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Wiemers et al.(10) **Pub. No.: US 2015/0001161 A1**(43) **Pub. Date: Jan. 1, 2015**(54) **LIQUID TREATMENT STATION INCLUDING
PLURAL MOBILE UNITS AND METHODS
FOR OPERATION THEREOF**(52) **U.S. Cl.**CPC **C02F 1/56** (2013.01)USPC **210/739; 210/241; 210/201; 210/143;
210/137; 210/96.1; 210/108; 210/192**(71) Applicant: **Rockwater Resource, LLC**, Denver, CO
(US)(72) Inventors: **Reginald A. Wiemers**, Littleton, CO
(US); **Bardia B. Khalili**, Denver, CO
(US); **Werner Roeder**, Stuttgart (DE)

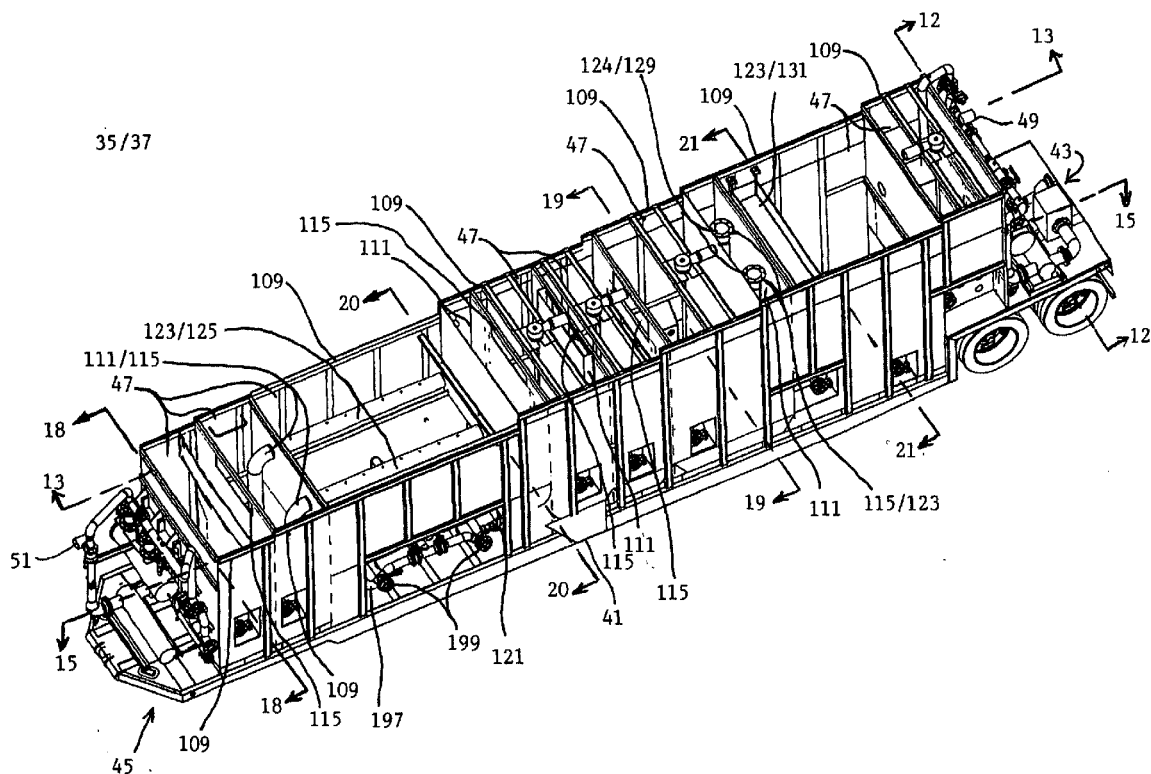
(57)

ABSTRACT

A mobile liquid treatment station and operation methods are disclosed, the station having a mobile treatment unit and separate mobile treatment management unit. A plurality of serial containment compartments at the treatment unit for performance of chemical dosing and solids separation are provided and are monitored with sensors. The management unit includes a plurality of chemical dosing platforms, and a power and processing assembly. A bus links the units for data and control signal transfer and chemical feed lines are connected between the units for transfer of dosing chemicals.

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C02F 1/56

(2006.01)



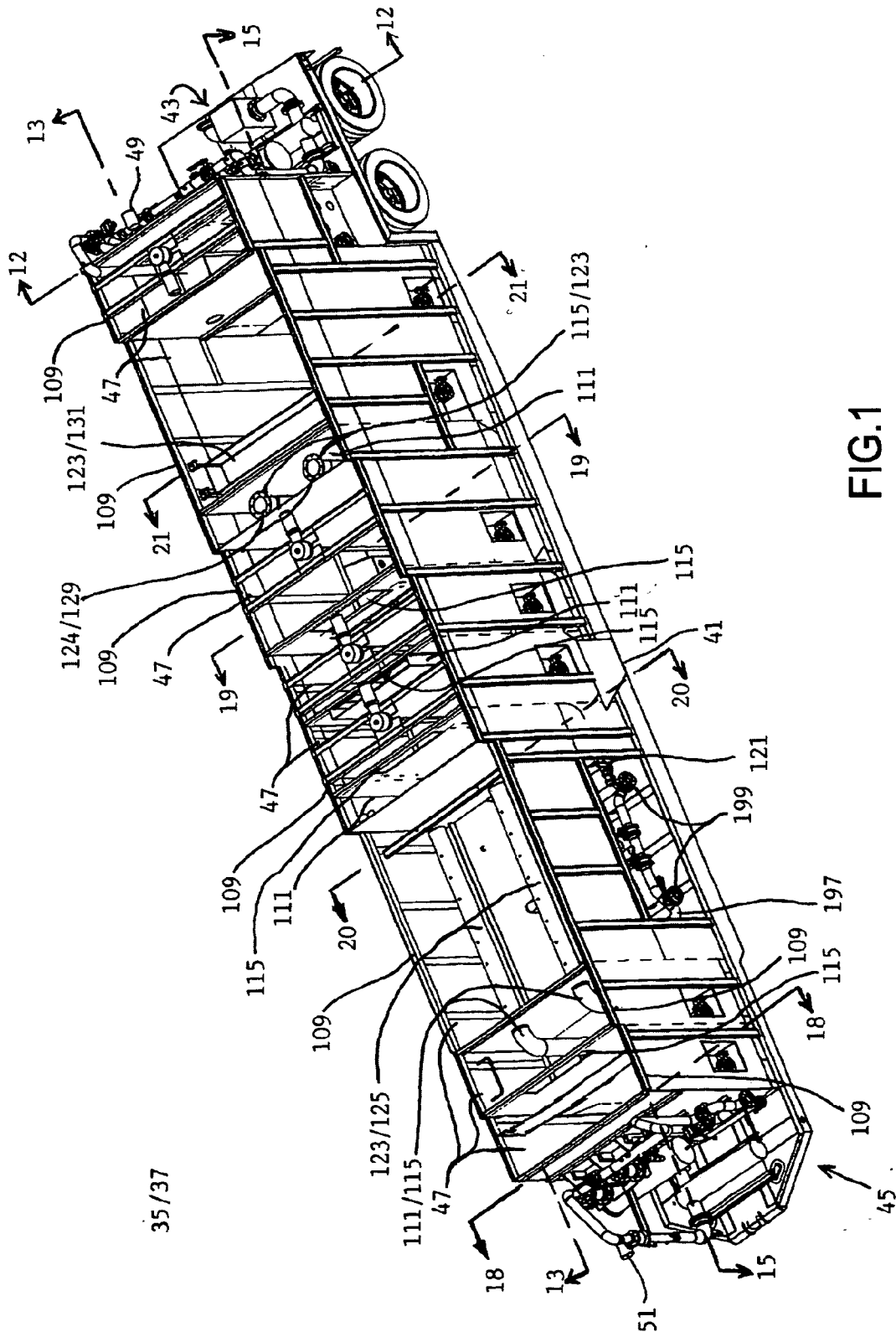


FIG. 1

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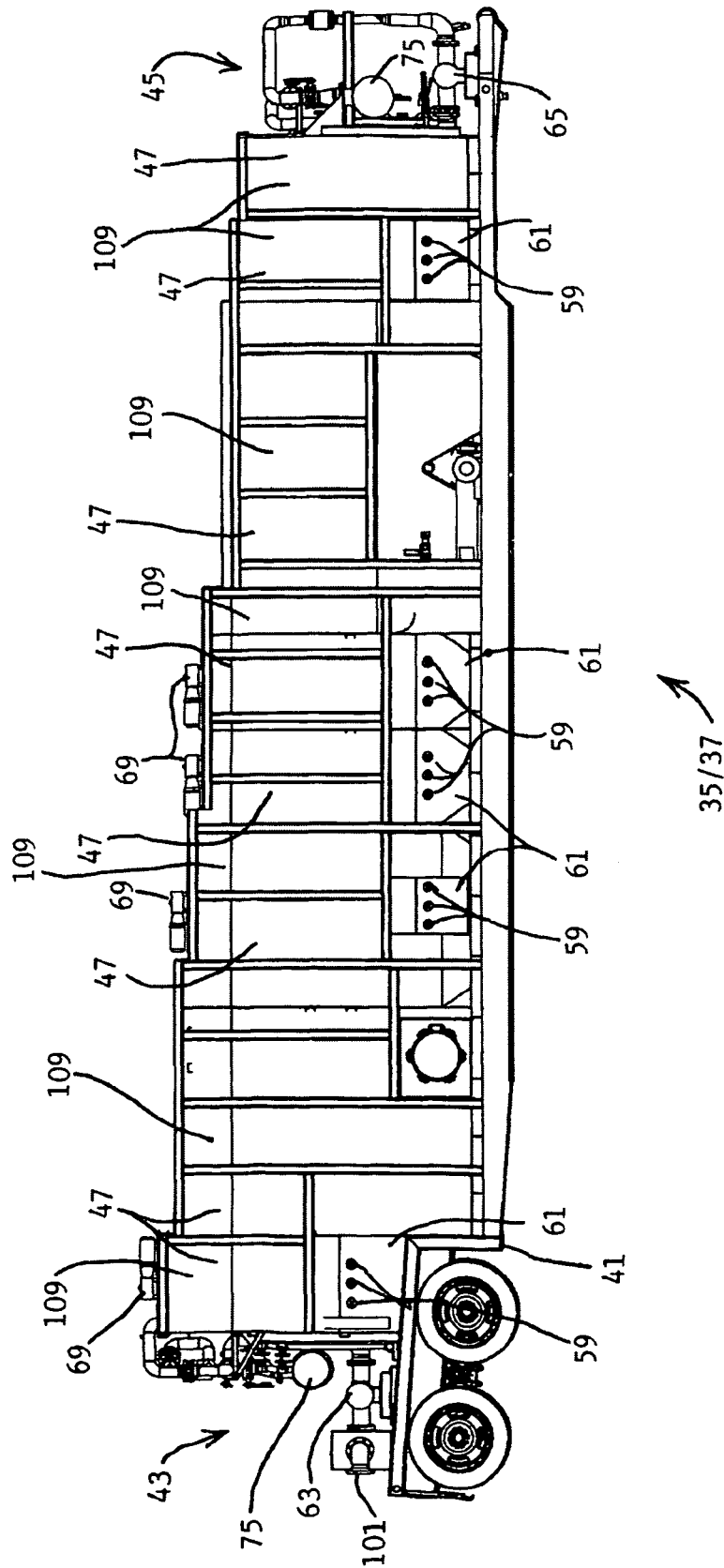


