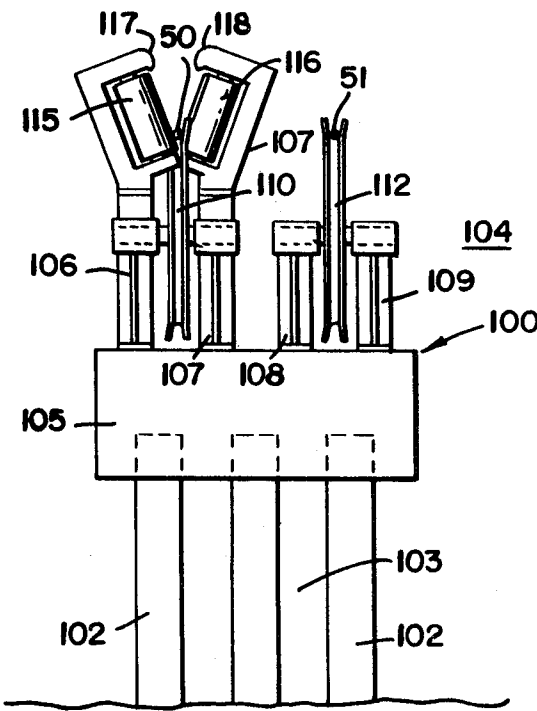
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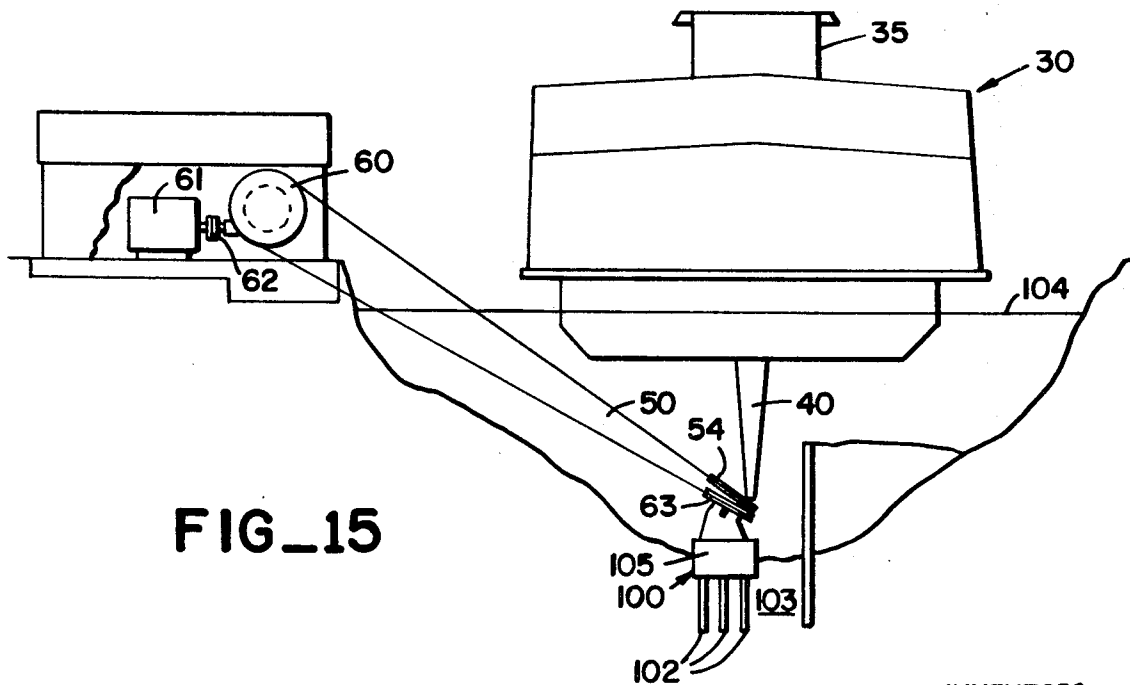
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FIG_13



FIG_14



FIG_15

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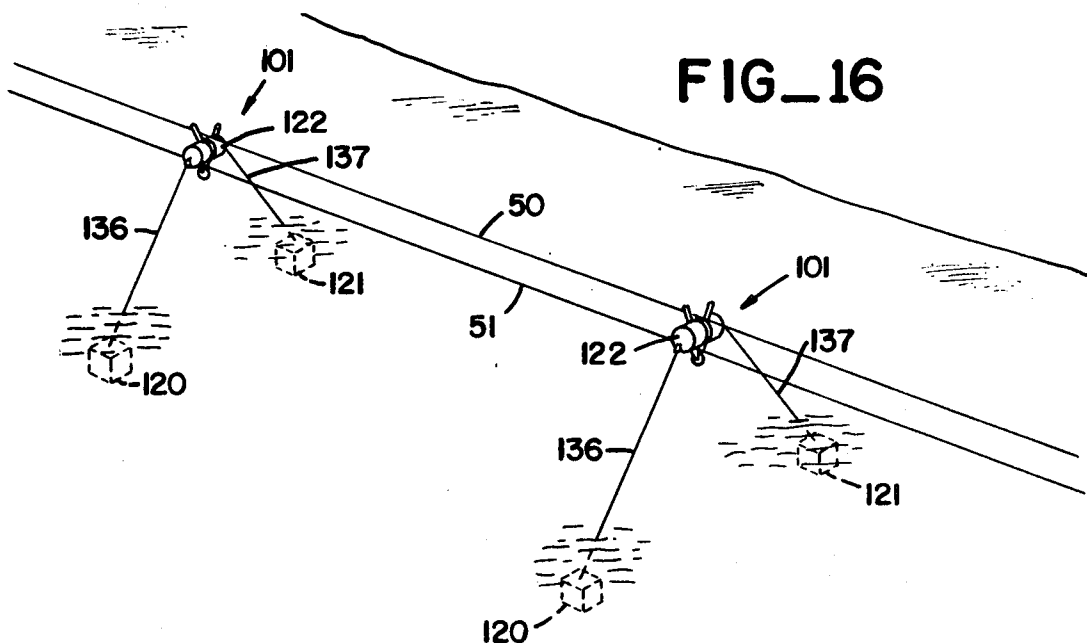


FIG. 16

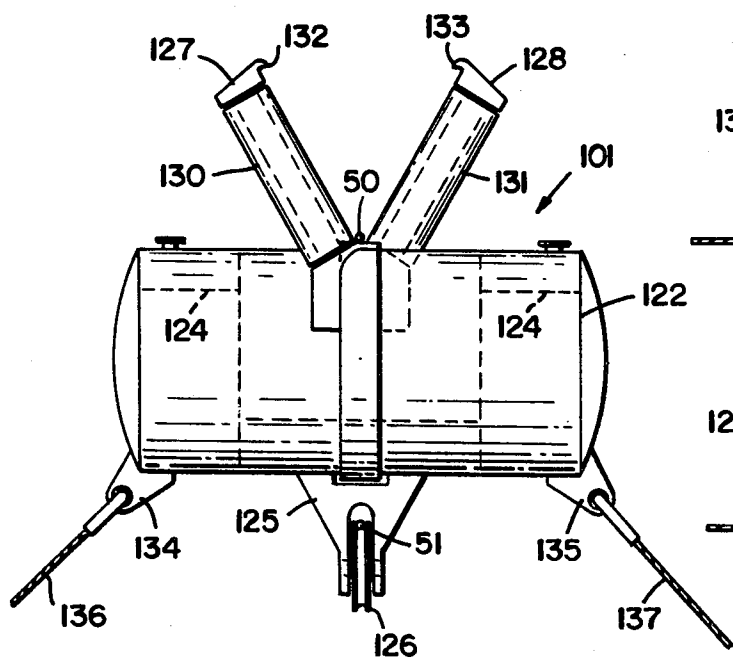


FIG. 17

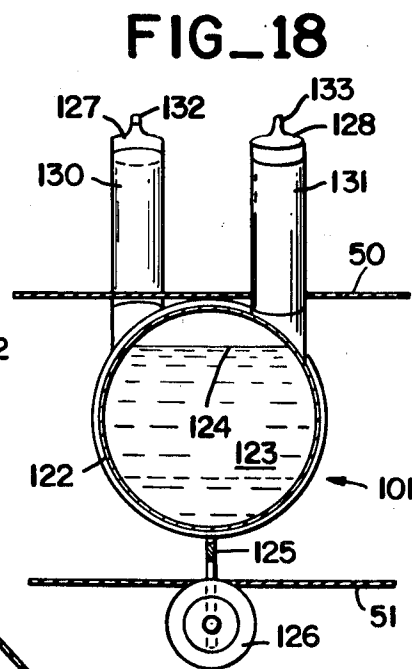
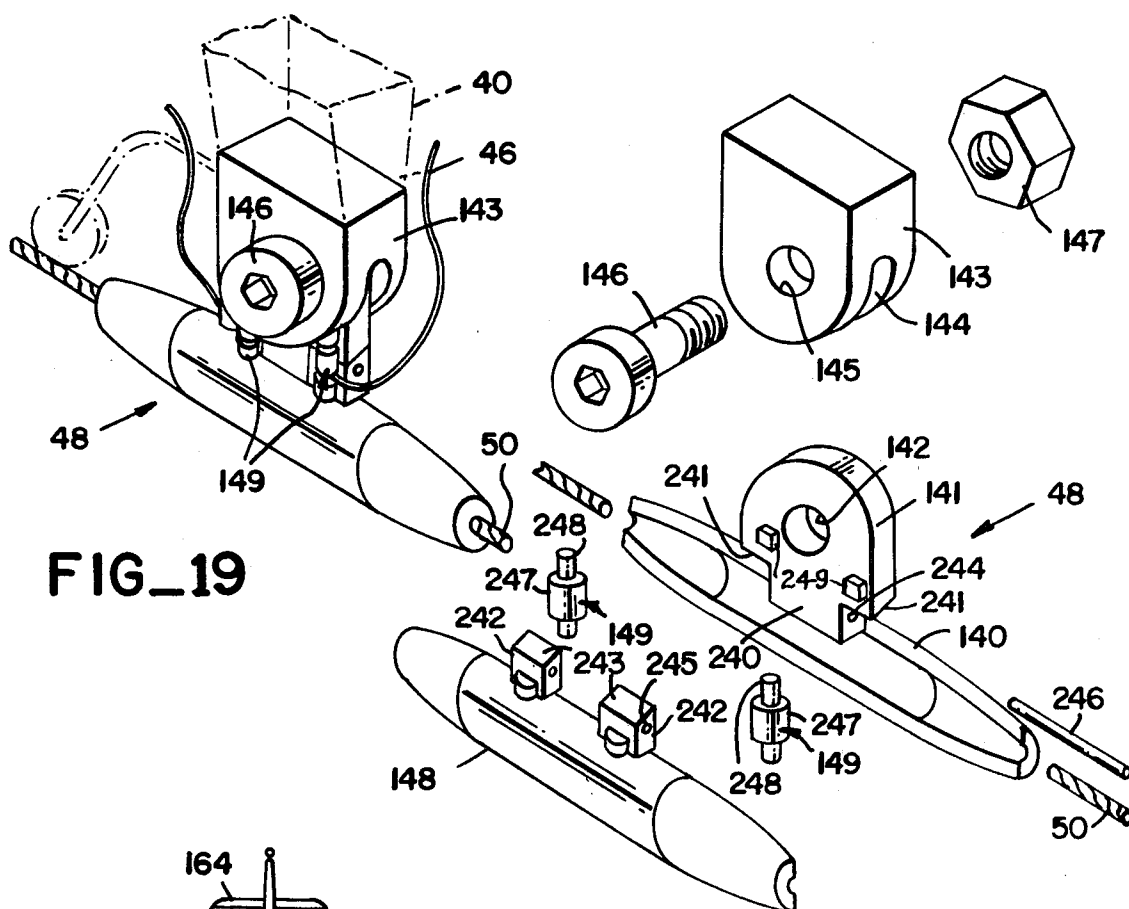
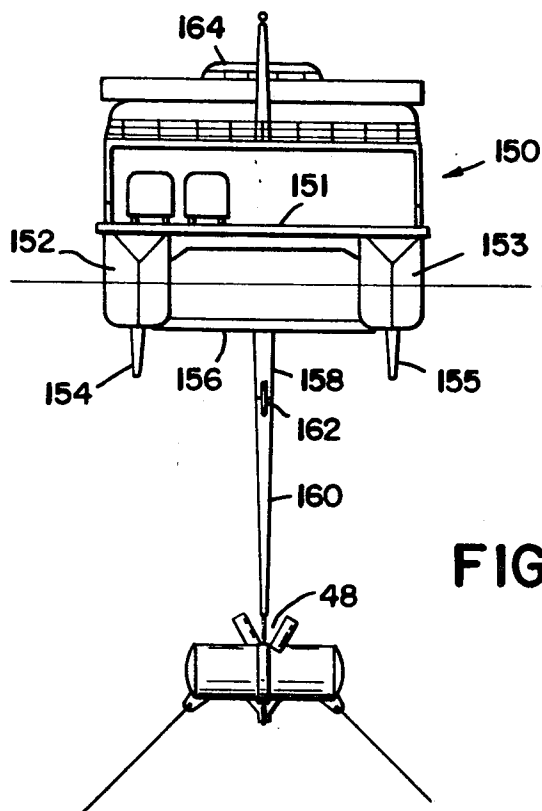


