CLAIMS

1. A dialysis system, comprising:

a chamber including a membrane that is movable in the chamber and that fluidly separates a first portion of the chamber from a second portion of the chamber, the chamber including a first inlet to the first portion and a second inlet to the second portion; and

a blood leak sensor associated with the chamber and arranged to detect blood in the first portion of the chamber.

2. The system of claim 1, wherein the blood leak sensor is arranged to measure a first level in the first portion and a second level in the second portion for comparison of the first and second levels to each other to determine whether blood is present in the first portion.

3. The system of claim 2, wherein the blood leak sensor is arranged to measure the first level with the first portion substantially full of fluid and the second portion substantially empty of fluid, and is arranged to measure the second level with the first portion substantially empty of fluid and the second portion substantially full of fluid.

4. The system of claim 3, wherein the chamber includes a wall that defines an interior volume of the chamber, and the membrane is arranged to contact the chamber wall when the first and second portions are substantially full of fluid.

5. The system of claim 1, wherein the blood leak sensor includes:

a light emitter arranged to emit light into the chamber; and

a light detector arranged to detect light emitted by the light emitter.

6. The system of claim 5, wherein the light emitter and light detector are arranged on opposed sides of the chamber such that a straight light path extends from the light emitter to the light detector.

7. The system of claim 5, wherein the light emitter and the light detector are arranged so that light emitted by the light emitter and received by the light detector passes through the membrane.

8. The system of claim 5, wherein the chamber includes a wall that defines an interior volume of the chamber, and wherein the light emitter and the light detector are arranged so that light emitted by the light emitter and received by the light detector passes through the chamber wall.

9. The system of claim 1, wherein the membrane is transparent and the blood leak sensor is arranged to detect light transmitted through the first or second portion and at least a part of the membrane.

10. The system of claim 9, wherein the blood leak sensor includes a light emitter positioned outside of the chamber and a light detector positioned outside of the chamber.

11. The system of claim 1, wherein the blood leak sensor is arranged to detect blood in a dialysate solution where the blood is in a concentration of about 0.2 ml blood per liter or more, where the blood has a hematocrit of about 40%.

12. The system of claim 1, wherein the chamber is a balancing chamber arranged to receive used dialysate from a dialyzer into the first portion of the chamber, and arranged to receive clean dialysate for delivery to the dialyzer into the second portion of the chamber.

13. The system of claim 12, wherein the blood leak sensor is arranged to determine a presence of blood in the first portion by comparing a light level detected when the first portion is substantially full of used dialysate to a light level detected when the second portion is substantially full of clean dialysate.

14. The system of claim 1, wherein the chamber has a substantially spherical shape and the membrane has a substantially hemispherical shape in at least one configuration.

15. The system of claim 14, wherein the blood leak sensor includes:

a light emitter arranged to emit light into the chamber; and

a light detector arranged to detect light emitted by the light emitter,

wherein the light emitter and light detector are arranged on diametrically opposed sides of the chamber.

16. A method for detecting blood in a dialysate circuit of a dialysis system, comprising:

transmitting light through a first portion of a chamber having a movable membrane that separates the first portion of the chamber from a second portion of the chamber; and

determining a presence of blood in the first portion based on a light level detected for light transmitted through the first portion.

17. The method of claim 16, further comprising:

detecting a first light level for light transmitted through the first portion of the chamber;

transmitting light through the second portion;

detecting a second light level for light transmitted through the second portion of the chamber; and

determining the presence of blood in the first portion based on a comparison of the detected first and second light levels.

~~17~~18. The method of claim 16, comprising:

prior to transmitting light through the first portion, substantially filling the first portion of the chamber with used dialysate;

transmitting the light through the first portion of the chamber while the first portion is substantially filled with used dialysate;

prior to transmitting light through the second portion, substantially filling the second portion of the chamber with clean dialysate; and

transmitting light through the second portion of the chamber while the second portion is substantially filed with clean dialysate.

~~18~~19. The method of claim 16, wherein the step of transmitting light through the first portion comprises transmitting the light through the second portion and the membrane.

~~19~~20. The method of claim 16, wherein the step of transmitting light through the first portion comprises transmitting the light through a wall of the chamber.

~~20~~21. A method for detecting blood in a dialysate circuit of a dialysis system, comprising:

providing a chamber having a movable membrane that separates the first portion of the chamber from a second portion of the chamber;

providing used dialysate received from a dialyzer into the first portion of the chamber; and

determining whether blood is present in the used dialysate in the first portion based on a detected characteristic of the used dialysate in the first portion.

~~21~~22. The method of claim 20, wherein the detected characteristic includes an absorption of light by the used dialysate.

~~22~~23. The method of claim 20, further comprising:

providing clean dialysate for delivery to the dialyzer into the second portion of the chamber; and

detecting a characteristic of the clean dialysate in the second portion.

~~23~~24. The method of claim 22, wherein the step of determining comprises comparing detected characteristics of the used dialysate and the clean dialysate.

~~24~~25. The method of claim 23, wherein the characteristic of the used dialysate is detected with the first portion substantially filled with used dialysate and the second portion substantially empty, and the characteristic of the clean dialysate is detected with the second portion substantially filled with clean dialysate and the first portion substantially empty.

~~25~~26. The method of claim 20, further comprising:

detecting the characteristic of the used dialysate by transmitting light through the used dialysate and detecting a light level of light transmitted through the used dialysate.

~~26~~27. The method of claim 20, wherein the chamber is a balancing chamber of the dialysate circuit in the dialysis system.

~~27~~28. A method for detecting blood in a dialysate circuit of a dialysis system, comprising:

providing a blood leak sensor associated with a chamber having a membrane that separates a first portion of the chamber from a second portion of the chamber;

using the blood leak sensor to detect a characteristic of clean dialysate in the second portion of the chamber; and

using the detected characteristic of clean dialysate to determine whether blood is present in used dialysate, received from a dialyzer, in the first portion of the chamber.

~~28~~29. The method of claim 27, wherein the step of using the blood leak sensor to detect a characteristic of clean dialysate comprises:

using the blood leak sensor to detect the characteristic of clean dialysate with the second portion of the chamber substantially filled with clean dialysate and the first portion substantially empty.

~~29~~30. The method of claim 27, wherein the step of using the blood leak sensor to detect a characteristic of clean dialysate comprises:

transmitting light through the clean dialysate to detect the characteristic of the clean dialysate.

~~30~~31. The method of claim 29, wherein the step of using the detected characteristic of clean dialysate comprises:

transmitting light through the used dialysate in the first portion to detect a characteristic of the used dialysate; and

comparing the characteristics of the clean dialysate and the used dialysate to determine whether blood is present in the used dialysate.

~~31~~32. The method of claim 30, wherein the characteristic of the clean dialysate is detected for a condition in which the second portion is substantially filled with clean dialysate, and the characteristic of the used dialysate is detected for a condition in which the first portion is substantially filled with used dialysate.

~~32~~33. The method of claim 31, further comprising:

operating the chamber to alternately substantially fill the first portion with used dialysate and substantially fill the second portion with clean dialysate;

using the blood leak sensor to detect a characteristic of clean dialysate for each of a plurality of operations that substantially fills the second portion with clean dialysate; and

using the detected characteristic of clean dialysate for each of the plurality of operations to determine whether blood is present for each of a plurality of operations that substantially fills the first portion with used dialysate.