FIG. 2

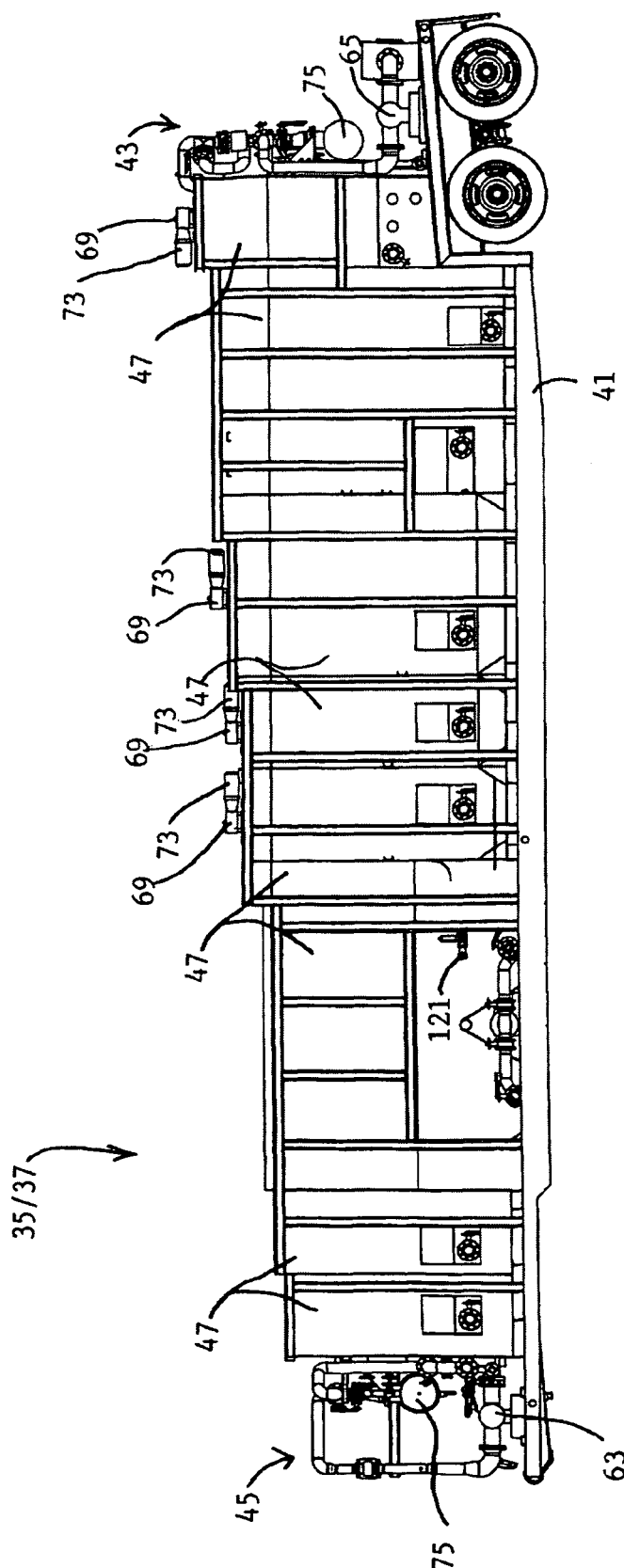


FIG.3

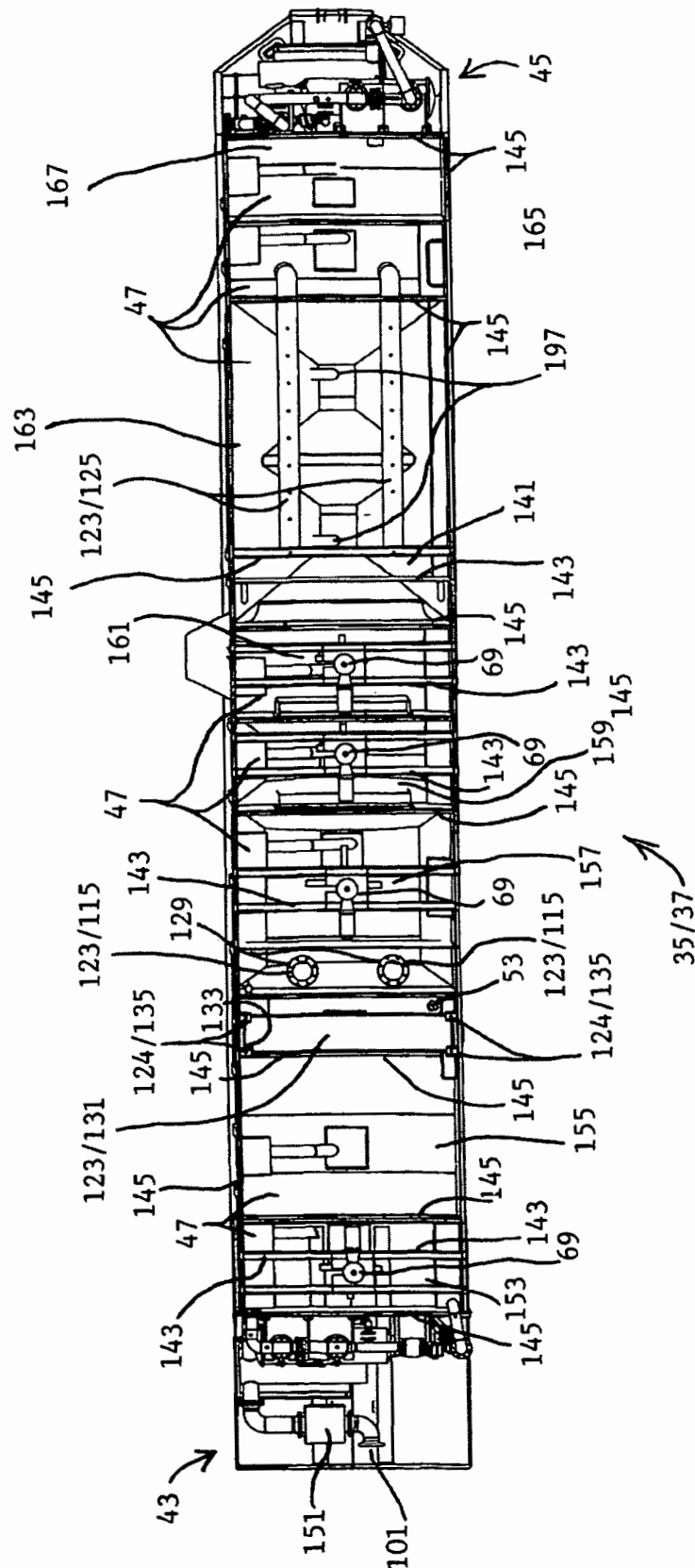


FIG.4

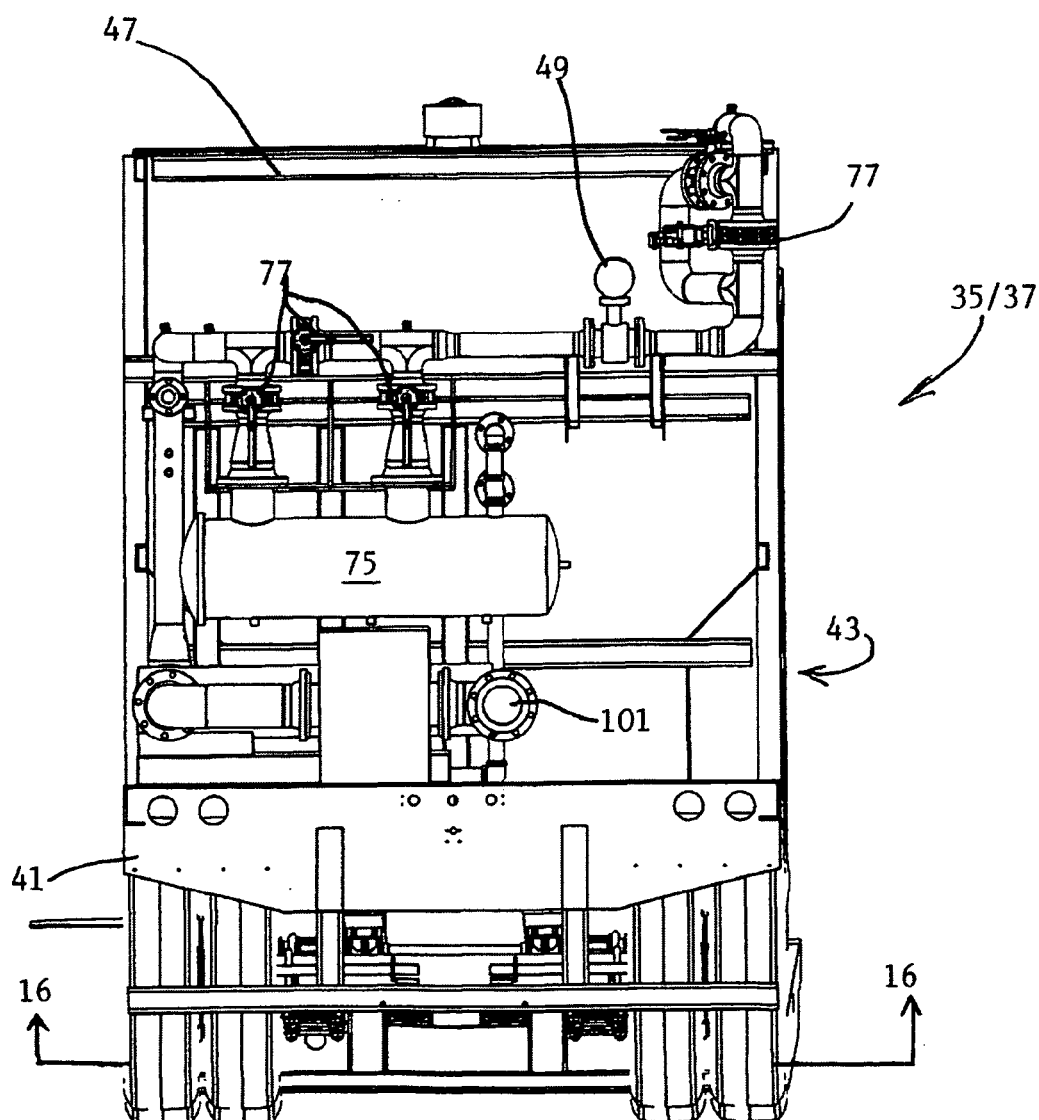


FIG.6

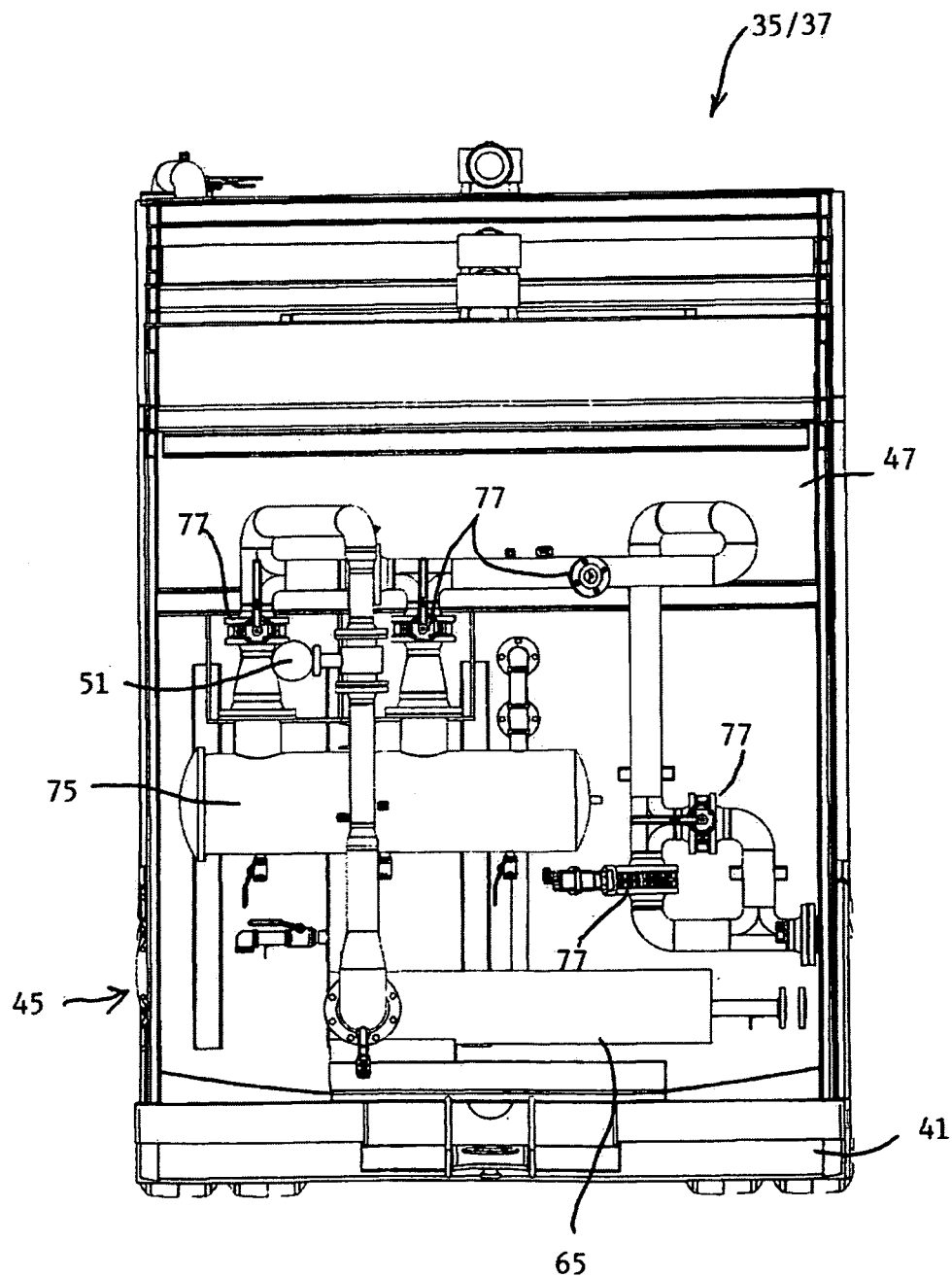


FIG. 7

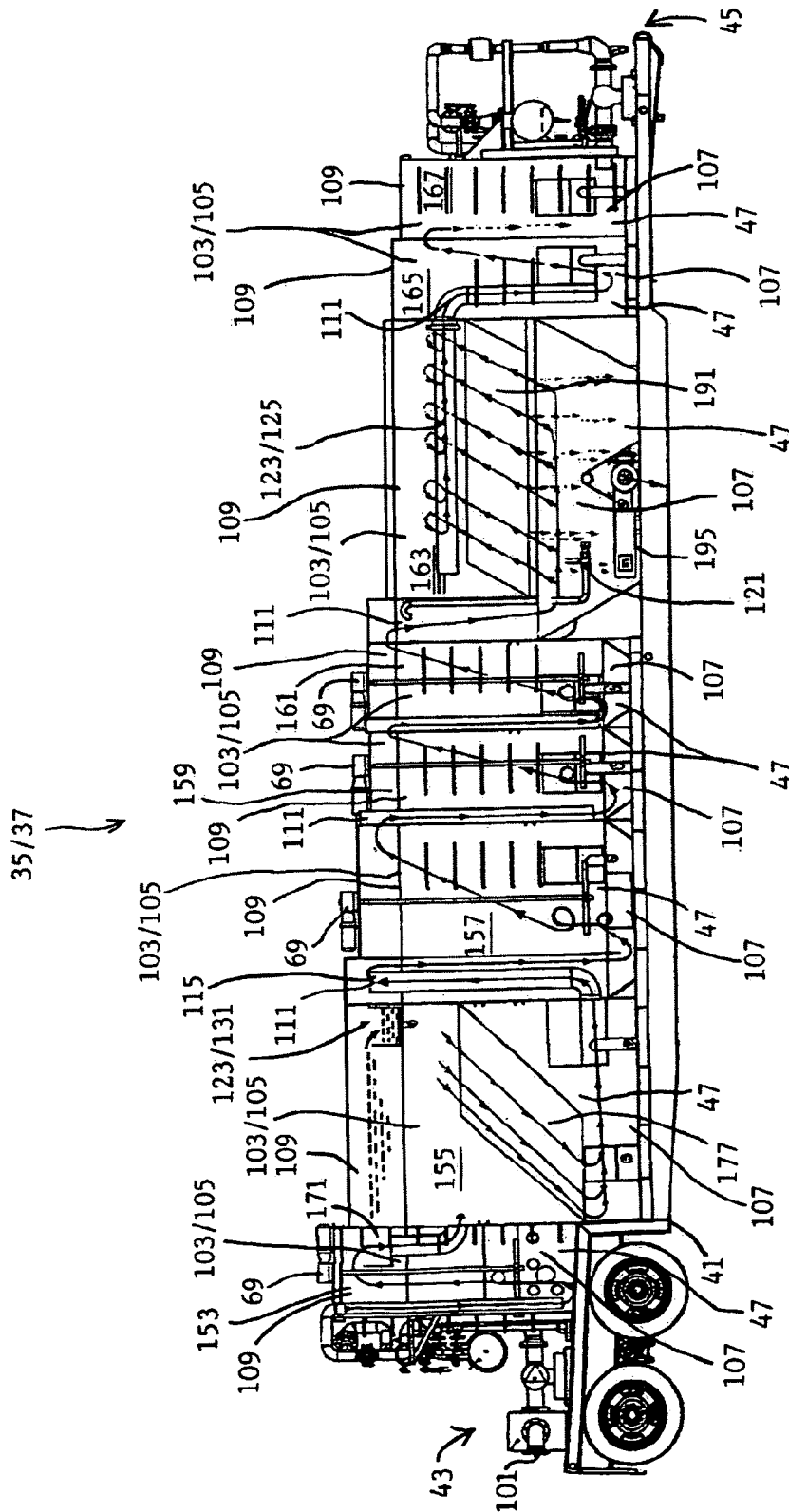


FIG.8

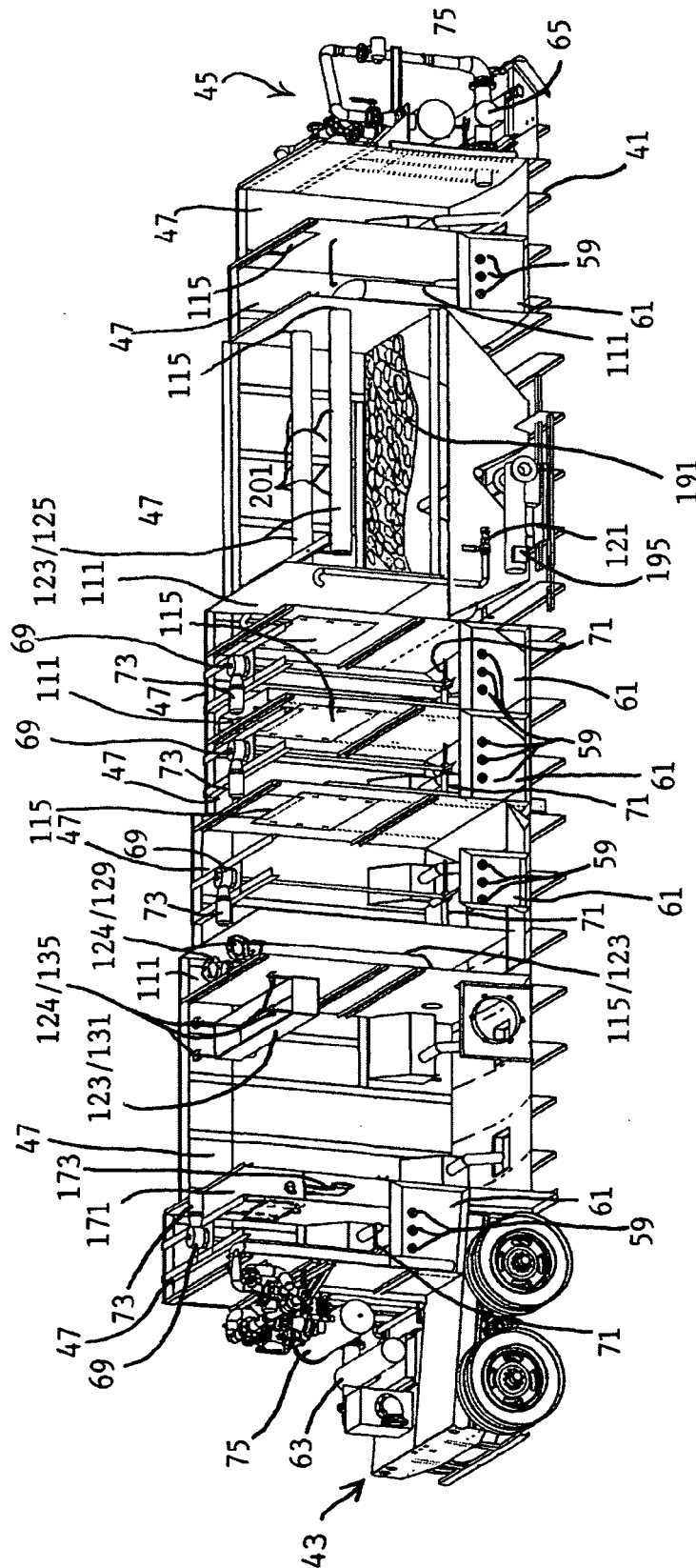


FIG.9

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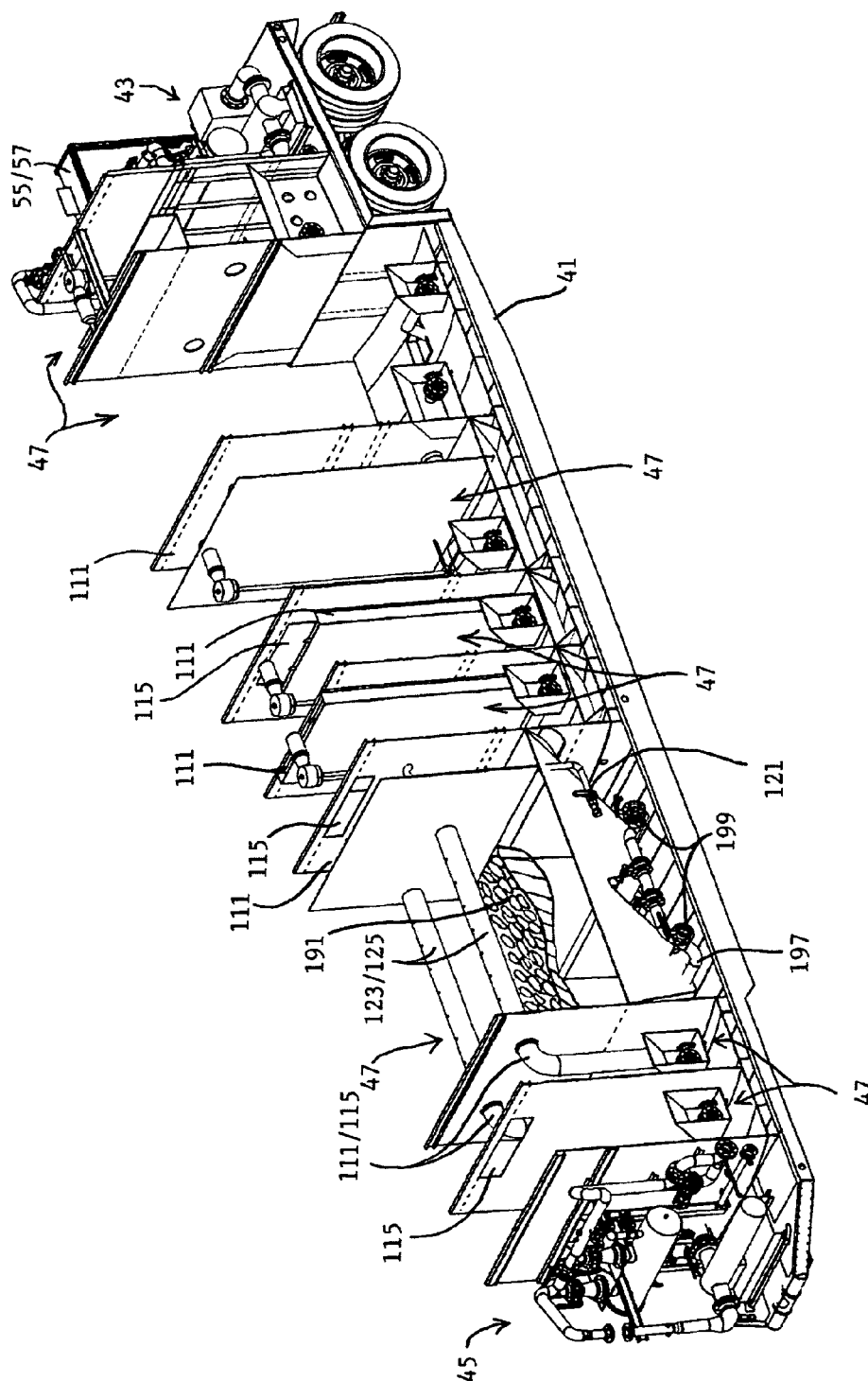