FIG. 18

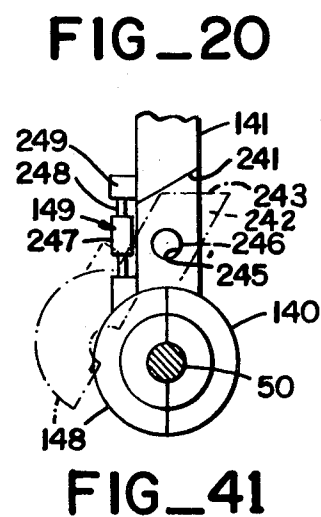
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FIG_19



FIG_22



FIG_41

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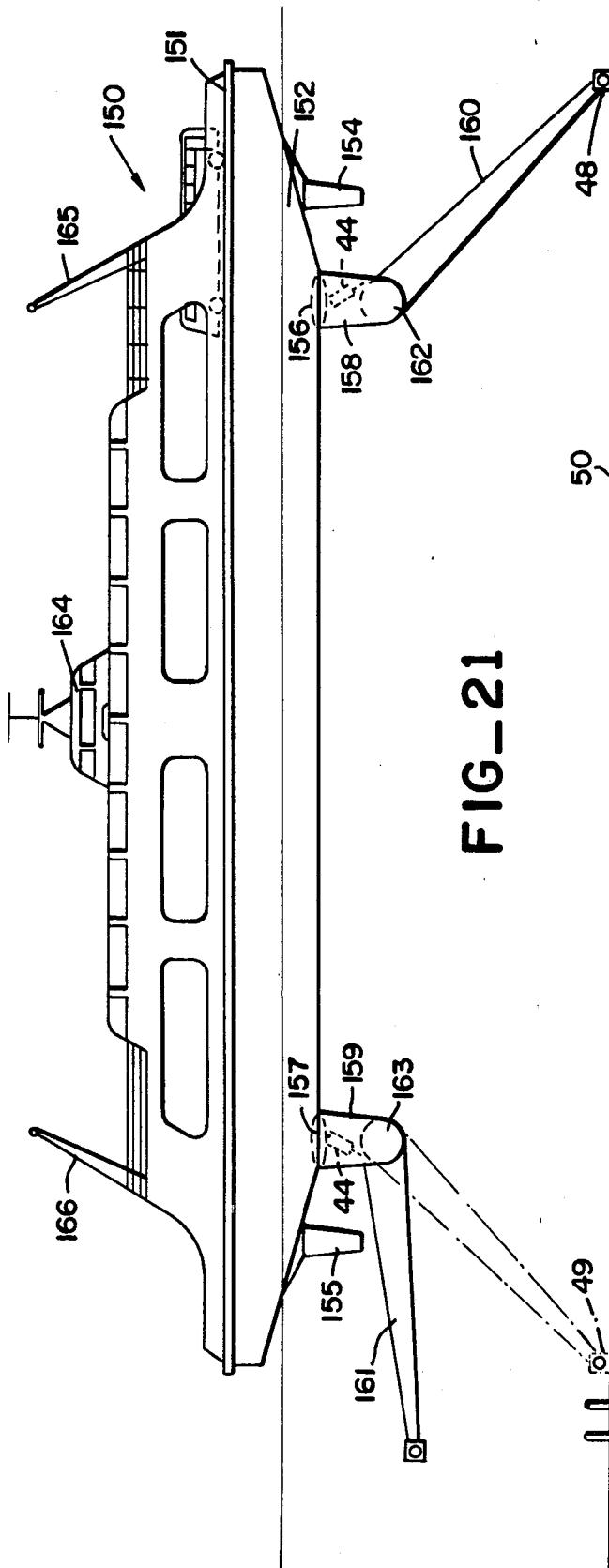
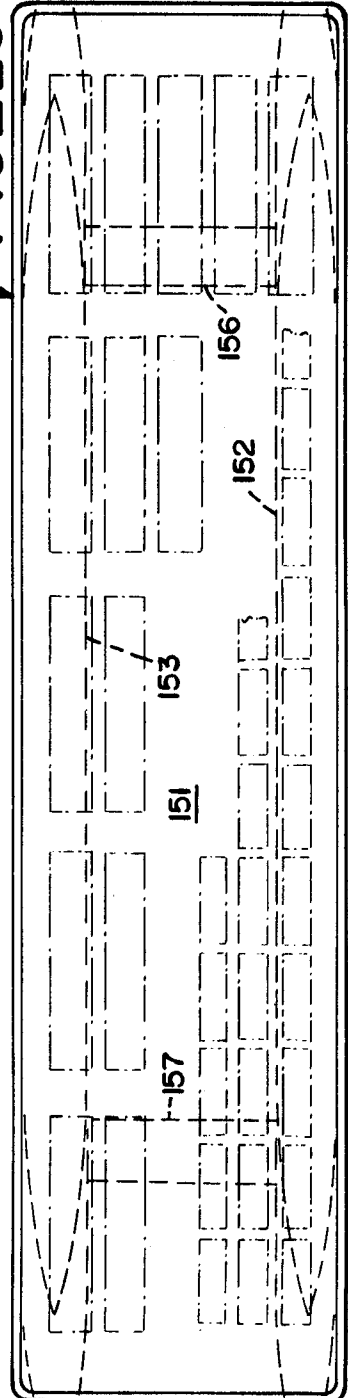
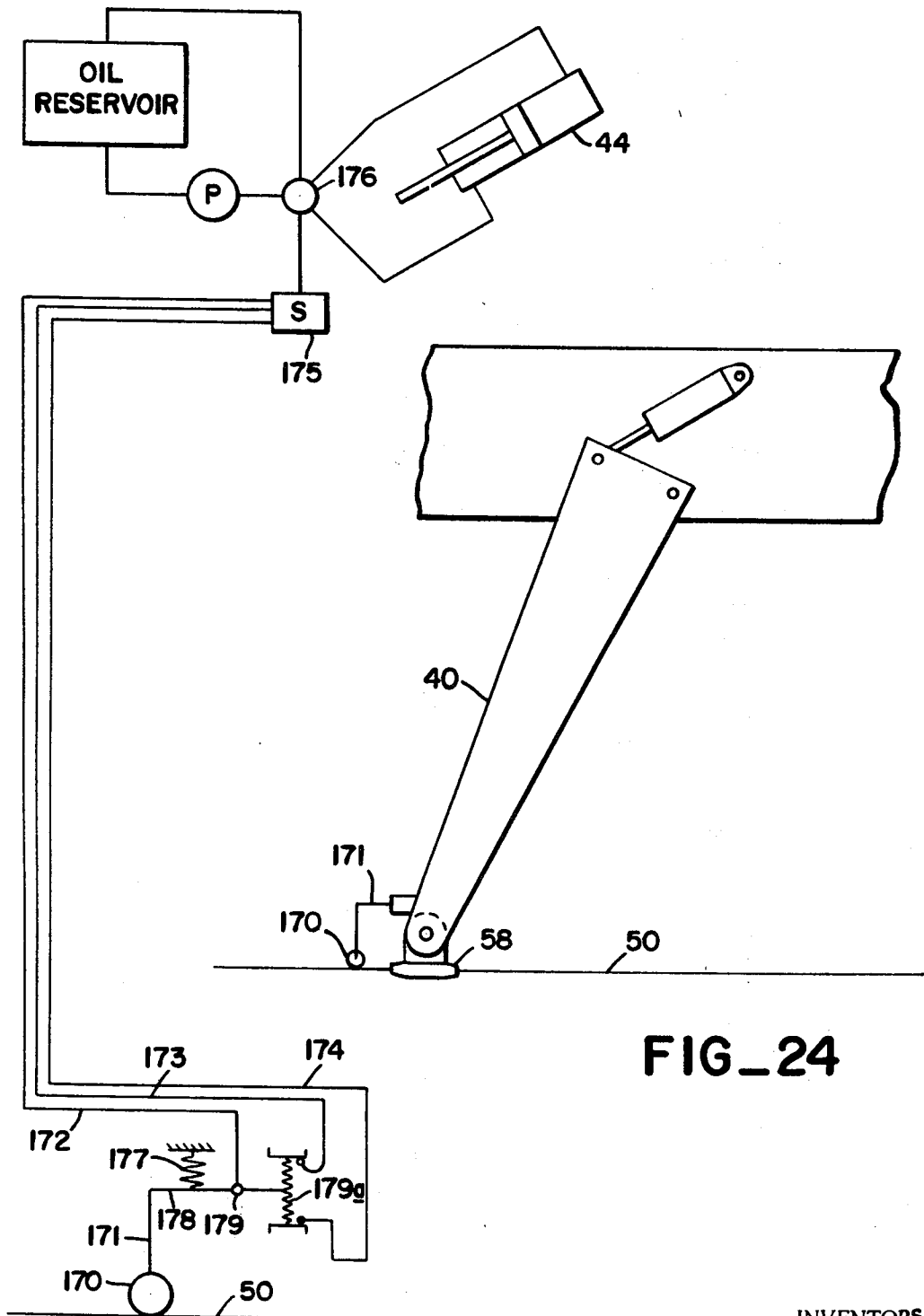


