HEMODIALYSIS SYSTEM

FIELD OF INVENTION

The present invention generally relates to hemodialysis and similar dialysis systems, e.g., systems able to treat blood or other bodily fluids extracorporeally.

BACKGROUND

Many factors make hemodialysis inefficient, difficult, and expensive. These factors include the complexity of hemodialysis, the safety concerns related to hemodialysis, and the very large amount of dialysate needed for hemodialysis. Moreover, hemodialysis is typically performed in a dialysis center requiring skilled technicians. Therefore any increase in the ease and efficiency of the dialysis process could have an impact on treatment cost or patient outcome.

SUMMARY OF INVENTION

According to a first aspect of the present invention, there is provided a pair of first and second engagement devices for a blood circuit assembly mounted on a panel of a dialysis unit, the first engagement device positioned on a first side of the blood circuit assembly mounted to the panel, and the second engagement device positioned on a second side of the blood circuit assembly mounted to the panel, each engagement device including: an actuator movably mounted to the panel of the dialysis unit adjacent a plurality of control ports that are configured to connect with mating control ports on a back side of the blood circuit assembly, the actuator movable between a retention position and an ejection position; a retainer element coupled to the actuator and arranged, with the actuator in the retention position, to contact a portion of a front side of the blood circuit assembly, and retain the blood circuit assembly on the panel of the dialysis unit, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the panel of the dialysis unit; and an ejector element coupled to the actuator or to the panel and arranged, with the actuator moved from the retention position to the ejection position, to contact a portion of the back side of the blood circuit assembly to urge the blood circuit assembly away from the panel, wherein the actuators are movable away from each other from respective retention positions to ejection positions, and wherein the first and second sides are opposed to each other such that the actuators of the engagement devices are movable by respective first and second thumbs of a user.

According to a second aspect of the present invention, there is provided an engagement device for a dialysis unit, including: an actuator movably mounted to a panel of the dialysis unit adjacent a plurality of control ports that are configured to connect with mating control ports on a back side of a blood circuit assembly, the actuator movable between a retention

position and an ejection position; a retainer element coupled to the actuator and arranged, with the actuator in the retention position, to contact a portion of a front side of the blood circuit assembly, and retain the blood circuit assembly on the panel of the dialysis unit, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the panel of the dialysis unit; and an ejector element coupled to the actuator or to the panel and arranged, with the actuator moved from the retention position to the ejection position, to contact a portion of the back side of the blood circuit assembly to urge the blood circuit assembly away from the panel, wherein the ejector element is pivotable about an axis between an inactive or retracted position and an ejection position, with a proximal portion on a first side of the axis configured to contact an ejector contact arm of the actuator, and a distal portion on a second opposing side of the axis configured to make contact with the blood circuit assembly.

According to a third aspect of the present invention, there is provided an engagement device for a dialysis unit, including: a pair of actuators movably mounted to a panel of the dialysis unit adjacent to and on opposing sides of a plurality of control ports that are configured to connect with mating control ports on a back side of a blood circuit assembly, the actuators movable between a retention position and an ejection position; a pair of retainer elements, each coupled to a respective actuator and arranged, with the actuators in the retention position, to contact portions of a front side of the blood circuit assembly, and retain the blood circuit assembly on the panel of the dialysis unit, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the panel of the dialysis unit; and a pair of ejector elements, each coupled to a respective actuator or to the panel and arranged, with the actuators moved from the retention position to the ejection position, to contact portions of the back side of the blood circuit assembly to urge the blood circuit assembly away from the panel, wherein the actuators are movable away from each other from respective retention positions to ejection positions.

According to a fourth aspect of the present invention, there is provided an engagement device for a dialysis unit, including: a pair of actuators movably mounted to a panel of the dialysis unit adjacent to and on opposing sides of a plurality of control ports that are configured to connect with mating control ports on a back side of a blood circuit assembly, the actuators movable between a retention position and an ejection position; a pair of retainer elements, each coupled to a respective actuator and arranged, with the actuators in the retention position, to contact portions of a front side of the blood circuit assembly, and retain the blood circuit assembly on the panel of the dialysis unit, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the panel of the dialysis unit; and a pair of ejector elements, each coupled to a respective actuator or to the panel and arranged, with the actuators moved from the retention position to the ejection

position, to contact portions of the back side of the blood circuit assembly to urge the blood circuit assembly away from the panel, wherein each retainer element includes two opposing arms, and is arranged, with the respective actuator in the retention position and a blood circuit assembly mounted to the panel, to contact an outer surface of the blood circuit assembly at two locations to secure the blood circuit assembly in place.

According to a fifth aspect of the present invention, there is provided engagement device for a dialysis unit, including: a pair of actuators movably mounted to a panel of the dialysis unit adjacent to and on opposing sides of a plurality of control ports that are configured to connect with mating control ports on a back side of a blood circuit assembly, the actuators movable between a retention position and an ejection position; a pair of retainer elements, each coupled to a respective actuator and arranged, with the actuators in the retention position, to contact portions of a front side of the blood circuit assembly, and retain the blood circuit assembly on the panel of the dialysis unit, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the panel of the dialysis unit; and a pair of ejector elements, each coupled to a respective actuator or to the panel and arranged, with the actuators moved from the retention position to the ejection position, to contact portions of the back side of the blood circuit assembly to urge the blood circuit assembly away from the panel, wherein each ejector element is pivotable about an axis between an inactive or retracted position and an ejection position, with a proximal portion on a first side of the axis configured to contact an ejector contact arm of the respective actuator, and a distal portion on a second opposing side of the axis configured to make contact with the blood circuit assembly.

According to a sixth aspect of the present invention, there is provided a pair of first and second engagement devices for a blood circuit assembly mounted to a control port assembly of a dialysis unit, the control port assembly including a plurality of pneumatic control ports configured to connect with mating valve and pump control ports on a back side of the blood circuit assembly, the first engagement device positioned on a first side of the blood circuit assembly mounted to the control port assembly, and the second engagement device positioned on a second side of the blood circuit assembly mounted to the control port assembly, each of the first and second engagement devices including: an actuator movably mounted to the control port assembly of the dialysis unit, the actuator movable between a retention position and an ejection position; a retainer element coupled to the actuator and arranged, with the actuator in the retention position, to contact a portion of a front side of the blood circuit assembly, and secure the blood circuit assembly to the control port assembly, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the control port assembly; and an ejector element coupled to the actuator or to the control port assembly and arranged, with the actuator moved from the retention position to the

ejection position, to contact a portion of the back side of the blood circuit assembly to urge the blood circuit assembly away from the control port assembly, wherein the first and second sides are opposed to each other such that the actuators of the engagement devices are movable by respective first and second thumbs of a user, and wherein the actuators are movable away from each other from respective retention positions to ejection positions.

According to a seventh aspect of the present invention, there is provided an engagement device for a dialysis unit, including: an actuator movably mounted to a control port assembly of the dialysis unit, the control port assembly including a plurality of pneumatic control ports configured to connect with mating valve and pump control ports on a back side of a blood circuit assembly, the actuator movable between a retention position and an ejection position; a retainer element coupled to the actuator and arranged, with the actuator in the retention position, to contact a portion of a front side of the blood circuit assembly, and secure the blood circuit assembly to the control port assembly, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the control port assembly; and an ejector element coupled to the actuator or to the control port assembly and arranged, with the actuator moved from the retention position to the ejection position, to contact a portion of the back side of the blood circuit assembly to urge the blood circuit assembly away from the control port assembly, wherein the ejector element is pivotable between an inactive or retracted position and an ejection position, and wherein the ejector element is pivotable about an axis, with a proximal portion on a first side of the axis configured to contact an ejector contact arm of the actuator, and a distal portion on a second opposing side of the axis configured to make contact with the blood circuit assembly.