FIG.10

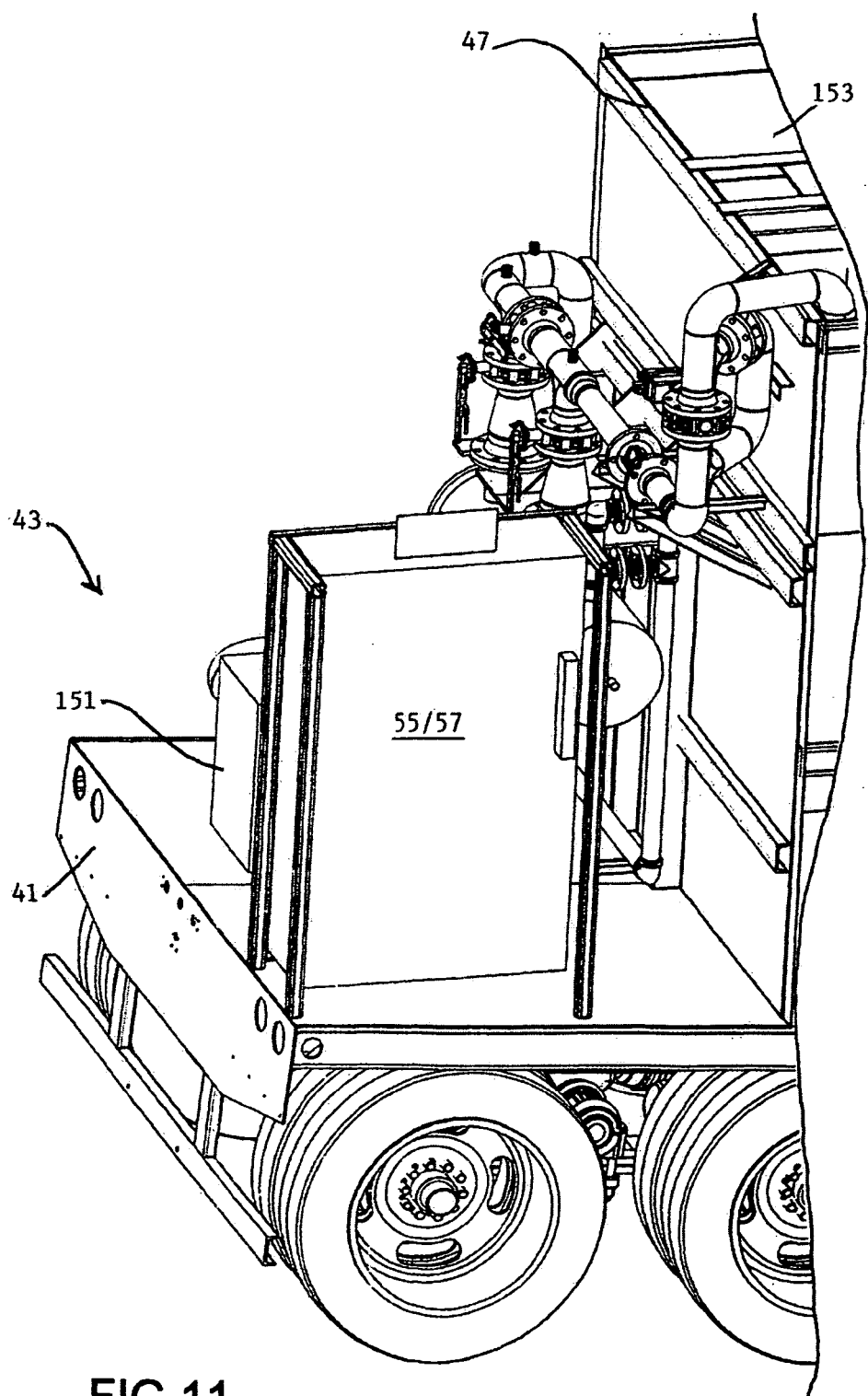


FIG. 11

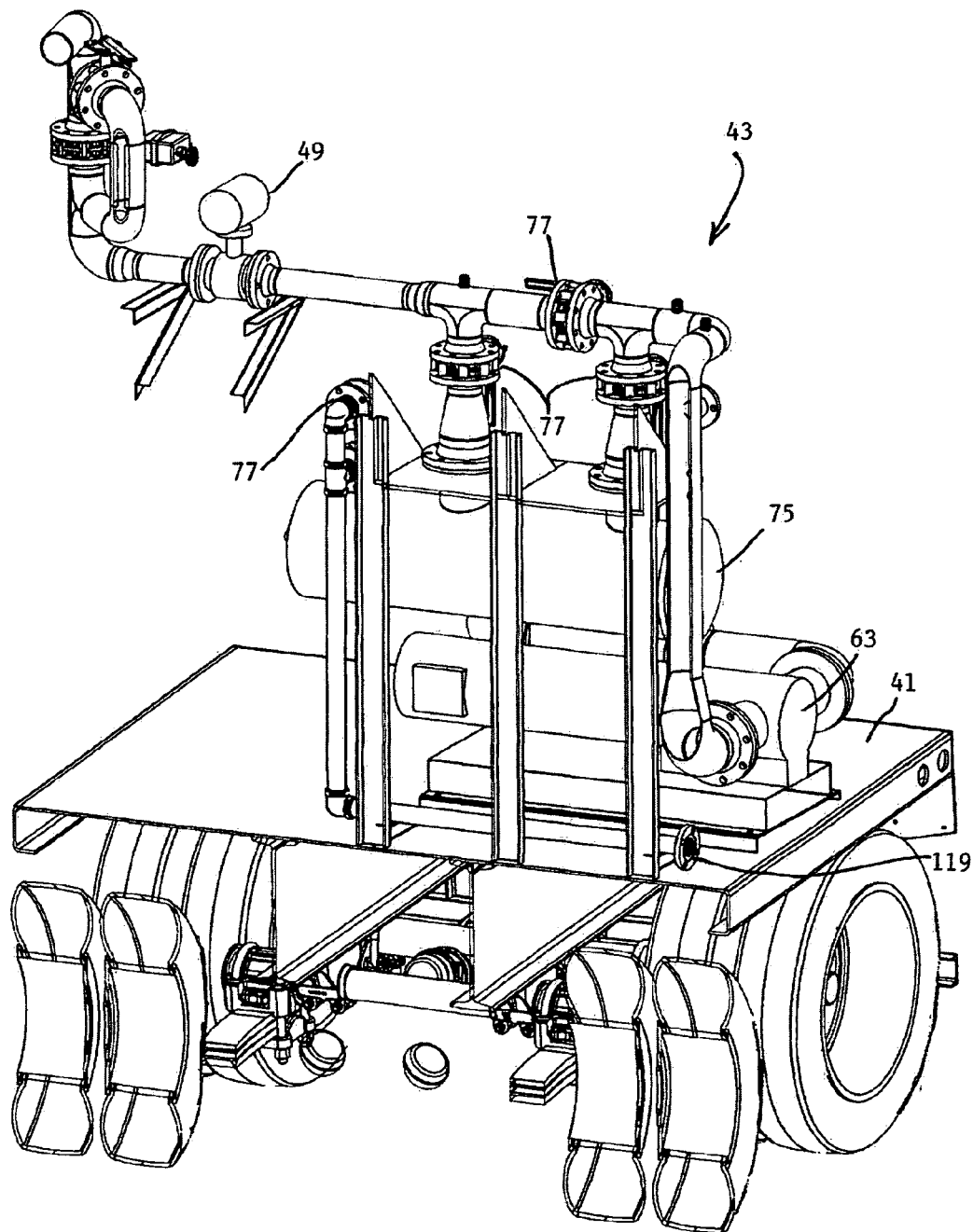


FIG.12

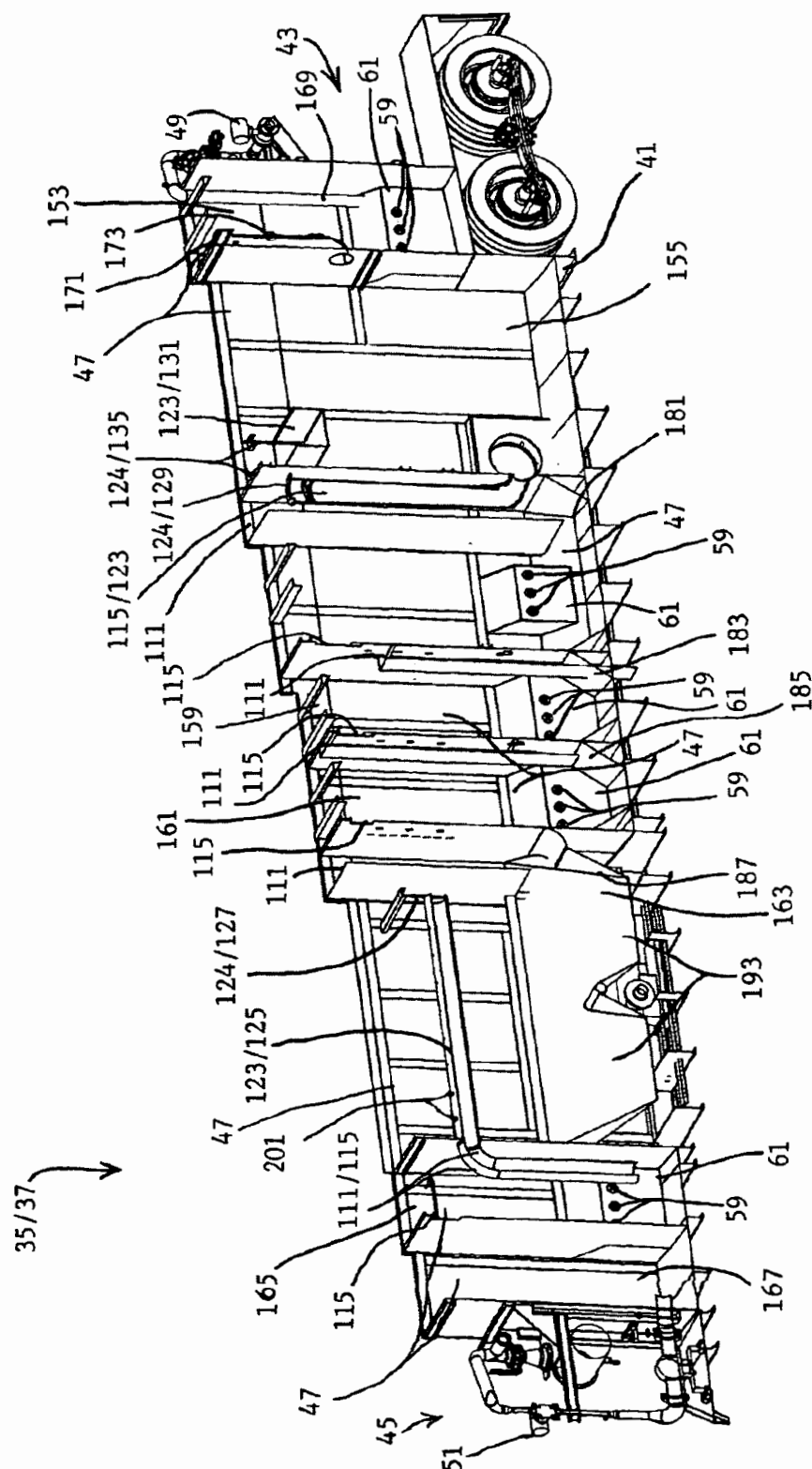


FIG.13

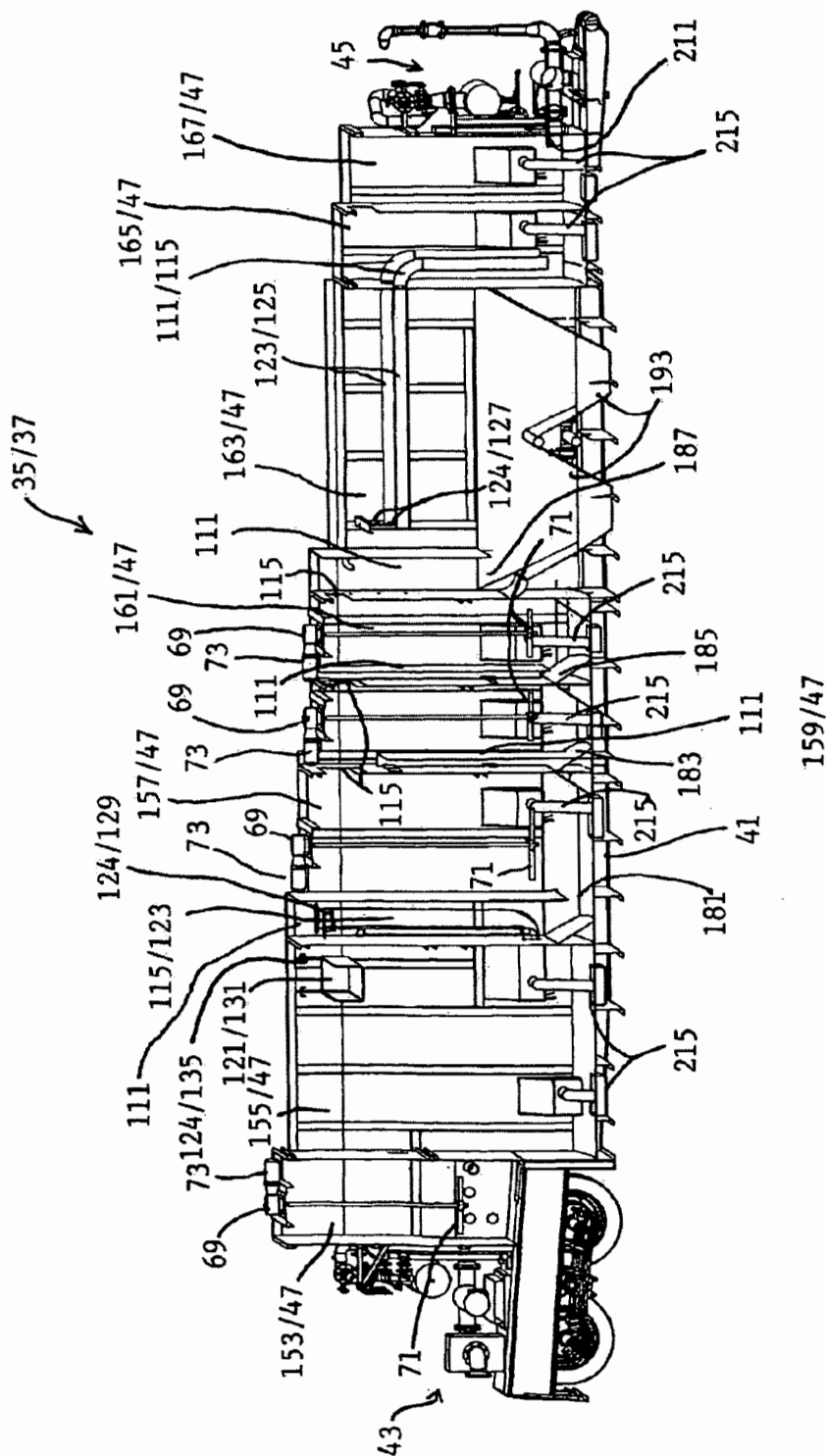


FIG. 14

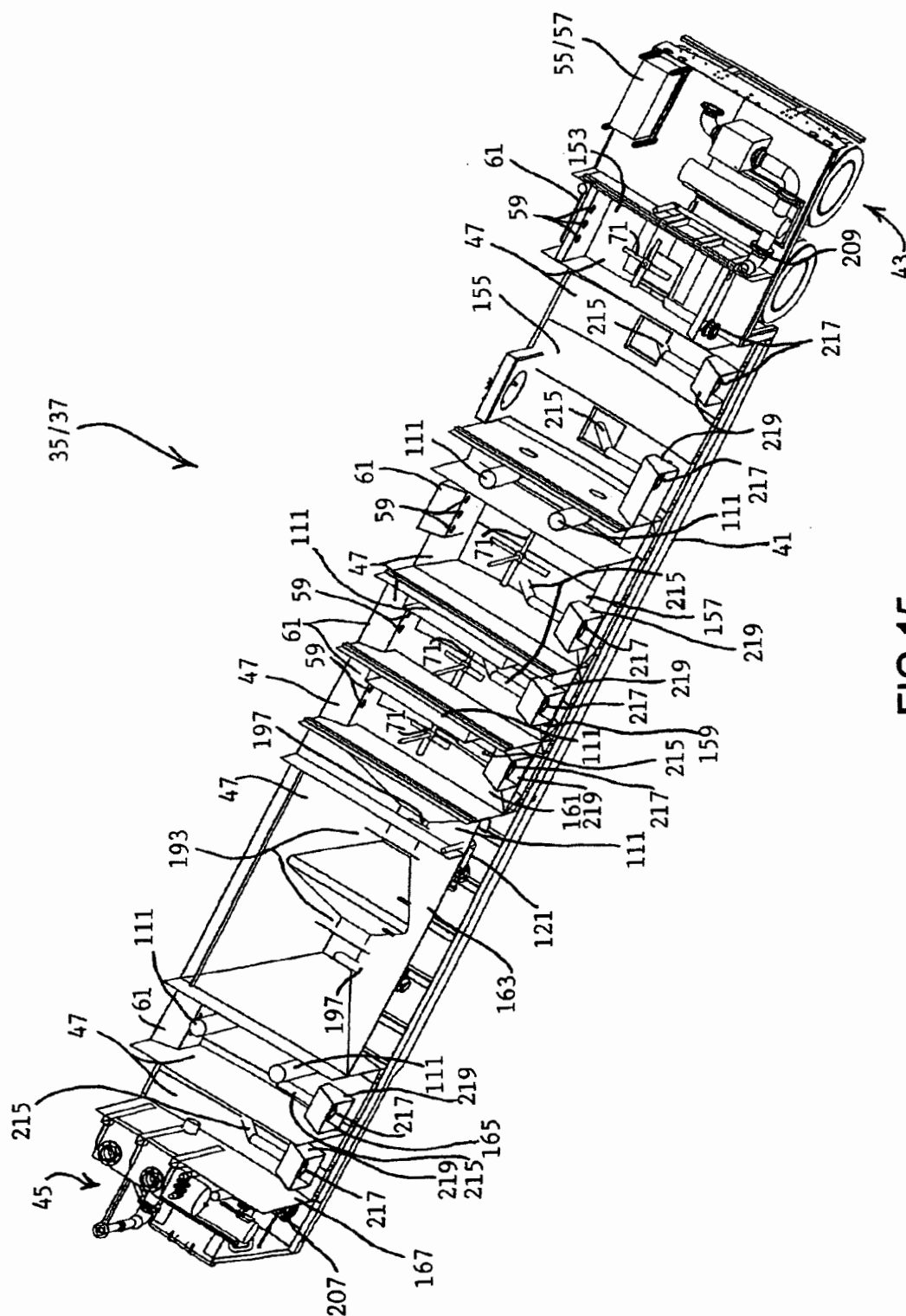


FIG.15

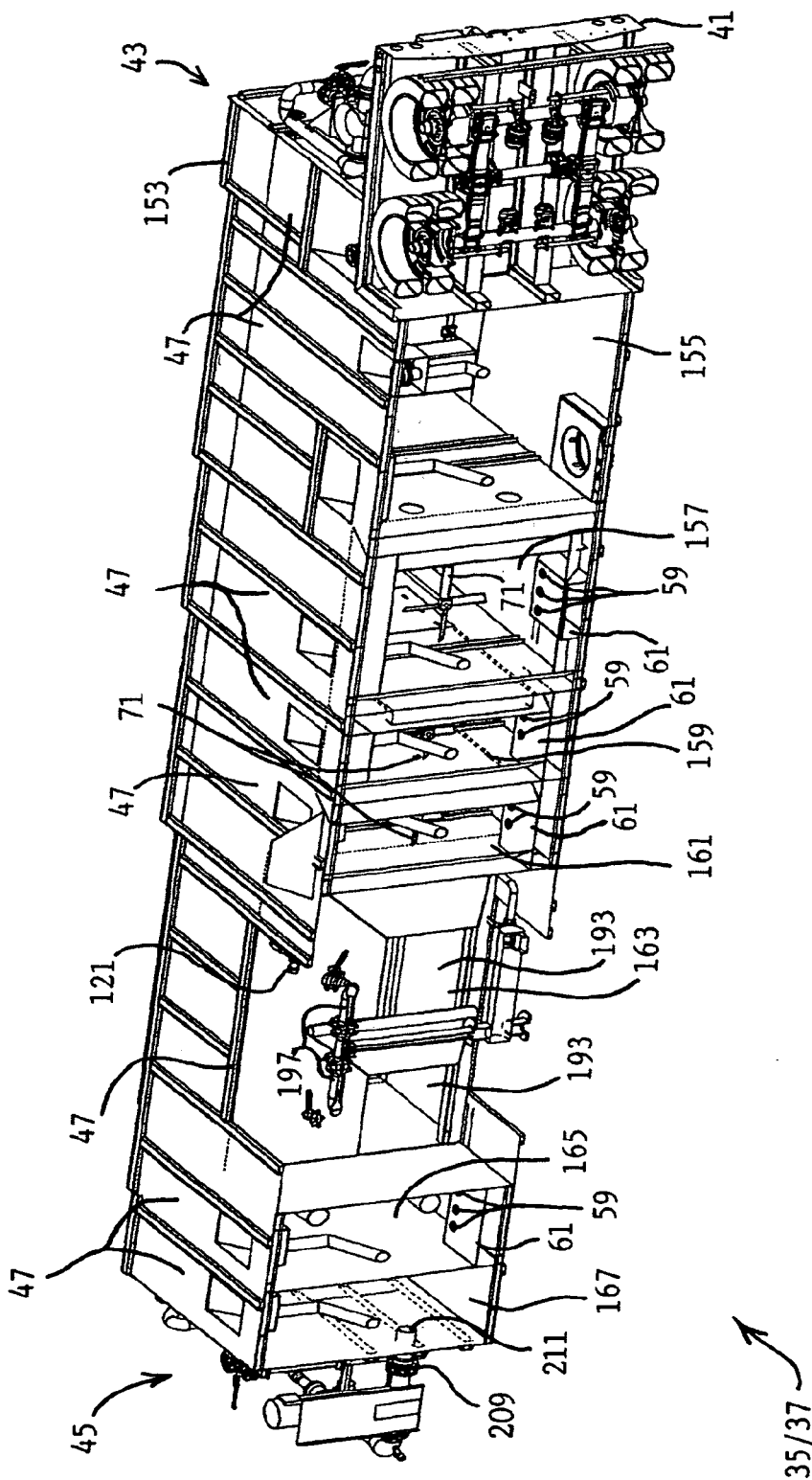


FIG.16

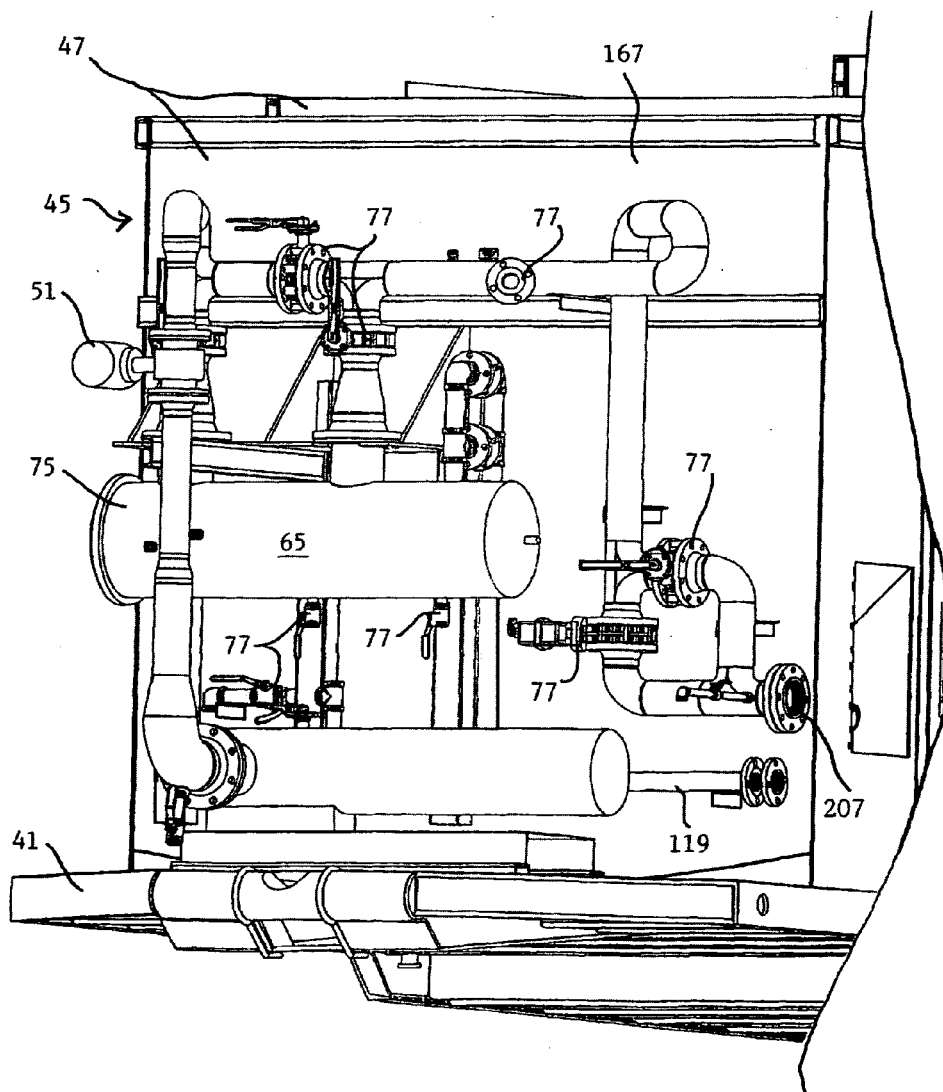


FIG.17

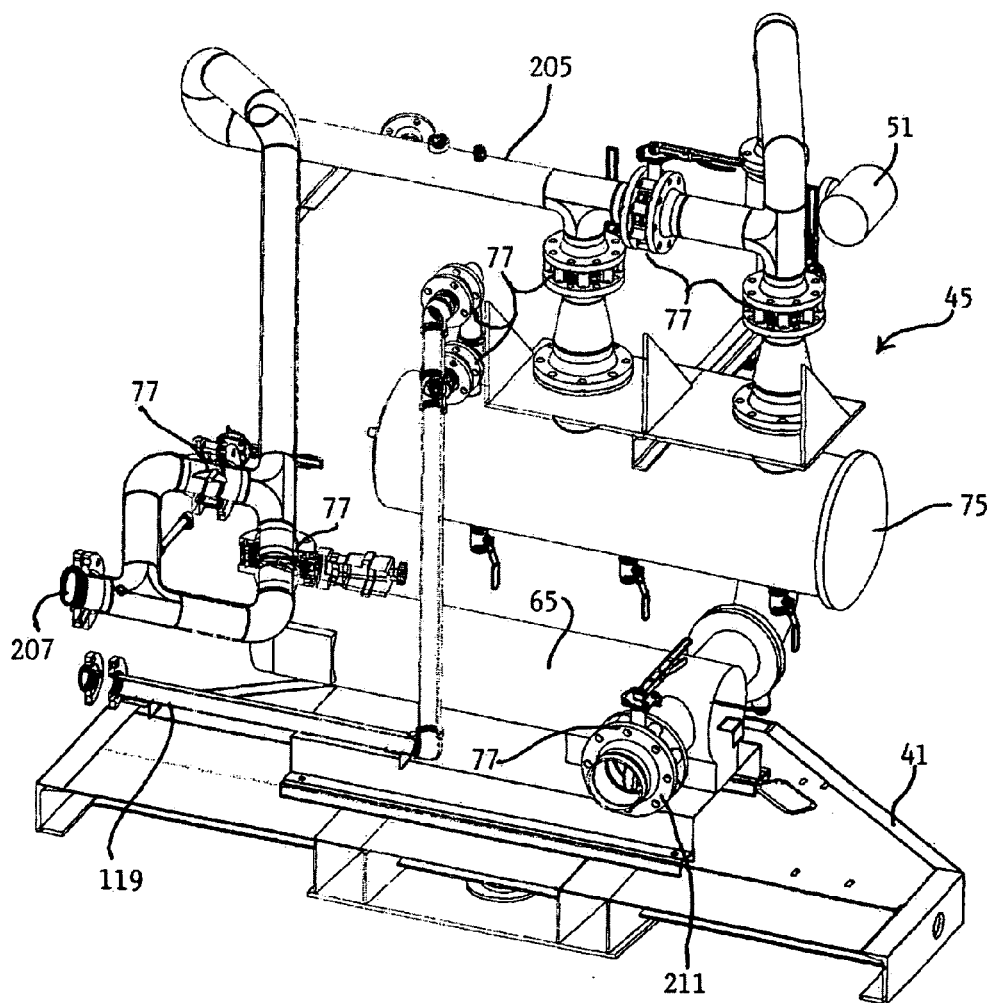


FIG.18

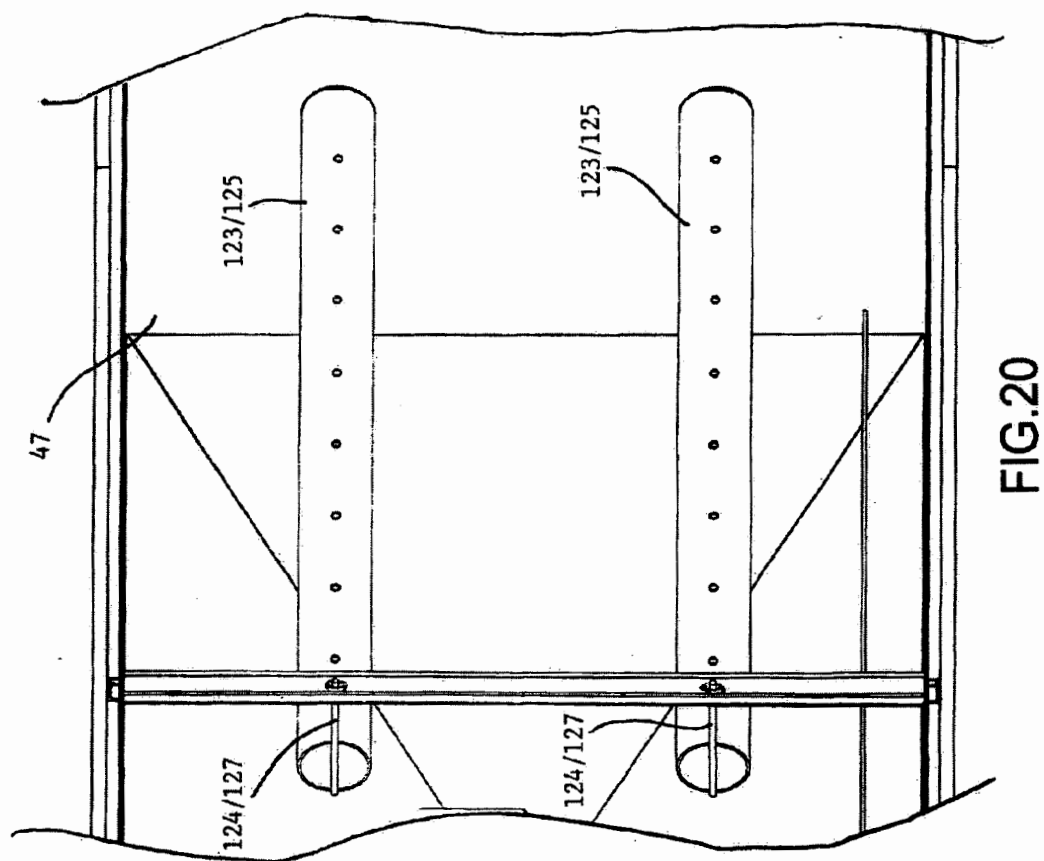


FIG. 20

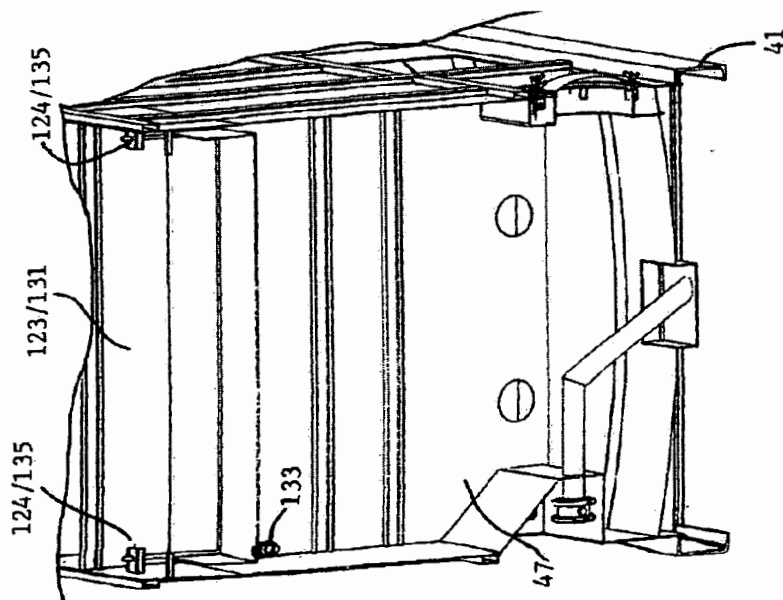


FIG. 21

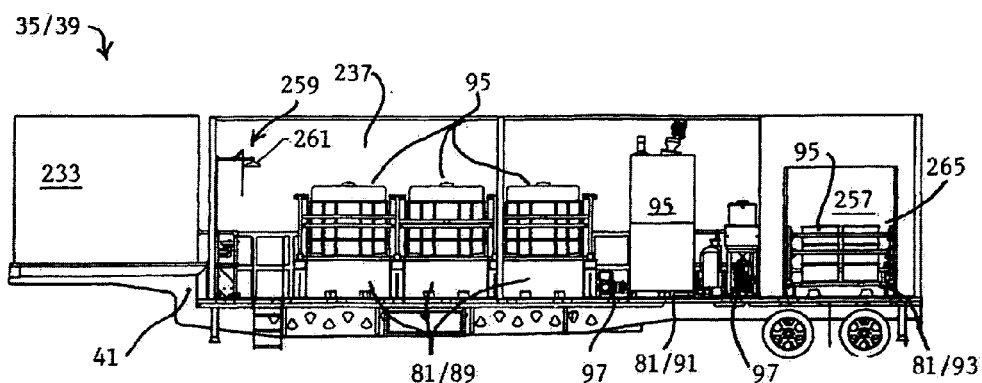


FIG. 24

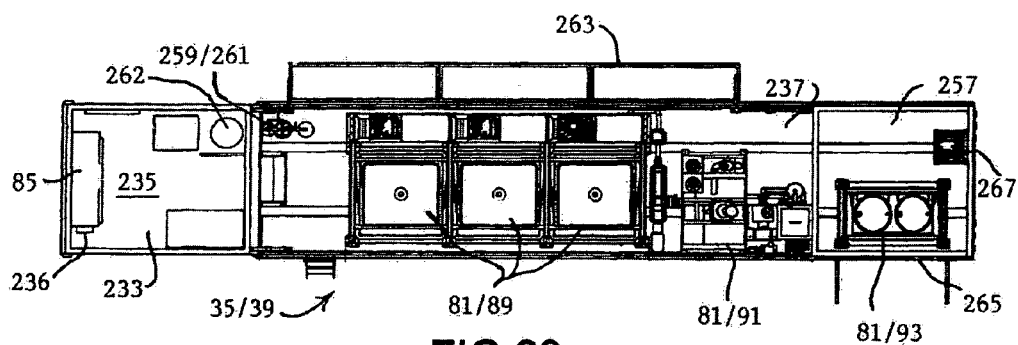


FIG. 23

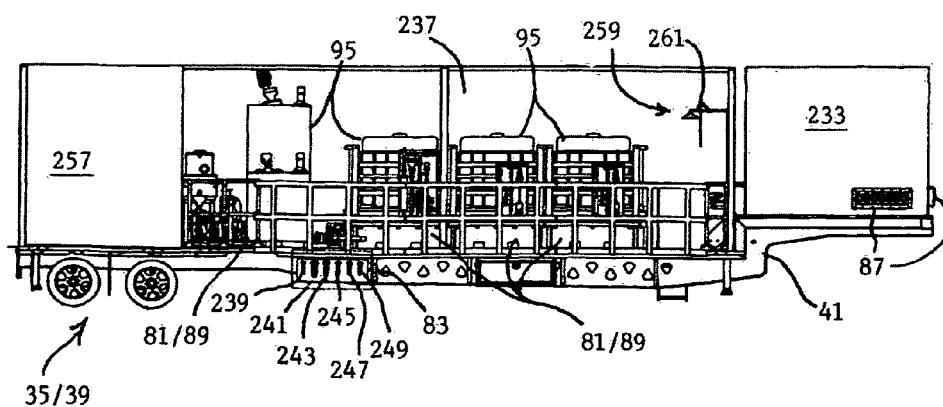


FIG. 22

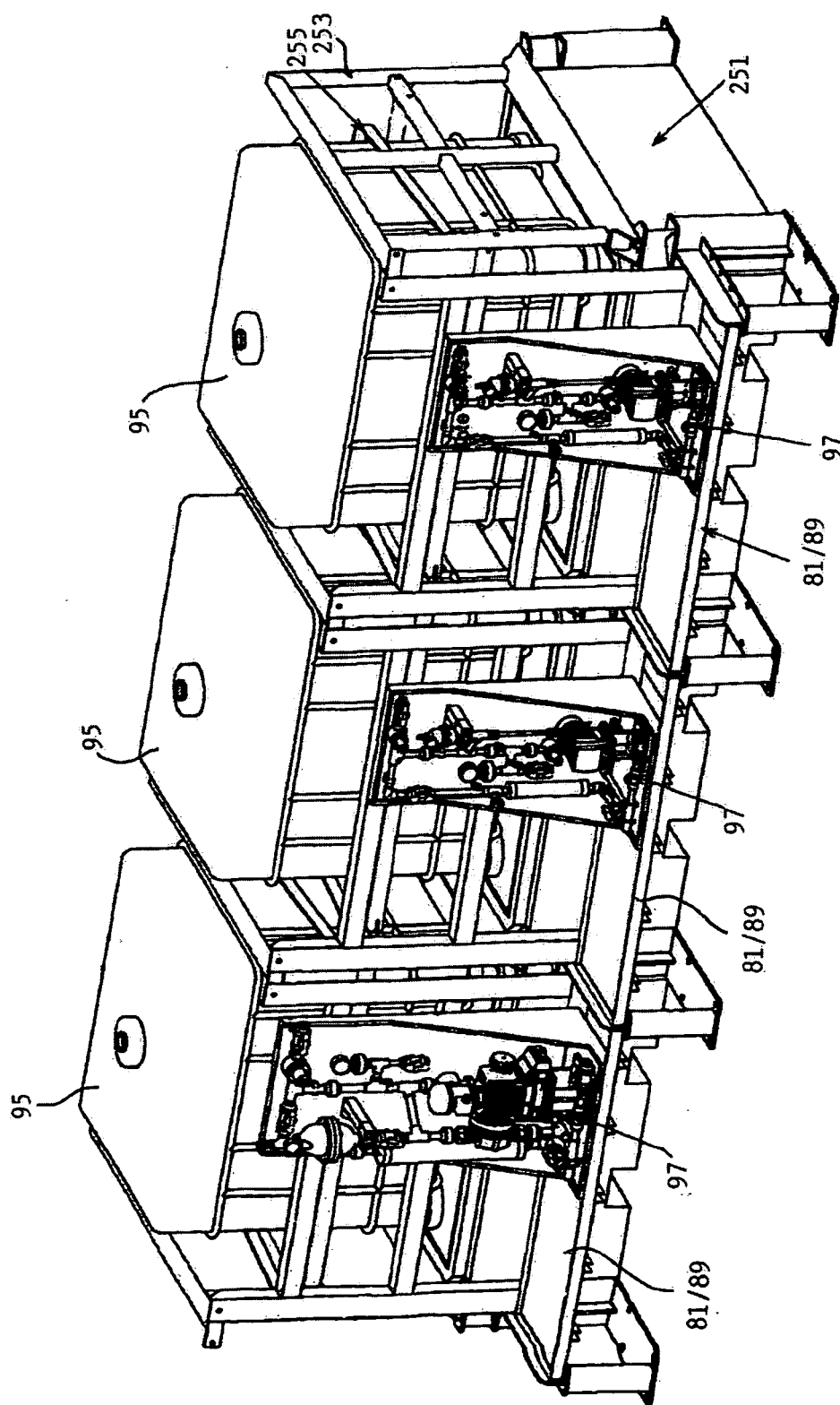


FIG. 25

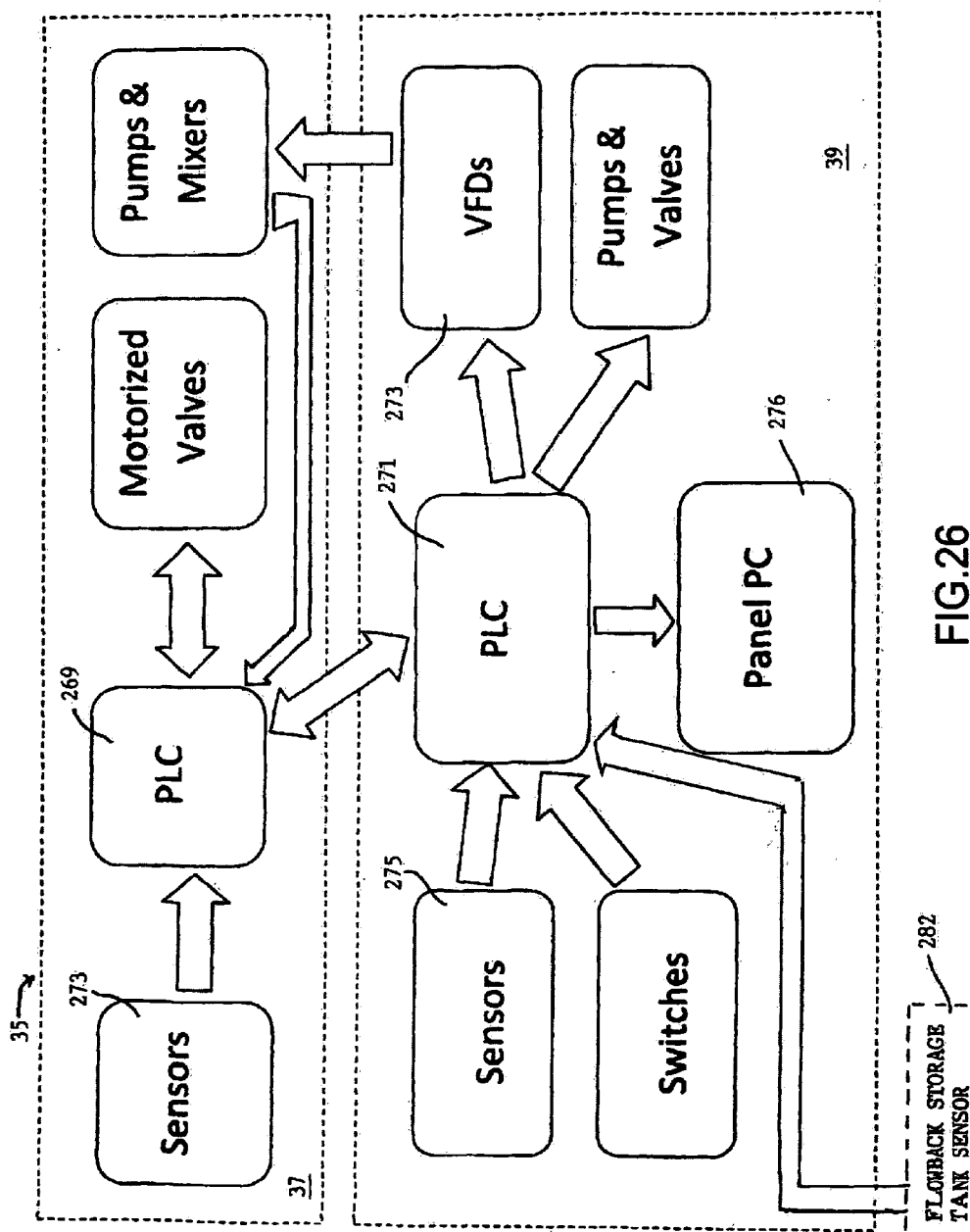


FIG. 26

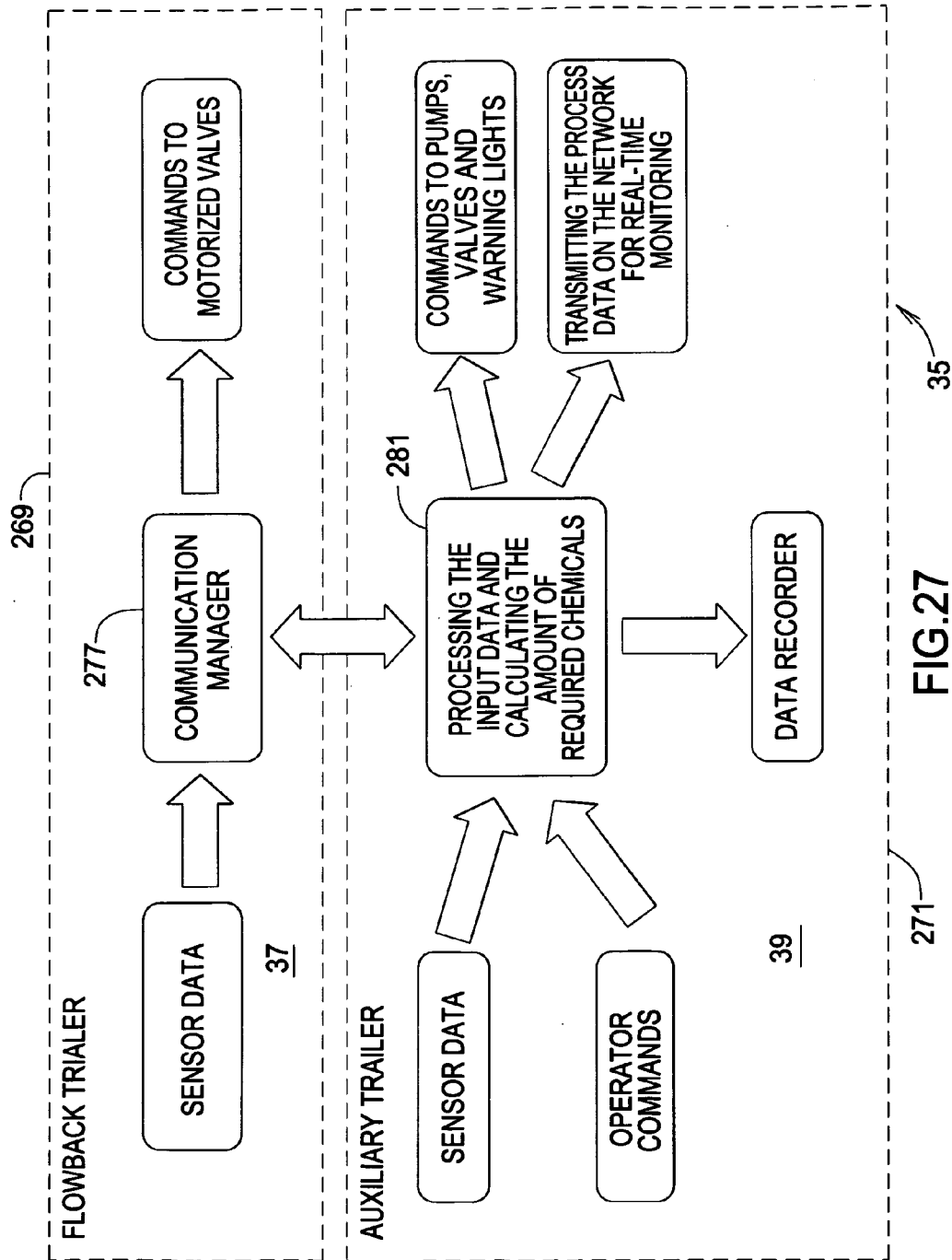


FIG.27

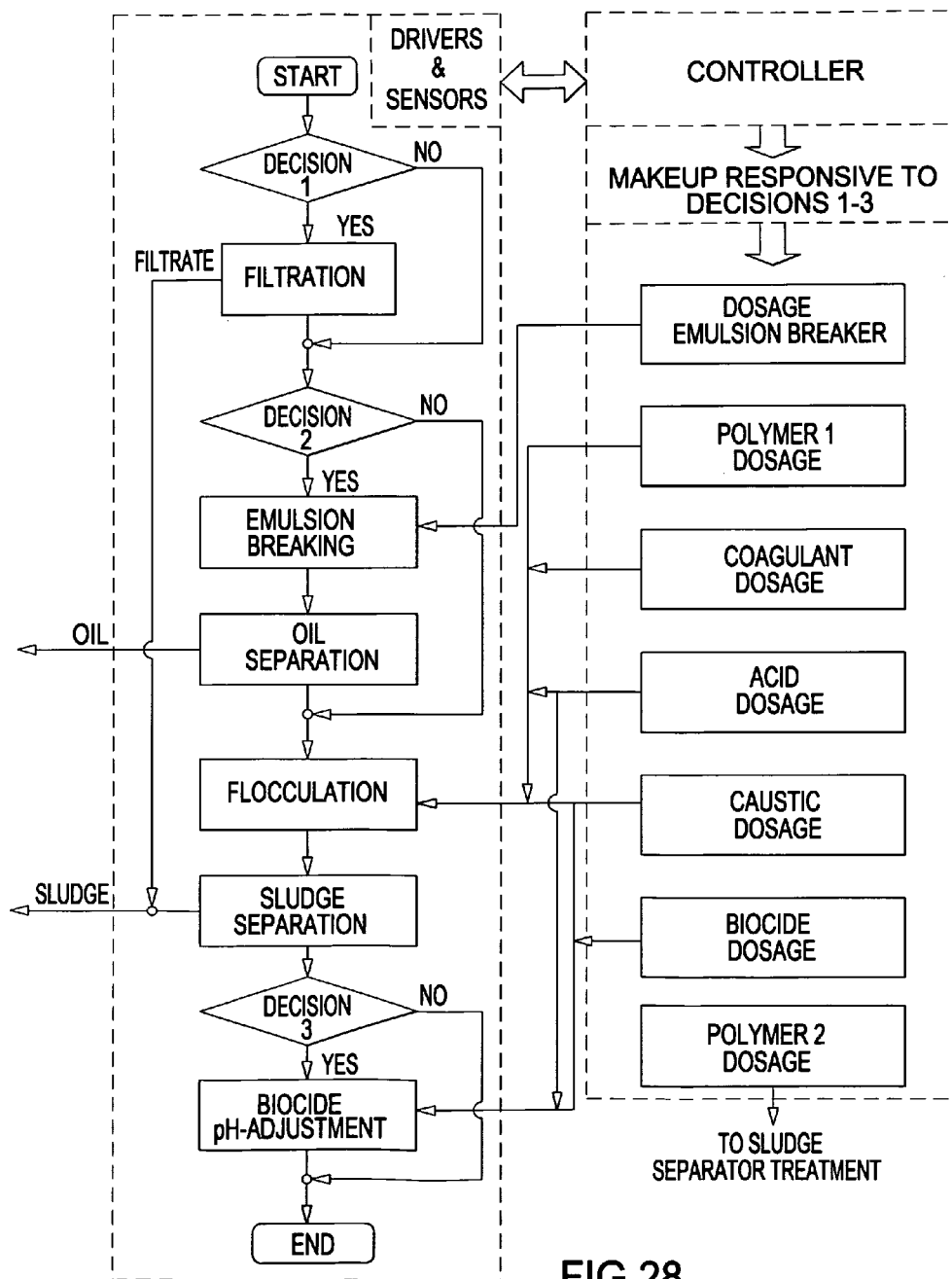


FIG.28

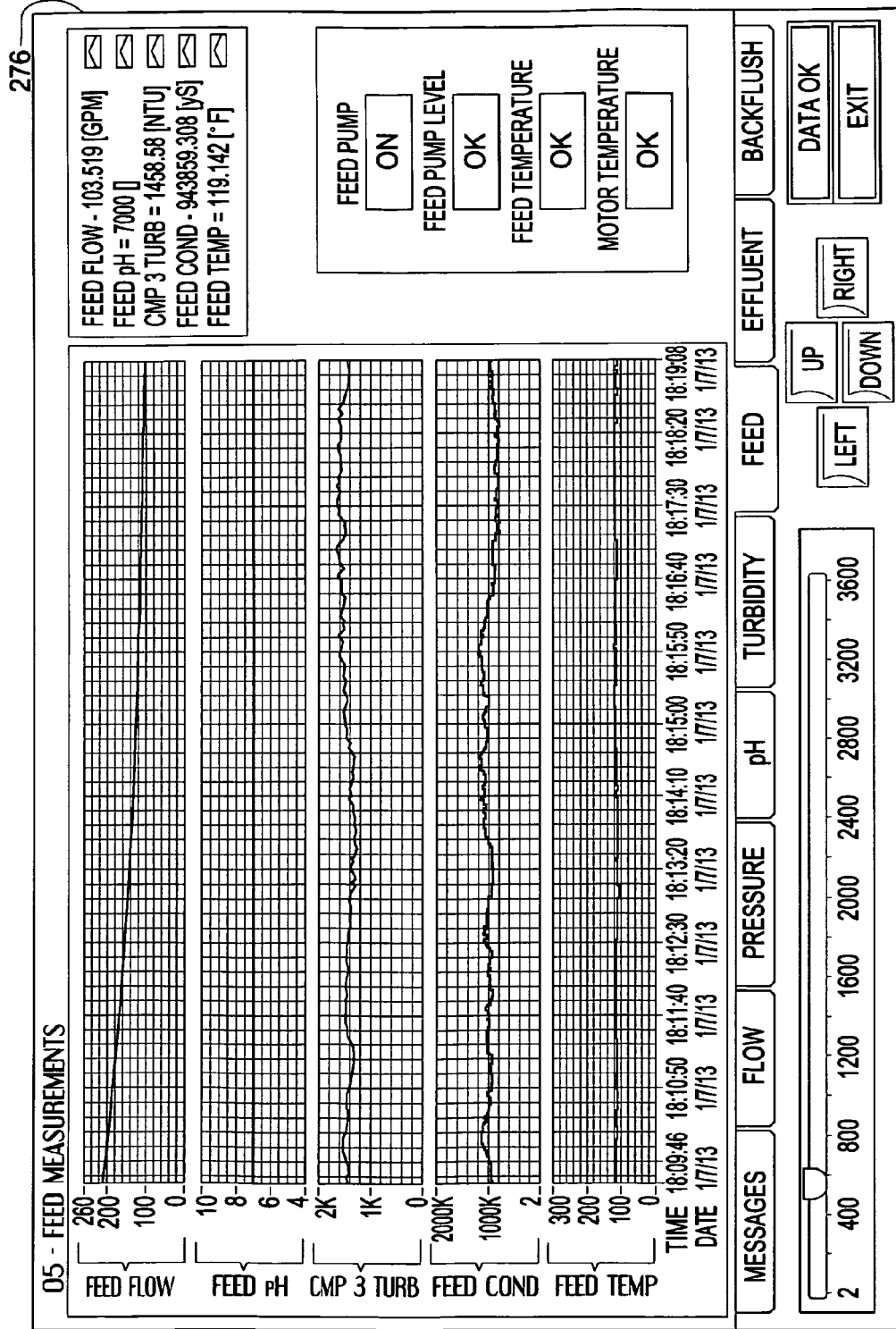


FIG.29A

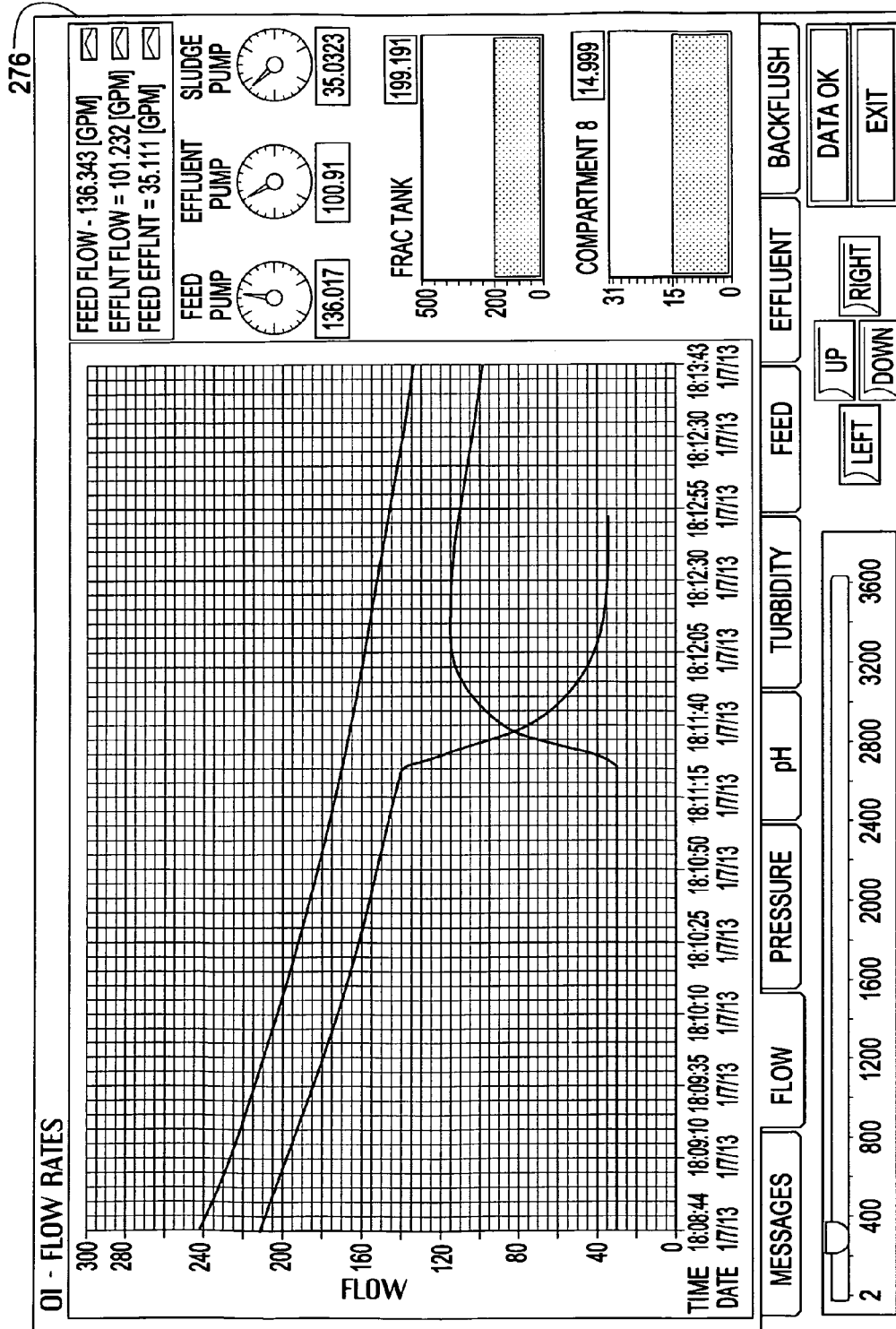


FIG.29B

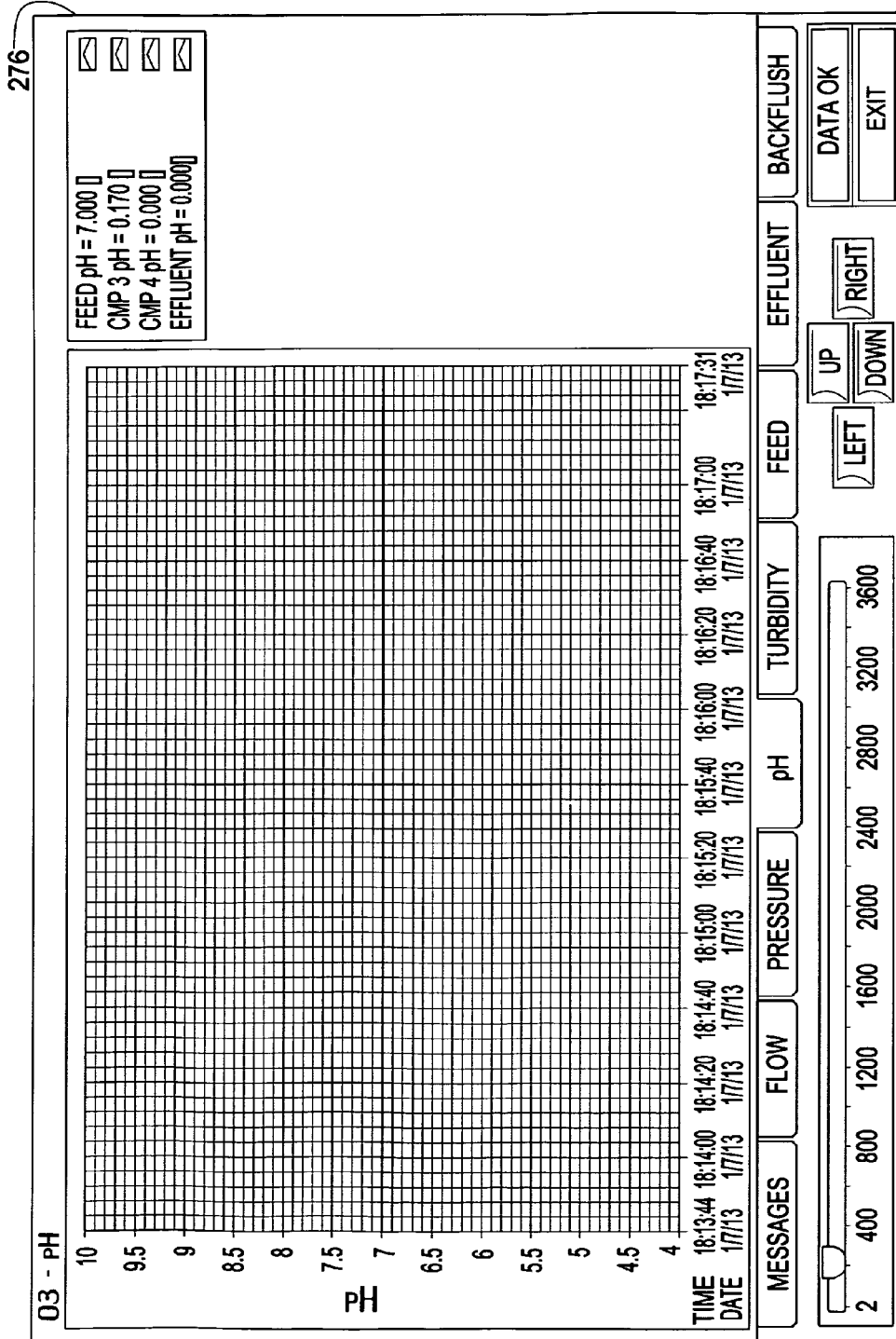


FIG.29C

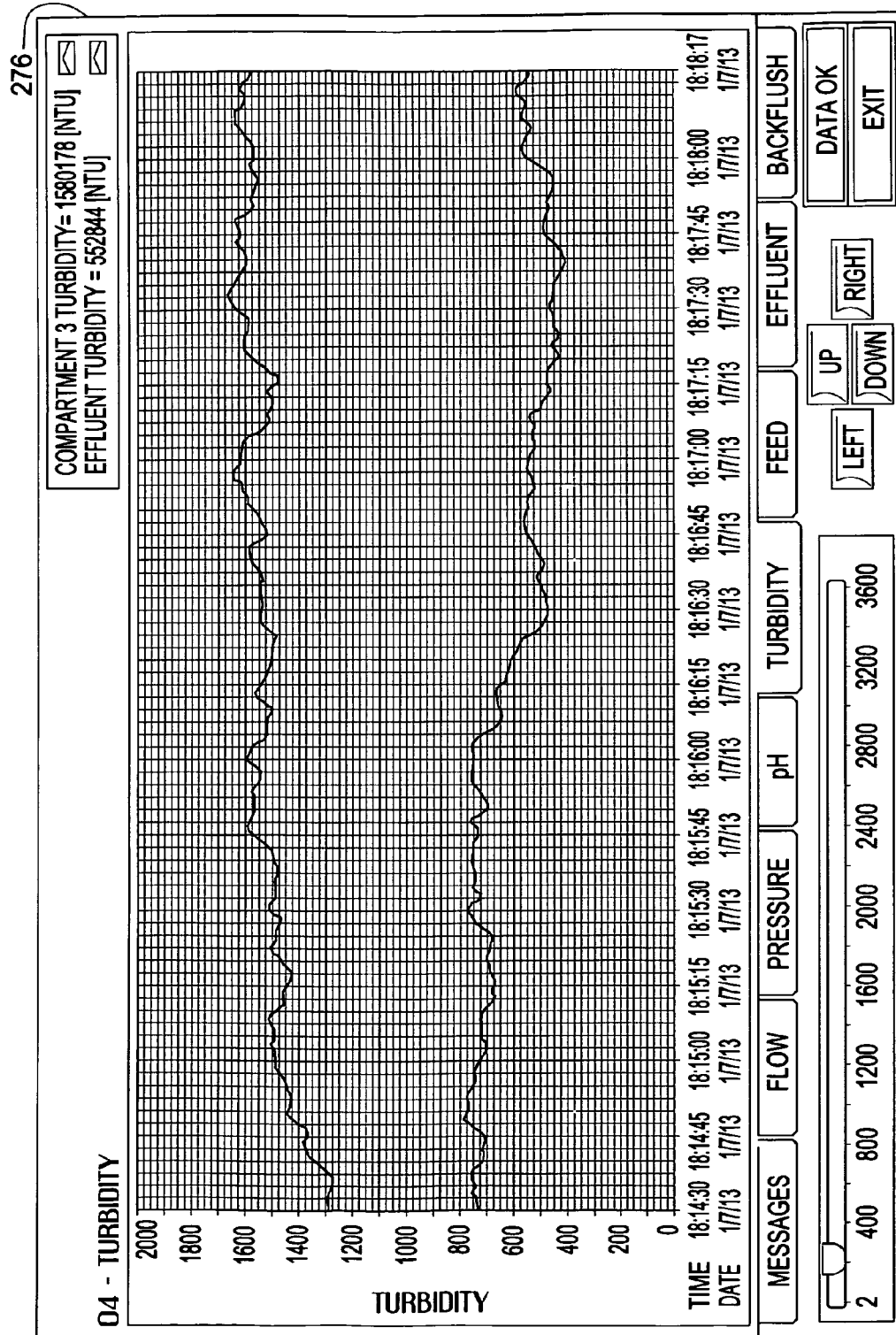


FIG.29D

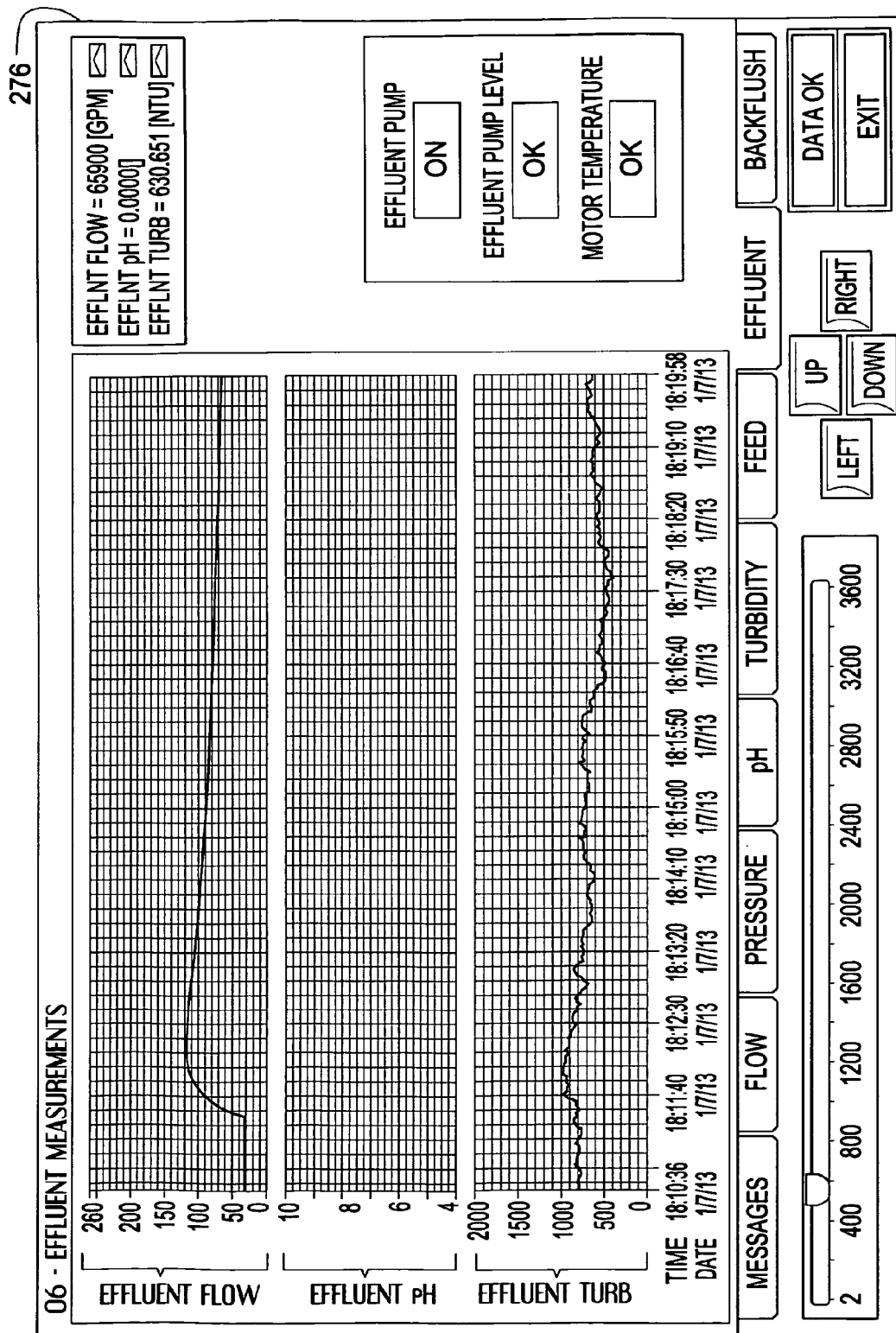


FIG.29E

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URGENT

EFFLUENT PIPE IS EMPTY

SLUDGE PIPE IS EMPTY

ERROR

COMPARTMENT 8 LEVEL IS TOO LOW

INFORMATION

FRAC TANK LEVEL IS ABOVE THE DESIRED VALUE

READY

MESSAGES

FLOW

PRESSURE

pH

TURBIDITY

FEED

EFFLUENT

BACKFLUSH

2

400

800

1200

1600

2000

2400

2800

3200

3600

UP

DOWN

LEFT

RIGHT

DATA OK

EXIT

FIG.29F

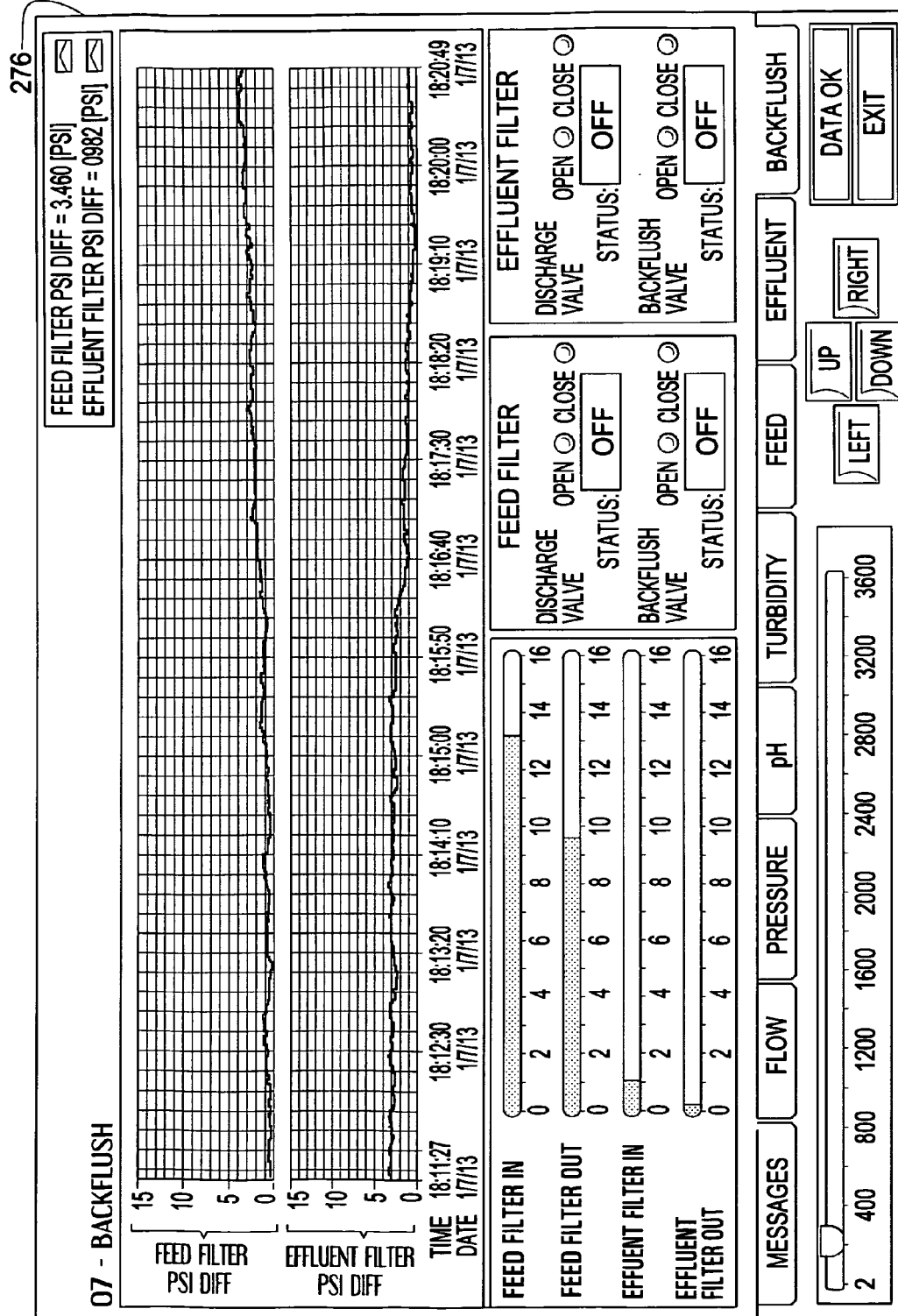


FIG.29G

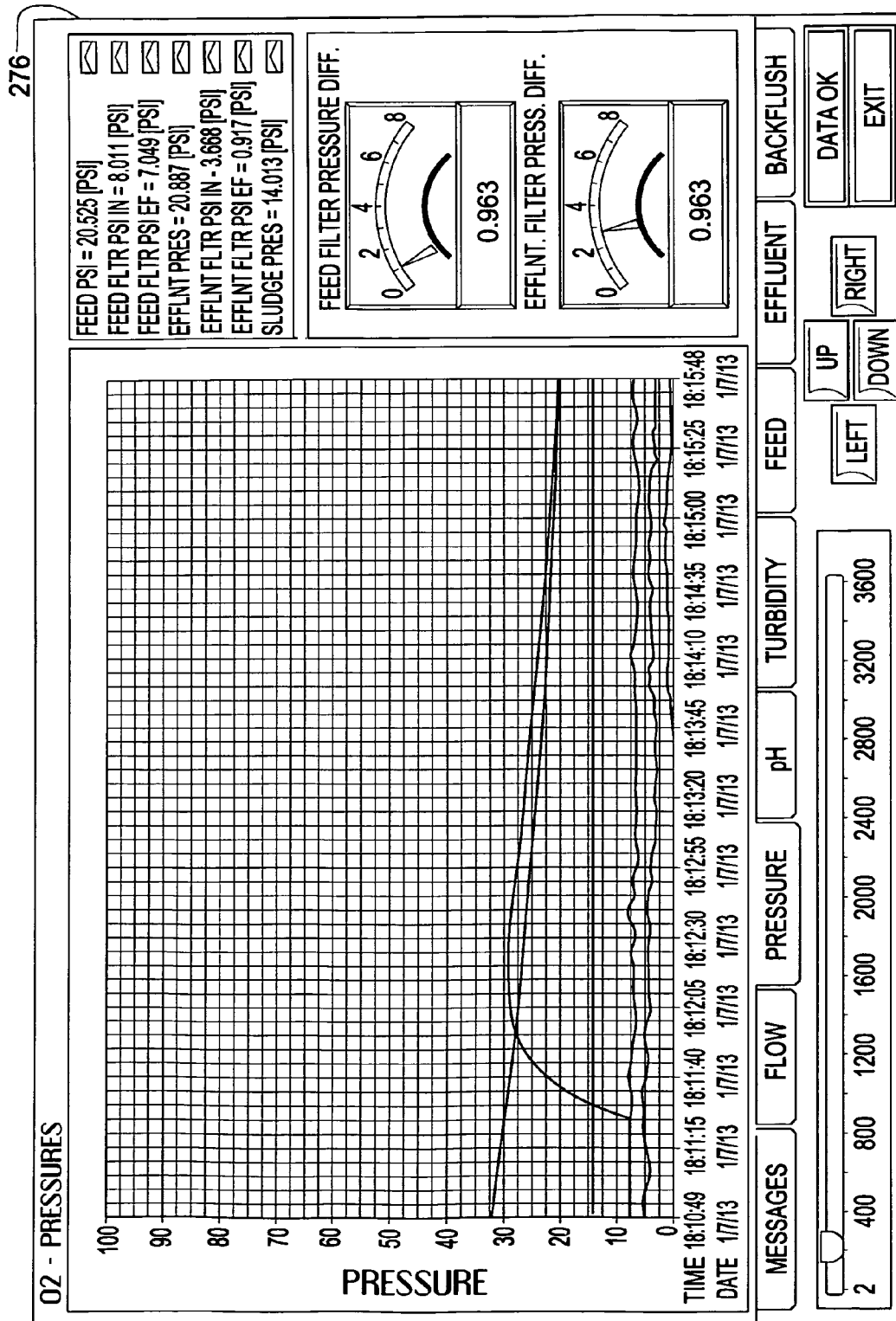


FIG.29H

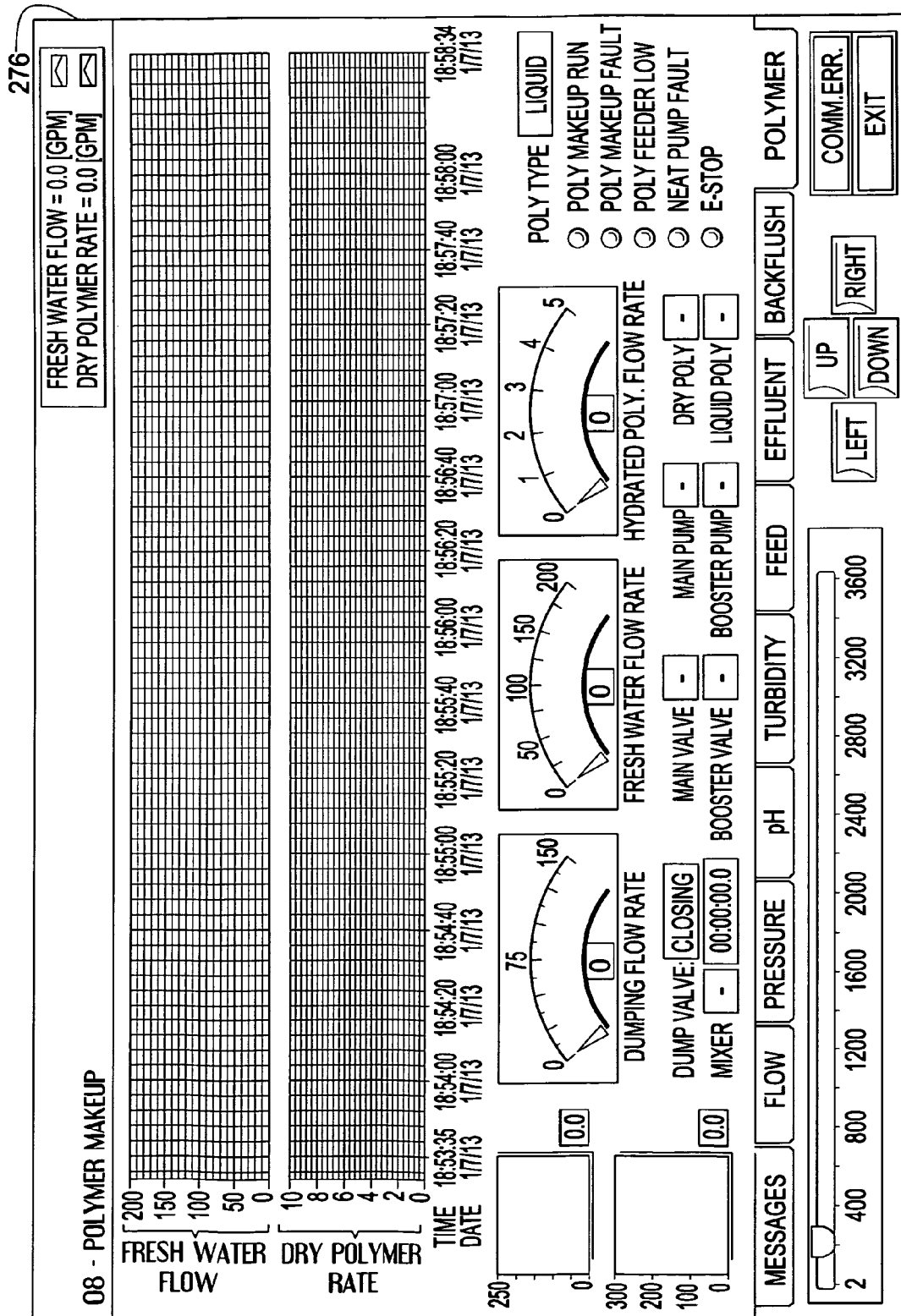


FIG.29I

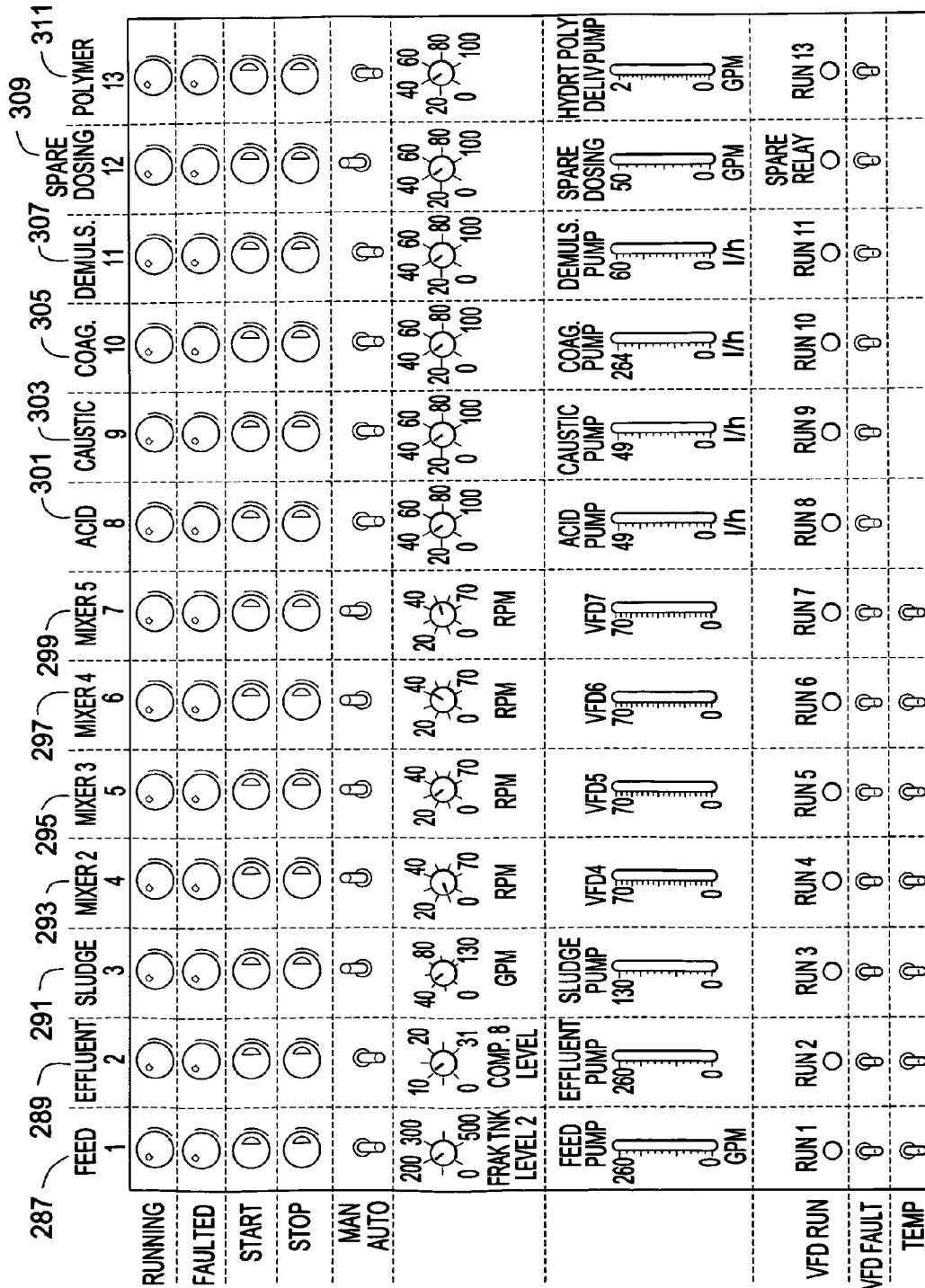


FIG. 30

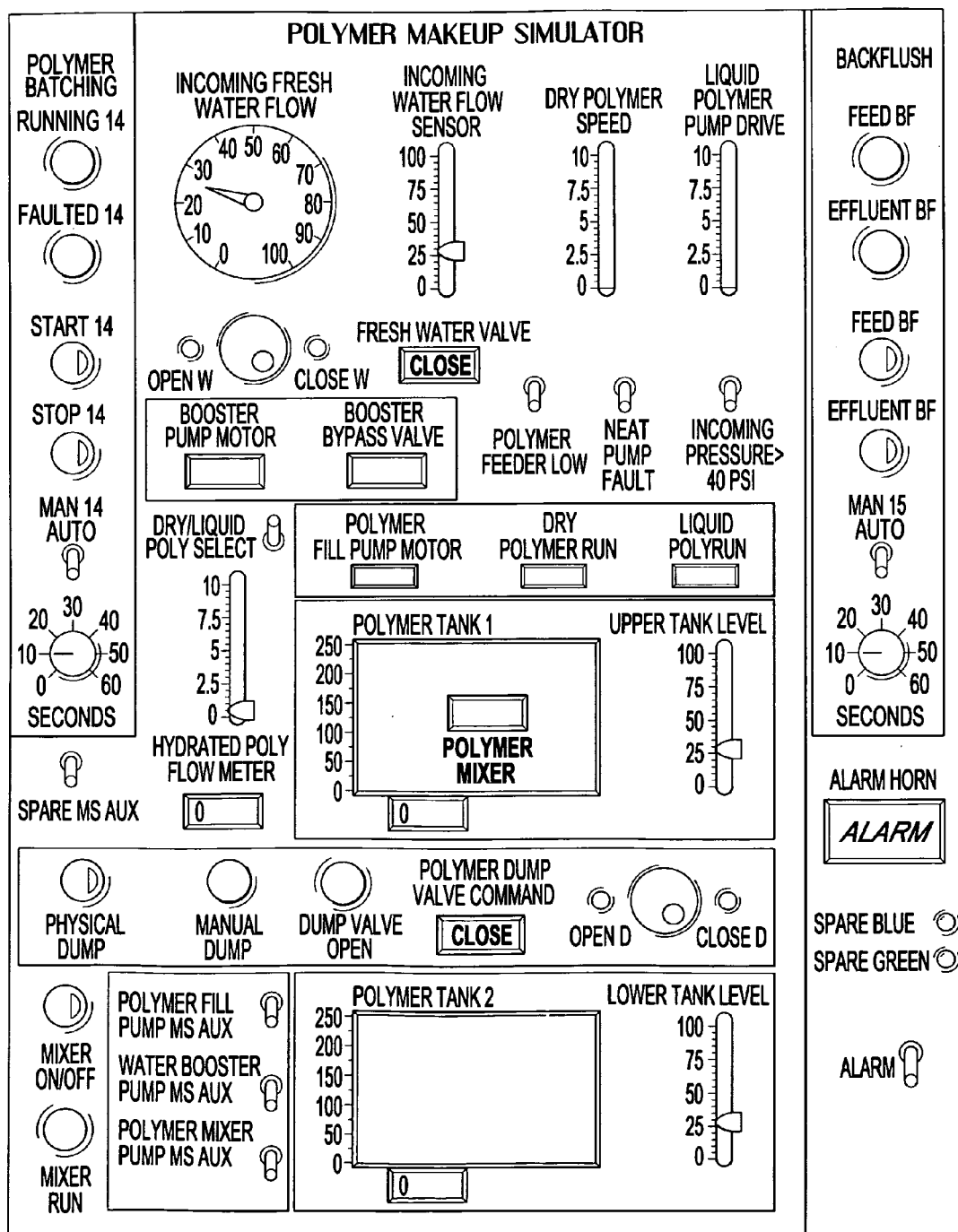


FIG.31

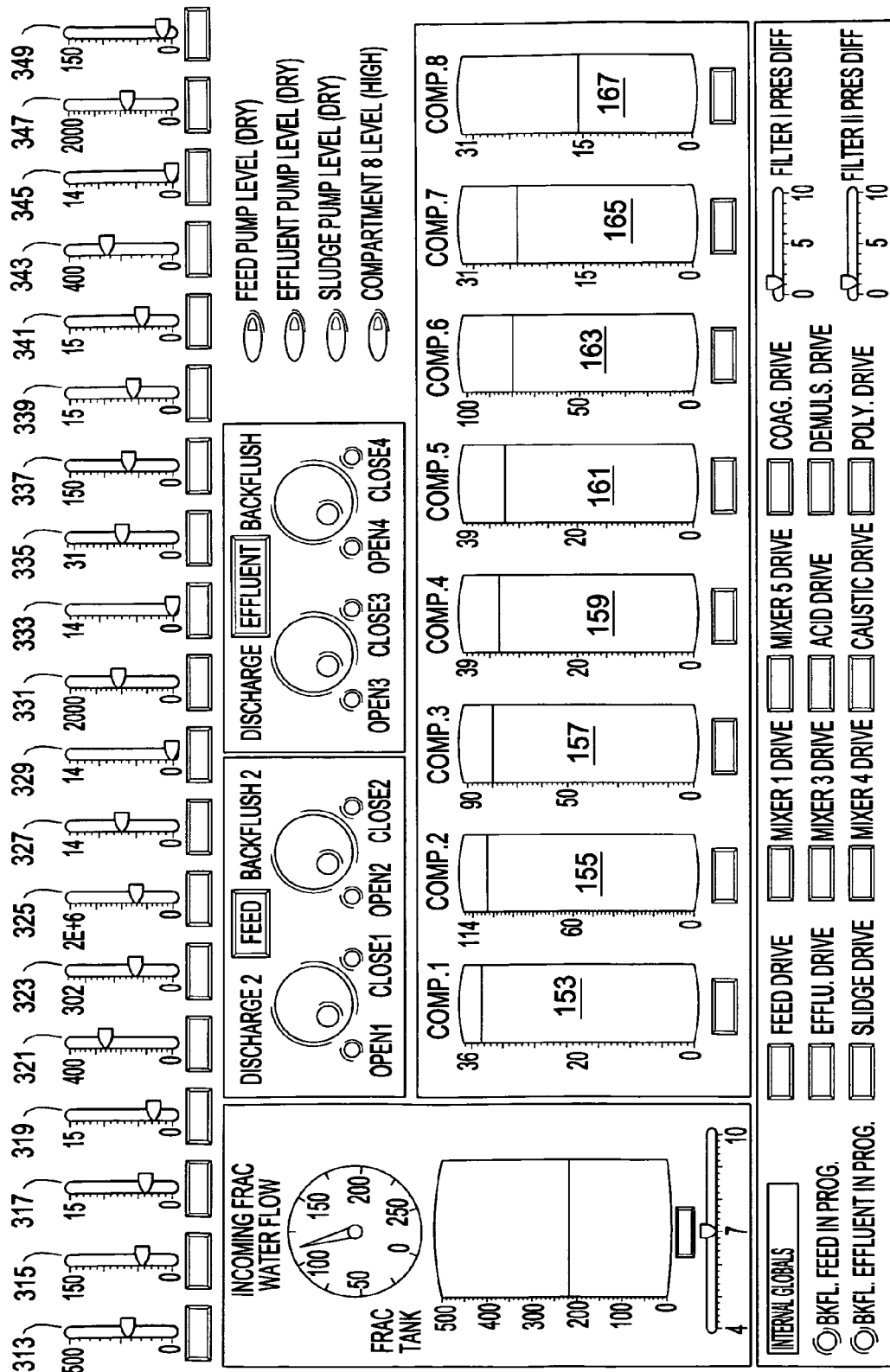


FIG. 32

LIQUID TREATMENT STATION INCLUDING PLURAL MOBILE UNITS AND METHODS FOR OPERATION THEREOF

FIELD OF THE INVENTION

[0001] This invention is related to cleaning of liquids, especially water, and more particularly relates to industrial process liquid cleaning at remote locations such as oil or gas well drilling sites and the like.

BACKGROUND OF THE INVENTION

[0002] Mobile water treatment units have been heretofore suggested and/or utilized for various purposes including facilities modeling (see U.S. Patent Publication No. 2009/0032346), emergency or remote water supply (see U.S. Pat. Nos. 6,464,884, 5,632,892, 6,120,688, and 6,228,255), mining and industrial uses (see U.S. Pat. Nos. 4,383,920, 5,558,775, 5,547,584 and 6,607,668, and U.S. Patent Publication No. 2012/0312755), and addressing polluted water sources and waterways (see U.S. Patent Publication No. 2002/0033363 and U.S. Pat. Nos. 5,741,416 and 5,972,216). These units have often required extensive power supply installations and/or site preparations (leveling, leak sealing and the like). Moreover, such devices have not proven entirely effective (in terms of treatment efficacy, throughput and/or cost) for many industrial uses, particularly in the field of oil and gas drilling and production.

[0003] Induced hydraulic fracturing or hydro-fracturing, commonly known as “fracking”, is a technique using a slurry of water mixed with sand and chemicals (called “fracking fluids”). This mixture is injected at high pressure into oil and gas well bores to cause fracturing of surrounding rock structures and thereby create pathways for petroleum and natural gas to migrate through the rock and into the wellbore. Hydro-fracturing techniques have improved well production. However, fracking utilizes large quantities of water at the well site, often taken from a regional water supply having numerous alternative uses including industrial, agricultural and municipal uses. Fresh water used for such purposes must often be trucked to the well site for makeup of fracking fluids. Moreover, a large percentage of the fracking fluid returns to the surface of the well after mixing with fluid and other substances in the fractured rock formation (called “flowback”). Thus, a large quantity of unclean water (fracking flowback liquid) including the fracking fluid itself and liquids and solids that are native to the oil and gas producing formation (such as petroleum products and heavy metals) must be treated or safely disposed of. Trucking flowback fluids offsite for disposal or treatment is expensive.

[0004] Treatment of flowback liquid at the well site for reuse would result in large reductions of freshwater supplied to and used at the site while reducing waste water and the related costs thereof. Reduction in use of fresh water resources and related transportation costs and reduction of waste water volumes and related transportation and off-site treatment or disposal costs would thus be highly desirable in oil and gas extraction operations and would also benefit the communities where drilling occurs.

SUMMARY OF THE INVENTION

[0005] This invention provides a liquid treatment station and plural mobile treatment units and methods for control and operation thereof. This invention is particularly well adapted

for improved industrial process water treatment, for example flowback water treatment at oil and gas hydraulic fracturing sites. The station has separate mobile treatment and mobile treatment management units, the mobile liquid treatment unit being greatly improved over similar heretofore utilized treatment technologies. The liquid treatment management unit controls operation of the liquid treatment unit and provides control of chemical dosing. The station and units of this invention require minimal utility support/supply and site preparation, provide effective and safe treatment of water, and have enhanced throughput at reduced cost at industrial treatment sites such as oil and gas drilling and production sites. The units thereby reduce water hauling and related costs to well sites and waste water hauling away from well sites, while conserving water resources.