FIG-21

FIG-23



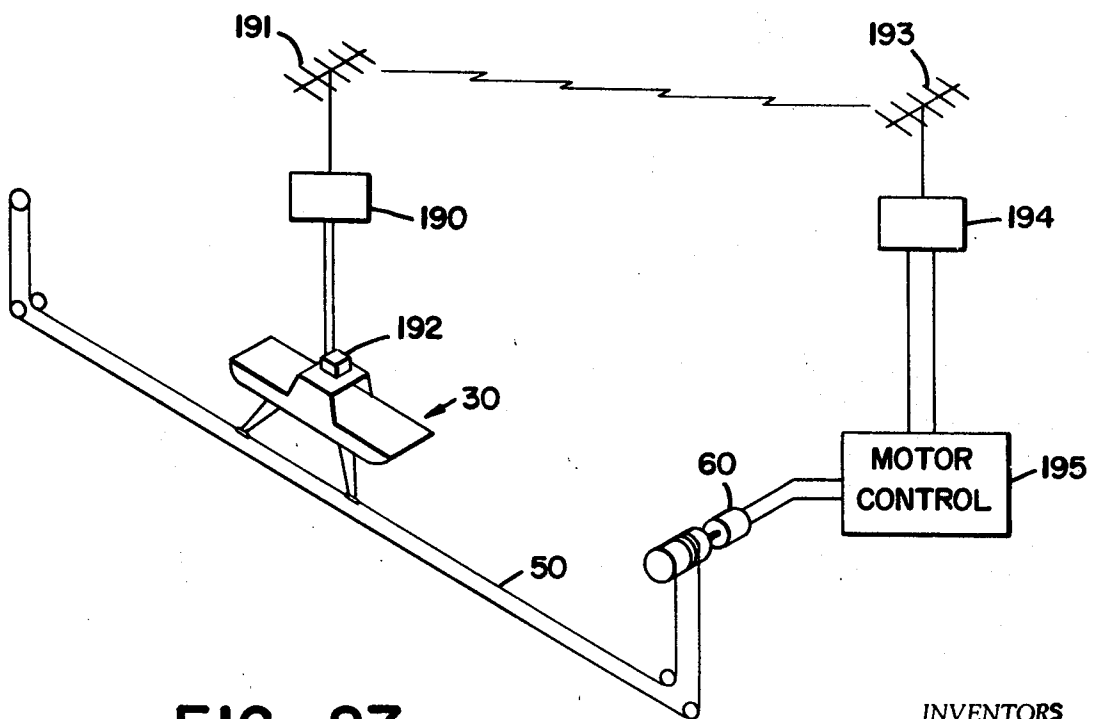
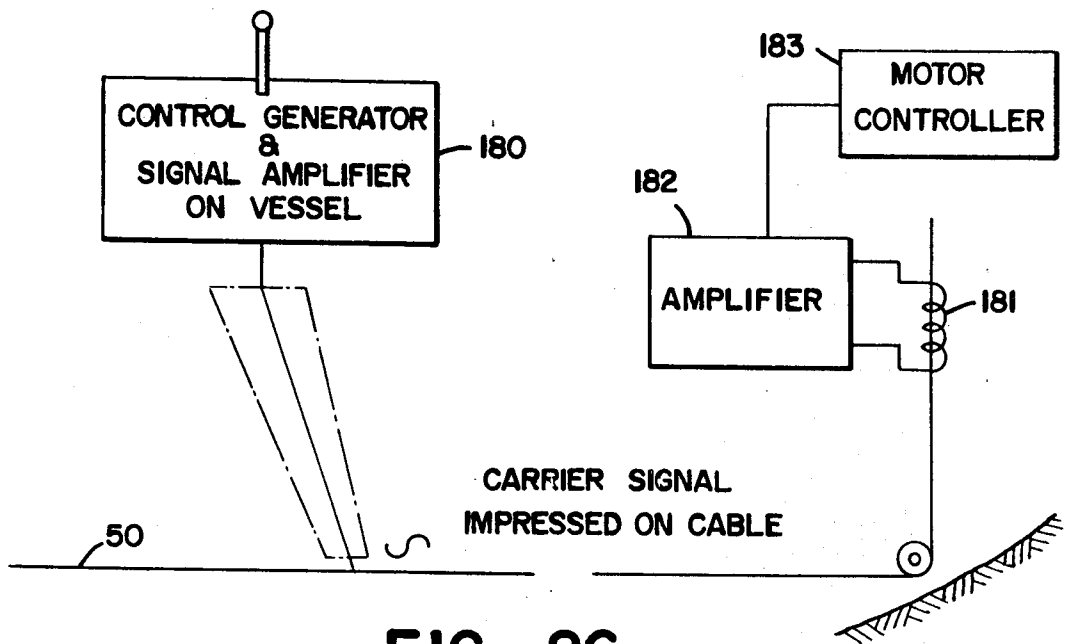
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FIG_24

FIG_25

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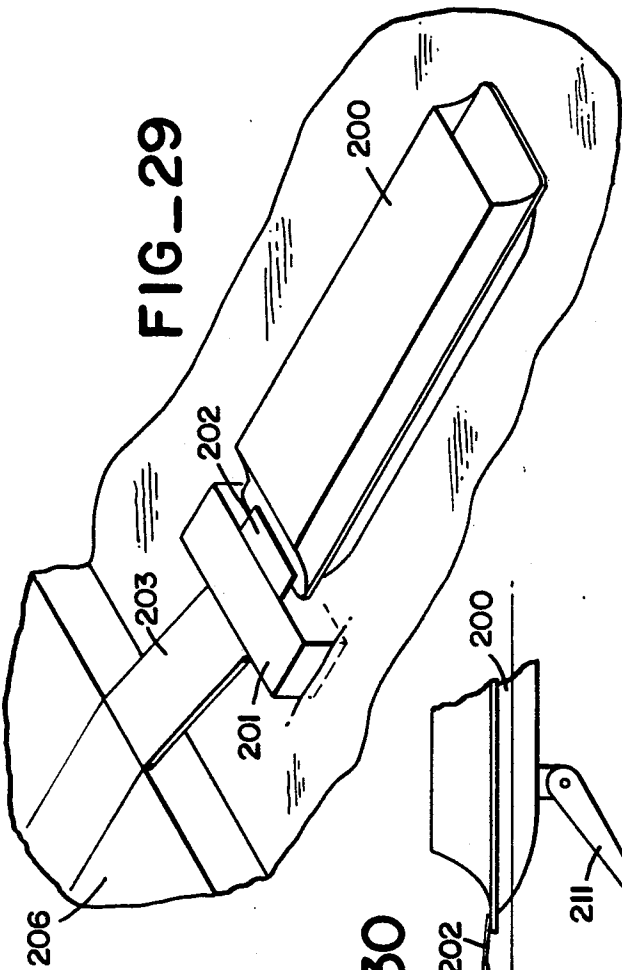


FIG-29

FIG-30

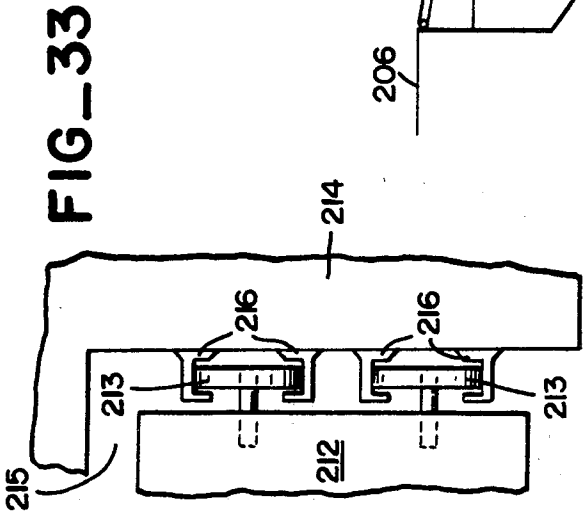
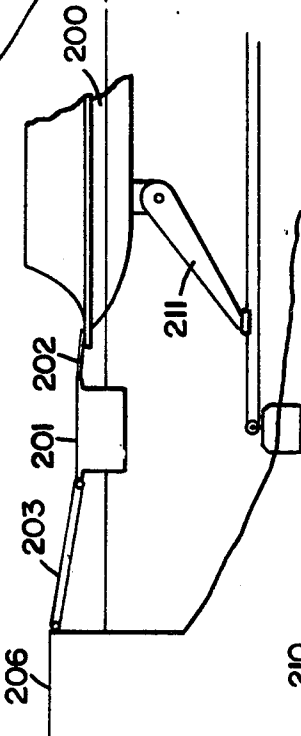


FIG-33

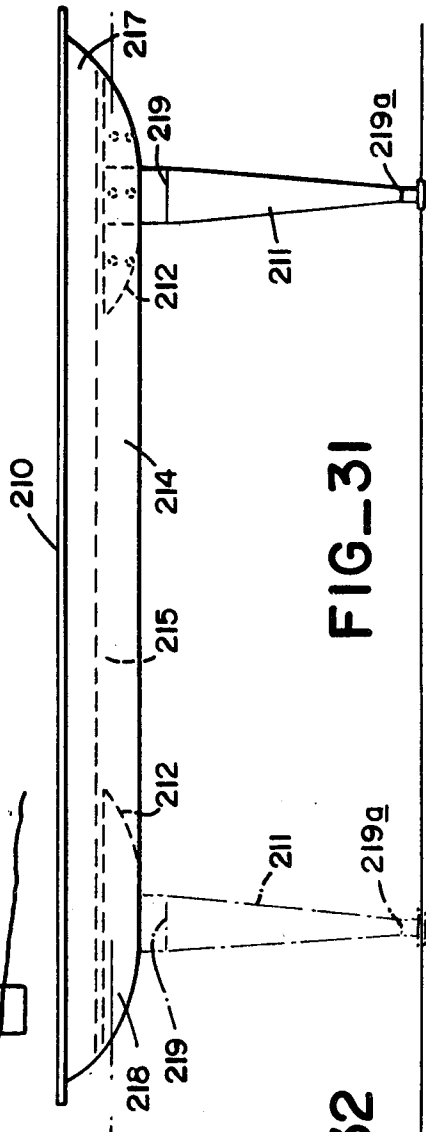


FIG-31

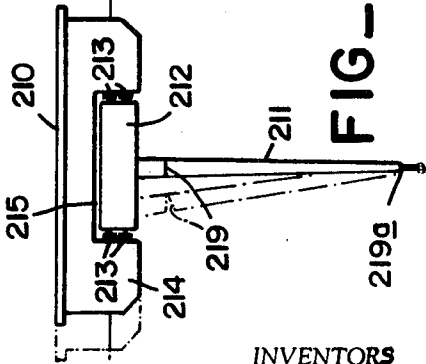


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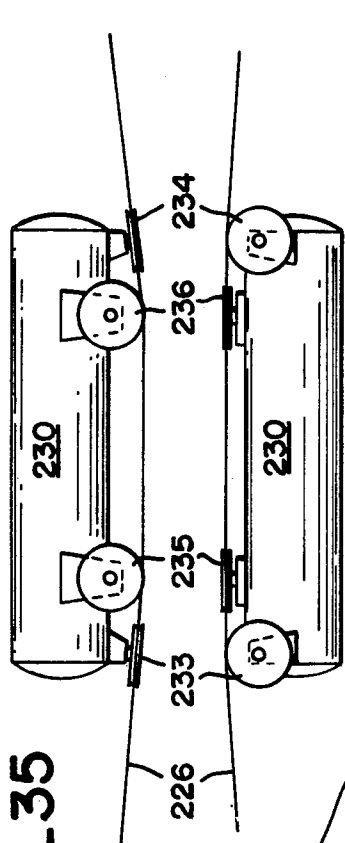