Embodiments of the invention generally relate to hemodialysis and similar dialysis systems. Illustrative embodiments described herein involve, in some cases, interrelated products, alternative solutions to a particular problem, and/or a plurality of different uses of one or more systems and/or articles. Although the various systems and methods described herein are described in relation to hemodialysis, it should be understood that the various systems and method described herein are applicable to other dialysis systems and/or in any extracorporeal system able to treat blood or other bodily fluids, such as hemofiltration, hemodiafiltration, etc.

In one embodiment of the invention, a drain cassette for a dialysis unit includes a venous connection port for connection to, and fluid communication with, a venous blood line connector, an arterial connection port for connection to, and fluid communication with, an arterial blood line connector, a fluid channel fluidly connecting the venous connection port and the arterial connection port, a drain outlet port in fluid communication with the fluid channel and arranged to removably couple with a drain connector on an exposed panel of the dialysis unit, and a valve arranged to control flow in the fluid channel. The valve may be

arranged to control in the fluid channel to either controllably open and close fluid communication in the fluid channel between the drain outlet port and the venous connection port, or to controllably open and close fluid communication in the fluid channel between the drain outlet port and the arterial connection port. Such an arrangement may allow for purging and/or rinsing of venous and arterial lines to drain, e.g., in preparation for a treatment. In addition, the drain cassette may be removable from the dialysis unit, allowing an operator to remove and replace blood-contacting portions of the drain cassette when preparing the dialysis unit for treating another patient.

In one embodiment, the drain cassette may include a body that defines the arterial and venous connection ports and the fluid channel. A check valve may be arranged to allow flow from the fluid channel and out of the drain outlet port and to resist flow from the drain outlet port to the fluid channel. Thus, fluid or other material in a drain line downstream of the check valve may be prevented from entering the fluid channel. The valve that controls flow in the fluid channel may be a pneumatically-controlled valve, and a pneumatic control port on the drain cassette may be arranged to removably mate with a port on the exposed panel of the dialysis unit and fluidly couple the valve with the port on the exposed panel to allow control of the valve.

In one embodiment, the drain cassette may include a latch arranged to releasably lock the drain cassette to the exposed panel. For example, the latch may include a handle and a male bayonet-type connector arranged to engage with a female bayonet-type receiver on the panel of the dialysis unit. Thus, the latch may be operated, e.g., by inserting the bayonet connector into the receiver and turning the handle, to both connect and disconnect the drain cassette with respect to the panel. Such mounting and dismounting of the cassette may also cause coupling/uncoupling of one or more ports, electrical connectors or other components of the drain cassette with a corresponding port, connector, etc. on the panel. For example, a drain port, pneumatic valve control port and electrical connector coupled with one or more sensors in the drain cassette may simultaneously couple with corresponding ports/connectors on the panel in a single connection operation, which may include pushing the drain cassette onto the panel and turning the latch handle.

The drain outlet port may fluidly communicate with the fluid channel at a point above where the arterial and venous connection ports communicate with the fluid channel, e.g., so that air in the fluid channel may be evacuated by introducing fluid at the connection ports. In one embodiment, the fluid channel has a U shape with the arterial and venous connection ports fluidly connected to the fluid channel at ends of the U shape, and the drain outlet port fluidly connected to the fluid channel at a central bend of the U shape.

One or more sensors may be included to detect characteristics of fluid in the fluid channel or elsewhere in the drain cassette. For example, a conductivity sensor may be

arranged to detect a conductivity of fluid in the fluid channel, and a temperature sensor may be arranged to detect a temperature of fluid in the fluid channel. The one or more sensors may be coupled to an electrical connector arranged to electrically connect the one or more sensors to a corresponding electrical connector on the exposed panel. In one embodiment, the electrical connector and the drain outlet port are arranged to simultaneously couple with a corresponding electrical connector and drain connector on the exposed panel of the dialysis unit in a single connection operation. In some arrangements, a pneumatic control port coupled to the valve may be arranged to removably mate with a control port on the exposed panel, and to simultaneously couple with the corresponding control port in the same single connection operation used to connect the drain port and electrical connector.

The valve may be arranged so that the drain outlet port is in permanently open fluid communication with the arterial connection port, and the valve may controllably open and close fluid communication in the fluid channel between the drain outlet port and the venous connection port. Alternately, the drain outlet port may be in permanently open fluid communication with the venous connection port, and the valve may be arranged to controllably open and close fluid communication in the fluid channel between the drain outlet port and the arterial connection port.

In another embodiment of the invention, a blood circuit assembly and a drain cassette may be engageable with an exposed panel of a dialysis unit for operation in a dialysis treatment, and may be removable from the exposed panel for replacement without the use of tools. Such an arrangement may allow for easy replacement of all blood-contacting components of a dialysis unit so that the dialysis unit can be used for multiple, different patients (e.g., in a clinical setting) while minimizing risk of a prior patient's blood borne materials from coming into contact with a subsequent patient's treatment components. For example, the blood circuit assembly may include a pair of pneumatic pumps for circulating blood received from a patient through a circuit including a dialyzer unit and returned to the patient, an air trap arranged to remove air from blood circulating in the circuit, a pair of dialyzer connections arranged to connect to the inlet and outlet of a dialyzer unit, and a pair of blood line connectors, including an arterial blood line connector for receiving blood from the patient and providing blood to the pneumatic pumps and a venous blood line connector for returning blood to the patient. The pneumatic pumps may have pneumatic control ports arranged for alignment and mating with corresponding ports located on an exposed panel of the dialysis unit by pushing the control ports into engagement with the corresponding ports with mounting of the blood circuit assembly to the exposed panel. Thus, the blood circuit assembly may be relatively easily mounted to, and dismounted from, the panel of the dialysis unit. The drain cassette may include a venous connection port for connection to, and fluid communication with, the venous blood line connector, an arterial connection port for

connection to, and fluid communication with, the arterial blood line connector, a fluid channel fluidly connecting the venous connection port and the arterial connection port, a drain outlet port in fluid communication with the fluid channel and arranged to removably couple with a drain connector on an exposed panel of the dialysis unit, and a valve arranged to control flow in the fluid channel. Like the blood circuit assembly, and discussed above, the drain cassette may be arranged to be easily mounted to the panel of the dialysis unit for control by the dialysis unit in the treatment process, and dismounted from the panel for replacement.

In one embodiment, flexible tubing may fluidly connect the pumps, the air trap, the dialyzer connections and the blood line connectors of the blood circuit assembly. For example, the flexible tubing may fluidly connect the arterial blood line connector to an inlet for the pump cassette, an outlet for the pump cassette to a dialyzer inlet connector, a dialyzer outlet connector to an inlet of the air trap, and an outlet of the air trap to the venous blood line connector. The blood line connectors may be arranged for a threaded luer-type connection to a patient access, and arranged for a press-in type connection to the drain cassette connection ports. Such arrangement may allow for easy connection to the drain cassette, as well as allow for disinfection of the connectors, e.g., the press-in connection to the drain cassette may allow disinfecting fluid to flow around the patient access connection part of the connector. The drain cassette may include other features mentioned above.