~~33~~34. The method of claim 30, wherein light transmitted through the used dialysate and the clean dialysate to detect the characteristics passes through the first and second portions of the chamber and the membrane.

~~34~~35. A method for detecting blood in a dialysate circuit of a dialysis system, comprising:

operating the dialysis system to provide dialysis treatment to a patient by, at least in part, circulating dialysate through a dialysate circuit including a balancing chamber and a dialyzer;

providing a blood leak sensor arranged to determine a presence of blood in used dialysate flowing from the dialyzer; and

using the blood leak sensor to measure a characteristic of clean dialysate while the dialysis system is in operation to provide the dialysis treatment to the patient.

~~35~~36. The method of claim 34, further comprising:

operating the dialysate circuit to alternately substantially fill the balancing chamber with clean dialysate and with used dialysate;

wherein using the blood leak sensor to measure a characteristic of clean dialysate includes operating the blood leak sensor to measure the characteristic of clean dialysate in the balancing chamber when the balancing chamber is substantially filled with clean dialysate.

~~36~~37. The method of claim 34, further comprising:

using the blood leak sensor to detect a presence of blood in the balancing chamber when the balancing chamber is substantially filled with used dialysate received from the dialyzer.

~~37~~38. The method of claim 36, wherein a presence of blood in the balancing chamber is determined based on a comparison of the measured characteristic of clean dialysate with a characteristic of used dialysate measured by the blood leak sensor when the balancing chamber is substantially filled with used dialysate.

AIR TRAP

~~38~~39. A dialysis system, comprising:

a mixing circuit arranged to combine at least water and one ingredient to form dialysate used in a dialysis treatment;

a water supply arranged to provide water to the mixing circuit via a water supply conduit; and

a water supply air trap arranged to trap air in the water supply conduit.

~~39~~40. The system of claim 38, wherein the water supply includes a container of water suitable for the formation of dialysate.

~~40~~41. The system of claim 38, wherein the water supply includes a reverse osmosis filter.

~~41~~42. The system of claim 38, wherein the water supply provides water to the water supply conduit at a pressure that is lower in absolute value relative to a reference pressure than a negative pressure used by the mixing circuit to draw water from the water supply conduit.

~~42~~43. The system of claim 41, wherein the water supply includes a pressure regulator.

~~43~~44. The system of claim 38, wherein the mixing circuit includes one or more pumps that draw water from the water supply conduit.

~~44~~45. The system of claim 38, wherein the mixing circuit includes one or more pumps that intermittently draw water from the water supply conduit.

~~45~~46. The system of claim 44, wherein the water supply is arranged to provide water to the water supply conduit on a continuous basis.

~~46~~47. The system of claim 38, wherein the air trap is arranged to trap up to about 1.5 ml of air.

~~47~~48. The system of claim 38, wherein the air trap is arranged to trap air at a rate of up to about 10 ml/hour with a flow of water of about 1200 ml/minute through the air trap.

~~48~~49. The system of claim 38, further comprising an accumulator in fluid communication with the water supply conduit between the air trap and the water supply.

~~49~~50. The system of claim 48, wherein the accumulator includes a moveable diaphragm that separates a liquid side of the accumulator from a gas side of the accumulator.

~~50~~51. The system of claim 49, wherein the gas side of the accumulator is vented to atmospheric pressure.

~~51~~52. The system of claim 48, wherein the accumulator is arranged to store a volume of water equal to about 27 ml.

~~52~~53. The system of claim 48, wherein the mixing circuit, the water supply, the water supply conduit and/or the accumulator are arranged to cause a negative pressure to be present in the air trap during at least a portion of a cycle in which a pump of the mixing chamber draws water from the water conduit.

~~53~~54. The system of claim 38, wherein the air trap includes an inlet near a top of the air trap and an outlet near a bottom of the air trap.

~~54~~55. The system of claim 53, wherein the air trap includes only two ports, one port for the inlet and one port for the outlet.

~~55~~56. The system of claim 38, wherein the system is arranged to reverse flow in the air trap and the water supply conduit to remove air from the air trap.

~~56~~57. A dialysis system, comprising:

a liquid supply arranged to provide liquid for use in dialysis treatment;

a liquid supply conduit fluidly coupled between the liquid supply and a directing circuit of the dialysis system; and

a water supply air trap arranged to trap air in the water supply conduit.

~~57~~58. A method for operating a dialysis system, comprising:

receiving water from a water supply at a mixing circuit via a water supply conduit, the mixing circuit being arranged to combine at least water and one ingredient to form dialysate used in a dialysis treatment; and

trapping air in the water at an air trap in communication with the water supply conduit.

~~58~~59. The method of claim 57, wherein the water supply provides water to the water supply conduit at a pressure that is lower in absolute value and in relation to a reference pressure than a negative pressure used by the mixing circuit to draw water from the water supply conduit.

~~59~~60. The method of claim 58, wherein the water supply includes a pressure regulator.

~~60~~61. The method of claim 57, wherein the step of receiving includes drawing water from the water supply conduit using one or more pumps in the mixing circuit.

~~61~~62. The method of claim 60, wherein the one or more pumps are operated to intermittently draw water from the water supply conduit.

~~62~~63. The method of claim 61, wherein the water supply is arranged to provide water to the water supply conduit on a continuous basis.

~~63~~64. The method of claim 57, wherein the air trap is arranged to trap up to about 1.5 ml of air.

~~64~~65. The method of claim 57, wherein the air trap is arranged to trap air at a rate of up to about 10 ml/hour with a flow of water of about 1200 ml/minute through the air trap.

~~65~~66. The method of claim 57, further comprising:

accumulating water in an accumulator that is in fluid communication with the water supply conduit between the air trap and the water supply.

~~66~~67. The method of claim 65, wherein the accumulator includes a moveable diaphragm that separates a liquid side of the accumulator from a gas side of the accumulator.

~~67~~68. The method of claim 66, further comprising venting the gas side of the accumulator to atmospheric pressure.

~~68~~69. The method of claim 65, wherein the accumulator is arranged to store a volume of water equal to about 27 ml.

~~69~~70. The method of claim 57, wherein the step of receiving includes;

causing a negative pressure to be present in the air trap during at least a portion of a period in which the mixing chamber receives water from the water conduit.

~~70~~71. The method of claim 69, wherein the negative pressure causes dissolved gas in the water to be released from the water and trapped in the air trap.

~~71~~72. The method of claim 69, wherein the negative pressure is caused, at least in part, by one or more pumps of the mixing circuit drawing water from the water supply conduit.

~~72~~73. The method of claim 69, wherein the step of causing a negative pressure includes:

supplying water from an accumulator into the water supply conduit during at least a portion of a time when a negative pressure is present in the air trap.

~~73~~74. The method of claim 72, wherein the accumulator is arranged to maintain the negative pressure after the one or more pumps of the mixing circuit stop drawing water from the water supply conduit.

~~74~~75. The method of claim 57, wherein the air trap includes an inlet near a top of the air trap and an outlet near a bottom of the air trap.

~~75~~76. The method of claim 57, further comprising:

removing air from the air trap by reversing flow in the water supply conduit.

~~76~~77. The method of claim 57, wherein the air trap includes only two ports, one for an inlet and one for an outlet.