FIG-35

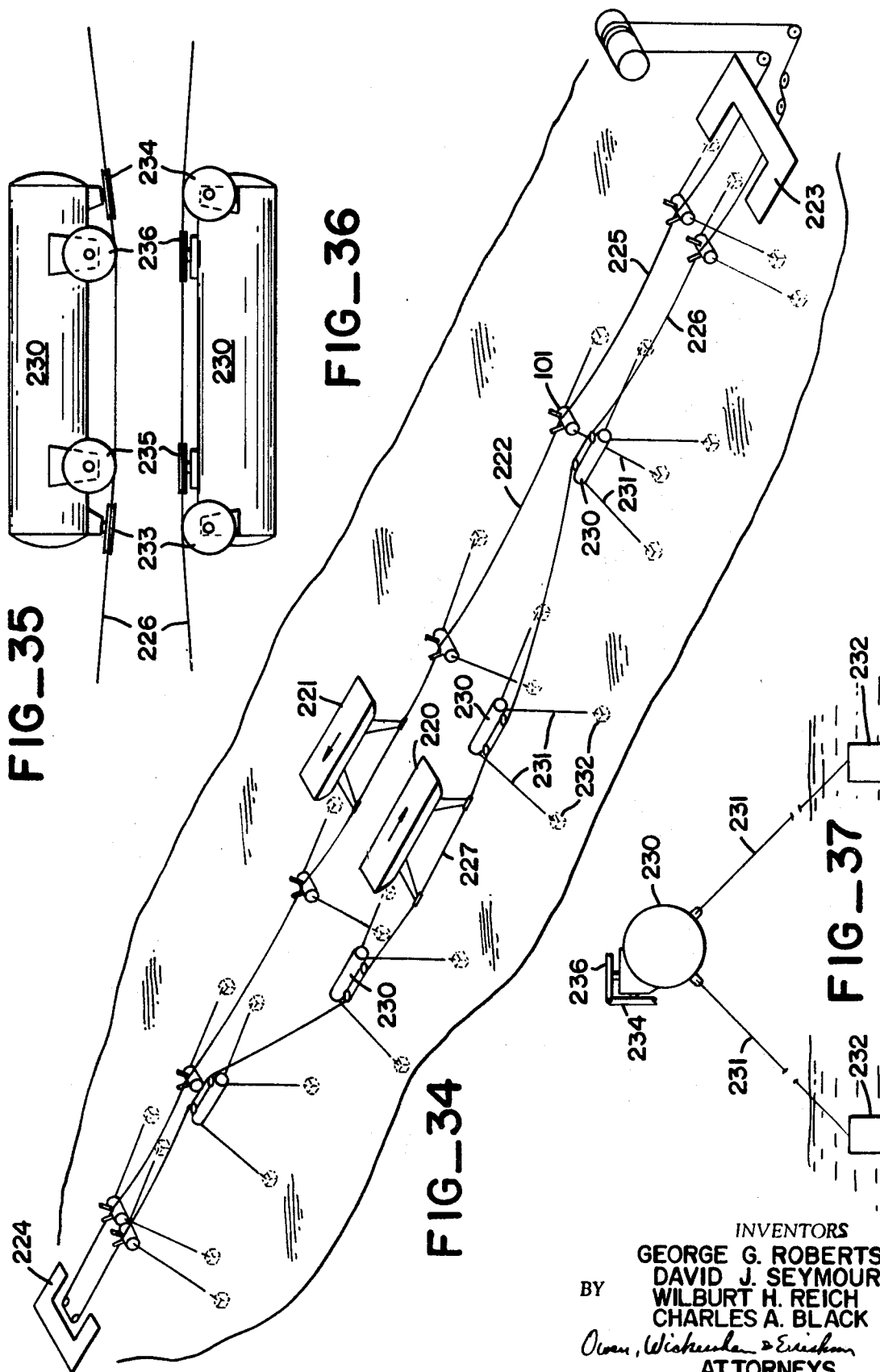
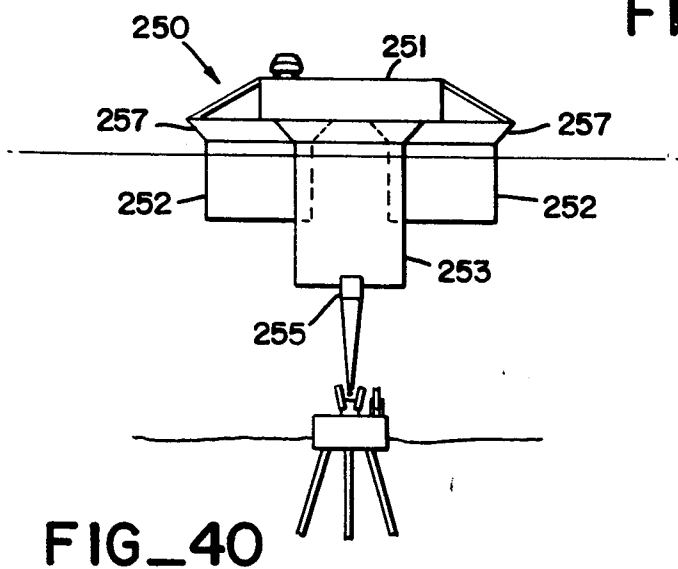
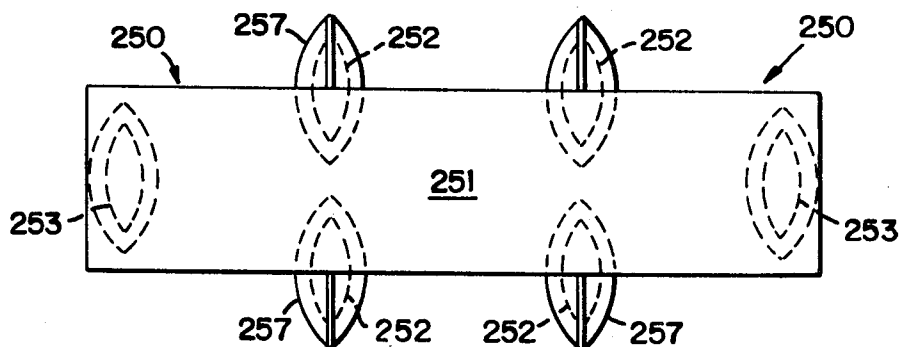
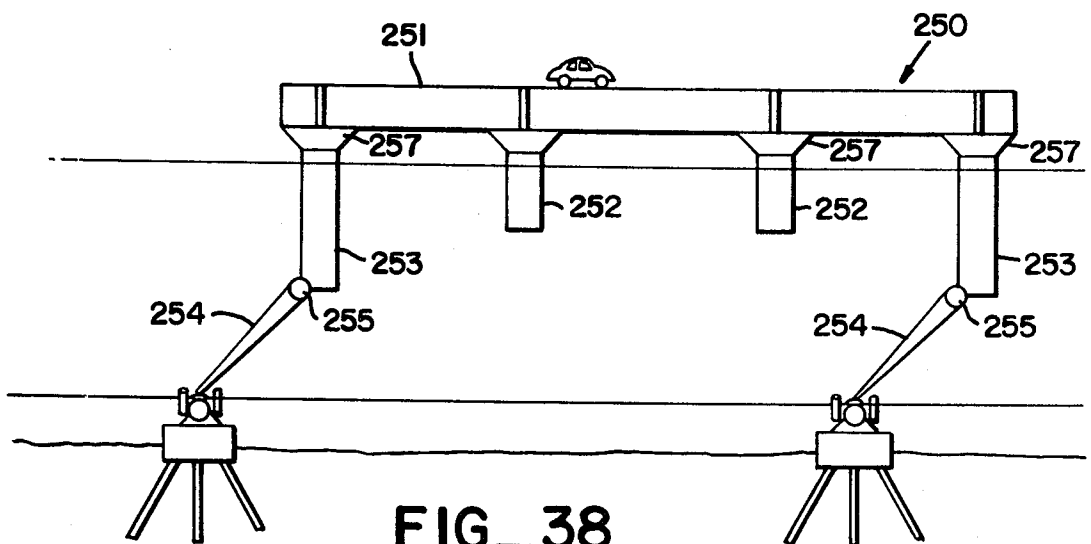


FIG-34

FIG-36

FIG-37

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WATER TRANSPORTATION SYSTEM WITH SHORE-BASED PROPULSION

This invention relates to a water transportation system across navigable waters between two or more land destinations that lie as far as a few miles apart. It also relates to improvements in vessels, to improvements in a cable-operated ferry system, to improved means for linking vessels with a cable, to improvements in connections between a vessel and terminals, to improved directional control, and to other related devices and components including damage-resistant floating terminals, with ramps that remain in a constant position.

The invention includes a cable ferry system over a route between two or more points, in which a vessel is attached to an underwater cable that is maintained at a deepwater level for all except possibly those portions nearest the shoreline. In fact, for a substantial distance, especially across ship-navigated channels and often for nearly the entire length of the ferry systems, the cable is maintained at a level well below the keel depth of all navigating surface vessels, as prescribed by the appropriate regulatory bodies, such as the U. S. Corps of Army Engineers in United States territorial waters.

The present invention controls a buoyant carrier which is free from the bottom and is moved by a submerged cable or other conveying means that does not interfere with other surface traffic. The term "submerged cable" is here intended to denote not only standard wire cable, whether protected by plastic coatings or coverings or not, but also chains, ropes, and other generally flexible linear bodies. The buoyant carrier is a novel type of vessel which in many ways resembles a ferryboat but has distinct differences which are explained below. This buoyant carrier is connected to the cable by a fixed or semifixed connection, so that there is normally one buoyant carrier per cable. In some instances, an endless cable loop may have a buoyant carrier on each of its two passes between two points, and there may be other instances where the use of more than one carrier per cable is desirable.

The system of the invention enables rapid and efficient transportation of people, vehicles, equipment, and cargo across short distances (i.e., up to a few miles) of navigable waterways at relatively low cost, at very low risk, and with very high safety factors. It can provide transportation across water at a relatively high speed, i.e., 15 to 25 knots, and at the same time it enables the installation of a system having very low construction costs as well as low maintenance and operation costs. It makes it possible to maintain continuous scheduled service at frequent starting intervals without lost trips, even when there is fog or other inclement weather.

The invention may be contrasted with the use of boats, bridges, and tubes.

Bridges and tubes offer the advantage of continuous movement of vehicular traffic, so long as there is no traffic accident upon or within them and so long as they are able to accommodate the traffic without congestion. They are economically efficient for short distances; however, as distances get longer and longer and, as the water over which or through which they pass gets deeper and deeper, bridges and tubes become less and less economically feasible, reaching extremely high costs for crossings of several miles of deep water. For instance, bridges must be constructed either with very high clearances for fixed spans, or with movable spans to enable the passage of water traffic and deep draft vessels, which, when opened, can back traffic up for miles on both sides.

In contrast with bridges and tubes, this new system is relatively inexpensive to build and to operate, and the presence of deepwater channels does not add to the expense. The system can operate over relatively long distances and can accommodate large numbers of passengers and vehicles, and provide frequent, continuous service.

Ferryboats have often been used for the shorter distances to which this invention applies, just as ships are standard transportation for cargoes and passengers over relatively long water distances, as across oceans. Ferryboats, however,

represent a major capital cost to construct, and they have also become more expensive to operate, due to increased crew, fuel and other operating costs. Frontage, docks and terminals have also become increasingly more expensive to acquire, build and to maintain. Furthermore, in many locations ferryboats generally have an effective or economic life of only about 25 years, which is much shorter than that of bridges and tubes. Hence, the total cost of construction, operation, maintenance, and replacement of a ferryboat system is often as high as that for a bridge or tube, especially over the shorter ferry routes.

Ferryboats also have had the disadvantages of being relatively slow and unwieldy, and of having to carry large crews to insure the emergency safety of the passengers. Frequent service can be provided to carry loads comparable with the traffic rates of bridges and tubes, only by demanding high fares to compensate for the extra trips, and for the lightly loaded trips during greatly reduced traffic hours. Ferryboats have normally been unable to operate efficiently during heavy fogs and other bad weather; as a result, frequent and prolonged schedule delays have occurred. Even if they do not miss trips, ferries characteristically fall behind schedule in bad weather, and the risk to the safety of the passengers and crew is increased. If a ferryboat is damaged or collides with a ship or boat, as has frequently happened, it is liable to sustain serious damage or to sink, carrying down with it the crew and passengers and cargo. Even if not sunk or seriously damaged, it tends to be relatively easily damaged, and it tends to damage the docks and terminals which it services. Typical ferryboat docks are very susceptible to damage during periods of fog or inclement weather, due to the problems in controlling a free-floating vessel with little weight on. All these factors add to the expenses of such prior art systems.

In comparison with ferryboats the system of the present invention is less expensive, being initially less costly to build, having longer effective life and being much less expensive in every phase of ferryboat operations. There is only a minimum crew afloat on the buoyant carrier itself, and in certain circumstances the crew can be eliminated altogether and the system operated semiautomatically, or can be operated from ashore. Competent studies conclude that this new system reduces the crew expense by approximately 75 percent, reduces engine maintenance and repair costs by about the same percentage, and also reduces the fuel expense by about 75 percent. The buoyant carrier is much simpler than a ferryboat to construct, because expensive engine systems and inside-the-hull installations are eliminated, and its hull can be filled with permanently buoyant flotation material that makes it impossible to sink the craft and eliminates corrosion and maintenance inside the hull. Thus, safety requirements are reduced, and the system becomes both less expensive and safer than ferryboats. It also becomes possible to obtain much more deck area by eliminating the standard fore-and-aft centerline engine room casing, thereby increasing the carrying capacity of the deck area. An unobstructed loading deck thereby becomes possible, reducing the terminal detention time in the unloading and loading of vehicles by better than 50 percent, because the connecting ramp can be made much wider and can accommodate simultaneous unloading (or simultaneous loading) of all traffic lanes.

It should be noted that this vessel can be operated without any propulsion installation on board; in fact, the absence of onboard propulsion unit and fuel tanks is one factor that enables the hull to be filled with flotation material. There can be more clear deck space, and the unloading, loading and stowage operations can be made simpler and more efficient. The costs of propulsion energy are reduced sharply due to the high efficiency of a direct relationship between energy input and vessel movement. This new system substantially eliminates operating damage to terminals, whether floating or standard, and its depreciable life is more than twice as long as that of a typical ferryboat.

The novel, floating terminals as described herein, have the advantage of eliminating costly land acquisition and expensive dock protection, and enable the vessel to maintain its proper position in the slip without the use of positioning dolphins and piles. A loading ramp, which can be the same width as the car deck, enables connection between the floating terminal and the land at relatively low cost. The efficiency of such terminals is enhanced by the ability to make the shore connections between the vessel and rails or roads automatic and positive, without reference to constantly variable tidal and sea conditions. In addition, standard ferry slips can be used if desired, for the system is not limited to use with floating terminals or slips.