In another embodiment of the invention, a blood circuit assembly for a dialysis unit includes a pair of pneumatic pumps for circulating blood received from a patient through a circuit including a dialyzer unit and returning the blood to the patient, an air trap arranged to remove air from blood circulating in the circuit, a pair of dialyzer connections arranged to connect to the inlet and outlet of a dialyzer unit, a pair of blood line connectors, including an arterial blood line connector for receiving blood from the patient and providing blood to the pneumatic pumps and a venous blood line connector for returning blood to the patient, and flexible tubing fluidly connecting the pumps, the air trap, the dialyzer connections and the blood line connectors. The pneumatic pumps may have pneumatic control ports arranged for alignment and mating with corresponding ports located on an exposed panel of the dialysis unit by pushing the control ports into engagement with the corresponding ports with mounting of the blood circuit assembly to the exposed panel.

Also, the pumps may be defined, at least in part, by a single unitary member that additionally defines a plurality of routing channels for at least a portion of the flexible tubing. In one embodiment, the single unitary member or other organizing tray configuration defines an air trap cavity that receives the air trap. In some arrangements, the inlet of the air trap is supported by the air trap cavity or other support at a position above an outlet of the air trap when the blood circuit assembly is mounted to a dialysis unit. This configuration may make removal of air from the blood lines more effective.

In another embodiment, the single unitary member may define the pneumatic control ports for the pumps, a concave chamber portion for the pumps, a chamber portion of a plurality of valves used to control flow through the pumps, routing channels for flexible tubing to position the tubing for engagement with an occluder when the assembly is mounted to the dialysis unit, and/or other features. For example, the organizing tray may include circuit tube engagement members having a hole through which a respective circuit tube passes that engage with the tube to allow the circuit tube to be pulled and stretched for engagement with an occluder of the dialysis unit. Having a single part define multiple portions of the blood circuit assembly and/or to accurately route flexible tubing may make assembly of the blood circuit assembly easier and more effective, e.g., by ensuring that various components are properly positioned on the panel of the dialysis unit.

In another embodiment, the flexible tubing may connect components as follows: the arterial blood line connector may be connected to an inlet for the pump cassette, an outlet for the pump cassette may be connected to a dialyzer inlet connector, a dialyzer outlet connector may be connected to an inlet of the air trap, and an outlet of the air trap may be connected to the venous blood line connector.

In some embodiments, the blood circuit assembly may include an anticoagulant connection for engaging with an anticoagulant source and providing anticoagulant into the circuit. For example, a pump for pumping anticoagulant from the anticoagulant source to the circuit may be included, e.g., as part of a pump cassette. The anticoagulant connection may include a vial holder and a spike, and the anticoagulant source may be a vial of heparin.

In another embodiment of the invention, a blood circuit assembly engagement device for a dialysis unit includes an actuator, movable between a retention position and an ejection position, mounted to a panel of the dialysis unit adjacent a plurality of control ports, a retainer element coupled to the actuator and arranged, with the actuator in the retention position, to retain a blood circuit assembly mounted to the panel of the dialysis unit on the panel, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the panel of the dialysis unit, and an ejector element coupled to the actuator and arranged, with the actuator moved from the retention position to the ejection position, to urge the blood circuit assembly away from the panel. Such an arrangement may make mounting, retention and removal of a blood circuit assembly with respect to a dialysis unit more accurate and effective. For example, if the retainer element is not positioned in the retention position with a blood circuit assembly mounted to the panel, a user can easily verify that the assembly is not properly engaged with the panel. The actuator can then be used to eject the assembly, allowing replacement of the assembly on the panel.

In one embodiment, the actuator is pivotally mounted to the panel, and the retainer element is fixed to the actuator. The ejector element may be pivotable between an inactive

position and an ejection position, and pivoted based on movement of the actuator. For example, the actuator may be arranged to be moved from the retention position and the ejection position by a user's thumb. In one arrangement, first and second blood circuit assembly engagement devices are provided on the panel, with the first engagement device arranged on a first side of a blood circuit assembly mounted to the panel, and the second engagement device arranged on a second side of the blood circuit assembly. The first and second sides may be opposed to each other such that the actuators of the engagement devices are movable by respective first and second thumbs of a user. For example, using both thumbs, a user may press on the actuators to move the actuators away from each other to move the actuators from respective retention positions to ejection positions. The ejection members may be arranged to contact a portion of a pump chamber in the ejection position, e.g., a rear chamber wall portion of the pump, and the retention elements may be arranged, with the actuator in the retention position and a blood circuit assembly mounted to the panel, to contact an outer surface of the blood circuit assembly to lock the blood circuit assembly in place.

Also described herein are occlusion assemblies configured to facilitate the opening and closing by occlusion of flexible tubing. In particular embodiments, the occlusion assemblies are associated with or form part of a medical infusion device, such as a hemodialysis device, peritoneal dialysis device, plasmapheresis device, etc., and may be controllably and automatically operated to facilitate fluid handling by such devices. The occlusion assemblies may be designed to position and immobilized the tubing and may include a frame or other support feature providing tubing guides and/or configured for attachment to or integration with a fluid handling assembly of a device of which they are part or with which they are used. The occlusion assemblies comprise a tubing occluder, which may be a mechanism constructed and positioned to apply a force to the tube(s) associated with the occlusion assembly to occlude the tubes and to release the force to allow the tubes to open for fluid flow. The occlusion assemblies and tubing occluders may be configured to include a single tube in certain cases, and in other cases to occlude multiple tubes, whether an odd number of tubes or an even number of tubes. Certain occlusion assemblies are specifically configured for occluding one or more pairs of tubes and may include tubing occluders having a separate occluding member for occluding each of the pair of collapsible tubes. The occlusion assemblies may include automatic actuators for operating the tubing occluders, and in certain cases also include a manual actuator to provide an override function. The occlusion assemblies may include a door designed and positioned to cover at least a portion of the tubes be included and tubing occluder mechanism. Such occlusion assemblies may include safety features, for example, to prevent a release of occlusion force on the tubing when the door is not in a closed position and/or convenience features, for example a retainer mechanism to hold the tube occluder in a

non-occluding position when the door is open with the tube occluder in the non-occluding position.

In one embodiment, a variety of occlusion assemblies for occluding at least one collapsible tube of a medical infusion device are described. In certain embodiments, the occlusion assembly is configured for occluding at least one pair of collapsible tubes and comprises, for each pair of collapsible tubes, a first occluding member and a second occluding member, the first occluding member positioned adjacent to a first collapsible tube of the pair and the second occluding member positioned adjacent to a second collapsible to the pair, when the tubes are installed in the occlusion assembly for operation. The first occluding member and the second occluding member are further positioned adjacent from each other such that a space is defined between them. These space is on an opposite side of each occluding member then is the collapsible tubes to which it is adjacent. The occlusion assembly further comprises a spreader positioned within the space between the occluding members and movable from a first position to a second position, wherein movement from the first position to the second position causes the spreader to force at least a portion of the first and second occluding members to move apart from each other to increase the size of the space between them and forced a tube-contacting portion of each occluding member against the collapsible tube to which it is adjacent to occlude the collapsible tube. The occlusion assembly further comprises at least one actuator constructed and positioned to move the spreader between the first and second positions.