[0006] The mobile primary liquid treatment unit of this invention includes a mobile platform having a foul liquid intake end and a purified liquid output end. A plurality of liquid containment compartments each having a volume with an upper portion and a lower portion are defined and serially arranged at the mobile platform. The compartments in turn define plural serial cascade stages, each of the stages cascading from one to the next between the intake end and the output end. A Majority of the compartments have structure for liquid inflow at the lower portion of the volume thereof from an adjacent compartment and structure for liquid outflow at the upper portion of the volume thereof to another adjacent compartment.

[0007] The liquid treatment station of this invention includes both the mobile primary liquid treatment unit and an independently mobile treatment management unit. Selected liquid treatment functions are performed at the containment compartments of the primary treatment unit including chemical dosing and mixing and solids separation. A plurality of sensors with sensor outputs, a plurality of chemical dosing pumps, mixers and valves having connections for operational control and feedback, and a power and data transfer terminal are located at the primary treatment unit. The management unit preferably includes a mobile platform having a treatment controller center, a chemical dosing control center and at least a first auxiliary functions center thereat. A plurality of chemical dosing platforms and a central power and processing assembly including an externally located power and data input and output terminal are located at the management unit, the dosing platforms including chemical storage connectable with dosing pump assemblies operatively associated with the power and processing assembly and have dosing outputs connected with a dosing manifold.

[0008] A bus is connectable between the power and data input and output terminal at the management unit and the power and data transfer terminal at the primary treatment unit. Chemical feed line assemblies are selectively connectable between the dosing manifold of the management unit and the dosing inputs at the primary treatment unit. In this manner chemical dosing control, pump, mixer and valve operational control, and feedback and data acquisition at both the units are controlled at the power and processing assembly of the management unit.

[0009] A pressure sensor is connected between the power and processing assembly at the management unit and an on-site source of foul fluid received at a feed pump located at the intake end of the primary treatment unit. Infeed and throughflow are monitored and controlled by reference to available volume of foul fluid at the source.

[0010] The treatment unit includes at least seven water containment and treating compartments (preferably eight, including a buffer compartment). The structure for liquid inflow include a plurality of intervening diving structures one of adjacent to or located between at least some of the compartments for receiving and directing liquid to an adjacent compartment at the lower portion thereof. Each of the compartments has flow accommodating components thereat. At least some of the compartments include liquid flow leveling features for independent adjustment of the flow accommodating components in both longitudinal and transverse directions. The features thereby selectively compensate for unlevel location of the mobile platform at a treatment site and thus unit sloping.

[0011] The methods of this invention for process control of a mobile liquid treatment unit include the steps of sensing attributes of liquid to be treated at the treatment unit and providing first electronic outputs indicative thereof. Attributes of operational functioning of selected treatment unit components are sensed and second electronic outputs indicative thereof are provided. The electronic outputs are received remotely from the treatment unit at an automated treatment management unit and process control signals are generated responsive thereto. Chemical dosing at the management unit is prepared responsive to the control signals. The control signals are received at the treatment unit for selectively adapting the attributes of operational functioning responsive thereto, and chemical dosing is received at the treatment unit from the prepared chemical dosing at the treatment management unit. Volume of liquid to be treated at a source tank is sensed and third electronic output indicative thereof is provided, this output also received remotely from the source tank at the management unit. Flow rate control signals are generated responsive thereto, the control signals received at the treatment unit for adapting the attributes of operational functioning related to liquid infeed and through-flow responsive thereto.

[0012] The methods for operation of a mobile liquid treatment station include the steps of intake of liquid to be treated at a mobile primary liquid treatment unit and cascading the liquid serially through a plurality of liquid treatment compartments. Selected liquid treatment functions are performed at the compartments responsive to process control programming at an independently mobile treatment management unit, the treatment functions including chemical dosing and mixing and solids separation. Attributes of the liquid at the treatment unit and of operational functioning of selected treatment unit components are sensed and electronic outputs indicative thereof are provided. The outputs are received at the treatment management unit whereat chemical dosing is prepared responsive thereto. The prepared chemical dosing is fed from the treatment management unit to selected ones of the compartments of the treatment unit. After treatment completion, the treated liquid is output from the treatment unit.

[0013] It is therefore an object of this invention to provide a liquid treatment station and plural mobile treatment units and methods for control and operation thereof.

[0014] It is another object of this invention to provide a liquid treatment station having separate mobile treatment and mobile treatment management units.

[0015] It is yet another object of this invention to provide improved mobile liquid treatment units and methods.