~~77~~78. The method of claim 57, wherein the step of receiving includes:

intermittently receiving water from the water supply circuit at the mixing circuit.

~~78~~79. A dialysis system, comprising:

a mixing circuit arranged to combine at least water and one ingredient to form dialysate used in a dialysis treatment;

a water supply arranged to provide water to the mixing circuit via a water supply conduit; and

an accumulator arranged to receive and release water in fluid communication with the water supply conduit.

~~79~~80. The system of claim 78, wherein the accumulator includes a moveable diaphragm that separates a liquid side of the accumulator from a gas side of the accumulator.

~~80~~81. The system of claim 79, wherein the gas side of the accumulator is vented to atmospheric pressure.

~~81~~82. The system of claim 78, wherein the accumulator is arranged to store a volume of water equal to about 27 ml.

~~82~~83. The system of claim 78, wherein the accumulator is arranged to receive and hold water from the water supply conduit during periods when the mixing circuit is not drawing water from the water supply conduit, and is arranged to supply water to the water supply conduit during periods when the mixing circuit is drawing water from the water supply conduit.

~~83~~84. The system of claim 78, wherein the water supply includes a container of water suitable for the formation of dialysate.

~~84~~85. The system of claim 78, wherein the water supply includes a reverse osmosis filter.

~~85~~86. The system of claim 78, wherein the water supply provides water to the water supply conduit at a pressure that is lower in absolute value than a negative pressure used by the mixing circuit to draw water from the water supply conduit.

~~86~~87. The system of claim 85, wherein the water supply includes a pressure regulator.

~~87~~88. The system of claim 78, wherein the mixing circuit includes one or more pumps that draw water from the water supply conduit.

~~88~~89. The system of claim 78, wherein the mixing circuit includes one or more pumps that intermittently draws water from the water supply conduit.

~~89~~90. The system of claim 88, wherein the water supply is arranged to provide water on a continuous basis.

~~90~~91. The system of claim 78, further comprising an air trap in fluid communication with the water supply conduit and arranged to trap air in the water supply conduit.

~~91~~92. The system of claim 90, wherein the air trap is arranged to trap up to about 1.5 ml of air.

~~92~~93. The system of claim 90, wherein the air trap is arranged to trap air at a rate of up to about 10 ml/hour with a flow of water of about 1200 ml/minute through the air trap.

~~93~~94. The system of claim 90, wherein the mixing circuit, the water supply, the water conduit and/or the accumulator are arranged to cause a negative pressure to be present in the air trap during at least a portion of a cycle in which a pump of the mixing chamber draws water from the water conduit.

~~94~~95. A method for operating a dialysis system, comprising:

receiving water from a water supply at a mixing circuit via a water supply conduit, the mixing circuit being arranged to combine at least water and one ingredient to form dialysate used in a dialysis treatment;

providing water from an accumulator into the water supply conduit when the mixing circuit draws water from the water supply conduit; and

receiving water from the water supply conduit in the accumulator when the mixing circuit does not draw water from the water supply conduit.

~~95~~96. The method of claim 94, wherein the water supply provides water to the water supply conduit at a pressure that is lower in absolute value than a negative pressure used by the mixing circuit to draw water from the water supply conduit.

~~96~~97. The method of claim 95, wherein the water supply includes a pressure regulator.

~~97~~98. The method of claim 94, wherein the step of receiving includes drawing water from the water supply conduit using one or more pumps in the mixing circuit.

~~98~~99. The method of claim 97, wherein the one or more pumps are operated to intermittently draw water from the water supply conduit.

~~99~~100. The method of claim 98, wherein the water supply is arranged to provide water to the water supply conduit on a continuous basis.

~~100~~101. The method of claim 94, further comprising:

trapping air in the water supply conduit in an air trap.

~~101~~102. The method of claim 100, wherein the air trap is arranged to trap up to about 1.5 ml of air.

~~102~~103. The method of claim 100, wherein the air trap is arranged to trap air at a rate of up to about 10 ml/hour with a flow of water of about 1200 ml/minute through the air trap.

~~103~~104. The method of claim 100, wherein the accumulator is in fluid communication with the water supply conduit between the air trap and the water supply.

~~104~~105. The method of claim 94, wherein the accumulator includes a moveable diaphragm that separates a liquid side of the accumulator from a gas side of the accumulator.

~~105~~106. The method of claim 94, wherein the step of receiving water from the water supply conduit in the accumulator includes venting the gas side of the accumulator to atmospheric pressure.

~~106~~107. The method of claim 105, wherein the step of providing water from the accumulator to the water supply conduit includes venting the gas side of the accumulator to atmospheric pressure.

~~107~~108. The method of claim 94, wherein the accumulator is arranged to store a volume of water equal to about 27 ml.

~~108~~109. The method of claim 94, wherein the step of receiving includes;

causing a negative pressure to be present in the water supply conduit when the mixing chamber draws water from the water conduit.

~~109~~110. The method of claim 108, wherein the negative pressure causes dissolved gas in the water to be released from the water and trapped in an air trap.

~~110~~111. The method of claim 108, wherein the negative pressure causes water to be provided from the accumulator to the water supply conduit.

~~111~~112. The method of claim 108, wherein the negative pressure is caused, at least in part, by one or more pumps of the mixing circuit drawing water from the water supply conduit.

~~112~~113. The method of claim 111, wherein the accumulator is arranged to maintain the negative pressure after the one or more pumps of the mixing circuit stop drawing water from the water supply conduit.

~~113~~114. An accumulator, comprising:

a chamber having at least one port for receiving liquid into the chamber;

a moveable diaphragm in the chamber that separates a liquid side of the chamber from a gas side of the chamber; and

a vent arranged to vent the gas side of the chamber to atmospheric pressure.

~~114~~115. The accumulator of claim 94, wherein the vent includes an orifice having a size of about 0.004 inches.

~~115~~116. The accumulator of claim 94, wherein the vent is arranged to maintain a positive or negative pressure in the chamber for an extended period.

~~116~~117. The accumulator of claim 94, wherein the chamber is arranged to store a volume of water equal to about 27 ml in the liquid side.

~~117~~118. The accumulator of claim 94, wherein the chamber is arranged to receive and hold water from a water supply conduit of a dialysis system.

~~118~~119. The accumulator of claim 117, wherein chamber is arranged to receive water from the water supply conduit when a pressure above atmospheric is present in the water supply conduit, and is arranged to release water to the water supply conduit when a pressure below atmospheric is present in the water supply conduit.

~~119~~120. The accumulator of claim 118, wherein the accumulator is arranged to maintain a negative pressure in the gas side of the chamber for an extended period after a negaribe pressure is present in the water supply conduit.

~~110~~121. The accumulator of claim 94, wherein the membrane includes a flexible, hemispherically shaped element attached to the chamber.

~~111~~122. A method of measuring the clearance of a dialyzer in a hemodialysis system comprising the dialyzer, the dialyzer comprising a semi-permeable membrane separating a first side of the dialyzer from a second side of the dialyzer, wherein the first side of the dialyzer is connected in line with a blood flow pathway of the hemodialysis system and the second side of the dialyzer is connected in line with a dialysate flow pathway of the hemodialysis system; the method comprising:

creating flow of a first liquid through the blood flow pathway and a second liquid through the dialysate flow pathway;

adding ions to either the first liquid or the second liquid to create a change in ionic strength of flowing liquid to which the ions have been added;

passing the liquid to which the ions have been added through the dialyzer;

measuring a parameter indicative of the ions added to the first or second liquid which pass across the semi-permeable membrane; and

determining from the measured parameter a measure of the clearance of the dialyzer.