In certain embodiments the occlusion assembly is configured for occluding at least one collapsible tube and comprises a frame comprising a tubing guide configured for positioning the collapsible tube, a tubing occluder mounted to the frame and comprising an occluding member constructed and positioned to controllably occlude or release occlusion of the collapsible tube, a door hingeably mounted to the frame and positioned to cover at least a portion of the collapsible tube and tubing occluder when in a closed position and to provide user access to the collapsible tube when in an open position, and a switch configured and positioned to detect when the door is in a closed position and to permit operation of the tubing occluder to release occlusion of the collapsible tube only when the door is in the closed position.

In certain embodiments and occlusion assembly for collapsing at least one collapsible tube comprises a tubing occluder comprising an occluding member constructed and positioned to controllably occlude or release occlusion of the collapsible tube, and automatic actuator operatively coupled to the tubing occluder to cause essentially linear motion of at least a portion of the tubing occluder to cause the occluding member to move from an occluding position to a non-occluding position, and an override mechanism operatively coupled to the tubing occluder to cause essentially linear motion of at least a portion of the tubing occluder to

cause the occluding member to move from an occluding position to a non-occluding position upon manual operation of the override mechanism by a user.

In certain embodiments, and occlusion assembly for occluding at least one collapsible tube comprises a frame comprising a tubing guide configured for positioning the collapsible tube, a tubing occluder mounted to the frame and comprising an occluding member constructed and positioned to controllably occlude or release occlusion of the collapsible tube, a door hindgeably mounted to the frame and positioned to cover at least a portion of the collapsible tube and tubing occluder when in a closed position and to provide user access to the collapsible tube when in an open position, and a retainer mechanism engaged by the door when the door is in the closed position and configured to permit operation of the tubing occluder to occlude or release occlusion of the collapsible tube when the door is in the closed position and configured to engage and retain the tubing occluder in a non-occluding configuration when the door is opened while the tubing occluder is positioned in the non-occluding configuration.

In another embodiment a method of operating an occlusion assembly for occluding at least one pair of collapsible tubes of a medical infusion devices disclosed. In one embodiment, the method involves moving a spreader of the occlusion assembly from a first position to a second position, wherein the spreader is positioned within a space defined between a first occluding member and a second occluding member to cause the spreader to force at least a portion of the first and second occluding members to move apart from each other to increase the size of the space between them and force a tube-contacting portion of each occluding member against a collapsible tube to which it is adjacent to occlude the collapsible tube.

In another embodiment of the invention, an enclosure for containing a portable hemodialysis unit is provided, where the hemodialysis unit includes suitable components for performing hemodialysis including a dialyzer, one or more pumps to circulate blood through the dialyzer, a source of dialysate, and one or more pumps to circulate the dialysate through the dialyzer. The enclosure may include a housing that supports the components of the hemodialysis unit and has a front panel at which blood circuit connections and dialysate fluidic connections are located. For example, the front panel may support blood line connections for patient blood access, connections for a reagent supply, dialyzer connections for both blood flow and dialysate, etc. Thus, in one embodiment, an operator may complete all necessary fluid circuit connections for the blood circuit and reagent supply at the housing front panel. The enclosure may also include a pair of vertical, side-by-side doors hingedly mounted to the housing at opposite sides of the front panel so that the doors are movable between open and closed positions. With the doors in an open position, an operator may have access to the blood circuit connections and dialysate fluidic connections. Also, with the doors

in the closed position, access to the patient access and dialysate fluidic connections may be blocked, and the doors may allow for the retention of heat in the housing suitable for disinfection during a disinfection cycle. For example, at least one of the doors may include a seal to resist air exchange between an interior and an exterior of housing when the doors are in the closed position to help retain heat and/or help resist entry of dust, dirt or other contaminants.

In one embodiment, each of the vertical, side-by-side doors is mounted to the housing via a hinge plate that is pivotally mounted to the door at a first end, and is pivotally mounted to the housing at a second end opposite the first end. Thus, the doors may be positionable at two open positions, e.g., a first open position in which blood circuit connections and dialysate fluidic connections are exposed and the hinge plate is adjacent the housing, and a second open position in which the hinge plate is positioned away from the housing. One or more retainer members may be included to maintain the doors in an open position relative to a corresponding hinge plate. For example, the retainer member may include at least one magnet attached to the door or the hinge plate that tends to keep the door in an open position relative to the hinge plate and the housing. Also, one or more retainer members may maintain the hinge plates in a closed position relative to the housing, e.g., in a position close to the housing, and/or maintain the hinge plates in an open position away from the housing.

In one embodiment, at least one of the doors may include a container holder that is movable between a folded position and an extended position in which the container holder is arranged to support a container, such as reagent supply container. In addition, or alternately, one or both of the doors may include a hook to support a control interface for the hemodialysis unit, such as a remote interface unit that is connected to the housing by a communication cable. These features may make use of the dialysis unit easier by supporting components in a convenient location.

In another embodiment, the front panel may include at least one flanged portion to support blood lines of a blood circuit assembly. For example, the front panel may include several flanged sections arranged at a periphery of the front panel, such as at lower corners and at a top edge of the front panel. Blood circuit lines that connect to a patient may be relatively long (e.g., up to 3-4 feet or more), and may be wrapped around the periphery of the front panel and retained in place by the flanged portions. The flanged portions may be arranged to support the blood lines and allow the doors to be moved to the closed position without contacting the blood lines, e.g., to avoid pinching of the blood lines at door hinge points.

In one embodiment, the blood circuit connections at the front panel include arterial and venous blood line connectors for the blood circuit, and the dialysate fluidic connections at the front panel include a connection point for a reagent supply, dialyzer dialysate connections, and

a blood line connection point for connecting the arterial and venous blood lines to a directing circuit of the dialysis unit.

The hemodialysis unit may include a control interface that is connected to the housing by a flexible cable and that is arranged to allow a user to receive information from and provide information to the hemodialysis unit. In one embodiment, the enclosure may include a control interface mounting area at a top of the enclosure where the control interface is mountable. For example, the control interface may include a foldable leg or other support that permits the control interface to be stood in a near vertical orientation on the top of the housing.

In another embodiment, the enclosure may include an electronics section that is separated and insulated from a disinfection section that is heated to disinfect components of the hemodialysis unit. For example, the disinfection section may include all of the liquid circuit components, such as valves, pumps, conduits, etc., of the various portions of the dialysis unit. The electronics section may include motors, computers or other data processing devices, computer memory, and/or other temperature sensitive electronics or other components. By isolating the electronics section from the disinfection section (at least to some degree), components in the electronics section may be spared exposure to the heat or other environmental conditions in the disinfection section whether during a disinfection operation or otherwise.

In another embodiment of the invention, a portable hemodialysis system may be arranged so that power for the fluid circuit pumps of a dialysis unit may be provided by a modular power unit, e.g., a unit that can be selectively connected to or disconnected from the dialysis unit. As a result, failure of a power unit need not necessarily disable the entire dialysis system. Instead, the power unit may be replaced with another power unit, allowing for treatment to continue. For example, a modular assembly for a portable hemodialysis system may include a dialysis unit, e.g., including a housing that contains suitable components for performing hemodialysis, such as a dialyzer, one or more pumps to circulate blood through the dialyzer, a source of dialysate, and one or more pumps to circulate the dialysate through the dialyzer. The housing may have a front panel at which blood circuit connections and dialysate fluidic connections are located, e.g., where an operator may make patient blood access connections, connect a reagent supply, and/or connect a dialyzer. The modular assembly may also include a power unit having a housing that contains suitable components for providing operating power to the pumps of the dialysis unit. The power unit may be selectively connected to the dialysis unit and provide power to the dialysis unit for the pumps when connected to the dialysis unit, but may be incapable of providing power to the dialysis unit when disconnected from the dialysis unit. The power unit may be selectively connected to and disconnected from the dialysis unit by operation of a single handle, e.g., an operator may turn or otherwise operate a single handle to disconnect the power unit from the dialysis

unit. In one embodiment, the dialysis unit and the power unit are sized and weighted to each be carried by hand by a human.