[0016] It is another object of this invention to provide a mobile liquid treatment management unit and methods for control of a liquid treatment unit.

[0017] It is still another object of this invention to provide methods for separate control of chemical dosing and liquid treatment at a liquid treatment station.

[0018] It is another object of this invention to provide improved flowback water treatment and methods at oil and gas fracking sites.

[0019] It is still another object of this invention to provide a mobile liquid treatment station and units which require minimal utility support/supply and site preparation.

[0020] It is yet another object of this invention to provide a mobile liquid treatment station and methods that provide effective and safe treatment of water and have enhanced throughput at reduced cost at industrial treatment sites such as oil and gas drilling and production sites.

[0021] It is still another object of this invention to provide a mobile liquid treatment station having mobile units and methods that reduce water hauling to and from treatment sites, use of precious water supply and water treatment resources, and related costs.

[0022] It is yet another object of this invention to provide a mobile liquid treatment unit that includes a mobile platform having a foul liquid intake end and a purified liquid output end, and a plurality of liquid containment compartments each having a volume with an upper portion and a lower portion, the compartments defined and serially arranged at the mobile platform for defining plural serial cascade stages from the intake end to the output end, each of the stages cascading from one to the next between the intake end and the output end, and a majority of the compartments each including structure for liquid inflow at the lower portion of the volume thereof from an adjacent compartment and structure for liquid outflow at the upper portion of the volume thereof to another adjacent compartment.

[0023] It is yet another object of this invention to provide a mobile liquid treatment station that includes a mobile primary liquid treatment unit having a foul liquid intake end and a purified liquid output end with a plurality of liquid containment compartments defined and serially arranged therebetween for performance of selected liquid treatment functions thereat including chemical dosing and mixing and solids separation, the primary treatment unit having a plurality of sensors thereat with sensor outputs, a plurality of chemical dosing inputs at different ones of the compartments, a plurality of pumps, mixers and valves having connections for operational control and feedback, and a power and data transfer terminal connected with the connections of the pumps, mixers and valves and the sensor outputs from the sensors, an independently mobile treatment management unit having a plurality of chemical dosing platforms, an externally located dosing manifold and a central power and processing assembly therein, the power and processing assembly including an externally located power and data input and output terminal, and the chemical dosing platforms including chemical storage connectable with dosing pump assemblies operatively associated with the power and processing assembly and having dosing outputs connected with the manifold, a bus connectable between the power and data input and output terminal of the power and processing assembly of the management unit and the power and data transfer terminal of the primary treatment unit, and chemical feed line assemblies selectively connectable between the dosing manifold of the management

unit and the dosing inputs at the compartments of the primary treatment unit, wherein chemical dosing control, pump, mixer and valve operational control, and feedback and data acquisition at both the units are controlled at the power and processing assembly of the management unit.

[0024] It is another object of this invention to provide a mobile liquid treatment station having a primary treatment unit and a separate treatment management unit than includes a pressure sensor connected between the treatment management unit and an on-site source of foul fluid received at a feed pump located at the intake end of the primary treatment unit for infeed and throughflow control and monitoring based on available volume of foul fluid at the source.

[0025] It is still another object of this invention to provide a treatment unit for receiving and processing industrial process water that includes a mobile platform having a foul water intake end and a purified water output end, at least seven water containment and treating compartments at the mobile platform serially arranged between the ends and each having an upper portion and a lower portion, and a plurality of intervening diving structures one of adjacent to or located between at least some of the compartments for receiving and directing the process water to an adjacent compartment at the lower portion thereof.

[0026] It is still another object of this invention to provide a mobile liquid treatment unit locatable at a selected site having a mobile platform with a foul liquid intake end and a purified liquid output end, and a plurality of liquid containment and treating compartments defined at the mobile platform and serially arranged between the ends to provide cascading flow between at least some of the compartments and each having flow accommodating components thereat, at least some of the compartments including liquid flow leveling features for independent adjustment of the flow accommodating components located therein in both longitudinal and transverse directions to selectively compensate for unlevel location of the mobile platform at the site and thus unit sloping.

[0027] It is yet another object of this invention to provide a mobile liquid treatment management unit which includes a mobile platform, a treatment controller center located at the platform and including a remotely accessible control output and feedback input, a chemical dosing control center located at the platform and operatively associated with the controller center and including remotely accessible chemical dosing outputs, and at least a first auxiliary functions center located at the platform.