~~112~~123. A method of measuring the clearance of a dialyzer in a hemodialysis system comprising the dialyzer, the dialyzer comprising a semi-permeable membrane separating a first side of the dialyzer from a second side of the dialyzer, wherein the first side of the dialyzer is connected in line with a blood flow pathway of the hemodialysis system and the second side of the dialyzer is connected in line with a dialysate flow pathway of the hemodialysis system; the method comprising:

creating flow of a first liquid through the blood flow pathway and a second liquid through the dialysate flow pathway;

passing the first liquid and the second liquid through the dialyzer, wherein the first liquid and the second liquid contained in the dialyzer have different ionic strengths;

measuring the conductivity of both the first liquid and the second liquid; and

determining from the measured conductivity of both the first liquid and the second liquid a measure of the clearance of the dialyzer.

~~113~~124. A method of measuring the clearance of a dialyzer in a hemodialysis system comprising the dialyzer, the dialyzer comprising a semi-permeable membrane separating a first side of the dialyzer from a second side of the dialyzer, wherein the first side of the dialyzer is connected in line with a blood flow pathway of the hemodialysis system and the second side of the dialyzer is connected in line with a dialysate flow pathway of the hemodialysis system; the method comprising:

creating a recirculating flow of a first liquid through the blood flow pathway such that at least a portion of the first liquid passes through the dialyzer at least twice;

creating a non-recirculating flow of a second liquid through the dialysate flow pathway, such that the no portion of the second liquid passes through the dialyzer more than once;

measuring a parameter indicative of the ionic strength of at least one of the first liquid and the second liquid; and

determining from the measured parameter a measure of the clearance of the dialyzer.

~~114~~125. A method of measuring the clearance of a dialyzer in a hemodialysis system comprising the dialyzer, the dialyzer comprising a semi-permeable membrane separating a first side of the dialyzer from a second side of the dialyzer, wherein the first side of the dialyzer is connected in line with a blood flow pathway of the hemodialysis system and the second side of the dialyzer is connected in line with a dialysate flow pathway of the hemodialysis system; the method comprising:

creating flow of a first liquid through the blood flow pathway and a second liquid through the dialysate flow pathway;

passing the first liquid and the second liquid through the dialyzer;

during a first time period after creating the flow, creating conditions within the dialyzer such that ions permeate across the membrane from the second fluid to the first fluid to decrease the ionic strength of the second fluid and increase the ionic strength of the first fluid;

during a second time period after creating the flow, creating conditions within the dialyzer such that ions permeate across the membrane from the first fluid to the second fluid to decrease the ionic strength of the first fluid and increase the ionic strength of the second fluid; and

measuring a parameter indicative of the ionic strength of at least one of the first liquid and the second liquid; and

determining from the measured parameter a measure of the clearance of the dialyzer.

~~115~~126. A method of measuring the clearance of a dialyzer in a hemodialysis system comprising the dialyzer, the dialyzer comprising a semi-permeable

membrane separating a first side of the dialyzer from a second side of the dialyzer, wherein the first side of the dialyzer is connected in line with a blood flow pathway of the hemodialysis system and the second side of the dialyzer is connected in line with a dialysate flow pathway of the hemodialysis system; the method comprising:

creating flow of a first liquid through the blood flow pathway and a second liquid through the dialysate flow pathway;

passing the first liquid and the second liquid through the dialyzer, wherein the first liquid and the second liquid contained in the dialyzer have different ionic strengths;

obtaining a plurality of measurements of the conductivity of one or both the first liquid and the second liquid; and

determining from the plurality of conductivity measurements a parameter indicative of the ion clearance of the dialyzer; and

determining from the parameter indicative of the ion clearance of the dialyzer a measure of the urea clearance of the dialyzer, wherein the relationship between the urea clearance of the dialyzer and the parameter indicative of the ion clearance of the dialyzer is substantially linear.

~~116~~127. The method of any of claims 111-115, wherein initially, both the first liquid and the second liquid is water.

~~117~~128. The method of any of claims 111-115, wherein ions are added to the second liquid.

~~118~~129. The method of claim 117, wherein ions are added to the second liquid by adding a bolus of a solution comprising a dissolved salt to the second liquid.

~~119~~130. The method of claim 118, wherein a plurality of boulses of the solution are added to the second liquid at a plurality of time intervals during the measurement of clearance to create at least one flowing bolus of the second liquid having an increased ionic strength relative to other portions of the second liquid, which flowing bolus of the second liquid is passed through the dialyzer during the passing step.

~~120~~131. The method of any of claims 111, 113 or 114 wherein the parameter indicative of the ions added to the first or second liquid comprises a measure of the conductivity of at least one of the first and second liquid.

~~121~~132. The method of claim 120, wherein in the measuring step the conductivity of both of the first and second liquid are determined and used to determine the clearance of the dialyzer.

~~122~~133. The method of any of claims 111, 112, 114 or 115 wherein the flow of the first liquid through the blood flow pathway comprises a recirculating flow such that at least a portion of the first liquid passes through the dialyzer at least twice.

~~123~~134. The method of claim 122, wherein the flow of the second liquid through the dialysate flow path comprises a non-recirculating flow such that the no portion of the second portion passes through the dialyzer more than once.

~~124~~135. The method of claim 115, wherein a plurality of conductivity measurements of both the first and second liquid are obtained at each of a plurality of time intervals while the first liquid and the second liquid are passed through the dialyzer; and wherein the parameter indicative of the ion clearance of the dialyzer is a fitting constant K determined from the following model:

$$Model[i] = (1 - K) * Average(Model[i - n : i - 1]) + K * CondDialysate[i - m]$$

where i is a selected time interval, $Model[i]$ is a calculated value of conductivity measured in the first liquid at the time interval i, *Average* ($Model[i\text{-}n: i\text{-}1]$) is the average value of previous values of *Model* determined over the range of time intervals from $i\text{-}n$ to $i\text{-}1$, $CondDialysate[i\text{-}m]$ is a measured value, or average of measured values, of the conductivity of the second fluid determined at a m time intervals prior to i, wherein $n \geq 2$ and $m \geq 0$, and wherein K is determined by fitting the equation for $Model[i]$ to $CondBloodSide[i]$ over a range of measurement time intervals, wherein $CondBloodSide[i]$ is a measured value, or average of measured values, of the conductivity of the first fluid determined at time interval i.

~~125~~136. The method of claim 124, wherein $n > m$.

~~126~~137. The method of claim 125, wherein $n = m + 1$.

~~127~~138. A method for making dialysate for use in a hemodialysis system from water contained within or supplied to the hemodialysis system and at least one supply of solutes contained within or supplied to the hemodialysis system, comprising:

within the fluid circuit of the hemodialysis system, mixing a bolus of water with a quantity of the solutes to form a bolus of solution;

determining a parameter indicative of the solute concentration of the solution;

comparing the parameter and/or a measure of the concentration derived from the parameter to a dialysate concentration quality criteria to determine if the parameter and/or a measure of the concentration satisfies the dialysate quality criteria; and

directing the bolus of solution to a dialysate supply only if the parameter and/or a measure of the concentration satisfies the dialysate quality criteria.