In addition, so far as the surrounding community is concerned, this system has five marked advantages: First, greatly reduced pollution of the atmosphere and the water due to use of electrical rather than fossil fuel energy; second, elimination of landfills associated with causeways, and the elimination of the effects of landfills on the marine ecology; third, low construction and operating costs, which enable low fares; fourth, vastly increased safety; and fifth, ability to eliminate transit delays and cancellations because it can maintain continuous scheduled sailings and service in substantially any weather.

Still another significant operating advantage inherent in the new system is that it eliminates any difference between the engine miles run and the actual miles run relative to ground. In contrast, a self-propelled ferryboat encounters currents which sweep the boat along or hold it back, and such drift forces the ferryboat to traverse a longer path than the minimum straight line distance between points.

The present invention, having no main propulsion system on the ship, has no shaft and bearings, no propellers, no steering gear or steering controls, no main engine, no fuel system, no anchor system, no engine room, and requires none of the safety equipment associated with engine rooms, such as a fixed carbon dioxide system. It needs no lifeboats, davits, or liferafts, and it needs no navigational radar equipment.

A significant mechanical feature is that the propulsive power for the ferry is generated ashore, where it can utilize more economic power sources, where space is not at a premium, and where maintenance and service resources are easier. Thus operation at the same power consumption is less expensive, and less power is needed, as has already been established.

Several of the fundamental theories underlying this invention are hydrodynamic in nature and are manifested in improved propulsion characteristics that are provided through the cable drive system. First, a free-floating self-propelled vessel would have a propulsive coefficient of 45 percent to 50 percent, contrasted to the new cable ferry vessel. In other words, about half of the power supplied to the propeller would be lost through inefficiencies of the shaft bearings, propeller, wake, and thrust factors. The remaining half of the power is all that is available to overcome the drag of the free-floating vessel and propel it. The cable ferry substantially eliminates such losses, having no propeller to drive it through the water, which itself imparts a viscous drag. The drag added by the cable and connecting struts is much less than the losses in the self-propelled vessel. The propulsion coefficient of a cable ferry is approximately 75 percent for a 1-mile crossing.

Secondly, a hydrodynamic advantage is in the rapid acceleration and deceleration possible with the cable drive and not possible with self-propelled vessels. The new system can change from full stop to full speed and from full speed back to stop in less than half the time that a conventional ferryboat can achieve such changes. This positive control feature has significant favorable safety, control, and energy efficiency implications.

Thirdly, another hydrodynamic feature of this invention is the directional stability provided by the cables, so that no rudders are needed for steering except when extreme side forces develop from winds or currents. Such conditions are, of course, abnormal. Even then, the cable provides the principal forces of directional stability, and the side loading can be sub-

stantially reduced by placing the cable-guiding sheaves closer together, and, in special instances of abnormal side loading, rudders may be utilized to efficiently "crab" the vessel against these side forces.

Thus the system is novel and so are some of its basic components. The buoyant carrier itself is novel, and so are the means for connecting it to the cable. The underwater sheave system, like the connecting means, are unlike anything heretofore known. Another important element of the full system is its novel floating terminals or slips, and its peripheral control and connecting features.

Other objects and advantages of the invention will appear from some preferred embodiments described below.

In the drawings:

FIG. 1 is a view in side elevation of a portion of a cable ferry system embodying a single-hull buoyant carrier attached to an underwater cable by a pair of pivoted struts. The cable and the attachment struts are shown in two different positions, an upper solid-line position and a lower position shown in broken lines. Parts of the hull are broken away and shown in the section.

FIG. 2 is a fragmentary view in perspective of a waterway system employing the components of FIG. 1.

FIG. 3 is a fragmentary view of part of the cable system of FIG. 2, illustrating how the underwater cable may go around a curve.

FIG. 4 is a diagrammatic view in perspective of a preferred cable system embodying the principles of the invention and employing a continuous cable with a return run of the cable.

FIG. 5 is a similar view of a modified form of system embodying the principles of the invention and employing a single-wire cable system.

FIG. 6 is a profile diagram illustrating how the cable can be placed underwater with minor dredging of underwater peaks, the cable, also bridging deepwater channels.

FIG. 7 is a view in side elevation, similar to FIG. 1, of a modified form of buoyant carrier having a catamaran-type hull and vertically slidable struts, also embodying the principles of the invention.

FIG. 8 is a top plan view of the carrier of FIG. 7 showing the deck with commuter trains carried thereon.

FIG. 9 is a view in side elevation of a floating terminal of the invention used in connection with the vessel of FIG. 7 for transportation of railcars.

FIG. 10 is a top plan view of the floating terminal of FIG. 9.

FIG. 11 is a fragmentary view in end elevation of the buoyant carrier of FIG. 7.

FIG. 12 is a bottom plan view of one of the hulls of FIG. 11.

FIG. 13 is a view in side elevation of a ground-anchored and ground-supported cable support members with its sheave assembly.

FIG. 14 is a view in end elevation of the support member of FIG. 13.

FIG. 15 is a somewhat diagrammatic view in end elevation of one end of a system of this invention showing a cable drive, in conjunction with a single-hull type of vessel.

FIG. 16 is a fragmentary view in perspective of a portion of an underwater cable and two deepwater ground-anchored floating sheave assemblies.

FIG. 17 is a view in side elevation of one of the floating sheave assemblies of FIG. 16.

FIG. 18 is a view in end elevation of the sheave assembly of FIG. 17.

FIG. 19 is a view in perspective of a preferred form of grip for connecting the cable to the strut of the buoyant carrier.

FIG. 20 is an exploded view in perspective of the grip assembly of FIG. 19.

FIG. 21 is a view in side elevation of another modified form of catamaran-type buoyant carrier embodying the principles of the invention, with its strut connection to the underwater cable. This carrier is especially well adapted to transport automobiles and trucks.

FIG. 22 is a view in end elevation of the carrier of FIG. 21, shown over a floating sheave assembly of FIG. 17.

FIG. 23 is a top plan view of the carrier of FIG. 21.

FIG. 24 is a diagrammatic view in side elevation of a cable declivity tracking system which may be used in the system of the invention.

FIG. 25 is a circuit diagram of the declivity tracking system of FIG. 24.

FIG. 26 is a diagrammatic view and circuit diagram of a wire signal-carrier control for the system of the invention.

FIG. 27 is a diagrammatic view in perspective of a similar system employing radio control.

FIG. 28 is a top plan view of a ground-anchored sheave assembly and ground support for use in going around curves.

FIG. 29 is a fragmentary view in perspective of a vessel of this invention docked at a very simple floating dock connected to land by a ramp.

FIG. 30 is a fragmentary view in side elevation of the assembly of FIG. 29 showing only a part of the vessel but showing the underwater parts of the installation.

FIG. 31 is a view in side elevation of a buoyant carrier or vessel of this invention having only a single strut, for use over relatively short distances across quiet water; the strut is movable, longitudinally relative to the vessel, and an alternative position of the strut for movement in the opposite direction is shown in broken lines.

FIG. 32 is a view in front elevation of the buoyant carrier of FIG. 31 showing in broken lines an alternative position.

FIG. 33 is an enlarged fragmentary view in elevation of a portion of the roller mechanism by which the strut is moved fore-and-aft.

FIG. 34 is a somewhat diagrammatic view in perspective of another modified form of the invention showing a system employing one continuous cable with two buoyant carriers in tandem, so that they dock at opposite ends at the same time and pass each other in the middle.

FIG. 35 is a top plan view of one of the ground-anchored floating sheave assemblies of the system of FIG. 34.

FIG. 36 is a view in side elevation of the sheave assembly of FIG. 35.

FIG. 37 is a view in end elevation of the sheave assembly of FIGS. 35 and 36.

FIG. 38 is a view in side elevation of another modified form of vessel for use in this invention.

FIG. 39 is a top plan view of the vessel of FIG. 38.

FIG. 40 is a view in end elevation of the vessel of FIG. 38.

FIG. 41 is a view in elevation and partly in section of the cable-gripping device of FIG. 19, shown in its closed position, with a broken line showing of the open position of the movable element.

FIGS. 1-4 illustrate some of the major features of a cable ferry system embodying the principles of the invention. Its buoyant carrier 30 is a vessel superficially resembling a self-propelled ship but has no motive power aboard. Its hull 31 is here shown by way of example as a single hull. Instead of being hollow, the hull 31 is filled with lightweight cellular material 32 (such as polystyrene foam or polyurethane foam), so that it cannot be flooded or sunk. The vessel 30 has an above-the-waterline lower deck 33, an upper deck 34, and a bridge or observation and control deck 35. The deck 33 is available for vehicles or for passengers or cargo, as may be desired, and the deck 34 is also available for passengers and cargo. The hull 31 has two cavities 36 and 37 enabling the swinging movement of two struts 40 and 41, both arranged on the fore-and-aft centerline of the vessel 30 and mounted on horizontal transverse pivots 42 and 43.

Each strut 40, 41 is swung around its pivot 42, 43 by a suitable servomotor such as a hydraulic servo system 44 or 45, with its cylinder piston, and piston rod. Each strut 40, 41 can thus move approximately 90° from a lowermost position (shown in broken lines) where it goes straight down to an uppermost position where it is approximately horizontal. (It may be enabled to move approximately 90° from vertical in the opposite direction when the vessel 30 is moving in the opposite direction, being prevented from movement past vertical during either direction of movement of the vessel). At its distal

end 46, 47 each strut 40, 41 is secured by a grip 48, 49 to a movable cable 50. The length of the struts 40, 41 is typically 50 or 60 feet, for the cable 50 is normally submerged 50 or more feet below the surface; however, this depth may be less or greater subject to circumstances.

The cable 50 may be endless, as shown in FIGS. 2-4, with a return path 51 running parallel to the path of the cable 50, preferably at a slightly lower level, and moving in the opposite direction. There is, in this embodiment, only one vessel 30 for each cable 50, and the struts 40 and 41 of that vessel 30 may be attached to the cable 50 without slippage and with release therefrom only in emergency situations. The endless cable system of FIG. 4 runs between two terminals 52 and 53. At each terminal 52, 53 a sheave 54, 55, at least one of which may be provided with a spring 56, mounted so as to provide constant spring tension, sends the cable 50 upwardly to another sheave 57 or 58. At the terminal 52, the cable 50 then passes over and is wrapped, e.g., about 1½ times, around a driving pulley 60 operated by a power unit 61 (an engine, an electric motor, or any such device) and shaft 62 (see also FIG. 15), and passes down to a sheave 63 for its return run 51. A set of spring-mounted idler sheaves 58, 64 and 65 may be provided at the other terminal 53. The terminals 52 and 53 may be permanent land terminals or they may be floating terminals, floating terminals being especially desirable where tides are a factor, or where land costs are judged excessive, or in the loading and discharging of railroad cars, or where the use of floating terminals enables reduction of terminal detention time of the vessel and enhancement of operating efficiency.

At the power terminal 52 there may be various maintenance and inspection equipment, such as a cable-scrubbing device 66 to remove marine growth and accretions, a cable inspection station 67, where the cable is inspected visually or by X-ray, or by other suitable equipment, and a tensionometer 68, where check is kept of the tension exerted on the cable 50, with or without automatic corrective equipment or warning devices.

The cable 50 is maintained well below the surface of the water over both runs and preferably lies quite deep, so that other navigable vessels may use the same water without any precaution or interference. The cable may be held there and guided by permanently attached ground-anchored sheave assemblies, two types of which are shown. In FIGS. 13 through 15 the sheaves are directly supported by ground-anchored structures beneath relatively shallow water. In very deep water, as in FIGS. 16 through 18, the sheave assembly may be secured by chains or cables to heavy anchors. Both of these structures are discussed in detail below. FIGS. 2, 3, 28, and 34-37 show how either type of sheave assembly may be supplied with horizontal sheaves and used to route the cable ferry along a curved course, when that is desirable for any reason, such as because of varied channel depth or to round a point of land or to skirt an obstacle or underwater obstructions.

As shown in FIG. 5, the endless cable system of FIG. 4 may be replaced by a two-end cable system in which a cable 70 is controlled by drums or windlasses 71 and 72 at each end, for winding up about half the length of the cable 70 so that when the vessel 30 is nearing one terminal 52, most of the cable 70 is wound around the windlass 71 and the windlass 72 is nearly empty, and vice versa when the vessel 30 returns to the opposite side 53. This system enables greater vessel speeds, due to there being less cable drag, but is less desirable as distances get long and make the cable storage at each end difficult and inconvenient.