In one embodiment, the pumps of the dialysis unit are pneumatic pumps and the power unit provides pneumatic power to the dialysis unit. For example, the power unit may provide air pressure and/or vacuum to the dialysis unit to power the pumps. The power unit may include one or more air pressure pumps and/or air vacuum pumps, and the dialysis unit may include a plurality of valves to control application of pneumatic power to the pumps. To aid with use of the hemodialysis system in the home, the power unit and dialysis unit electrical power requirements may be provided by standard residential electrical power, e.g., approximately 110V, 15amp electrical power. The dialysis unit may provide electrical power to the power unit, and the power unit may use the electrical power to generate operating power for the pumps.

In another embodiment of the invention, a blood circuit assembly for a dialysis unit may be arranged to allow the replacement of most or all blood circuit components in a single operation. For example, the blood circuit assembly may include an organizing tray, a pair of pneumatic pumps mounted to the organizing tray for circulating blood received from a patient through a circuit including a dialyzer unit and returned to the patient, an air trap mounted to the organizing tray arranged to remove air from blood circulating in the circuit, a pair of dialyzer connections arranged to connect to the inlet and outlet of a dialyzer unit, and a pair of blood line connectors, one inlet blood line connector for receiving blood from the patient and providing blood to the pneumatic pumps and the other outlet blood line connector for returning blood to the patient.

In one embodiment, an anticoagulant connection is provided for engaging with an anticoagulant source and providing anticoagulant into the blood circuit. For example, the anticoagulant connection may include a pump for pumping anticoagulant from the anticoagulant source, such as heparin from a vial of heparin, to the circuit. The anticoagulant connection may include a vial holder arranged to hold two or more differently sized vials, and a spike to pierce the vial. In one embodiment, the pair of pneumatic pumps, the anticoagulant connection, and the anticoagulant pump are part of a pump cassette.

In another embodiment, the blood circuit assembly may be selectively mounted to and removed from a dialysis unit. To aid in handling of the blood circuit assembly, the organizing tray may include a pair of handles arranged for gripping by a user. The organizing tray may also include openings adjacent each of the handles for receiving retaining tabs on a dialysis unit that engage with the blood circuit assembly and retain the blood circuit assembly on the dialysis unit.

In one embodiment, the inlet blood line connector is connected to an inlet for the pump cassette, an outlet for the pump cassette is connected to a dialyzer inlet connector, a dialyzer

outlet connector is connected to an inlet of the air trap, and an outlet of the air trap is connected to the outlet blood line connector. The inlet of the air trap may be located above the outlet of the air trap when the blood circuit assembly is mounted to a dialysis unit, e.g., to aid in trapping of air circulating in the circuit during treatment. The blood line connectors may be arranged for a threaded luer-type connection to a patient access, as well as be arranged for a press-in type connection to the dialysis unit. Such an arrangement may make it easier for an operator to connect the blood line connectors to the dialysis unit after treatment (e.g., for later disinfection and/or priming of the blood circuit) while allowing the connectors to engage with standard luer-type connectors at a patient blood access.

In one embodiment, the organizing tray may include circuit tube engagement members having a hole or slot through which a respective circuit tube passes. The engagement members may engage with the respective circuit tube to allow the circuit tube to be pulled and stretched for engagement with an occluder of the dialysis unit. For example, the circuit tubes of the blood circuit assembly may include silicone tubing that has to be stretched (and thereby reduced in diameter) to engage with an occluder. The circuit tube engagement members may resist the pull of an operator on the tubes, allowing the tubes to be stretched and placed in engagement with the occluder.

In another embodiment of the invention, a method for replacing a blood circuit assembly of a dialysis unit includes grasping a pair of handles on an organizing tray of a blood circuit assembly that is mounted to a dialysis unit, disengaging locking tabs of the dialysis unit from the blood circuit assembly to free the blood circuit assembly from the dialysis unit, and pulling on the handles on the organizing tray of the blood circuit assembly to remove the blood circuit assembly from the dialysis unit. Disengagement of the locking tabs may be performed by flexing the locking tabs away from each other such that each locking tab is moved toward a nearest one of the handles. After removal of the blood circuit assembly, a replacement blood circuit assembly may be provided, openings in the organizing tray of the replacement blood circuit assembly may be aligned with the locking tabs so that each locking tab is received into a respective opening, and the organizing tray may be pushed relative to the dialysis unit such that the locking tabs engage with the replacement blood circuit assembly to mount the replacement blood circuit assembly to the dialysis unit. Mounting the replacement blood circuit assembly may also involve connecting control ports on the dialysis unit to mating ports on the assembly so that fluid control signals may be provided for pumps and valves of the blood circuit assembly. Other blood circuit connections may be made, such as inlet and outlet connections for the dialyzer, and the blood line connectors may be connected to receive dialysate into the blood circuit.

In another embodiment of the invention, an air trap for a blood circuit in a dialysis unit includes a blood inlet supply line, a blood outlet supply line, and a container having an

approximately spherical internal wall, an inlet at a top end of the container connected to the blood inlet supply line, and an outlet at a bottom end of the container connected to the blood outlet supply line. The inlet may be offset from a vertical axis of the approximately spherical internal wall such that blood entering the container through the inlet is directed to flow in around the approximately spherical wall in a spiral-like path. Such flow in the container may help to remove air bubbles from the blood as it flows from the inlet to the outlet, with any removed air remaining near the top of the container. The inlet port may be arranged to introduce blood into the container in a direction that is approximately tangential to the approximately spherical inner wall of the container and/or in a direction that is approximately perpendicular to the vertical axis of the container.

In one embodiment, a self-sealing port may be located at a top of the container, e.g., in the form of a split septum that is arranged to permit introduction of fluid into, and withdrawal of liquid from, the container by inserting a needleless device through the split septum. The self-sealing port may be arranged to be self-cleaning when disinfection liquid is circulated through the container, e.g., the port may be suitably exposed to flowing disinfection liquid to remove debris and/or heat material on the port to achieve desired disinfection.

In another embodiment of the invention, a tube securing arrangement of a blood circuit assembly includes a organizing tray that supports components of a blood circuit assembly and includes a pair of tube engagement members each having a hole, a pair of patient inlet and outlet lines arranged to connect with patient access points for receiving liquid from and/or providing liquid to the patient, and a pair of stops on the patient inlet and outlet lines, respectively. The patient inlet and outlet lines may each pass through a hole of a respective tube engagement member so that the stop engages with the tube engagement member. With this arrangement, the tube engagement members may resist pulling and stretching of the inlet and outlet lines when engaging the lines with an occluder. The tube engagement members may be flexible to allow a user to press inwardly on the engagement member and seat the respective inlet or outlet line in the occluder, yet resist downward pulling of the line.