~~128~~139. A method for making dialysate for use in a hemodialysis system from water contained within or supplied to the hemodialysis system and at least one supply of solutes contained within or supplied to the hemodialysis system, comprising:

within the fluid circuit of the hemodialysis system, mixing a bolus of water with a quantity of the solutes to form a bolus of solution;

directing the bolus of solution to a dialysate supply;

determining a parameter indicative of the solute concentration of a dialysate contained in the dialysate supply;

determining from the parameter and/or a measure of the concentration derived from the parameter a target quantity of water of a subsequent water bolus and a target quantity of solutes of a subsequent bolus of solutes to form a subsequent bolus of solution, the target quantities selected to so that the dialysate contained in the dialysate supply satisfies a dialysate quality criteria to determine if the parameter and/or a measure of the concentration satisfies the dialysate concentration quality criteria; and

within the fluid circuit of the hemodialysis system, mixing a bolus containing the target quantity of water with a bolus containing the target quantity of the solutes to form the subsequent bolus of solution.

~~129~~140. A method for making dialysate for use in a hemodialysis system from water contained within or supplied to the hemodialysis system and at least one supply of solutes contained within or supplied to the hemodialysis system, comprising:

within the fluid circuit of the hemodialysis system, measuring a conductivity of a bolus of a concentrate solution of the solutes;

determining from the measured conductivity of the concentrate a target quantity of water in a bolus of water needed to form a solution meeting a dialysate concentration quality criteria;

determining if the target quantity of water is satisfies a predetermined mixing safety criteria; and

forming a bolus of a dialysate solution from the water and the concentrate solution of the solutes to be added to a dialysate supply only if the predetermined mixing safety criteria is satisfied.

~~130~~141. The method of claim 127 or 128, wherein the parameter indicative of the solute concentration is a measured conductivity of the solutes in solution.

~~131~~142. The method of claim 130, wherein the measured conductivity is corrected for variations in a temperature at which the conductivity is measured.

~~132~~143. The method of claim 131, wherein temperature corrected conductivity measurements are used to determine a measure of the concentration of the solutes in solution.

~~133~~144. The method of claim 130, wherein the measured conductivity comprises an average of a plurality of conductivity measurements determined only while the solution if flowing.

~~134~~145. A pressure distribution module comprising:

one or more manifold blocks;

at least one gasket;

one or more output ports;

one or more supply lines; and

at least one valve wherein,

a first manifold block includes a face therein in which is formed multiple channels, the channels being sealed to form fluid passages by compressing a first gasket against the channels with a rigid backing plate, wherein

the supply lines are formed as passages through the manifold block that pass under one or more of the channels, each supply line being connected to a separate source of pneumatic pressure or vacuum, and wherein

the valve is fluidically connected to at least one supply line and an output port via holes in the manifold block fluidically connecting the one or more channels to the valve, supply line and output port.

~~135~~146. The pressure distribution module of claim 134, further comprising:

one or more cartridge valves mounted in a face of the first manifold block that is perpendicular to the face that includes the channels.

~~136~~147. The pressure distribution module of claim 134, further comprising at least one pressure sensor or valve mounted on a face of the first manifold block located opposing the face that includes the channels.

~~137~~148. The pressure distribution module of claim 134 comprising a second manifold block positioned adjacent to the first manifold block, wherein the backing plate is positioned between two gaskets, the first gasket sealing the channels of the first manifold block, and a second gasket sealing a plurality of channels formed on a face of the second manifold block.

~~138~~149. The pressure distribution module of claim 134 comprising at least two manifold blocks, each manifold block being separated from another manifold block

by a backing plate sandwiched between two gaskets, wherein holes or slots provided in the gaskets and backing plates are positioned to mate with raised features provided on the manifold blocks to align the manifold blocks with one another, with the backing plates and with the gaskets.

~~139~~150. The pressure distribution module of claim 135 wherein the cartridge valves are mounted in cavities arranged in two staggered rows on the face of the first manifold block that is perpendicular to the face that includes the channels, and wherein at least one hole extends from at least one of the channels to at least one cavity on a first row and one valve cavity on the second row.

~~140~~151. A pressure distribution module comprising:

two or more manifold blocks;

two or more gaskets;

one or more output ports;

one or more supply lines; and

at least one valve wherein,

a first manifold block includes a face having a plurality of channels formed therein,

a second manifold block includes a first face having a plurality of channels formed therein and an opposing second substantially smooth face, wherein

the channels on the first manifold block are sealed to form fluid passages by compressing one of the gaskets against the channels with the second substantially smooth face of the second manifold block, wherein

the supply lines are formed by passages through the manifold blocks that pass under at least some of the channels, each supply line being connected to a separate source of pneumatic pressure or vacuum when the module is configured in an operative configuration, and wherein

at least one valve is fluidically connected to at least one of the supply lines and to at least one output port via at least one hole penetrating from one or more of the channels to the valve, the supply line and the output port.

~~141~~152. The pressure distribution module of claim 140, further comprising one or more cartridge valves mounted in cartridge valve cavities positioned in one or both of the first manifold block and the second manifold block in a face of the manifold block oriented substantially perpendicular to the face comprising the channels.

~~142~~153. The pressure distribution module of claim 140, further comprising at least one pressure sensor or valve mounted on a face of the first manifold block that is oriented opposite to the face comprising the channels.

~~143~~154. The pressure distribution module of claim 140, wherein the first and second manifold blocks are fluidly interconnected via holes in the gasket positioned between the manifold blocks.

~~144~~155. The pressure distribution module of claim 141, wherein the cartridge valves cavities are arranged in at least two staggered rows on the face of the manifold blocks in which they are formed, and wherein at least one hole extends from at least one of the channels to at least one valve cavity on a first row and at least one valve cavity on the second row.

~~145~~156. A hemodialysis system comprising:

a plurality of pneumatically operated diaphragm pumps and valves that control the flow of blood and dialysate in a hemodialysis apparatus, the pumps and valves being actuated by a pressure source having a first positive pressure, a pressure source having a second positive pressure that is less than the first positive pressure, or a pressure source having a negative pressure, wherein

the pumps and valves that contact blood in an extracorporeal circuit of the system, when the system is connected to a patient, are fluidly connected to the second positive pressure source or the negative pressure source.

~~146~~157. The system of claim 145, wherein at least some valves controlling the flow of dialysate are fluidly connected to the first positive pressure source or the negative pressure source.

~~147~~158. A system of claim 145, wherein pumps and valves of the system in contact with dialysate solution operate under pressures greater than or equal to ambient or atmospheric pressures.

~~148~~159. A hemodialysis system comprising:

a plurality of diaphragm based reciprocating pumps;

a plurality of diaphragm based valves; and

a pressure distribution module comprising a plurality of valves requiring electrical power for actuation and configured for supplying a pressurized fluid to operate the diaphragm based reciprocating pumps and the diaphragm based valves to control the flow of blood and dialysate in the hemodialysis system, wherein

the pressure distribution module is configured to facilitate control of the system to operate the pumps and valves to assume open or closed positions as necessary to allow blood in an extracorporeal circuit of the system as connected to a patient during operation to be pushed back to the patient upon the loss of electrical power or control in the hemodialysis system.