[0028] It is yet another object of this invention to provide a method for process control of a mobile liquid treatment unit including the steps of sensing attributes of liquid to be treated at the treatment unit and providing first electronic outputs indicative thereof, sensing attributes of operational functioning of selected treatment unit components and providing second electronic outputs indicative thereof, receiving the electronic outputs remotely from the treatment unit at an automated treatment management unit and generating process control signals responsive thereto, preparing chemical dosing at the automated treatment management unit responsive to the control signals, receiving the control signals at the treatment unit for selectively adapting the attributes of operational functioning responsive thereto, and receiving chemical dosing at the treatment unit from the prepared chemical dosing at the treatment management unit.

[0029] It is another object of this invention to provide a method for process control of a mobile liquid treatment unit

including the steps of sensing volume of liquid to be treated at a source tank and providing electronic output indicative thereof, receiving the electronic output remotely from the source tank at an automated treatment management unit and generating flow rate control signals responsive thereto, and receiving the flow rate control signals at a treatment unit for adapting attributes of operational functioning related to liquid infeed and throughflow responsive thereto.

[0030] It is yet another object of this invention to provide a method for operation of a mobile liquid treatment station that includes the steps of intake of liquid to be treated at a mobile primary liquid treatment unit, cascading the liquid serially through a plurality of liquid treatment compartments, performing selected liquid treatment functions at the compartments responsive to process control programming at an independently mobile treatment management unit, the treatment functions including chemical dosing and mixing and solids separation, sensing attributes of the liquid at the treatment unit and attributes of operational functioning of selected treatment unit components and providing electronic outputs indicative thereof, receiving the outputs at the treatment management unit, preparing chemical dosing at the treatment management unit responsive to the received outputs, feeding prepared chemical dosing from the treatment management unit to selected ones of the compartments of the treatment unit, and output of treated liquid from the treatment unit.

[0031] With these and other objects in view, which will become apparent to one skilled in the art as the description proceeds, this invention resides in the novel construction, combination, and arrangement of parts and methods substantially as hereinafter described, and more particularly defined by the appended claims, it being understood that changes in the precise embodiment of the herein disclosed invention are meant to be included as come within the scope of the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] The accompanying drawings illustrate a complete embodiment of the invention according to a mode devised for the practical application of the principles thereof, and in which:

[0033] FIG. 1 is a perspective view of the mobile primary treatment unit of the mobile liquid treatment station of this invention with the top walking grate, inclined plate interceptor pack and lamella separators removed;

[0034] FIG. 2 is a side view of the unit of FIG. 1;

[0035] FIG. 3 is an opposite side view of the unit of FIG. 1;

[0036] FIG. 4 is a top view of the unit of FIG. 1;

[0037] FIG. 5 is a bottom view of the unit of FIG. 1;

[0038] FIG. 6 is a front view of the unit of FIG. 1;

[0039] FIG. 7 is a rear view of the unit of FIG. 1;

[0040] FIG. 8 is an illustration of throughflow at the unit of FIG. 1;

[0041] FIG. 9 is a sectional view taken through section lines 9-9 of FIG. 5;

[0042] FIG. 10 is an illustration of the unit of FIG. 1 without its side liquid containment walls;

[0043] FIG. 11 is a partial perspective view of the fluid uptake end of the unit of FIG. 1;

[0044] FIG. 12 is a sectional view taken through section lines 12-12 of FIG. 1;

[0045] FIG. 13 is a sectional view taken through section lines 13-13 of FIG. 1;

[0046] FIG. 14 is a sectional view taken through lines 14-14 of FIG. 5;

[0047] FIG. 15 is a sectional view taken through lines 15-15 of FIG. 1;

[0048] FIG. 16 is a sectional view taken through lines 16-16 of FIG. 6;

[0049] FIG. 17 is a partial perspective view of the clarified liquid output end of the unit of FIG. 1;

[0050] FIG. 18 is a sectional view taken through section lines 18-18 of FIG. 1;

[0051] FIG. 19 is a sectional view taken through section lines 19-19 of FIG. 1;

[0052] FIG. 20 is a partial sectional view taken through lines 20-20 of FIG. 1;

[0053] FIG. 21 is a partial sectional view taken through lines 21-21 of FIG. 1;

[0054] FIG. 22 is a side view illustration of the mobile treatment management unit of the mobile liquid treatment station of this invention;

[0055] FIG. 23 is a top view of the unit of FIG. 22;

[0056] FIG. 24 is an opposite side view of the unit of FIG. 22;

[0057] FIG. 25 is a perspective view of dosing cabinets and chemical storage of the unit of FIG. 22;

[0058] FIG. 26 is a schematic wiring and unit interconnections diagram of the mobile liquid treatment station of this invention;

[0059] FIG. 27 is a diagram illustrating control and feedback operations between the units of FIGS. 1 and 22;

[0060] FIG. 28 is a flow chart illustrating software control of the various apparatus in the units of FIGS. 1 and 22;

[0061] FIGS. 29A through 29H are illustrations of the process and data acquisition controls of this invention;

[0062] FIG. 30 is an illustration showing a software controller and training simulator of this invention;

[0063] FIG. 31 is another illustration of the software controller and simulator of this invention; and

[0064] FIG. 32 is yet another illustration of the software controller and simulator of this invention.