In another embodiment of the invention, a hemodialysis system includes a dialyzer mount arranged to support a plurality of differently sized and/or shaped dialyzer units and to accommodate different distances between dialysate connections on the dialyzer units. The dialyzer mount, which may be located on a front panel of the dialysis unit, may include a pair of flange portions that are each arranged to engage with a respective dialysate quick-connect fitting connected to a dialysate port of the dialyzer. Each flange portion may be arranged to engage with a groove on the quick connect fitting that is located between a portion of the base of the quick connect fitting and a slide element of the quick connect fitting. For example, the dialyzer mount may include a pair of keyhole features with each keyhole feature having an upper insertion area sized to receive a portion of the base of the quick-connect fitting inserted

into the upper insertion area, and a lower flanged portion having a width that is smaller than an overall a width of the base of the quick-connect fitting and that engages with a groove on the quick connect fitting. The lower flanged portion may include a pair of opposite flanges that engage with the groove and allow the quick-connect fitting to slide along the flanges.

In one embodiment, the bottom keyhole feature may include an adjustable support that is moveable in a vertical direction. For example, the adjustable support may be movable along the opposed flanges. Thus, the adjustable support may be fixable in a plurality of different positions on the flanges to support the weight of the dialyzer. In one arrangement, the adjustable support includes a "U" shaped member and at least one thumb screw that may be tightened to fix the "U" shaped member in place. .

In another embodiment of the invention, a blood line connector for a blood circuit of a hemodialysis unit may have the ability to make two different types of fluid tight connections, e.g., a screw-type connection with a luer connector at a patient access and a press-in type connection with a dialysate circuit of the hemodialysis unit. For example, the blood line connector may include a tube connection end arranged to sealingly engage with a blood circuit tube, and a patient access connection end with a frustoconical member having an internally threaded portion arranged to engage with an externally threaded patient access, and a pair of locking arms extending rearwardly from the frustoconical member. The locking arms may each have a finger depression portion and a barbed portion, and may be arranged to engage with a mating connector on the dialysis unit at the barbed portions to lock the frustoconical member in sealing engagement with the mating connector when making a press-in type connection. The barbed portions may disengage from the mating connector when the finger depression portions are urged toward each other. In one embodiment, the patient access connection end may include a central tube extending from the center of the frustoconical member. The internally threaded portion of the frustoconical member and the central tube may be arranged to mate with a female luer-type patient access connector or any other suitable screw-type connection.

In another embodiment of the invention, a method for operating a dialysis unit includes connecting blood line connectors of arterial and venous blood lines for a dialysis unit to patient access connectors in communication with a patient blood system. In one embodiment, the patient access connectors may require a corresponding blood line connector to establish a threaded engagement with the patient access connector, thereby forming a luer or screw-type connection between the blood line connectors and the patient access connectors. The dialysis unit may be operated to withdraw blood from a patient access connector and into an arterial blood line, subject the withdrawn blood to a dialysis process to produce treated blood, and return the treated blood to the patient via the venous blood line and the other patient access connector. Thereafter, the blood line connectors may be disconnected from the patient access

connectors by unscrewing the blood line connectors from a corresponding patient access connector, and the blood line connectors may be connected to a directing circuit of the dialysis unit. The blood line connectors may be connected to the directing circuit by a press-in connection with a corresponding connection point on the dialysis unit, e.g., by pushing the blood line connectors into the connection points to establish the press-in connection.

In another embodiment of the invention, a reagent supply arrangement for a hemodialysis system may be arranged to provide two or more reagent materials for use in preparing a dialysate and may include a connector arranged to help prevent the connection of a reagent material to the wrong port. For example, the reagent supply may include an E-prong connector having three parallel prongs with two outer prongs arranged in a common plane and a center prong arranged above the common plane, a first supply line for a first reagent connected in fluid communication with one of the outer prongs, a second supply line for a second reagent connected in fluid communication with the other of the outer prongs, a liquid line connected in fluid communication with the center prong, and a container for housing the first reagent having an inlet connected to the liquid line and an outlet connected to the first supply line for the first reagent. The E-prong connector may help prevent the improper connection of the first and second supply lines to the dialysis unit, e.g., because the central prong being located out of the plane of the two outer prongs ensure connection of the E-prong connector in only one way to the dialysis unit.

In one embodiment, the container includes a bicarbonate material suitable for use in generating a dialysate for the hemodialysis system. The liquid line may be a water supply line that provides water to the container, allowing the water to mix with the bicarbonate (which may be in powder or other solid form) and flow to the first supply line. The second supply line may be an acid supply line that includes a connector and provides acid material to the E-prong connector. The reagent supply may also include an acid bag spike that is removably engaged with the connector of the acid supply line. The acid bag spike may include a spike member and a pair of spring clips at an end of the acid bag spike opposite the connector of the acid supply line, allowing the acid bag spike to be fluidly connected with an acid bag or other acid source.

In another embodiment of the invention, a method for operating a hemodialysis system includes providing a dialysis unit having an enclosure containing suitable components for performing hemodialysis including a dialyzer, one or more pumps to circulate blood through the dialyzer, a source of dialysate, and one or more pumps to circulate the dialysate through the dialyzer. The enclosure may include a housing that supports the components and has a front panel at which blood circuit connections and dialysate fluidic connections are made. A reagent supply may be provided including an E-prong connector, a first supply line for a first reagent connected in fluid communication with one of the outer prongs, a second supply line

for a second reagent connected in fluid communication with the other of the outer prongs, a liquid line connected in fluid communication with the center prong, and a container for housing the first reagent having an inlet connected to the liquid line and an outlet connected to the first supply line for the first reagent. The E-prong connector may be engaged with a connection point at the front panel of the dialysis unit, thereby allowing the dialysis unit to provide water to the liquid line of the reagent supply, and allowing the dialysis unit to receive the first and second reagents from the first and second supply lines.

Other advantages and novel features of the present invention will become apparent from the following detailed description of various non-limiting embodiments of the invention when considered in conjunction with the accompanying figures. In cases where the present specification and a document incorporated by reference include conflicting and/or inconsistent disclosure, the present specification shall control. If two or more documents incorporated by reference include conflicting and/or inconsistent disclosure with respect to each other, then the document having the later effective date shall control.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects of the invention are described with reference to illustrative embodiments, which are described with reference to the drawings in which like numerals reference like elements, and wherein:

FIG. 1 is a schematic representation of fluid handling components of a hemodialysis system in an illustrative embodiment;

FIG. 2 shows a schematic fluid flow diagram for the dialysis system of FIG. 1;

FIG. 3 is a schematic fluid flow diagram for the blood flow circuit of the FIG. 2 embodiment;

FIG. 4 is a schematic fluid flow diagram for the balancing circuit of the FIG. 2 embodiment;

FIG. 5 is a schematic fluid flow diagram for the directing circuit of the FIG. 2 embodiment;

FIG. 5A is a schematic fluid flow diagram illustrating a flow path for a drain assembly in an illustrative embodiment;

As shown in FIG. 37, a low-pass filter 9 can be formed by resistor Rf and capacitor Cf, to filter out high-frequency noise. In one exemplary arrangement, Rf can have a value of 1K ohms, and Cf can have a value of 0.001 uF. Buffer amplifier 10 and analog-to-digital converter (ADC) 111 can then measure the sensed voltage for a computer or digital signal processor (not shown).