~~149~~160. The hemodialysis system of claim 148, wherein

upon loss of electrical power to the valves of the pressure distribution module, the diaphragm based pumps and valves in fluid communication with the blood handling extracorporeal circuit and diaphragm based pumps and valves in a dialysate circuit of the system in fluid communication with a reservoir of dialysate solution are biased in a non-powered state to open a fluid path from the dialysate reservoir to the patient, and to close any dialysate fluid paths to drain.

~~150~~161. A heater circuit for a dialysis unit, comprising:

a dialysate path flow for carrying a flow of dialysate for use in a dialysis unit;

a heater arranged to heat dialysate in the dialysate flow path;

a heater temperature sensor arranged to sense a heater temperature of a portion of the heater;

a pump to controllably move fluid in the dialysate flow path;

a heater control circuit to control the heater using a first control loop to achieve a desired heater temperature by providing a heater control signal to control a heater power, wherein one or more gains are used by the heater control circuit to generate the heater control signal and the one or more gains are varied based on an operating mode of the dialysis unit.

~~151~~162. The heater circuit of claim 150, wherein the heater control circuit is arranged to select a maximum heater power to control the heater during start up of the dialysis unit.

~~152~~163. The heater circuit of claim 150, wherein the one or more gains comprises a proportional gain and an integral gain, and the heater control circuit prevents the integral gain from being increased when the heater power is at a maximum value for the operating mode of the dialysis unit.

~~153~~164. The heater circuit of claim 150, wherein the one or more gains comprises a proportional gain and an integral gain, and the heater control circuit sets the heater power to zero and stores a current integral gain value when dialysate flow in the dialysate flow path stops, and the heater control circuit sets the heater power above zero and uses the stored integral gain value to control heater power when dialysate flow restarts in the dialysate flow path.

~~154~~165. The heater circuit of claim 150, further comprising a liquid temperature sensor downstream of the heater to detect a temperature of dialysate in the dialysate flow path, and wherein the heater control circuit uses a second proportional integral control loop to control the temperature of dialysate downstream of the heater by varying the desired heater temperature.

~~155~~166. The heater circuit of claim 150, wherein the pump is controlled to limit dialysate flow through the dialysate flow path to reach a desired fluid temperature downstream of the heater.

~~156~~167. The heater circuit of claim 154, where the second control loop comprises a proportional gain and an integral gain, and the heater control circuit prevents the integral gain value from increasing when either the heater power of the first control loop or the desired heater temperature of the second control loop are at maximum values for the operating mode of the dialysis unit.

~~157~~168. The heater circuit of claim 154, where the second control loop comprises a proportional gain and an integral gain, and the heater control circuit sets the heater power to zero and stores the current integral gain value when dialysate flow in the dialysate flow path stops, and the heater control circuit sets the heater power above zero and uses the stored integral gain value and the one or more gains to control heater power when dialysate flow restarts in the dialysate flow path.

~~158~~169. The heater circuit of claim 150, wherein the heater control circuit functionally checks the heater circuit by providing a heater control signal corresponding to a non-zero heater power at a set value for a first duration, and provides a heater control signal corresponding to a zero heater power for a second duration while monitoring the heater temperature, wherein the heater circuit is deemed functional if the heater temperature rise during a sum of the first and second durations is greater than a first value and less than a second value.

~~159~~170. The heater circuit of claim 150, wherein the heater control circuit evaluates the heater during operation by monitoring the heater temperature at a time when the heater is commanded to use maximum power, wherein the heater is deemed functional if the heater temperature rise rate is above a set value.

~~160~~171. A dialysis unit including:

a dialysate flow circuit including a dialyzer; and

a field programmable gate array (FPGA) that monitors at least conductivity and temperature of dialysate in the flow circuit upstream of a dialyzer and enters a fail-safe state if the measured conductivity exceeds a value, and/or is outside of a range of values,

wherein the value or range of values is different for different modes of therapy, or the value or range of values is different for different patients.

~~161~~172. The dialysis unit of claim 160, wherein the FPGA corrects the conductivity of dialysate based on the temperature of the dialysate.

~~162~~173. A dialysis unit including:

a dialysate flow circuit including a dialyzer and an ultra-filtration pump; and

a field programmable gate array that monitors an amount of ultrafiltration fluid withdrawn from a patient during dialysis treatment by the dialysis unit by setting a given register to a first value and increasing the value of the register by a first incremental value for every pump stroke of the ultra-filtration pump and decreasing the value of the register by a second incremental value for each pre-determined increment of time, wherein the field programmable gate array enters a fail-safe state if the value of the register exceeds a pre-determined maximum value.

~~163~~174. A dialysis unit including:

a dialysate flow circuit including a dialyzer; and

an automatic computer processing unit that verifies before a start of a treatment that a safety system mediated by a field programmable gate array (FPGA) is operating properly by exposing sensors in fluid paths in the dialysis unit to temperatures or conductivities that are outside pre-determined permissible ranges of values, and confirming that the FPGA safety system enters a fail-safe state in response to the temperatures or conductivites outside the predetermined permissible ranges of values, wherein the computer processing unit resets the FPGA after verifying that the safety system is operating properly by writing to one or more registers in the FPGA within a pre-determined interval of time.

~~164~~175. A method implemented by an operative set of processor executable instructions configured for execution by a computer processor, the method comprising:

determining if a tablet is connected to a base through a physical connection;

establishing a first communications link between the tablet and the base through the physical connection;

updating, if necessary, an interface program on the tablet and the base through the first communications link;

establishing a second communications link between the tablet and the base using the first communications link; and

communicating data from the base to the tablet using the second communications link.

~~165~~176. The method according to claim 164, wherein the processor is located on the tablet.

~~166~~177. The method according to claim 164, wherein the processor is located on the base.

~~167~~178. The method according to claim 164, wherein the act of communicating data from the base to the tablet using the second communications link includes transmitting the data, by the base, to the tablet using the second communications link.

~~168~~179. The method according to claim 164, wherein the act of communicating data from the base to the tablet using the second communications link includes receiving the data, by the tablet, using the second communications link.

~~169~~180. The method according to claim 164, further comprising displaying data on the tablet in accordance with the data communicated from the base.

~~170~~181. The method according to claim 164, further comprising initializing treatment of a patient using the tablet.

~~171~~182. The method according to claim 170, further comprising treating the patient using the base.

~~172~~183. The method according to claim 171, wherein the base is a hemodialysis system.

~~173~~184. The method according to claim 164, further comprising using the tablet to send a start treatment signal to the base.

~~174~~185. The method according to claim 164, further comprising removing the physical connection between the tablet and the base.

~~175~~186. The method according to claim 174, further comprising continuing to communicate between the tablet and the base using the second communications link.

~~176~~187. The method according to claim 175, further comprising monitoring a link quality value of the second communications link.

~~177~~188. The method according to claim 164, further comprising communicating the data between the tablet and the base as long as a link quality value is above a predetermined threshold.

~~178~~189. The method according to claim 164, further comprising entering the tablet into a headless state when a link quality value falls below a first predetermined threshold.

~~179~~190. The method according to claim 178, wherein the tablet displays a message on a user interface in response to the headless state.

~~180~~191. The method according to claim 178, wherein the message indicates to a user to move the tablet closer to the base.

~~181~~192. The method according to claim 178, further comprising periodically determining a respective link quality value to determine if the respective link quality value is above the first predetermined threshold.