DESCRIPTION OF THE INVENTION

[0065] A mobile liquid treatment station 35 of this invention is illustrated in the FIGURES. The station can be used at selected sites in any number of liquid (primarily water) treatment applications, and, as illustrated herein, is well adapted for treating industrial process liquids, such as flowback water at oil and gas fracking sites. The station includes primary mobile liquid treatment unit 37 (see FIGS. 1 through 21) and independently mobile treatment management unit 39 (see FIGS. 22 through 25). Each unit 37/39 is mounted on a mobile (wheeled) platform 41, typical two axle long haul trailers, for example.

[0066] Mobile primary liquid treatment unit 37 has an intake end 43 for receipt of liquid to be treated (hereinafter “foul liquid” or “foul water”, for example fracking process flowback water) and a purified liquid output end 45 with a plurality of liquid containment and treatment compartments 47 defined and serially arranged therebetween. The compartments are dimensioned and located for promoting cascading flow and for performance of selected liquid treatment functions thereat (such as chemical dosing and mixing and solids separation as further disclosed hereinafter). Compartments 47 provide staged, sequential, chemical treatment and phase or solid separation (while any number of compartments suitable to the particular tasks at hand can be incorporated into unit 37 and fall within the scope of this invention, at least 7

compartments are particularly illustrated herein, which number is often best suited for many if not most operations, with eight being preferred including the buffer tank).

[0067] A plurality of sensors (pH meter 49 and turbidity meter 51 at intake and output ends 43 and 45, respectively, for example—see FIGS. 6 and 7) are provided and attached to sensor probes (53, for example, in FIG. 4) selectively positioned throughout the unit. Meter location and number, together with probe location, type and number, may be varied from application to application and as the treatment situation may dictate. Placement of sensors/probes early in the flow path is better suited to characterization of foul water quality, while positioning later in the path is better suited to characterization of treatment efficacy. Other sensor positioning may be particularly adapted to characterization of particular treatment functions and attributes of operational functioning of selected treatment unit components. All such sensors include output connections for electronic signal outputs indicative of sensor measurement data connected to power and data transfer terminal 55 (located in utilities box 57 as illustrated in FIG. 11).

[0068] A plurality of chemical dosing inputs 59 are located at support boxes 61 (see FIGS. 2 and 9) at different ones of compartments 47. As shown in FIGS. 6, 7, 9, 12, 17 and 18, a plurality of pumps (feed pump 63 and outflow pump 65, for example), mixers 69 (including impellers 71 connected with drive motors 73), automated back flush filter assemblies 75, and motorized/manual valves 77 having connections for operational control and feedback through terminal 55 are provided in conventional arrangement for the various functions as described hereinafter.

[0069] Independently mobile treatment management unit 39 in FIGS. 22 through 25 includes a plurality of chemical dosing platforms 81, an externally located dosing manifold 83 and a central power and processing assembly 85 serviced through externally located power and data input and output terminal 87 (as more fully discussed hereinafter). Terminal 87 may include multiple nodes (for pumps and mixers control output from connection nodes at the side of the unit, and for 120 V power, an emergency stop, an Ethernet bus for movement of control and data signals, and sensory feedback at nodes on the rear of the unit, for example). Chemical dosing platforms 81 include dosing cabinets 89, polymer storage and flocculant makeup system 91, and demulsifier storage and makeup room 93. Chemical storage 95 are connectable with a plurality of dosing pumps 97 connected with power and processing assembly 85 and having dosing outputs connected with manifold 83. A conventional bus or busses are connectable between terminal 87 at management unit 39 and transfer terminal 55 of primary treatment unit 37. Conventional chemical feed line assemblies are selectively connectable between dosing manifold 83 of management unit 39 and dosing inputs 59 at compartments 47 of treatment unit 37. Thus, as may be appreciated, dosing control, component operations and data acquisition and feedback at both units 37 and 39 are controlled and received at power and processing assembly 85 of management unit 39.

[0070] While not illustrated, station 35 of this invention employs a pressure sensor connected between power and processing assembly 85 at management unit 39 and an on-site source of foul fluid (a third party flowback receiving tank, for example) into which the sensor is inserted (via lance, for example). Fluid from the source is received at variable speed feed pump 63 through input connection 101 (FIG. 6) located

at intake end 43 of treatment unit 37. Unit 37 infeed and throughflow control and monitoring may thus be based on available volume of foul fluid at the source sensed by the pressure sensor inserted thereat.

[0071] Liquid containment compartments 47 each have a volume 103 with an upper volume portion 105 and a lower volume portion 107 (see FIG. 19, for example, typical of all compartments 47 in this regard). Compartments 47 define plural serial cascade stages 109 (preferably seven, as shown in FIGS. 1, 2 and 8) between intake end 43 and output end 45. As illustrated in FIG. 8, each stage 109 cascades from one to the next between intake end 43 and output end 45. Moreover, a majority of compartments 47 include either a diving wall or pipe structure 111 for liquid inflow at lower portions 107 of volume 103 thereof below chemical dosing inputs 59 and impellers 71 from an adjacent compartment 47, and a weir or weir pipe structure 115 (water level adjustable openings of selected size) for liquid outflow at upper portion 105 of volume 103 thereof to another adjacent compartment (see FIGS. 8 through 10 and 13 through 15). Hydrostatic pressure in the system and configuration of impellers 71 of mixers 69 promote fluid lifting during mixing (i.e. reinforcing upflow currents in compartments 47 during mixing). This over-under cascading flow design using overall unit height variation and diving walls or pipes feeding the lower portions of the compartment volumes, and with chemical injection at the lower portions of the compartment volumes, and lifting/mixing for overflow over an adjustable pipe or weir structure allows for pumpless flow between compartments with greater mixing efficacy while minimizing chemical usage.

[0072] As shown in FIGS. 8 through 10, 12 and 18, back flush filter assemblies 75 both include a by-pass back flush liquid output line 119 for directing back flush liquid (using hoses) directly to input line 121 feeding into solids separation stage upon performance of a back flush. Various flow accommodating components 123 are located in compartments 47 (in addition to diving wall or pipe structures 111 and weir or weir pipe structures 115), at least some compartments 47 also including liquid flow leveling features 124 for independent internal leveling of flow accommodating components 123 located therein in both longitudinal and transverse directions. The leveling features 124 at components 123 serve to selectively compensate for unlevel location of the mobile platform at the site and thus unit 37 sloping. These components include first and second horizontally disposed clarified liquid outflow pipes 125 in a compartment 47 more adjacent to output end 45 of mobile platform 41 (see FIGS. 4 and 20), wherein the leveling features 124 include threaded or equivalent apparatus 127 for independently selectively raising and lowering a distal end of each of outflow pipes 125. Components 123 also include first and second upright pipes 115 in a compartment 47 more adjacent to intake end 43 of mobile platform 41, leveling features 124 including height adjustable fluid outlet ends 129 (i.e., weir tops) at a top portion of upright pipes 115 (see FIGS. 13 and 14). Oil separator trough 131 at one of compartments 47 and having a separated oil outlet 133 at a corner thereof is another example of the components 123, the leveling features 124 including threaded or equivalently functional apparatus 135 for adjusting tilt of the trough in both longitudinal and transverse directions (see FIGS. 4 and 21).

[0073] Mobile liquid treatment station 35 employs chemically enhanced oil/water separation, coagulation, pH-buffering, flocculation and settling for onsite treatment of industrial process water such as flowback water, for example, for the

purpose of onsite or nearby site reuse. The multi-compartment cascading tank unit 37 of station 35 is used in a selective sequential treatment train controlled from management unit 39 of station 35 which also houses chemical treatment dosing apparatus and supplies.

[0074] For on-site operation in an oil/gas fracking process, additional equipment is needed for operation and completion. These include a mobile dewatering system (a centrifuge, screw press or filter press, for example), a solids containment unit, an effluent catch tank with return pump, connection hoses and power cords, a 3-phase generator for all of the above (100 kW for example, depending on the equipment), a diesel fuel tank, a fresh water tank, and a flowback storage tank. These are generally provided by the site operator or a contract service company.

[0075] Onsite flowback tanks are used for the storage of flowback water, where several frack tanks are connected together. At manhole cover level, above the tank bottom, an effluent conduit is located to minimize suspensions in the feed to mobile treatment unit 37. The effluent conduit is provided with a hydrostatic pressure sensor attached to a manhole cover or other designated outlet from the storage tank. Sensor output signals are linked to processing assembly 85 of management unit 39. The tank outlet is then connected to treatment unit 37 by a flexible suction hose. The pressure sensor measurement signals are utilized for control of feed into treatment unit 37 based upon the volume of flowback fluid remaining in the tank. Withdrawal of the flowback fluid from the tank for receipt by treatment unit 37 is controlled by the process control software program at assembly 85. The flowback tank need not be modified. The pressure sensor is preferably designed to be inserted into the flowback tank with a lance, but could be directly attached to one of the tank's available suction or discharge valves via a quick disconnect such as a CAMLOK fitting.

[0076] For a flexible flowback treatment process, treatment unit 37 is configurable with at least seven different serially arranged treatment compartments 47 (preferably eight). Pre-treatment and post-treatment equipment is located at intake end 43 and output end 45, respectively, on platform 41, with pre-treatment equipment situated above the trailer's double axle assembly 137 and post-treatment equipment located above the trailer's hook-up king pin area 139 (FIG. 5). Pre-treatment and post-treatment equipment consists of specific pumps, filters, flow control devices (motorized and manual valves, for example) and process control instrumentation.

[0077] Unit 37 for use in flowback treatment is preferably constructed from A36 low carbon steel and coated inside with an epoxy resin for protection from corrosion. Polyurethane paint is used on the outside of the unit for protection from oilfield use. All flowback processing pipe spools and adjustable weirs are constructed from 300 series stainless steel to resist corrosion from high salinity flowback water. All chemical injection pipe spools, except the demulsifier pipe spool, are constructed from schedule 80 UV stabilized PVDF or other non-corrosive material. The demulsifier pipe spool is constructed from 316L stainless steel. While not shown, the open top 141 of unit 37 of the unit is covered with a removable, worker supporting grating resting on cross members 143 and tank walls 145 also supporting various equipment such as mixers 69, for example (see FIG. 4). Handrails, which are folded down during transport, are provided at the grating.

Access for inspection, maintenance and repair of unit **37** is preferably provided through designated grating doors, man-holes and access ports.

[0078] Because of the wide range of the flow rate ($6 \text{ m}^3/\text{h}$ to $60 \text{ m}^3/\text{h}$) and the wide discharge head range (0.1 bar up to 3 bars), feed pump **63** is preferably a positive displacement, variable speed rotary lobe pump for feeding flowback water received at input connection **101** to unit compartments **47**, the speed of which is controlled by the readings from the hydrostatic pressure sensor in the flowback tank. The variable speed of the pump accommodates continuous feed, which prevents liquid freezing and allows downstream chemical injection equipment to operate on a continuous basis. The process controlled continuous feed of chemicals allows operation without resetting chemical feed rates. Feed pump lobes are preferably coated with VITON, and pump **63** preferably meets explosion-proof (XP) requirements, particularly the variable frequency drive (VFD) motor thereof. In comparison with other pumps, maintenance of the rotary lobe pump is simple since all wetted parts can be replaced through the front cover thereof without disconnecting pipes.

[0079] Turning now to FIGS. **4**, **8**, **9** and **11** through **18**, specific components and functions of unit **37** of station **35** will be addressed in greater detail. In order to eliminate larger solids in the feed water, strainer **151** is interposed between input connection **101** and feed pump **63**. Back flush filter **75** eliminates or minimizes finer solids, and an automated back flush filter, such as a VAF **1000** with a mesh size of $500 \mu\text{m}$, is preferable. Back flushing starts when the pressure drop over the back flush filter exceeds 0.4 bar as sensed and provided as feedback to process controls at processing assembly **85** of management unit **39**. Filter back flush requires a water volume of about 0.1 m^3 . As noted, back flush water is either conducted back to the flowback storage tanks or, preferably, to sludge separation compartment **47** by discharge hoses.

[0080] The size of the back flush filter may be modified by changing screen size. Process control software continuously receives data which permits development of programming for optimizing screen size best suited for a particular category of flowback fluid. Flowback fluid characteristics will be similar when common fracking fluids are used in common geological formations. Optimum screen size information can be based, for example, upon back flush frequency.

[0081] In serial order, compartments **47**, and thus defined stages **109**, include emulsion breaking compartment **153**, oil separation compartment **155**, chemical dosing and polymer treatment compartments **157**, **159** and **161**, solids separation compartment **163**, and final dosing compartment **165**. A buffer compartment **167** is provided at output end **45** for flow control purposes. Emulsion breaking compartment **153** preferably has a volume of about 5.73 m^3 . Flowback water is conducted through diving pipe **169** into compartment **153** into which a demulsifier is dosed from management unit **39** through dosing inputs **59**. The specific dosing rate of the demulsifier is about $0.51/\text{m}^3$. For mixing, a worm drive top-entry mixer **69**, such as a BURHANS-SHARPE mixer, with a VFD-motor **73** is used. The speed of the mixer is about 90 rpm for most operations. A hydrofoil impeller **71** preferably has a diameter of about 28 inches to avoid settling of solids. To avoid an increase of the oil layer on the water surface in compartment **153**, treated water passes over stationary weir trough **171** and through pipe(s) **173** into compartment **155**. A heater may be provide at compartment **153** and is controlled automatically by measurement of oil content on the fly. Grab

samples are analyzed in a lab facility provided at management unit **39** to measure hydrocarbon content and the extent of emulsification. From the sample data, and with continuous pH and turbidity measurements, software is developed to control the rate of demulsifier injected and the mixing intensity delivered by the variable frequency drive motor controlled mixer motor **73**. As with all chemicals used, data acquisition software at processing assembly **85** will also keep a record of the amount of demulsifier used. In the embodiment illustrated, compartment **153** has a length of about one meter, a width of about 2.4 m, and a weir level of about 3.1 m from datum level.

[0082] Oil separation compartment **155** for oil and grease separation as shown in this embodiment preferably has a volume of about 18.12 m^3 . Oil and grease are separated from the pre-treated flowback liquid by a cocurrent (downflow) inclined plate interceptor pack (IPI) **177**, such as a PIELK-ENROD IPI, conventionally positioned in compartment **155** as illustrated in FIG. **8**. IPI plate pack **177** material is preferably glass-reinforced epoxy. IPI plate pack **177** has a plate distance of about 20 mm, and the plates are set at an angle of about 45 degrees to the horizontal. Plate pack **177** arrangement has a total installed surface area of 175 m^2 so that oil droplets greater than about $50 \mu\text{m}$ and solids greater than about $20 \mu\text{m}$ are separated at the maximum flow rate of $60 \text{ m}^3/\text{hr}$.

[0083] Oil is collected in oil trough **123/131** adjusted for location at the fluid surface level in the compartment as hereinabove disclosed at four points to accommodate oil entry at the volume of water's top and oil draining from the trough through outlet **133** regardless of level of unit **37** at the site. The oil and grease free water is conducted through upright pipes **115/123** from below IPI plate pack **177** into the top of intervening diving structure **111**, fluid levelling from pipes **115/123** adjustable at weir tops **124/129** in order to control the fluid level height in compartment **155** and to compensate for the slope of treatment unit **37** in the longitudinal and transverse directions as positioned at the site. Diving structure **111** has an outlet opening **181** at the bottom thereof into compartment **157**. In the embodiment illustrated, compartment **155** has a length of about 2.5 m, a width of about 2.4 m, and an oil trough level of about 3 m from datum level.

[0084] Compartment **157** is primarily for dosage of coagulants, particularly metal ion base coagulants, through one of dosing inputs **59** and preferably has a volume in the embodiment illustrated of about 14.3 m^3 . The typical expected dosing rate of coagulants is approximately $2 \text{ l}/\text{m}^3$. The specific dosing rate is dependent on the type of coagulant and the constitution of the flowback. For mixing the coagulants, worm drive top-entry mixer **69** is preferred with VFD-motor **73** for high speed mixing. Hydrofoil impeller **71** in such case has a diameter of about 32 inches used to avoid settling of solids. Compartment **157** also accommodates pH level adjustment to optimize the coagulants to their maximum efficiency by dosing acid or caustic. The type of pH buffer dosing, acid or caustic, is dependent upon the type of coagulant used, such as an aluminium ion or ferric ion based coagulant. Each coagulant has its own optimum pH range in which it is effective as a coagulant, for example pH 6.0-7.5 for aluminium ion or pH 4.5 to 7.5 for ferric ion. The pH level is measured by pH sensor **53** (FIG. **4**). The treated water passes over adjustable weir **115** and via diving wall structure **111** into the lower portion of compartment **159** through outlet opening **183**. In the embodiment illustrated, compartment

157 has a length of about 2 m, a width of about 2.4 m, and a weir level of about 2.7 m from datum level.

[0085] Compartment **159** in the embodiment illustrated is for adjusting the pH level and has a volume of about 6.2 m³. The pH level is adjusted by dosing acid or caustic if needed through one of dosing inputs **59** to accommodate the type of polymer used in compartment **161**. For proper blending, worm drive top-entry mixer **69** with a VFD motor **73** is used. Speed of the mixer is about 90 rpm. Hydrofoil impeller **71** with a diameter of about 28 inches is used to avoid settling of solids. Process water passes over adjustable weir **115** into the lower portion of compartment **161** through opening **185** at the lower part of diving wall structure **111**. In this embodiment, compartment **159** preferably has a length of about 1 m, a width of about 2.4 m, and a weir level of about 2.7 m from datum level.

[0086] Compartment **161** is for dosage of polymer flocculants and in the embodiment illustrated preferably has a volume of about 6.2 m³. Water soluble, synthetic and/or organic polymers are added through one of dosing inputs **59** as coagulants or flocculants in compartment **161**. For selection of a suitable polymer, molecular weight, charge type, charge density and product form need to be considered and tested prior to full-scale application. The expected dosing rate of the flocculants at 0.1% concentration is about 10 l/m³. The specific dosing rate is dependent on polymer product and flowback water quality. For mixing the polymer with the flowback water, worm drive top-entry mixer **69** with a VFD motor **73** is preferably used. The rotary speed of the mixer is adjusted to minimize shear of the floc structure. Hydrofoil impeller **71** with a diameter of about 32 inches is preferred to avoid settling of the flocculated solids. The flocculated flowback water suspension passes over adjustable weir **115** into compartment **163** via diving wall structure **111** through opening **187**. Efficiency of the polymer treatment is sensed and reported at turbidity meter **51**. In this embodiment, compartment **161** preferably has a length of about 1 m, a width of about 2.4 m, and a weir level of about 2.7 m from datum level.

[0087] Compartment **163** is for solid separation and sludge removal and in this embodiment preferably has a volume of about 15.9 m³. Flocculated solids (sludge) are separated by a lamella separator assembly **191** (partially illustrated in FIG. 9). The solids phase of the flocculated flowback water suspension is precipitated out from the liquid phase in this compartment, with enhanced precipitation provided by use of a counter current (upflow) lamella tube settler **191** such as a DEGREMONT separator from HAGER+ELSASSER. The material used in construction of this lamella tube settler is polyethylene, the lamella pack in this case having a total height of about 650 mm and a lamella slope angle of about 60° to the horizontal. In the embodiment illustrated, the preferred length of compartment **163** is about 3.6 m, with a width of about 2.4 m, and a weir level of about 2.7 m from the datum level.

[0088] The precipitated sludge settles out into two tapered (trapezoids) sludge cones **193** located under the lamella separator, where it is further compressed by gravity (a dual separation and concentration cone device). The settled sludges are pumped by means of variable speed rotary lobe pump **195** through cone outlet piping **197** and outlet connections **199** to a dewatering unit for solid/liquid separation. Clarified dewatered effluent from the dewatering unit can be returned to compartment **163** through input line **121** (using flexible hose—see also FIG. 10). Clarified water leaves compartment

163 through two outflow pipes **123/125** positioned horizontally above lamella separator assembly **191**. These outflow pipes avoid taking in solids through the pump suction cone which occurs when using typical suction pumps, and are adjustable to take uneven site location into account as disclosed above. Each pipe **123/125** has a plurality (15 preferably) of 1³/₁₆ inch holes **201** at their tops providing water intake in a calm, clarified liquid region just below the liquid level in the compartment (i.e., the pipes are fully submerged) thus avoiding water surface contamination accumulations from being transferred together with the clarified water to the next compartment/stage. Because of the height difference, pipes **123/115** are submerged, even if the flow rate is very low.

[0089] At their outlet ends, pipes **123/125** provide diving pipes **115/111** to transport the clear fluid into compartment **165**. This arrangement overall eliminates or greatly reduces fine solids not separated out in the lamella separator **191** by requiring the clear water to circulate to the top of compartment **163** and through holes **201** in the tops of the pipes **123/125**. As noted heretofore, back flush sludge from back flush filter **75** bypasses compartments **153** through **161** and is introduced into compartment **163** through input line **121** emptying into the top of adjacent intervening diving wall structure **111**.

[0090] Diving pipes **115/111** from compartment **163** dive down to approximately one foot above the bottom of compartment **165**. Compartment **165** as shown in this embodiment has a length of about 0.9 m, a width of about 2.4 m, and a weir level of about 2 m from datum level providing a volume of about 4.9 m³. Compartment **165** is utilized for again adjusting the pH of the clarified liquid if needed using acid or caustic introduced through one of dosing inputs **59**. Optionally, a biocide could be dosed into compartment **165** through one of dosing inputs **59** to eliminate or greatly retard the re-proliferation of harmful organisms, e.g., sulphur reducing bacteria (SRB), in the treated flowback. Output from compartment **165** is through weir **115** (preferably adjustable) into flow buffer compartment **167**.

[0091] Installation of a mixer could be accommodated but, for most applications, is not necessary because dive pipes **115/111** create their own mixing energy and because mixing is provided through outflow pump **65** at output end **45** of platform **41**. Efficacy of the pH level is measured at a sensor (for data acquisition and further dosing adjustment) in effluent pipe **205** leading to purified liquid output connector **207** after passing through compartment **167**.

[0092] Compartment **167** in the embodiment illustrated preferably has a volume of about 4.9 m³, and serves as a buffer tank for variable speed effluent pump **65** and is equipped with dry run and overflow protection. Valved outlet piping **209** carries the purified liquid between compartment outlet opening **211** and pump **65**. In the embodiment shown, compartment **167** has a length of about 0.9 m, a width of about 2.4 m, and a weir level of about 2 m from datum level.

[0093] As may be appreciated, individual compartments **47** may be bypassed. Each dosing compartment has triple injection inputs **59** to accommodate different chemicals. Because of the wide range of the flow rate (6 m³/h to 60 m³/h) and the wide range of the discharge head (0.1 bar up to 3 bars), a positive displacement outflow pump **65**, such as a rotary lobe pump, is preferred. The lobes of the pump are coated with VITON. The whole pump meets XP requirements, particularly the VFD motor. The speed of the pump is controlled by sensed or calculated fluid level in compartment **167**.

[0094] In order to eliminate or greatly reduce suspended solids, an automatic backflush filter 75 (for example, a VAF 1000 with a mesh size of 100 μm) is provided at output end 45. Back flushing starts when the pressure drop over the back flush filter exceeds 0.4 bar. The back flush fluid is conducted using flexible hose to either the dewatering unit or to solids separation compartment 163 through input line 121 emptying into the top of adjacent intervening diving wall structure 111. Each backflush needs a volume of about 0.1 m³ of liquid. Outgoing water quality is measured and recorded as discussed hereinabove, and overall treatment efficiency is measured by backflush frequency.

[0095] Turning now to FIGS. 14, 15 and 19, compartment drains 215 are provided at each of compartments 153, 155, 157, 159, 161, 165 and 167 for solids collection and final or emergency draining of unit 37 through drain outlet connections 217 held at mounting boxes 219. The sludge in compartment 163 is removed continuously as previously noted. Adjustable weirs 115 each include opening 221 and weir plates 223 in tracks 225 held on pegs 227 in slots 229 (see FIG. 19, all weir structures herein being of similar design except for the pipe weirs used). The fluid levels in the individual compartments are fixed by the adjusted level of their weirs. All mixers 69 include shafts 231 for imparting rotatory motion to impellers 71.

[0096] When placed at a site, flow adjustments are made by manipulation of internal levelling of components for proper operation of unit 37. These include oil trough 123/131, individual effluent pipe weirs 124/129, and individual effluent pipes 123/125 end heights. It is not necessary to adjust the adjustable weirs between the compartments to compensate for onsite slope of flowback unit 37 but only for flow balancing.