The reference voltages V+ and V- may be advantageously derived from a voltage divider 8 so that V+ is close to the reference voltage Vref of the ADC 111, and V- is close to the ground reference voltage of the ADC 111. For example, for R1=10ohms, R2=2 kohms, and Vref=4.0V, then V+=3.980V, and V-=0.020V. This places both voltages within but near the edges of the active sensing region of the ADC 111, where they can be used for calibration (discussed below). Switch SW1 12 may be used to help calibrate the load resistance sensing.

Several improvements may decrease errors related to variations of component values. First, a calibration step can be introduced where VA is switched to V+ for a relatively long period of time, until settles and is approximately equal to V+, at which point ADC 111 can take a measurement of Vsense. A second calibration step can involve switching VA to V- for a relatively long period of time, until Vsense settles and is approximately equal to V-, at which point ADC 111 can take another measurement of Vsense. This allows the ADC 111 to measure both V+ and V-.

Secondly, as shown in FIG. 38, while the square wave is switching, ADC 111 readings before and after both edges of the switching waveform may be used to compute the dimensionless quantity $\Delta\alpha$:

$$\Delta\alpha=\Delta Vsense/(V+-V-)=[(V2-V1)+(V3-V4)]/2(V+-V-)$$

As a result, both edges of the waveform can be used to measure $\Delta Vsense=[(V2-V1)+(V3-V4)]/2$, so that asymmetric responses to the circuit are likely to be canceled out. Alternatively, an average voltage at about the midpoint of the waveform may be used; so that, for example, $\Delta\alpha=\Delta Vsense/(V+-V-)=[(V7-V6)+(V7-V8)]/2(V+- V-)$, and $\Delta Vsense=[(V7-V6)+(V7-V8)]/2$. In addition, only differential measurements of the input signal Vin of the ADC 111 can be used. Thus, any offset errors of the buffer amplifier 10 and ADC 111 can be canceled out. Also, $\Delta\alpha$ is a ratiometric quantity based on measurements using the same signal path. Thus, any gain errors of the ADC 111 can also be canceled out.

The reference resistor Rref 4 may be optimally chosen to be equal to the geometric mean of the endpoints of the desired range of unknown resistances, taking series resistances Rs 7 into account. For example, if Rs=100ohms and Rx varies from 100ohms to 3000ohms, then Ry=Rx+2R, varies from 300ohms to 3200 ohms, and Rref should be approximately the square root of (300ohms3200ohms)=980ohms. To measure an unknown resistance in the range of 100 k-300 k ohms (as in, for example, a column of blood extending from one electrode to another via an arterio-venous fistula), the reference resistor Rref 4 can be changed to approximately 200 k ohms and the filter capacitor Rf of low pass filter 9 at the input to the buffering amplifier 10 can be removed completely.

Because a voltage divider's output is a nonlinear function of its resistance ratio, errors or noise in readings from the ADC 111 produce their lowest fractional error (sensitivity) in the resultant calculation of Ry when it is equal to Rref, and the sensitivity increases the more Ry diverges from the reference resistance Rref. Specifically, it can be shown that the sensitivity in resistance ratio is as follows:

$$S\rho = (1/\rho) \bullet \partial\rho/\partial\Delta\alpha = 2/[(1+\Delta\alpha)(1-\Delta\alpha)] = 2/[1-(\Delta\alpha)^2]$$

When Ry=Rref, $\rho=1$, $\Delta\alpha=0$ and $S\rho=2$. Thus, for a change in $\Delta\alpha$ of 0.001 (0.1% of the ADC full-scale) around this point, the calculated resistance Ry changes by 0.002 or 0.2%. The sensitivity increases as ρ diverges from 1, as shown in Table 1.

TABLE 1

P	$\Delta\alpha$	$S\rho$
1 0 2		
2, 0.5	.+-.0.333	2.25
4, 0.25	.+-.0.6	3.13
5.83, 0.172	.+-.0.707	4
10, 0.1	.+-.0.818	6.05

CLAIMS

1. A pair of first and second engagement devices for a blood circuit assembly mounted on a panel of a dialysis unit, the first engagement device positioned on a first side of the blood circuit assembly mounted to the panel, and the second engagement device positioned on a second side of the blood circuit assembly mounted to the panel, each engagement device comprising:

an actuator movably mounted to the panel of the dialysis unit adjacent a plurality of control ports that are configured to connect with mating control ports on a back side of the blood circuit assembly, the actuator movable between a retention position and an ejection position;

a retainer element coupled to the actuator and arranged, with the actuator in the retention position, to contact a portion of a front side of the blood circuit assembly, and retain the blood circuit assembly on the panel of the dialysis unit, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the panel of the dialysis unit; and

an ejector element coupled to the actuator or to the panel and arranged, with the actuator moved from the retention position to the ejection position, to contact a portion of the back side of the blood circuit assembly to urge the blood circuit assembly away from the panel,

wherein the actuators are movable away from each other from respective retention positions to ejection positions, and wherein the first and second sides are opposed to each other such that the actuators of the engagement devices are movable by respective first and second thumbs of a user.

2. The engagement devices of claim 1, wherein the actuator is pivotally mounted to the panel.

3. The engagement devices of claim 1, wherein the retainer element is fixed to or formed with the actuator.

4. The engagement devices of claim 1, wherein the ejector element is pivotable between an inactive or retracted position and an ejection position.

5. The engagement devices of claim 1, wherein the actuator is arranged to be moved from the retention position to the ejection position by a user's thumb.

6. The engagement devices of claim 1, wherein the ejector element is arranged to contact a portion of a pump chamber of the blood circuit assembly in the ejection position.

7. The engagement devices of claim 6, wherein a portion of the ejector element adjacent the contacting portion of the pump chamber is positioned in a recess when the blood circuit assembly is mounted on the panel and the ejector element is in an inactive or retracted position.

8. The engagement devices of claim 1, wherein the retainer element comprises two opposing arms, and is arranged, with the actuator in the retention position and a blood circuit assembly mounted to the panel, to contact an outer surface of the blood circuit assembly at two locations to lock the blood circuit assembly in place.

9. The engagement devices of claim 1, wherein the actuator is spring biased to move toward the retention position.

10. An engagement device for a dialysis unit, comprising:

an actuator movably mounted to a panel of the dialysis unit adjacent a plurality of control ports that are configured to connect with mating control ports on a back side of a blood circuit assembly, the actuator movable between a retention position and an ejection position;

a retainer element coupled to the actuator and arranged, with the actuator in the retention position, to contact a portion of a front side of the blood circuit assembly, and retain the blood circuit assembly on the panel of the dialysis unit, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the panel of the dialysis unit; and

an ejector element coupled to the actuator or to the panel and arranged, with the actuator moved from the retention position to the ejection position, to contact a portion of the back side of the blood circuit assembly to urge the blood circuit assembly away from the panel,

wherein the ejector element is pivotable about an axis between an inactive or retracted position and an ejection position, with a proximal portion on a first side of the axis configured to

contact an ejector contact arm of the actuator, and a distal portion on a second opposing side of the axis configured to make contact with the blood circuit assembly.

11. The engagement device of claim 10, wherein the ejector contact arm of the actuator is configured to depress the proximal portion of the ejector element and raise the distal portion of the ejector element into the ejection position when the actuator is depressed and placed in the ejection position.