~~182~~193. The method according to claim 178, further comprising leaving the headless state when the link quality value is above the first predetermined threshold.

~~183~~194. The method according to claim 178, further comprising leaving the headless state when the link quality value is above a second predetermined threshold greater than the first predetermined threshold.

~~184~~195. The method according to claim 164, wherein the act of updating, if necessary, the interface program on the tablet through the first communications link comprises:

communicating a version number of an interface program from the tablet to the base through the first communications link;

determining if the interface program on the tablet is the latest version;

retrieving, by the base, an updated version of the interface program from a server; and

overwriting the interface program with the updated version of the interface program.

~~185~~196. The method according to claim 164, wherein the act of establishing the second communications link between the tablet and the base using the first communications link comprises:

determining if the base if paired with another tablet;

interrupting, if necessary, any pairing between the another tablet and the base;

generating, using the base, a configuration file;

communicating the configuration file from the base to the tablet using the first communications link;

reading, by the tablet, the configuration file received from the base; and

pairing the base to the tablet for wireless communications to establish the second communications link between the tablet and the base in accordance with the configuration file.

~~186~~197. The method according to claim 164, further comprising:

entering the tablet into a headless state when a link quality value falls below a predetermined threshold;

suspend communications of the data between the base and the tablet; and

display on a graphical user interface a message request a user to move the tablet closer to the base.

~~187~~198. The method according to claim 164, further comprising:

entering the base into a headless state when a link quality value falls below a predetermined threshold;

suspend communications of the data between the base and the tablet; and

indicating that the base has entered into the headless state.

~~188~~199. A method implemented by an operative set of processor executable instructions configured for execution by a computer processor, the method comprising:

communicating data between a tablet and a base as long as a link quality value is above a predetermined threshold;

entering into a headless state if the link quality value falls below the predetermined threshold;

remaining in the headless state as long as the link quality value remains below the predetermined threshold; and

determining if the link quality value returns above the predetermined threshold; and

exiting the headless state if the link quality value has returned to above the predetermined threshold.

~~189~~200. A method implemented by an operative set of processor executable instructions configured for execution by a processor, the method comprising:

communicating data between a tablet and a base as long as a link quality value is above a first predetermined threshold;

entering into a headless state if the link quality value falls below the first predetermined threshold;

remaining in the headless state as long as the link quality value remains below a second predetermined threshold;

determining if the link quality value increases above the second predetermined threshold; and

exiting the headless state if the link quality value exceeds the second predetermined threshold.

~~190~~201. A pumping system comprising:

a reciprocating positive-displacement pump comprising:

a rigid chamber wall;

a rigid limit structure;

a flexible membrane attached to the rigid chamber wall and interposed between the rigid chamber wall and the rigid limit structure, such that the flexible membrane and rigid chamber wall together define a pumping chamber and the flexible membrane and the rigid limit structure together define an actuation chamber, and wherein the rigid limit structure is constructed and positioned to limit movement of the membrane and limit a maximum volume of the pumping chamber;

an inlet for directing flow through the rigid chamber wall into the pumping chamber; and

an outlet for directing flow through the rigid chamber wall out of the pumping chamber;

an actuation system that alternately provides either a positive or a negative pressure to the actuation chamber; wherein the actuation system includes:

a reservoir containing a control fluid at either a positive or a negative pressure, and

a valving mechanism for controlling a flow of control fluid between the actuation chamber and the reservoir;

an actuation-chamber pressure transducer for measuring a pressure of the actuation chamber; and

a controller that receives pressure information from the actuation-chamber pressure transducer and controls the valving mechanism via a valve control signal to provide a given pressure with a superimposed periodic variation to the actuation-

chamber, and calculates a first cross-correlation between the said valve control signal and said actuation-chamber pressure and calculates a second cross-correlation between the said valve control signal shifted a quarter period and said actuation-chamber pressure and calculates a correlation number by the sum of the squares of the said first and second cross-correlation values and uses said correlation number in evaluating the flow through the pump.

~~191~~202. The pumping system of claim 190, wherein a frequency of the superimposed periodic variation varies with a desired flow rate of fluid out of the pumping chamber.

~~192~~203. The pumping system of claim 190, wherein the controller determines an end-of-stroke condition when the correlation number drops below a given value.

~~193~~204. The pumping system of claim 190, wherein the controller integrates the correlation number and uses said integrated correlation number to determine a progress of a stroke of the flexible membrane.

~~194~~205. The pumping system of claim 190, wherein the controller compares the integrated correlation number of the current stroke to previous strokes to determine the presence of an occlusion.

~~195~~206. The pumping system of claim 190, wherein the controller calculates a duration of a stroke of the flexible membrane and compares the current said stroke duration to previous stroke durations to determine a partial occlusion.

~~196~~207. The pumping system of claim 190, wherein the controller calculates an average correlation number over a stroke and compares a current said average correlation number to previous average correlation numbers to determine a partial occlusion.

~~197~~208. The pumping system of claim 190, wherein the controller uses the correlation number to evaluate an instantaneous flow rate out of the pump chamber.

~~198~~209. A pumping system comprising:

a reciprocating positive-displacement pump comprising:

a rigid chamber wall;

a rigid limit structure;

a flexible membrane attached to the rigid chamber wall and interposed between the rigid chamber wall and the rigid limit structure, such that the flexible membrane and rigid chamber wall together define a pumping chamber and the flexible membrane and the rigid limit structure together define an actuation chamber, and wherein the rigid limit structure is constructed and positioned to limit movement of the membrane and limit a maximum volume of the pumping chamber;

an inlet for directing flow through the rigid chamber wall into the pumping chamber; and

an outlet for directing flow through the rigid chamber wall out of the pumping chamber;

an actuation system that alternately provides either a positive or a negative pressure to the actuation chamber; wherein the actuation system includes:

a reservoir containing a control fluid at either a positive or a negative pressure, and

a valving mechanism for controlling a flow of control fluid between the actuation chamber and the reservoir;

an actuation-chamber pressure transducer for measuring a pressure of the actuation chamber; and

a controller that receives pressure information from the actuation-chamber pressure transducer and controls the valving mechanism via a valve control signal to provide a given pressure with a superimposed periodic variation to the actuation-chamber, and calculates a first cross-correlation between the said valve control signal and said actuation-chamber pressure and calculates a second cross-correlation between the said valve control signal shifted a quarter period and said actuation-chamber pressure and calculates a correlation angle as an inverse tangent of the second cross-correlation over the first cross correlation and uses said correlation angle in evaluating the flow through the pump.

~~199~~210. The pumping system of claim 198, wherein a frequency of the superimposed periodic variation varies with a desired flow rate of fluid out of the pumping chamber.

~~200~~211. The pumping system of claim 198, wherein controller determines an end-of-stroke condition when the first cross correlation approaches zero.

~~201~~212. The pumping system of claim 198, wherein the controller uses said correlation angle to determine a progress of a stroke of the flexible membrane in the pumping chamber.

~~202~~213. The pumping system of claim 198, where the controller compares a magnitude of a largest correlation angle of a current stroke to a magnitude of a largest correlation angle of previous strokes to determine a presence of an occlusion.

~~203~~214. The pumping system of claim 198, wherein the controller uses a rate of change of the correlation angle to evaluate an instantaneous flow rate of fluid out of the pumping chamber.