[0097] A more detailed examination of management unit 39 of station 35 is now undertaken with reference to FIGS. 22 to 25. Treatment controller center 233 is located on platform 41 and houses central power and processing assembly 85 therein as well as auxiliary function lab center area 235 and networking facility 236 (resident with assembly 85). Assembly 85 of controller center 235 includes both manual and automated switching controls (see FIG. 32, for example) and supports a programmable controller or controllers. Remotely accessible control output and feedback input terminal 87 is located on an outer wall thereof for operative association with unit 37. Chemical dosing control center 237 is located adjacent thereto on platform 41, includes dosing platforms 81 thereat, and is operatively associated with assembly 85 at controller center 233. Remotely accessible chemical dosing and fluids output manifold 83 is located at platform 41 therebelow. Manifold 83 includes demulsifier output 239, water supply output 241, polymer output 243, caustic output 245, acid output 247 and coagulant output 249. Dosing platforms 81 are defined at primary platform 251 including storage securement railing and brace assembly 253 and tote securement straps 255 all for locating and securing cabinets 89 and chemical storage totes 95 thereat. Demulsifier storage room 257 on platform 41 is for storage of demulsifier chemicals. Auxiliary functions shower and eye wash center 259 is located at one end of center 237 and includes shower 261 fed from water supply 262. An overhead folding door 263 accesses unit 39 and secures the unit for movement.

[0098] For the treatment of flowback water, different chemical additives can be employed and pumped from management unit 39 to treatment unit 37. The chemical treatment

product categories include emulsion breakers, coagulants, polymer flocculants, acids, caustics and biocides. While only a single polymer system is shown, an additional polymer system could be provided. For the dosing of polymer, a two tank system is shown (a three tank system could be utilized) using a dry polymer feeder and water intake for make-up of polymer solution from water and dry polymers at unit 39. While not shown, a liquid polymer dilutions system is also provided.

[0099] Each dosing cabinet 89 has one or two dosing pumps (for example, from PROMINENT). The dual dosing pump option per dosing cabinet allows for the dosing of two different chemicals through one dosing cabinet. The pipe spool fittings, valving and special flow parts are made of compatible synthetic material with FEP seals for dosing flocculants, acids, caustics and the like. Because emulsion breaker chemicals can form an explosive and/or hazardous atmosphere, the chemical containers and dosing cabinet therefore are placed in a separate, air conditioned room 257 having a separate access 265. Explosimeter 267 monitors the atmosphere in room 257. The piping and associated components of the dosing cabinet therein are made of 300 series stainless steel. The emulsion breaker flow rate is controlled by the flow rate of the flowback water under process control.

[0100] FIG. 26 illustrates wiring and data flow between units 37 and 39 of station 35. Programmable logic controllers 269 and 271 are located at units 37 and 39, respectively, at transfer terminal 55 and assembly 85, respectively. These controllers are in constant communication for transfer of feedback data and control signals between the units. Both units include sensing options 273 and 275 for monitoring fluid quality (as discussed hereinabove for unit 37), pump, valve and mixer performance, flowback tank pressure, and chemical storage use and status. All motorized valves at treatment unit 37 are directly controlled by controller 269 and by controller 271 via controller 269. Variable frequency drive pumps and mixers are controlled from drivers 273 at assembly 85 of unit 39 through terminal 55. Valve state feedback and mixer or pump overheating feedback to controller 271 is conducted via controller 269. Pumps and valves at management unit 39 are directly controlled by controller 271, which also directly monitors activity of all manual switches at unit 39. A panel pc 276 is located at unit 39 for operations monitoring from within unit 39 and for direct program control of controller 271 (see FIG. 29 showing various control and data monitoring displayed thereon).

[0101] Process control using controllers 269 and 271 is illustrated in FIG. 27. Treatment unit 37 controller 269 software includes a communications manager 277 which reads sensor and performance data at unit 37. Manager 277 reports this data to controller 271 for use by the process control software program thereat, and receives operating control output from controller 271. Responsive to receipt of the control output, manager 277 controls output of signals to the various motorized valves. Process control 281 at controller 271 receives sensor and performance data signals from the various assemblies in management unit 39 together with operator commands as additional input and sends commands to the pumps, valves and alarms on-board management unit 39 as well as to communications manager 277. Data recording and transmitting on the network or in resident memory is controlled by controller 271 process control 281.

[0102] Process control 281 includes basic programming which coordinates rate of chemical injection as a function of

feed rate measured by resident feed flow meter, and pH measurements, conductivity measurements, turbidity measurements and temperature measurements from treatment unit 37. Real time data acquisition accommodates process control program software development to automate the chemical injection rates and ratios.

[0103] Referring to FIGS. 26, 27, 28 and 29, process control of mobile liquid treatment unit 37 includes sensing attributes of liquid to be treated and operational functioning of unit components, such as speed and state attributes (on/off, for example), providing electronic outputs indicative thereof to controller 271. The outputs are then utilized by process control 281 to generate process control signals responsive thereto which direct the various dosing equipment in preparation of chemical dosing at management unit 39. The control signals are also received at treatment unit 37 for selectively adapting the attributes of operational functioning. The chemical dosing is pumped to treatment unit 37 from treatment management unit 39 for injection in the liquid being treated thereat. Data indicative of the electronic outputs and control signals is acquired and reported and/or saved at controller 271.

[0104] In addition, control signals related to back flush operation at treatment unit 37 are generated by controller 271 responsive to the electronic outputs. These are utilized at the treatment unit to initiate back flush operations, and for operator reference in maintaining or upgrading back flush equipment process control and performance (for example, by monitoring flow back frequency and utilizing the frequency data for filter screen size optimization).

[0105] Automation of dosing preparation may be controlled from controller 271, controlling, for example, metering of chemicals responsive to the control signals, pumping and pumping parameters of the metered chemicals to treatment unit 37, and recording of metering and pumping operational functioning. For control of flowback feed into treatment unit 37, process control software at controller 271 reads the sensed volume flowback tank sensor output indicative of liquid at the flowback tank and provides flow rate control signals responsive thereto which are received at treatment unit 37 for adapting the attributes of liquid infeed and throughflow control functioning. Process control software at controller 271 is thus able to continuously receive and monitor the various electronic outputs and responsive thereto continually generate process control signals for correcting or improving liquid treatment at the site. Continual monitoring of operations and process control and recording and/or transmitting the same assures quality record keeping and enables real-time remote monitoring.

[0106] FIG. 29 illustrates process monitoring and control displays at panel pc 276 from which an operator may run station 35 from management unit 39. FIG. 29A shows the home screen for feed measurements readout and control operations. The home screen for the various flow rate measurements and controls is shown in FIG. 29B, with pH and Turbidity monitoring of the various compartments shown in FIGS. 29C and 29D. The effluent measurement displays and controls home screen is illustrated in FIG. 29E, with FIG. 29F showing an operator alerts and alert clearing screen directed to urgent control issues arising at the station. FIG. 29G, 29H and 29I are home screens for back flush, pressure and polymer makeup monitoring and controls, respectively. Each of the home screens has multiple pages for detailed monitoring (controlled from the upper right pane). A series of tabs at the

bottom allow navigation through the various monitoring/control screens. Navigation on a particular screen is accommodated by the navigation controls at the bottom of each screen.

[0107] All process control can be simulated and utilized (for example on a laptop or other computer) for training, unit development, and off-site programming of process control functions. This simulation software is an exact duplication of the process control software programming onboard at management unit 39 and includes displays of the various treatment unit responses to operator activities or programming changes (see FIGS. 30 through 32).

[0108] The core process is a crucial part of the process software. It is used in both the main control program of controller 271 and also in the flowback simulator. The core process reads all sensors, reads state and value of all user controls, controls all pumps, mixers and motorized valves either in manual or automated mode, records all the process data locally, and makes available the process data through the network in real-time for remote monitoring.

[0109] The flow rate of feed pump 63 controls the overall speed of the process. It is important to maintain at least a minimum flow through the whole process in order to enhance the quality of the chemical treatment process. Process control programming of flow rate is based on the level of the fluid in the fracking tank as sensed and signaled by means of the sensor 282 in the fracking tank. The advantage of this method is that while the number of external sensors is kept to a minimum, the operator is still able to adjust the speed of the process based on different conditions. This method also allows processing of fracking liquids to begin even while new liquid is still being added to the fracking tank. For example, in a freezing environment the operator may anticipate that more fluids may come out of the well for the next 24 hours. The discharge of the fracking fluid from the well happens at sporadic times, and it is desirable to keep the process running without interruption to prevent freezing. Therefore, the operator can set the desired level of the fracking tank such that there is enough free space in the flowback tank to hold any new fluids from the well while maintaining enough fracking fluid reserve in the tank to keep the process running in between the periods of fracking fluid discharge.

[0110] Simulator operation is shown in FIGS. 30 through 32. FIG. 30 is columnar control and operations display. In the upper half FIG. 30 all the controls visible at the cover of the processing assembly 85 control cabinet at panel pc 276 are reproduced in simulation. The columns relate to (left to right) feed pump 63 at column 287, effluent pump 65 at column 289, sludge pump 195 at column 291, mixer 69 at compartment 153 at column 293, mixer 69 at compartment 157 at column 295, mixer 69 in compartment 159 at column 297, mixer 69 in compartment 161 in column 299, acid dosing pump(s) 97 at a dosing platforms 81 in column 301, caustic dosing pump(s) 97 at a dosing platforms 81 in column 303, coagulant dosing pump(s) 97 at a dosing platforms 81 in column 305, demulsifier dosing pump(s) 97 at a dosing platforms 81 in room 93 in column 307, spare dosing pump(s) 97 (if present) at a dosing platforms 81 in column 309, and dosing pump(s) 97 for polymer storage and flocculant makeup system 91 at column 311. As can be seen there are status lights, start/stop buttons and speed control potentiometers for each variable frequency drive (VFD) motor in the system. In the lower half of FIG. 30, the indicators for the speed of each VFD motor in the form of bar meters are presented. The lights below show

if a VFD motor is currently energized. There are switches for each VFD motor that simulate an overheating signal or any other kind of fault.

[0111] In FIG. 31, the polymer makeup and delivery functions are shown in simulation. The polymer makeup system can be run independently from the rest of the simulation. The water and polymer pumps start at the correct sequence to mix the concentrated polymer in the upper tank and to store it in the lower tank. Back flushing simulation at the right side of FIG. 31 replicates operator controls at assembly 85 for back flushing. Operation progress lights, and manual start buttons are provided as is an automatic back flush controller.

[0112] At the center of FIG. 32, simulation of operation of motorized valves that govern the flow of the fluids during the back flush process is shown. At the top of the FIGURE all the different sensors in treatment unit 37 are simulated with state and values displayed. These include (from left to right) feed level sensor 282 at column 313, feed pump pressure switch sensor at column 315, influent filter pressure sensor at column 317, effluent filter pressure sensor at column 319, feed flow rate sensor at column 321, feed temperature sensor at column 323, feed condition sensor at column 325, feed pH sensor at column 327, pH at compartment 157 sensor at column 329, compartment 157 turbidity sensor at column 331, compartment 159 pH sensor at column 333, compartment 167 level sensor at column 335, effluent pump pressure switch sensor at column 337, influent pressure sensor at column 339, effluent pressure sensor at column 341, effluent flow rate sensor at column 343, effluent pH sensor at column 345, effluent turbidity sensor at column 347, and sludge pump pressure switch sensor at column 349.

[0113] Reading of these sensors is used by the core process of process control software programming to either control the station or to store their values on non-volatile memory. The cascading compartments 47 of flowback unit 37 are simulated at the bottom right of the FIGURE. When feed pump 63 is running, the level of the fluid in compartment 153 will increase proportional to the flow rate. After the fluid level reaches a certain level, it will overflow to the next compartment and this display will continue for all the compartments. The reverse cycle is displayed at unit 37 is emptied. The status of the fracking fluid flowback tank (and thus incoming liquid flow availability) is simulated at the left of the FIGURE. In simulation it is possible to select the amount of the incoming flow to the flowback tank, while in real time operations the incoming flow rate is determined by the amount of fracking fluids that are being discharged from the well.

[0114] As may be appreciated from the foregoing, a highly responsive easily manipulable liquid treatment station is provided by this invention wherein liquid treatment functions are separated from treatment management functions. Use of the station will provide water purification to such an extent that most of the effluent is safe for industrial reuse on the site or at another site, and in many cases to such an extent that direct recycling may be possible (in a stream flow or well in the case of oil/gas well drilling flowback water, for example).

What is claimed is:

1. A mobile liquid treatment unit comprising:

a mobile platform having a foul liquid intake end and a purified liquid output end; and

a plurality of liquid containment compartments each having a volume with an upper portion and a lower portion, said compartments configured and serially arranged at said mobile platform for defining plural serial cascade

stages from said intake end to said output end, each of said stages cascading from one to the next between said intake end and said output end, and a majority of said compartments each including structure for liquid inflow at said lower portion of said volume thereof from an adjacent said compartment and structure for liquid outflow at said upper portion of said volume thereof to another adjacent said compartment.

2. The treatment unit of claim 1 wherein said structure for liquid inflow includes one of a diving wall structure and a pipe and wherein said structure for liquid outflow includes one of a weir and a pipe.

3. The treatment unit of claim 1 wherein at least some of said compartments include at least a first treating chemical input at said lower portion, said structure for liquid inflow providing inflow below said treating chemical input.

4. The treatment unit of claim 1 wherein at least some of said compartments include a variable speed mixer having an impeller at said lower portion, said structure for liquid inflow providing inflow below said mixer impeller.

5. The treatment unit of claim 1 wherein said stages include an emulsion breaking stage.

6. The treatment unit of claim 1 wherein said cascade stages include an oil separation stage, chemical dosing stages, and a solids separation stage.

7. The treatment unit of claim 6 wherein said foul liquid intake end of said mobile platform includes a feed pump and wherein at least one of said foul liquid intake end and said a purified liquid output end includes a back flush filter having a by-pass back flush liquid output line, said by-pass back flush liquid output line for directing back flush liquid directly to said solids separation stage upon performance of a back flush.

8. The treatment unit of claim 1 wherein one of said compartments is a solids separation compartment, and wherein a variable speed feed pump is connected at said foul liquid intake end of said mobile platform, wherein a variable speed effluent pump is connected at said output end of said mobile platform, and wherein a variable speed sludge pump is connected at said solids separation compartment.

9. A mobile liquid treatment station comprising:

a mobile primary liquid treatment unit having a foul liquid intake end and a purified liquid output end with a plurality of liquid containment compartments defined and serially arranged therebetween for performance of selected liquid treatment functions thereat including chemical dosing and mixing and solids separation, said primary treatment unit having a plurality of sensors thereat with sensor outputs, a plurality of chemical dosing inputs at different ones of said compartments, a plurality of pumps, mixers and valves having connections for operational control and feedback, and a power and data transfer terminal connected with said connections of said pumps, mixers and valves and said sensor outputs from said sensors;

an independently mobile treatment management unit having a plurality of chemical dosing platforms, an externally located dosing manifold and a central power and processing assembly therein, said power and processing assembly including an externally located power and data input and output terminal, and said chemical dosing platforms including chemical storage connectable with dosing pump assemblies operatively associated with said power and processing assembly and having dosing outputs connected with said manifold;

a bus connectable between said power and data input and output terminal of said power and processing assembly of said management unit and said power and data transfer terminal of said primary treatment unit; and chemical feed line assemblies selectively connectable between said dosing manifold of said management unit and said dosing inputs at said compartments of said primary treatment unit;

wherein chemical dosing control, pump, mixer and valve operational control, feedback, and data acquisition at both said units are controlled at said power and processing assembly of said management unit.

10. The treatment station of claim 9 further comprising a pressure sensor connected between said power and processing assembly at said management unit and an on-site source of foul fluid received at a feed pump located at said intake end of said primary treatment unit for infeed and throughflow control and monitoring based on available volume of foul fluid at the source.

11. The treatment station of claim 9 wherein said primary treatment unit includes cascading flow design between at least some of said compartments and internal leveling features for independent leveling of components located in at least some of said compartments.

12. The treatment station of claim 9 wherein said power and processing assembly of said management unit includes at least a first programmable controller.

13. The treatment station of claim 9 wherein said sensors of said primary treatment unit include at least one of liquid intake and liquid output location of turbidity and pH measurement devices providing feedback for use by said power and processing assembly of said management unit for refining control of chemical dosing and for ongoing data collection.

14. The treatment station of claim 9 wherein said management unit further includes a polymer storage and flocculant makeup system having an output connected with said manifold.

15. The treatment station of claim 9 wherein said management unit further includes a demulsifier storage and dosing system having an output connected with said manifold.

16. The treatment station of claim 9 wherein each of said units is mounted on wheeled platforms.

17. A treatment unit for receiving and processing industrial process water comprising:

a mobile platform having a foul water intake end and a purified water output end;

at least seven water containment and treating compartments at said mobile platform serially arranged between said ends and each having an upper portion and a lower portion; and

a plurality of intervening diving structures one of adjacent to or located between at least some of said compartments for receiving and directing the process water to an adjacent said compartment at said lower portion thereof.

18. The treatment unit of claim 17 further comprising a flow back filter at said intake end and having flow back frequency monitoring for filter screen size optimization based on back flush frequency.

19. The treatment unit of claim 17 wherein at least some of said compartments include water level adjustable openings at said upper portions thereof for water outflow to an adjacent one of said diving structures.

20. The treatment unit of claim 17 wherein said compartments include an emulsion breaking treatment compartment, an oil separation compartment, compartments for coagulant dosing and pH adjustment, a polymer treatment compartment, and a solids separation compartment.

21. The treatment unit of claim 20 wherein said solids separation compartment includes dual separation and concentration cones connected with a sludge removal pump.

22. The treatment unit of claim 17 further comprising a turbidity measurement device at said purified water output end of said mobile platform providing chemical treatment efficacy measurement and including a measurement data output for data collection remote from said unit.

23. A mobile liquid treatment unit locatable at a selected site comprising:

a mobile platform having a foul liquid intake end and a purified liquid output end; and

a plurality of liquid containment and treating compartments defined at said mobile platform and serially arranged between said ends to provide cascading flow between at least some of said compartments and each having flow accommodating components thereat, at least some of said compartments including liquid flow leveling features for independent adjustment of said flow accommodating components located therein in both longitudinal and transverse directions to selectively compensate for unlevel location of said mobile platform at the site and thus unit sloping.

24. The treatment unit of claim 23 wherein said flow accommodating components include first and second horizontally disposed clarified liquid outflow pipes in a said compartment more adjacent to said output end of said mobile platform, and wherein said leveling features include apparatus for independently selectively raising and lowering a part of each of said outflow pipes.

25. The treatment unit of claim 23 wherein at least some of said compartments include level adjustable weirs thereat.

26. The treatment unit of claim 23 wherein said flow accommodating components include first and second upright pipes in a said compartment more adjacent to said intake end of said mobile platform, and wherein said leveling features include height adjustable fluid outlets at a top portion of said upright pipes.

27. The treatment unit of claim 23 wherein said flow accommodating components include an oil separator trough at one of said compartments and having a separated oil outlet at a corner thereof, and wherein said leveling features include apparatus for adjusting tilt of said trough in both longitudinal and transverse directions.

28. The treatment unit of claim 23 wherein said compartments include a buffer compartment adjacent to said output end of said mobile platform and wherein said output end includes an outflow pump connected with said buffer compartment.

29. The treatment unit of claim 28 further comprising a plurality of compartment drains each connected to a different one of said compartments for completion of draining of said compartments.

30. A mobile liquid treatment management unit comprising:

a mobile platform;

a treatment controller center located at said platform and including a remotely accessible control output and feedback input;

a chemical dosing control center located at said platform and operatively associated with said controller center and including remotely accessible chemical dosing outputs; and

at least a first auxiliary functions center located at said platform.

31. The management unit of claim **30** wherein said controller center includes both manual and automated switching controls.

32. The management unit of claim **30** wherein said dosing control center includes plural storage and dosing cabinets, a polymer make-up system and a demulsifier storage and dosing room each having said dosing outputs, and wherein said chemical dosing outputs are connected to a manifold.

33. The management unit of claim **30** wherein said treatment controller center is operative responsive to a process control software program both resident at said unit and remotely manipulable.

34. The management unit of claim **30** wherein said auxiliary functions center includes at least one of a shower and wash facility, a laboratory, and networking facility.

35. A method for process control of a mobile liquid treatment unit comprising the steps of:

sensing attributes of liquid to be treated at the treatment unit and providing first electronic outputs indicative thereof;

sensing attributes of operational functioning of selected treatment unit components and providing second electronic outputs indicative thereof;

receiving the electronic outputs remotely from the treatment unit at an automated treatment management unit and generating process control signals responsive thereto;

preparing chemical dosing at the automated treatment management unit responsive to the control signals;

receiving the control signals at the treatment unit for selectively adapting the attributes of operational functioning responsive thereto; and

receiving chemical dosing at the treatment unit from the prepared chemical dosing at the treatment management unit.

36. The method of claim **35** further comprising acquiring, reporting and storing data indicative of the electronic outputs and control signals.

37. The method of claim **35** further comprising generating back flush operation control signals at the treatment unit responsive to the electronic outputs and receiving the back flush operation control signals at the treatment unit to initiate a back flush operation.

38. The method of claim **35** wherein the step of preparing chemical dosing includes the step of metering chemicals responsive to the control signals, pumping the metered chemicals to the treatment unit, and recording metering and pumping operational functioning.

39. The method of claim **35** further comprising the steps of sensing volume of liquid to be treated at a source tank and providing third electronic output indicative thereof, receiving the third electronic output remotely from the source tank at the automated treatment management unit and generating flow rate control signals responsive thereto, and receiving the flow rate control signals at the treatment unit for adapting the attributes of operational functioning related to liquid infeed and throughflow responsive thereto.

40. The method of claim **39** further comprising the steps of continuing to receive the electronic outputs remotely from the treatment unit at the automated treatment management unit and continually generating control signals responsive thereto, monitoring the process control steps, and displaying the monitored control steps at the treatment management unit.

41. The method of claim **35** further comprising simulating the process control and utilizing the simulation for at least one of operator training, unit development, and off-site programming of process control functions.

42. The method of claim **35** wherein the step of preparing chemical dosing at the automated treatment management unit responsive to the control signals includes the step of selecting chemical options including emulsion breaking chemicals, coagulants, acids, caustics, polymers and biocides available at the treatment management unit.

43. The method of claim **35** wherein the control signals include pump and valve control signals.

44. A method for operation of a mobile liquid treatment station comprising the steps of:

intake of liquid to be treated at a mobile primary liquid treatment unit;

cascading the liquid serially through a plurality of liquid treatment compartments;

performing selected liquid treatment functions at the compartments responsive to process control programming at an independently mobile treatment management unit, the treatment functions including chemical dosing and mixing and solids separation;

sensing attributes of the liquid at the treatment unit and attributes of operational functioning of selected treatment unit components and providing electronic outputs indicative thereof;

receiving the outputs at the treatment management unit;

preparing chemical dosing at the treatment management unit responsive to the received outputs;

feeding prepared chemical dosing from the treatment management unit to selected ones of the compartments of the treatment unit; and

output of treated liquid from the treatment unit.

45. The method of claim **44** further comprising the steps of generating process control signals at the automated treatment management unit responsive to the outputs received thereat and preparing chemical dosing at the treatment management unit and selectively adapting the attributes of operational functioning of the selected components at the treatment unit responsive to the control signals.

46. The method of claim **45** further comprising the steps of providing operator control inputs at the treatment management unit for operator control of selected operations at the treatment unit and adapting the control signals responsive to the sensed operator manipulation of the control inputs.

47. The method of claim **45** wherein the selected treatment unit components include pumps, mixers and valves and wherein the attributes of operational functioning include speed and state attributes.

48. The method of claim **45** further comprising the step of monitoring the chemical dosing, wherein the process control signals include signals generated at the automated treatment management unit indicative of the monitoring, wherein the selected treatment unit components include a sludge pump and wherein the attributes of operational functioning include pump speed.

49. The method of claim **45** further comprising the steps of receiving output indicative of sensed attributes of status of other variables at a site where the units are located at the treatment management unit and, responsive thereto, adapting the attributes of operational functioning of selected treatment unit components from the treatment management unit.

50. The method of claim **49** wherein the attributes of operational functioning include flow rate, wherein the selected treatment unit is a feed pump for controlling overall processing speed, and wherein the output indicative of sensed attributes of status of other variables at the site includes volume of the liquid to be treated at a source tank.

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