As shown in FIG. 6, the land profile 73 below the body 74 of water may make it advisable, in some instances, to dredge a channel 75 across underwater hills 76 in order to prevent running the cable 50 too high and interfering with navigation or to save the expense of having hinged struts. This is much simpler than the dredging required for most channels and, once done, requires little or no maintenance over years. Near the shore at each end, the cable 50 may slope upwardly to the

terminal 52 or 53, as shown in FIG. 9, so long as it does not interfere with navigation. A fixed strut 87, 88, (FIG. 7), can be shortened by use of the tidal adjustment slots 87a and 88a. The draft of the vessel 30 may be quite shallow, due to its buoyancy, and the servo systems 44, 45, FIG. 1, can swing the struts 40, 41 upwardly to follow the cable 50.

FIGS. 7 through 12 show an alternative form of buoyant conveyor 80 and illustrate the use of a floating railroad car roll-on of terminal 81 at either or both ends of the run. The vessel 80 uses a catamaran-type of hull for stability and for increased deck space at both ends. It may be designed for use in moving rail cars 82 or large commuter buses or trucks and other heavy rollon rolloff equipment. It may be made multihulled with two (or more) hull portions 83 and 84 connected by a platform 85 with a deck 86, the hull portions 83 and 84 being filled with lightweight material 32, (FIG. 1), such as polystyrene foam or other cellular materials or containers that make it impossible to sink. The shape of a single hull 83 is shown in FIG. 12.

The vessel 80 is connected to the cable 50 by struts 87, 88 which may be generally like the struts 40, 41 of FIG. 1, but which may, as shown by way of example, be rigid and not pivoted; they are made with an upper portion 87a or 88a that is slidable up and down in a guide slot 87b or 88b attached to the platform 85 of FIG. 11 to compensate for tides and vertical displacement changes. Both struts 87, 88 are secured to the cable 50, and the cable 50 is kept at a constant depth for the entire length of the ferry system, in the form of this invention.

As in the vessel 30, the vessel 80 is double ended and has a central control bridge 89. FIG. 8 shows how the railcars 82 may be lined up on the deck 86, with a dozen railcars shown there as an example. They may be driven on quickly under their own power, and then the cable ferry 80 may transport them a substantial distance across water to a railhead or floating terminal 81 of FIGS. 9-10. This makes a rapid transit system feasible in spite of a long stretch of water and tidal range and without the expense of building bridges or tubes over long distances. For example this system is feasible for distances of several miles, whereas a bridge or tube several miles long is exorbitantly expensive. The vessel 80 is locked into the floating terminal 81 by means of a tight fit; then the tracks 93 on the vessel can be rapidly connected to the terminal tracks 92. The vessel 80 and the floating terminal 81 will always lock regardless of the stage of the tide. The ramp 90 gently grades down to the level of the deck 86 and always keeps a transitable grade for discharging cars, and a ramp 91 connects the floating terminal 81 to the land. The ramp 91 is made long enough so that the grades at high and low tide do not exceed the maximum working grade for the movement of the railcars 82. The use of floating terminals make it unnecessary to acquire expensive land facilities; they also avoid the discharge problems and the lost time during various tidal stages occasioned by land facilities. The floating terminal 34-is easily constructed to dock vessels accurately, and it has none of the disadvantages of shore to installations including the cost of maintaining and repairing damage inflicted by a free-running vessel attempting to dock in inclement weather conditions, for such damage can be considerable. As stated above, the floating dock or terminal 81 better accommodates excessive ramp grades caused by large tidal differences and particularly troublesome in a standard system when transporting railroad cars, as the excessive angles of interface between vessel and pier preclude efficient unloading and loading. The floating terminal 81 can be filled with buoyant material, such as synthetic foam, making it unsinkable, eliminating interior maintenance, and building in tremendous resistance to damage. The power drive station for the cable 50 may be on adjacent land or on the dock 81, as shown in FIGS. 9 and 10.

FIGS. 13 and 14 indicate the use of ground-secured sheave assemblies 100, whereas FIGS. 16 through 18 indicate the use of floating submerged sheave assemblies 101 which are held in place by anchor means. It should be stressed at this point that

both or only one of these may be used in one cable system. Thus, a cable system may have ground-secured sheave assemblies 100 in shallow waters and submerged floating anchored sheave assemblies 101 in deep waters, or a system may have nothing but the ground-supported sheave assemblies 100 if the water is sufficiently shallow to make this more economical, or, if the water is sufficiently deep, it may have nothing but the floating assemblies 101.

The permanently affixed stations 100 include a plurality of piles 102 sunk into the bottom 103 underlying the water 104 to an adequate depth to secure anchorage. On top of these piles 102 is a suitable platform 105 which supports sheave brackets 106, 107, 108, and 109, which are preferably made detachable in order to enable the sheaves to have maintenance care. A sheave assembly 110 for the cable 50 is held by the brackets 106 and 107, while a sheave 112 engages the return line 51, when the endless cable system is used. The sheave 112, as shown in FIG. 14, may be directly beside the sheave 110, or it may, if desired, be located below it. As shown in FIGS. 13 and 14, the brackets 106 and 107 extend upwardly and then outwardly to carry a pair of angle-supported rollers 115 and 116, each of which acts as a sheave between which the drive cable 50 rides when the grip 48 passes through the assembly 110. Overhangs 117 and 118 on the mounting act to prevent the cable 50 from straying out from or being removed from their position between the two rollers 115 and 116. Thus the two rollers 115 and 116 make it easy for the cable 50 to rise and fall slightly during passage of the grip and also maintain the free-running cable 50 in place. It will be seen from FIGS. 3, 4, 28, and 35-37 how sheave assemblies can be made suitable for going around curves.

FIG. 15 shows a similarly mounted permanent sheave assembly 100 for taking the cable 50 at either end thereof and running it up by straight pull to the power drive pulley 60 for the cable 50, driven by the power unit 61 through a shaft 62.

In FIGS. 16, 17, and 18 the floating sheave assembly 101 is somewhat similar to the assembly 100 and is used in deep waters. Basically, the idea is to hold the assembly 101 in place by one or more heavy anchor weights. In this application, two anchors 120 and 121, are preferably employed; they rest on the bottom and are connected to the assembly 101 by chains or cables 136, 137. These anchors 120, 121, when first put in place, have their chains or cables 136, 137 attached to them and also to a surface vessel that is used in performing the operation. A hollow tank 122 is provided and is first filled with water 123 to such a level 124 as to make it barely heavier as a whole than the water in which it is to be sunk. The tank 122 includes three major attachments, one of these being a bracket clevis 125 and sheave 126 on its lower side for the return cable 51 and the others being two cylindrical angularly upwardly extending members 127 and 128, which may be provided with rollers 130 and 131, between which the drive cable 50 moves. Again, overhangs 132, 133 are provided at the end of each member 127, 128 to prevent the cable 50 from straying away from its support and guide.

The tank 122 is also provided with a pair of brackets 134, 135 to each of which is secured one cable 136, 137. When the tank 122 has been sunk to a desired level, air is forced in to drive out some or all of the water and to leave the tank 122 itself buoyant. The tendency of the tank 122 to rise vertically acts against the cables 136, 137 and anchors 120, 121 to maintain the position of the tank at a constant location and at the same attitude. In areas where rapid currents are experienced, the tank 122 may be made even lighter, to exert more upward force helping to stabilize its position. The degree of upward force required is tailored to meet the actual situation so that the unit 101 becomes vertically immovable. The underwater assemblies on the tank 122 are adapted for removal and replacement of parts for routine maintenance, some of this work being done at the surface or on shore. (Generally, a tank to be overhauled will be replaced with a maintained tank.)

An important feature of the invention, see FIGS. 1, 19, and 20 is the connection or grip 48 (or 49) between the cable 50

and the strut 40 or 41. At the distal end 46 of each strut, therefore, there may be a grip structure 48. A fixed grip portion 140 is secured to a leaflike bracket 141 having a bolt opening 142 therethrough, a clevised lower end 143 at the bottom of the strut 40 is provided with a central slot 144 and a bolt opening 145. When the leaf member 141 is pushed into the slot 144 of the clevis 143, a bolt 146 can be tightened by a nut 147. The fixed grip portion 140 is thereupon secured permanently to the strut 40. It is secured to the cable 50 by mating it with a movable grip portion 148 that may be clamped to it and simultaneously to the cable 50 by a pair of hydraulic grip actuators 149, controlled from the bridge of the vessel. The grip actuators 149 are used in order to provide an emergency release system, so that the system may have a static connection for full grip, a slip grip for enabling the cable 50 to move relatively for short distances or completely release in an emergency situation.

Below the leaflike bracket 141 of the fixed grip portion 140 is a narrower stem portion 240, and the portion 141 has overhanging ends with inclined bottom surfaces 241 (See FIGS. 20 and 41). The movable grip portion 148 has two upstanding projections 242 with inclined upper surfaces 243 that abut and mate with the bottom surfaces 241 when the grip 48 is fully closed. There is a lengthwise opening 244 through the stem portion 240, and openings 245 through the projections 242 are aligned with the opening 244; a pivot pin 246 is inserted through both openings 245 and the opening 244, so that the movable portion 148 pivots about this pin 246, the inclination of the surfaces 243 and 241 enabling the necessary relative swinging movement of the members 148 and 140. The grip actuators 149 may be hydraulic cylinders 247 with projecting piston rods 248 that engage members 249 on the portion 141 to cause the movable member 148 to swing, as shown in FIG. 41 to loosen its grasp on the cable 50 or to release the grip 48 completely from the cable 50, if that is desired. Thus, the grip 48 may be tightly clamped to the cable 50 or fully released therefrom or loosely and slidably mounted thereon, all these positions being controlled through the cylinder 247.

FIGS. 21, 22-23, show another vessel or buoyant carrier 150 for transporting automobiles, buses, and trucks upon a deck 151. The vessel 150 may have a catamaran-type construction with streamlined hull members 152 and 153 which can be filled with foamed or celled plastic. Each hull member 152, 153, may have one or two rudders used to maintain the vessel 150 against drift, by serving to "crab" the vessel, i.e., harness the currents to move the vessel sidewise rather than rotating it. The rudders 154, 155 are optional and need be used only when the ferry route is subject to strong side currents or winds. Crossbeams 156, 157 may join the hulls under water and support brackets 158 and 159 for pivotal support of struts 160 and 161 about a point 162 or 163. In some circumstances the pivoting can be lowered by gravity, not requiring the use of ram 44 but only a spring tension device. The craft is again double ended for forward movement in each direction and has a central control bridge 164. It also has fore-and-aft light towers 165 and 166.

In this form of the invention, the struts 160 and 161 swing in opposite directions, and the grip 48, 49 of FIGS. 1 and 19 is used so that in each direction of vessel movement, only the front grip 48 or 49 is tightly secured to the cable 50, while the trailing grip 49 or 48 engages the cable 50 with a free slip fit to guide and stabilize but not to grip. The idea here is that the struts 160, 161 may have to swing to follow the cable 50, and when they do, the distance between them changes and the forward direction of the vessel 150 is very steady when only the forward strut 160 or 161 is engaged to the cable 50.

Another feature of the invention is the use of a declivity detector and tracker arrangement, an example of which is illustrated in FIGS. 24 and 25. A wheel 170 is mounted for rotation in a structure 171 secured to the lower end of the strut 40 near the grip 58, and is connected by suitable electrical lines 172, 173, 174 to an actuating solenoid 175 that controls a valve 176 for the hydraulic system 44. A spring 177 helps to

keep the wheel 170 in contact with the cable 50. The cable declivity tracking wheel 170 is suspended from a rod 178 which is pivoted on a pivot 179 and its end moves across a rheostat 179a to vary the relative power sent along lines 173 and 174 to the solenoid 175. The hydraulic piston 44, as actuated by the valve 176 then adjusts the height of the strut 40. The purpose of this is to swing the strut 40 positively, rather than letting it simply follow the cable at a loose pivot, a requisite under certain current, wind or vessel speed conditions. This enables maintaining the distance desired while changing it when the cable declivity tracker indicates that a certain critical angle has been reached. Before the angle has been reached, it is desirable to keep the strut 40 moving straight at whatever level it is, but when an angle above a certain amount of degrees is reached, it is indication that it is approaching a place where the cable 50 is rising steadily or falling steadily and therefore the declivity tracker enables the mechanical and hydraulic systems to adjust the strut to match the cable depth.