~~204~~215. A pumping system comprising:

more than one reciprocating positive-displacement pump comprising:

a rigid chamber wall;

a rigid limit structure;

a flexible membrane attached to the rigid chamber wall and interposed between the rigid chamber wall and the rigid limit structure, such that the flexible membrane and rigid chamber wall together define a pumping chamber and the flexible membrane and the rigid limit structure together define an actuation chamber, and wherein the rigid limit structure is constructed and positioned to limit movement of the membrane and limit a maximum volume of the pumping chamber;

an inlet for directing flow through the rigid chamber wall into the pumping chamber; and

an outlet for directing flow through the rigid chamber wall out of the pumping chamber;

an actuation system that alternately provides either a positive or a negative pressure to the actuation chamber; wherein the actuation system includes:

a reservoir containing a control fluid at either a positive or a negative pressure, and

a valving mechanism for controlling a flow of control fluid between the actuation chamber and the reservoir;

an actuation-chamber pressure transducer for measuring a pressure of the actuation chamber; and

a controller that receives pressure information from the actuation-chamber pressure transducer and controls the valving mechanism via a valve control signal to provide a given pressure with a superimposed periodic variation to the actuation-chamber,

wherein a frequency of the said superimposed periodic variation is different for each reciprocating positive-displacement pump.

~~205~~216. A pumping system comprising:

a reciprocating positive-displacement pump comprising:

a rigid chamber wall;

a rigid limit structure;

a flexible membrane attached to the rigid chamber wall and interposed between the rigid chamber wall and the rigid limit structure, such that the flexible membrane and rigid chamber wall together define a pumping chamber and the flexible membrane and the rigid limit structure together define an actuation chamber, and wherein the rigid limit structure is constructed and positioned to limit movement of the membrane and limit a maximum volume of the pumping chamber;

an inlet for directing flow through the rigid chamber wall into the pumping chamber; and

an outlet for directing flow through the rigid chamber wall out of the pumping chamber;

an actuation system that alternately provides either a positive or a negative pressure to the actuation chamber; wherein the actuation system includes:

a reservoir containing a control fluid at either a positive or a negative pressure, and

a valving mechanism for controlling a flow of control fluid between the actuation chamber and the reservoir;

an actuation-chamber pressure transducer for measuring a pressure of the actuation chamber; and

a controller that receives pressure information from the actuation-chamber pressure transducer and controls the valving mechanism via a valve control signal to provide a given pressure with a superimposed periodic variation to the actuation-chamber, and calculates a first cross-correlation between the said valve control signal and said actuation-chamber pressure and uses said first cross-correlation value in evaluating the flow through the pump.

~~206~~217. The pumping system of claim 205, wherein the controller determines an end-of-stroke condition when the first cross-correlation value drops below a given value.

~~207~~218. The pumping system of claim 205, wherein the controller integrates the first correlation value and uses said integrated first correlation value to determine a progress of a stroke of the flexible membrane in the pumping chamber.

~~208~~219. The pumping system of claim 207, wherein the controller compares the integrated first correlation of the current stroke to previous strokes to determine the presence of an occlusion.

~~209~~220. The pumping system of claim 205, wherein the controller uses the first cross-correlation value to evaluate an instantaneous flow rate of fluid out of the pumping chamber.

~~210~~221. A method for performing hemodialysis using an ultrafiltration pump to control the volume of fluid removed from a patient comprising:

setting an ultrafiltration pumping rate over a planned duration of hemodialysis to achieve a pre-determined volume of fluid to be removed from the patient;

periodically backflushing a pre-determined volume of dialysate from a dialysate source through a dialyzer membrane to an extracorporeal blood circuit connected to the patient; and

adjusting the ultrafiltration pumping rate to remove the volume of fluid backflushed during the course of hemodialysis.

~~211~~222. A method according to claim 210, wherein the number of backflushing operations and the volume of each backflushing operation are pre-determined prior to a hemodialysis therapy, and the ultrafiltration pumping rate is preset to achieve the pre-determined volume of fluid to be removed from the patient plus the total volume of fluid to be backflushed during the hemodialysis therapy.

~~212~~223. A system for administering a dose of medication to a patient whose vascular system is fluidly connected to an extracorporeal blood circuit comprising an arterial flowpath for delivering fluid from the patient to a dialyzer and a venous flowpath for delivering fluid from the dialyzer to the patient comprising:

a vial of medication fluidly connected to a medication pump, the medication pump in valved fluid communication with a primary fluid pump in the extracorporeal circuit;

a first gas bubble detector for detecting gas bubbles in the arterial flowpath;

medication pump valves and primary fluid pump inlet and outlet valves under control of a controller to direct fluid flow from the dialyzer to the patient either via the arterial flowpath or the venous flowpath, wherein

in a first arrangement, the controller arranges the valves to cause medication to flow from the medication pump to the patient via the arterial flowpath, and

in a second arrangement, the controller arranges the valves to cause medication to flow from the medication pump to the patient via the venous flowpath if the controller receives a signal from the gas bubble detector indicating the presence of one or more gas bubbles in the arterial flowpath.

~~213~~224. The system of claim 212, wherein the venous flowpath includes an air trap to remove gas bubbles from the fluid in the venous flowpath.

~~214~~225. The system of claim 213, further comprising a second gas bubble detector in the venous flowpath, wherein the controller stops the flow of medication to the patient if the controller receives a signal from the first and second gas bubble detectors indicating the presence of one or more gas bubbles in the arterial and venous flowpaths.

~~215~~226. A pumping system comprising:

a reciprocating positive-displacement pump comprising:

a rigid chamber wall;

a rigid limit structure;

a flexible membrane attached to the rigid chamber wall and interposed between the rigid chamber wall and the rigid limit structure, such that the flexible membrane and rigid chamber wall together define a pumping chamber and the flexible membrane and the rigid limit structure together define an actuation chamber, and wherein the rigid limit structure is constructed and positioned to limit movement of the membrane and limit the maximum volume of the pumping chamber;

an inlet for directing flow through the rigid chamber wall into the pumping chamber;

an outlet for directing flow through the rigid chamber wall out of the pumping chamber; and

an actuation system that alternately provides either a positive or a negative pressure to the actuation chamber; wherein the actuation system includes:

a reservoir containing a control fluid at either a positive or a negative pressure, and

a valving mechanism for controlling a flow of control fluid between the actuation chamber and the reservoir;

an actuation-chamber pressure transducer for measuring a pressure of the actuation chamber; and

a controller that receives pressure information from the actuation-chamber pressure transducer and in a first time period controls the valving mechanism to complete a full stroke by moving the diaphragm from a position touching the rigid limit structure to a position touching the rigid chamber wall and to record the value of a stroke parameter at the end of said full stroke and in a subsequent time period controls the valving mechanism to complete partial strokes by moving the diaphragm until the said stroke parameter is a fraction of the full stroke value.

~~216~~227. The pumping system of claim 215, wherein the said stroke parameter is time

~~217~~228. The pumping system of claim 215, wherein the said stroke parameter is a correlation number derived from the cross-correlation of a time-varying signal superimposed on the pressure delivered to the control chamber with the time-varying pressure response measured in the control chamber.

~~218~~229. A pumping system of claim 215, wherein the controller periodically controls the valving mechanism to complete a full stroke to re-determine the value of the stroke parameter for a full stroke.