12. An engagement device for a dialysis unit, comprising:

a pair of actuators movably mounted to a panel of the dialysis unit adjacent to and on opposing sides of a plurality of control ports that are configured to connect with mating control ports on a back side of a blood circuit assembly, the actuators movable between a retention position and an ejection position;

a pair of retainer elements, each coupled to a respective actuator and arranged, with the actuators in the retention position, to contact portions of a front side of the blood circuit assembly, and retain the blood circuit assembly on the panel of the dialysis unit, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the panel of the dialysis unit; and

a pair of ejector elements, each coupled to a respective actuator or to the panel and arranged, with the actuators moved from the retention position to the ejection position, to contact portions of the back side of the blood circuit assembly to urge the blood circuit assembly away from the panel,

wherein the actuators are movable away from each other from respective retention positions to ejection positions.

13. The engagement device of claim 12, wherein the actuators are pivotally mounted to the panel.

14. The engagement device of claim 12, wherein the retainer elements are fixed to or formed with the actuator.

15. The engagement device of claim 12, wherein each ejector element is pivotable between an inactive or retracted position and an ejection position.

16. The engagement device of claim 12, wherein each actuator is arranged to be moved from the retention position to the ejection position by a user's thumb.

17. The engagement device of claim 12, wherein each ejector element is arranged to contact a respective portion of a pair of pump chambers of the blood circuit assembly in the ejection position.

18. The engagement device of claim 17, wherein a portion of each ejector element adjacent the contacting portion of the respective pump chamber is positioned in a recess when the blood circuit assembly is mounted on the panel and the ejector element is in an inactive or retracted position.

19. The engagement device of claim 12, wherein each actuator is spring biased to move toward the retention position.

20. An engagement device for a dialysis unit, comprising:

a pair of actuators movably mounted to a panel of the dialysis unit adjacent to and on opposing sides of a plurality of control ports that are configured to connect with mating control ports on a back side of a blood circuit assembly, the actuators movable between a retention position and an ejection position;

a pair of retainer elements, each coupled to a respective actuator and arranged, with the actuators in the retention position, to contact portions of a front side of the blood circuit assembly, and retain the blood circuit assembly on the panel of the dialysis unit, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the panel of the dialysis unit; and

a pair of ejector elements, each coupled to a respective actuator or to the panel and arranged, with the actuators moved from the retention position to the ejection position, to contact

portions of the back side of the blood circuit assembly to urge the blood circuit assembly away from the panel,

wherein each retainer element comprises two opposing arms, and is arranged, with the respective actuator in the retention position and a blood circuit assembly mounted to the panel, to contact an outer surface of the blood circuit assembly at two locations to secure the blood circuit assembly in place.

21. An engagement device for a dialysis unit, comprising:

a pair of actuators movably mounted to a panel of the dialysis unit adjacent to and on opposing sides of a plurality of control ports that are configured to connect with mating control ports on a back side of a blood circuit assembly, the actuators movable between a retention position and an ejection position;

a pair of retainer elements, each coupled to a respective actuator and arranged, with the actuators in the retention position, to contact portions of a front side of the blood circuit assembly, and retain the blood circuit assembly on the panel of the dialysis unit, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the panel of the dialysis unit; and

a pair of ejector elements, each coupled to a respective actuator or to the panel and arranged, with the actuators moved from the retention position to the ejection position, to contact portions of the back side of the blood circuit assembly to urge the blood circuit assembly away from the panel,

wherein each ejector element is pivotable about an axis between an inactive or retracted position and an ejection position, with a proximal portion on a first side of the axis configured to contact an ejector contact arm of the respective actuator, and a distal portion on a second opposing side of the axis configured to make contact with the blood circuit assembly.

22. The engagement device of claim 21, wherein the ejector contact arm of each actuator is configured to depress the proximal portion of the respective ejector element and raise the distal portion of the respective ejector element into the ejection position when the actuator is depressed and placed in the ejection position.

23. A pair of first and second engagement devices for a blood circuit assembly mounted to a control port assembly of a dialysis unit, the control port assembly comprising a plurality of pneumatic control ports configured to connect with mating valve and pump control ports on a back side of the blood circuit assembly, the first engagement device positioned on a first side of the blood circuit assembly mounted to the control port assembly, and the second engagement device positioned on a second side of the blood circuit assembly mounted to the control port assembly, each of the first and second engagement devices comprising:

an actuator movably mounted to the control port assembly of the dialysis unit, the actuator movable between a retention position and an ejection position;

a retainer element coupled to the actuator and arranged, with the actuator in the retention position, to contact a portion of a front side of the blood circuit assembly, and secure the blood circuit assembly to the control port assembly, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the control port assembly; and

an ejector element coupled to the actuator or to the control port assembly and arranged, with the actuator moved from the retention position to the ejection position, to contact a portion of the back side of the blood circuit assembly to urge the blood circuit assembly away from the control port assembly,

wherein the first and second sides are opposed to each other such that the actuators of the engagement devices are movable by respective first and second thumbs of a user, and wherein the actuators are movable away from each other from respective retention positions to ejection positions.

24. The engagement device of claim 23, wherein the actuator is pivotally mounted to the control port assembly.

25. The engagement device of claim 23, wherein the retainer element is fixed to or formed with the actuator.

26. The engagement device of claim 23, wherein the ejector element is pivotable between an inactive or retracted position and an ejection position.

27. The engagement device of claim 23, wherein the actuator is arranged to be moved from the retention position to the ejection position by a user's thumb.

28. The engagement devices of claim 23, wherein the ejector element is arranged to contact a portion of a pump chamber of the blood circuit assembly in the ejection position.

29. The engagement devices of claim 28, wherein a portion of the ejector element adjacent the contacting portion of the pump chamber is positioned in a recess when the blood circuit assembly is mounted on the control port assembly and the ejector element is in an inactive or retracted position.

30. The engagement devices of claim 23, wherein the retention retainer element comprises two opposing arms, and is arranged, with the actuator in the retention position and a blood circuit assembly mounted to the control port assembly, to contact an outer surface of the blood circuit assembly at two locations to lock the blood circuit assembly in place.

31. The engagement devices of claim 23, wherein the actuator is spring biased to move toward the retention position.

32. An engagement device for a dialysis unit, comprising:

an actuator movably mounted to a control port assembly of the dialysis unit, the control port assembly comprising a plurality of pneumatic control ports configured to connect with mating valve and pump control ports on a back side of a blood circuit assembly, the actuator movable between a retention position and an ejection position;

a retainer element coupled to the actuator and arranged, with the actuator in the retention position, to contact a portion of a front side of the blood circuit assembly, and secure the blood circuit assembly to the control port assembly, and arranged, with the actuator in the ejection position, to release the blood circuit assembly for removal from the control port assembly; and

an ejector element coupled to the actuator or to the control port assembly and arranged, with the actuator moved from the retention position to the ejection position, to contact a portion

of the back side of the blood circuit assembly to urge the blood circuit assembly away from the control port assembly,

wherein the ejector element is pivotable between an inactive or retracted position and an ejection position, and wherein the ejector element is pivotable about an axis, with a proximal portion on a first side of the axis configured to contact an ejector contact arm of the actuator, and a distal portion on a second opposing side of the axis configured to make contact with the blood circuit assembly.

33. The engagement device of claim 32, wherein the ejector contact arm of the actuator is configured to depress the proximal portion of the ejector element and raise the distal portion of the ejector element into the ejection position when the actuator is depressed and placed in the ejection position.