While the power unit 60 on shore as shown in FIG. 15 supplies the vessel 30 or 80 or 150 with its motive power through the cable 50, so that no power system for movement is on the vessel, the control may still be on the vessel. The operator may be on the bridge 35 or 89 or 164 with a signal system enabling him to control the speed at which the cable 50 moves, which is the speed at which the vessel 30, 80 or 150 moves. Two such control systems are here illustrated as simple examples in FIGS. 26 and 27.

A wire-signal carrier control system is shown in FIG. 26. Here, a carrier signal is impressed on the cable 50 from a control generator and signal amplifier 180 on the vessel. The signal is picked up from the cable by a signal detector 181 on shoe and sent through an amplifier 182 to a motor speed controller 183. This enables the man on board to control the speed of the buoyant carrier 30, 80, 150, while the actual driving power is on shore.

The wire-signal carrier control system of FIG. 26 is only one of many possibilities for controlling the movement of the carrier from aboard the buoyant carrier. Another system, shown in FIG. 27 uses radio signals. In this case the vessel 30 or 80 or 150 carries a transmitter 190 with an antenna 191, and a control device 192 sends signals through the transmitter 190 and the antenna 191 to an antenna 193 on shore. The antenna 193 sends signals to a receiver with an amplifier 194 which sends the amplified and detected signal to a motor control 195 which operates the motor 60. This enables the pilot on the vessel to stop the vessel and to go ahead from zero to maximum speed in either direction. There is no steering or directional control, since the cable 50 limits the movement to simply fore-and-aft movement, but that is all that is needed, since the cable 50 has provided the necessary path. Other control systems such as microwave or laser beam guidance systems may be used if desired. The operator may be ashore, employing any one of such systems, especially where distances of the run are short.

Other refinements may also be adapted, different hull shapes may be used, different types of attachments like the struts may be used, and so on, but the specific embodiments shown here are of considerable value and are believed to represent the best embodiment of the invention at the present time, and many have been verified through extensive model tank testing.

When the cable 50 is to pass around curves, the sheave assembly shown in FIG. 28, and sketchily indicated in FIGS. 2 and 3 is preferably used. There are two vertical sheaves 196, 196a and two horizontal sheaves 197, 197a for each of the cable runs 50 and 51, thus enabling very simple changes in direction without any binding between the sheaves 196, 197 and the cable 50. The vertical sheaves 196 have rollers 198 and 199 like the rollers 115 and 116 in FIG. 13.

The floating dock assembly shown in FIGS. 9 and 10 is a relatively complex one utilized particularly where railed vehicles such as are in a rapid transit system must be used. For

some uses, such as for walking passengers, automobiles, or bus ferry systems, this rather expensive installation is not necessary. Hence, as shown in FIGS. 29 and 30, a buoyant carrier 200 of this invention may be connected to a very simple floating dock 201 by means of a ramp 202 which enables foot passengers and vehicles to move onto or off of the floating dock 201. The floating dock 201 may be connected to land 206 by another ramp 203 which enables the variations in tide to be accommodated, and floating dock 201 is held securely in place without anchoring or piling. This very simple system can be used where it is suitable. It is illustrative again that the invention has many possible embodiments.

FIGS. 31, 32, and 33 illustrate another form of the invention in which a buoyant carrier 210 has only a single strut 211. For purposes of illustration only, the buoyant carrier 210 is shown here as with a simple flat deck, as it might be when operation and control are from the shore rather than from the ship. Of course, a single-strut carrier 210 may be used with a control tower and sets of decks. In this instance the strut 211 extends from a body 212, which, in turn, carries rollers 213 on each side. The hull 214, here shown as a catamaran, is provided with a central passage 215, in which the body 212 is movable, and the passage 215 has, on each side, a pair of tracks 216 in which the rollers 213 move. Suitable locking means may be provided at each end to hold the strut 211 in position there. The strut 211 may be, as shown, a stationary type without any swinging action, but it may also be a swinging strut if desired. The strut 211 is used near the front of the carrier 210, preferably no more than about 15 percent back from the front end 217. When the direction of the buoyant carrier 210 is reversed, the strut 211 is moved to the opposite end 218 so that it will again be at the front. Other single strut configurations can be used. The strut 211 may also be provided with a hinge 219 for limited swing about a transverse vertical plane, to compensate for side forces so that the vessel 210 would then move to one side of the cable 50 and relieve the listing moment on the vessel 210. The single strut 211 may also be provided near its lower end with a 360° swivel 219a, which in strong currents or in high-wind velocities enables the vessel 210 to find a position of least resistance to the force of the elements.

Although it is generally true that there is one buoyant carrier per cable, this need not be so, and FIG. 34 illustrates an embodiment of the invention in which there are two buoyant carriers 220 and 221 operated in connection with a single continuous cable 222. Here the two buoyant carriers 220 and 221 are arranged so that they pass each other in the center and at docking time both of them are docked, one at a dock 223 at one end and the other at a dock 224 at the other end of the run. The cable 222 may have its two runs 225 and 226 generally parallel to and on approximately the same level as each other. The run 225 may be straight run while the other run 226 may have its center portion 227 moved out away from the run 225 to give the necessary separation to enable passing of the two buoyant carriers 220 and 221 in spite of any force exerted by currents in the water.

A somewhat different cable system is shown in FIG. 34 though generally similar to that shown in FIGS. 16-18. It has some sheave assemblies 101 and some buoyant tanks 230 with anchor cables 231 extending down to anchors 232 on the bottom. On top of the buoyant tank 230 are two vertical sheaves 233 and 234 and two horizontal sheaves 235 and 236. See FIGS. 35 and 36. The horizontal sheaves 235 and 236 enable the curving path of the cable run 226 without binding action on the vertical sheaves 233, 234, which enable the maintenance of the proper cable depth. Guard means similar to those previously shown may be provided to assure that the cable will not come off the sheaves, and the positioning of the sheaves themselves also helps, as do deeply set flanges on sheaves 233, 234, 235 and 236.

Some form of cable guide sheave system is normally required except on quite short runs where the cable catenary is slight and the requirements for tension control are modest.

The novel submerged sheave systems of this invention not only serve to keep the vessel on a direct course and to reduce substantially the critical effects of side loading; they also control the amount of cable of or catenary. Without sheaves, the tension force required to keep the system operative across long distances through deep water would tend to exceed the breaking strain of the cable. Furthermore, it is, of course, desirable that the cable never actually touch bottom.

FIGS. 38-40 show a modified form of vessel 250 having a deck 251 supported by a plurality of laterally extending generally oval elliptical columns 252 and 253. This column-stabilized vessel 250 is designed for use across rivers, arms, and inlets, where strong side currents, in the order of five or more knots, or gale force winds or moving ice or debris are encountered. In such circumstances, the ferry speed is limited to about 3 to 5 knots, so that a route length of about one-quarter to one-half mile is probably most practical for this type of vessel 250. The cable size and the sheave support spacing are then designed to resist the side forces of current, wind, and ice. The generally elliptically shaped columns 252 and 253 are effective in minimizing the effects in the vessel 250 of the side force. Floating timber and debris can pass under the car deck 251. Ice cannot build up against the hull and exert the extreme side-loading effect that is possible on normal hulls and renders them inoperable where strong currents and ice are encountered laterally.

The front and rear columns 253 are centrally located, and each carry a strut 254, which are pivoted for fore-and-aft swinging movement about a pivot 255. At the tops of the columns 252 and 253 are rapidly flared portions 257, which join the deck base well above water level. This flaring commences at about extreme light draft, and it prevents the carrier 250 from rapidly increasing its draft when it is being loaded. It also maintains a clear space under the deck 251 and over the water surface. Thus, floating debris, ice, logs, etc., are deflected and pass beneath the cargo deck. In a slowly moving vessel, rudders have practically no effect; therefore, the faster moving lateral current encounters bow structures instead of the vessel's solid sidewalls, and the normal side-loading effect is greatly reduced. A vessel as shown in FIGS. 31 and 32 might also be used when fitted with swivel 219a across similar or longer distances.

Although vessels designed solely for this purpose are much preferred, it is possible to convert other vessels to cable ferry use by attaching to them a strut and grip means. It is also possible for a vessel of this invention to be disconnected, by disengagement of its grip, from the cable or by removal of its struts. Then, during time when traffic is low and during weekends, the vessel can be towed or can have an outboard motor attached, for utilization as a cruise ship, river boat, or otherwise. The vessel deck can readily be transformed into a gantic dance pavilion and recreational area. Of course, the vessel may, if desired, be provided with an engine, propeller, and so on for self-propulsion when not attached to the cable, though some advantages are thereby sacrificed.

In the event of a collision with another vessel, a reliable mechanism for preventing the swamping of the buoyant hull is found in the releasable feature of the cable grips. Additionally, a weak link between the cable grip and the strut may be made to break when a critical force is reached, thus providing another safety factor backup in the event of mechanical failure.

To those skilled in the art to which this invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the spirit and scope of the invention. The disclosures and the description herein are purely illustrative and are not intended to be in any sense limiting.

We claim:

1. A water transportation system having a plurality of terminals, a buoyant carrier, a submerged movable unsprocketed and fully exposed cable means secured to the buoyant carrier at a level far enough below the surface to enable deep-bot-

tomed navigation across it and extending between said terminals, and means adjacent to one of said terminals for moving said cable to transport said carrier between said terminals, said cable being attached to said carrier by a rigid member that is itself swingably attached to said carrier and to said cable.

2. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, ground-anchored sheaves between said terminals, a uniformly surfaced unsprocketed cable extending between said terminals in contact with said sheaves and unprotected between them below water at a depth deep enough not to interfere with the operation of deepwater navigation by surface craft across the water above said cable, a vessel having a hull, and means for individually and directly connecting the hull of said vessel to said cable for movement therewith between said terminals, said means being rigid in between said hull and said cable and flexing at its connections to them, and drive means for said cable adjacent to one of said terminals.

3. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, ground-anchored sheaves between said terminals, a uniformly surfaced unsprocketed cable extending between said terminals in contact with said sheaves and unprotected between them below water at a depth deep enough not to interfere with the operation of deepwater navigation by surface craft across the water above said cable, a vessel having a hull, and means for individually and directly connecting the hull of said vessel to said cable for movement therewith between said terminals, drive means for said cable adjacent to one of said terminals, a signal system for sending electrical signals along said cable, and means for controlling said drive means by said electrical signals.

4. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, a cable extending between said terminals below water at a depth deep enough not to interfere with the operation of surface craft across the water above said cable, a vessel, means for connecting said vessel to said cable for movement therewith between said terminals, drive means for said cable adjacent to one of said terminals, and control means for said drive means on said vessel, said control means including a signal system for sending signals by electromagnetic radiation between said vessel and the terminal having said drive means.

5. The system of claim 2 wherein said vessel has hull means that is substantially filled with buoyant material, preventing sinking of said vessel, said vessel being substantially free from below-deck compartments and free from engines and other automotive power.

6. The system of claim 2 wherein said vessel is connected to said cable by a pair of struts extending down along the fore-and-aft center plane of the vessel.

7. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, a cable extending between said terminals below water at a depth deep enough not to interfere with the operation of surface craft across the water above said cable, a vessel, strut means extending down along the fore-and-aft center plane of the vessel for connecting said vessel to said cable for movement therewith between said terminals, and drive means for said cable adjacent to one of said terminals, said strut means comprising two struts, each pivoted for swinging movement in said plane between a vertical position and a substantially horizontal one, and power means for positively controlling the swinging movement of each said strut.

8. The system of claim 7 wherein each of said struts is connected to said cable by grip means, and means for controlling said grip means so that one said grip means tightly grasps said cable and the other one engages said cable in a slip fit.

9. The system of claim 8 wherein said means for controlling includes means for enabling each said grip to slip relative to said cable, means for tightening each said grip means on said cable, and means for completely disengaging each said grip means from said cable.

10. The system of claim 7 wherein both said struts swing in the same direction.

11. The system of claim 7 wherein the two struts swing in opposite directions.

12. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, a cable extending between said terminals below water at a depth deep enough not to interfere with the operation of surface craft across the water above said cable, a vessel, strut means extending down along the fore-and-aft center plane of the vessel for connecting said vessel to said cable for movement therewith between said terminals, drive means for said cable adjacent to one of said terminals, and vertical guide means for said strut means so that said strut means can rise and fall relative to said vessel depending on sea and tidal forces and draft changes.

13. The system of claim 12 wherein there is a plurality of said strut means at all times extending vertically to said cable.

14. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, a cable extending between said terminals below water at a depth deep enough not to interfere with the operation of surface craft across the water above said cable, a vessel, strut means extending down along the fore-and-aft center plane of said vessel for connecting said vessel to said cable for movement therewith between said terminals, drive means for said cable adjacent to one of said terminals, declivity detector means secured to said strut means and tracking said cable, and means sensitive to declivities of a predetermined angle and length of declivity for raising and lowering said strut means to keep said strut means following the path of said cable. b

15. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, a cable extending between said terminals below water at a depth deep enough not to interfere with the operation of surface craft across the water above said cable, a vessel, a single strut for connecting said vessel to said cable for movement therewith between said terminals, drive means for said cable adjacent to one of said terminals, said strut extending down along the fore-and-aft center plane of the vessel, and means for moving said strut along the fore-and-aft centerline of the vessel to change its position so that in both directions of movement of said vessel along said centerline, said strut can be near the front of said vessel.

16. The system of claim 15 wherein said strut is connected to said cable by grip means, and means for tightening and releasing said grip means to enable it to move relatively to said cable and then be tightened in place.

17. The system of claim 16 wherein said strut has hinge means connecting it to said vessel and swivel means for connecting said strut to said grip means.

18. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, a cable extending between said terminals below water at a depth deep enough not to interfere with the operation of surface craft across the water above said cable, a vessel, strut means for connecting said vessel to said cable for movement therewith between said terminals, said strut means extending down along the fore-and-aft center plane of the vessel and being provided with pivoting means for enabling the reduction of side loading on said vessel under moderate side-loading conditions.

19. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, a cable extending between said terminals below water at a depth deep enough not to interfere with the operation of surface craft across the water above said cable, a vessel, means for connecting said vessel to said cable for movement therewith between said terminals, drive means for said cable adjacent to one of said terminals, and ground-anchored sheave assemblies spaced at intervals below the water to engage said cable and maintain the path thereof, some of said sheave assemblies having a buoyant tank, sheaves supported by said tank, anchor means anchored in the bottom of the waterway, and means for connecting said tank with said anchor means, for keeping said sheave assemblies submerged at a selected depth.

20. The system of claim 19 having ballast means for lowering and raising said tank, comprising inlet means for regulating the entrance of air or water into said tank and outlet means for regulating the exit of air or water out of said tank.

21. The system of claim 19 wherein each said tank has one sheave for the cable moving in the direction of said vessel and one sheave for a return run of said cable.

22. The system of claim 19 wherein said sheaves lie in a vertical plane and rotate upon a horizontal axis.

23. The system of claim 19 wherein said sheaves lie in a horizontal plane and rotate upon a vertical axis.

24. The system of claim 19 wherein said tank has four sheaves, two at opposite ends that lie in vertical planes for rotation about a horizontal axis and two in between that lie in a horizontal plane for rotation about a vertical axis.

25. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, ground-anchored sheaves between said terminals, a uniformly surfaced unsprocketed cable extending between said terminals in contact with said sheaves and unprotected between them below water at a depth deep enough not to interfere with the operation of deepwater navigation by surface craft across the water above said cable, a vessel having a hull, and means for individually and directly connecting the hull of said vessel to said cable for movement therewith between said terminals, and drive means for said cable adjacent to one of said terminals, some of said sheaves being mounted on assemblies comprising a structure having piers resting in the bottom of the waterway and supporting thereon two sheaves both lying in vertical planes, one for a vessel-transporting run of said cable and one for a return run thereof.

26. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, ground-anchored sheaves between said terminals, a uniformly surfaced unsprocketed cable extending between said terminals in contact with said sheaves and unprotected between them below water at a depth deep enough not to interfere with the operation of deepwater navigation by surface craft across the water above said cable, a vessel having a hull, and means for individually and directly connecting the hull of said vessel to said cable for movement therewith between said terminals, at least some of said sheaves being grouped into sheave assemblies, each sheave assembly comprising two sets of sheaves, each set having a pair of sheaves at opposite ends of the assembly, both lying in vertical planes, each set also having a pair of sheaves in between the end sheaves lying in a horizontal plane, one set being for a vessel-transporting run of said cable and one set being for a return run thereof, to enable course changing.

27. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, ground-anchored sheaves between said terminals, a uniformly surfaced unsprocketed cable extending between said terminals in contact with said sheaves and unprotected between them below water at a depth deep enough not to interfere with the operation of deepwater navigation by surface craft across the water above said cable, said cable being twice as long as the distance between said terminals, a vessel having a hull, and means for individually and directly connecting the hull of said vessel to said cable for movement therewith between said terminals, drive means for said cable adjacent to one of said terminals, and windlass means at each end for winding up said cable thereon.

28. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, ground-anchored sheaves between said terminals, a uniformly surfaced unsprocketed cable extending between said terminals in contact with said sheaves and unprotected between them below water at a depth deep enough not to interfere with the operation of deep-water navigation by surface craft across the water above said cable, a vessel having a hull, and means for individually and directly connecting the hull of said vessel to said cable for movement therewith between said terminals, and drive means for said cable adjacent to one of said terminals, said vessel having a plurality of hulls filled with buoyant material render-

ing said hulls unsinkable and bridged by deck means, said deck means comprising substantially all of the payload space of said vessel.

29. The system of claim 28 wherein there are rudder means on at least one of said hulls and at each end thereof, enabling crabbing of the vessel under strong side loading.

30. The system of claim 28 wherein said hulls extend lengthwise of said vessel, along the direction of movement of said vessel.

31. The system of claim 28 wherein said hulls extend laterally of said vessel and comprise a plurality of generally elliptical columns shaped to adjust to side loading.

32. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, ground-anchored sheaves between said terminals, a uniformly surfaced unsprocketed cable extending between said terminals in contact with said sheaves and unprotected between them below water at a depth deep enough not to interfere with the operation of deepwater navigation by surface craft across the water above said cable, a vessel having a hull, and means for individually and directly connecting the hull of said vessel to said cable means for said cable adjacent to one of said terminals, at least one of said terminals comprising a large floating pontoon having slip means to receive a said vessel during loading and discharge.

33. The system of claim 32 wherein said pontoon is provided adjacent said slip means with a ramp to adjust to the deck height of the vessel, as required by changes in the draft of the vessel.

34. The system of claim 33 wherein a double-hinged ramp structure connects the pontoon terminal to shore, so as to accommodate tidal height changes.

35. A cable-propelled, buoyant carrier vessel comprising hull means substantially filled with lightweight cellular material, no engines or propelling means being aboard, and deck means for accommodating passengers and land vehicles, said vessel having means attached to an underpart of said vessel and extending downward from beneath said hull means to a considerable depth and cable grip means at the distal end thereof.

36. A cable-propelled, buoyant carrier vessel comprising hull means substantially filled with lightweight cellular material, and deck means for accommodating passengers and land vehicles, said vessel having strut means attached to an underpart of said vessel and extending downward from beneath said hull means to considerable depth and cable grip means at the distal end of said strut means, said strut means being pivoted to swing the fore-and-aft plane of said vessel, and power means to swing the distal end of said strut.

37. The carrier of claim 36 having two strut means, one mounted forward on the centerline of said vessel and one mounted aft on the centerline, which swing in the same direction.

38. The carrier of claim 36 having two strut means, one mounted forward on the centerline of said vessel and one mounted aft on the centerline which swing in opposite direction.

39. A cable-propelled, buoyant carrier vessel comprising hull means substantially filled with lightweight cellular material, and deck means for accommodating passengers and land vehicles, said vessel having strut means attached to an underpart of said vessel and extending downward from beneath said hull means to a considerable depth and cable grip means at the distal end of said strut means, said strut means being pivoted to swing on a plane transverse to said vessel.

40. A cable-propelled, buoyant carrier vessel comprising hull means substantially filled with lightweight cellular material, and deck means for accommodating passengers and land vehicles, said vessel having unpivoted struts which elevate and lower vertically through cavities in said hull, said struts being attached to an underpart of said vessel and extending downward from beneath said hull means to a considerable depth, and cable grip means at the distal end of said struts.

41. A cable-propelled, buoyant carrier vessel comprising hull means substantially filled with lightweight cellular material, and deck means for accommodating passengers and land vehicles, said vessel having single strut means attached to the fore-and-aft sliding pontoon on the underpart of said vessel and extending downward from beneath said hull means to a considerable depth, and cable grip means at the distal end of said strut means.

42. A sheave assembly for use in an underwater cable assembly crossing a waterway comprising a buoyant tank, sheave means supported by said tank, anchor means anchored in the bottom of the waterway, means for connecting said tank with said anchor means for keeping said sheave assemblies submerged at a selected depth, and ballast means for lowering and raising said tank, comprising inlet means for regulating the entrance of air or water into said tank and outlet means for regulating the exit of air or water out of said tank.

43. The sheave assembly of claim 42 wherein each said tank has attached thereon sheaves to accommodate a cable moving in the direction of a cable vessel of said underwater cable assembly and sheaves to accommodate a return cable in the opposite direction.

44. The sheave assembly of claim 42 wherein said sheaves lie in a vertical plane and rotate upon a horizontal axis.

45. The sheave assembly of claim 42 wherein said tank has four sheaves, two at opposite ends that lie in vertical planes for rotation about a horizontal axis and two in between that lie in a horizontal plane for rotation about a vertical axis.

46. The system of claim 42 wherein said sheave assemblies comprise a structure having a pier resting firmly on and in the bottom of the waterway and supporting thereon sheave means in engagement with said cable.

47. The system of claim 46 wherein said sheave assembly comprises two sheaves both lying in vertical planes, one for a vessel-transporting run of said cable and one for a return run thereof.

48. The system of claim 46 wherein said sheave assembly comprises two pairs of end sheaves both lying in horizontal planes, one for a vessel-transporting run of said cable and one for a return run thereof, and two pairs of intermediate sheaves lying in vertical planes, one for each said cable run, to enable course changing.

49. A sheave assembly for use in an underwater cable assembly crossing a waterway, comprising a structure having a pier resting firmly on and in the bottom of the waterway and supporting thereon two pairs of end sheaves both lying in horizontal planes, one for a vessel-transporting run of said cable and one for a return run thereof, and two pairs of intermediate sheaves lying in vertical planes, one for each said cable run, to enable course changing.

50. A cable ferry system for transportation across a waterway, comprising a plurality of terminals, ground-anchored sheaves between said terminals, a uniformly surfaced unsprocketed cable extending between said terminals in contact with said sheaves and unprotected between them below water at a depth deep enough not to interfere with the operation of deepwater navigation by surface craft across the water above said cable, a vessel having a hull, and rigid means for individually and directly connecting the hull of said vessel to said cable for movement therewith between said terminals, and drive means for said cable adjacent to one of said terminals.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,604,389 Dated September 14, 1971

Inventor(s) George G. Roberts et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 7, line 9, "roll-on" should read --type--;
line 13, "rollon rolloff" should read --roll-on, roll-off--;
line 56, "34" should read --81--. Col. 10, line 34, "shoe"
should read --shore--; line 65, "t" should read --to--.
Col. 12, line 4, "cable of" should read --cable sag--.
Col. 14, line 30, "cable. b" should read --cable.--; line 58,
between "terminals," and "said" insert --and drive means for
said cable adjacent to one of said terminals,--. Col. 15,
line 41, between "terminals," and "at least" insert --and
drive means for said cable adjacent to one of said terminals,--;
line 72, "sad" should read --said--. Col. 16, line 21, after
"cable" insert --for movement therewith between said terminals,
and drive--; line 49, "swing the" should read --swing on the--;
line 58, "direction." should read --directions.--. Col. 18,
line 23, "wit" should read --with--.

Signed and sealed this 2nd day of May 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents