FIG. 29 is a perspective view of a blood circuit assembly in an alternate embodiment; and

FIG. 30 is a close up view of a portion of the blood circuit assembly of FIG. 29.

FIG. 31 shows an exemplary modular drain cassette in an illustrative embodiment;

FIG. 32 shows the drain cassette of FIG. 31 in an exploded view with an escutcheon positioned anterior to a front wall of the drain cassette in an illustrative embodiment;

FIG. 33 shows a perspective view of the front wall of the drain cassette of FIG. 31 in an illustrative embodiment;

FIG. 34 shows a main housing of the drain cassette of FIG. 31 with the front wall removed for clarity purposes in an illustrative embodiment;

FIG. 35 shows a rear, perspective view of the drain cassette of FIG. 31 in an illustrative embodiment;

FIG. 36 shows a front panel in which a drain cassette has been dismounted in an illustrative embodiment;

FIG. 37 is a schematic representation of a conductivity circuit in an illustrative embodiment;

FIG. 38 is a diagram of the electrical waveforms processed by the circuit of FIG. 37;

FIG. 39 is a representative graph of the noise/error sensitivity of the circuit of FIG. 37 plotted against the ratio of unknown/reference resistance in the circuit;

FIG. 40 is a schematic representation of an exemplary blood flow circuit of a hemodialysis system;

FIG. 41A is a side view of a connector that may be used in the blood flow circuit of FIG. 40;

FIG. 41B is a cross-sectional view of the connector of FIG. 41A;

FIG. 42 is a cross-sectional view of the connector of FIGS. 41A and 41B, with an attached wire and flexible tubing;

FIG. 43A is a perspective view of an alternate embodiment of a connector that may be used in the blood flow circuit of FIG. 40;

FIG. 43B is a top view of the connector of FIG. 43A;

FIG. 43C is a cross-sectional view of the connector of FIG. 43B;

FIGS. 44A-D are various cross-sectional views of a flexible tube incorporating a conductive wire;

FIG. 45 is a perspective view of a flexible double-lumen tube having a fluid-carrying lumen and a wire-carrying lumen;

FIG. 46 is a cross-sectional view of a connector similar to the connector of FIGS. 43A-C, with an attached wire and tubing;

FIG. 47 is a plan view of an extracorporeal blood flow circuit used in a representative hemodialysis system;

FIG. 48 is a perspective view of a hemodialysis apparatus configured to receive and operate the extracorporeal blood flow circuit of FIG. 47; and

FIG. 49 is a representative plot of the resistance measured by the conductivity circuit of FIG. 37 under various conditions;

FIG. 50 shows an exploded, perspective view of an occlusion assembly from a front angle in accordance with an embodiment of the present disclosure;

FIG. 51 shows an exploded, perspective view of the occlusion assembly of FIG. ~~1~~ 50 from a back angle;

FIG. 52 shows a front, perspective view of the occlusion assembly of FIG. ~~1~~ 50 with the door open and the button pressed to illustrate loading of a tube;

FIG. 53 shows a close-up perspective view of the occlusion assembly of FIG. ~~1~~ 50, showing the door engaging a switch when the door is closed;

FIG. 54 shows the front of the occlusion assembly of FIG. ~~1~~ 50 without the door and frame to illustrate the arms fully occluding flexible tubes;

FIG. 55 shows the front of the occlusion assembly of FIG. ~~1~~ 50 without the door and frame to illustrate the arms in a non-occluding position;

FIG. 56 is a rear/top perspective view of the occlusion assembly of FIG. ~~1~~ 50 with an actuator arm in a fully retracted position;

FIG. 57 is a rear perspective view of the occlusion assembly of FIG. ~~1~~ 50with an actuator arm in a fully extended position;

FIG. 58 shows a side perspective view of several working parts of the occlusion assembly of FIG. ~~1~~ 50 in a non-occluding state;

FIG. 59 shows a side perspective view of several working parts of the occlusion assembly of FIG. ~~1~~ 50 in an occluding state;

FIG. 60 shows a side, cross-sectional view of an actuator of the occlusion assembly of FIG. ~~1~~ 50, illustrating a location for a main spring for the assembly; and

FIG. 61 shows the occlusion assembly of FIG. 50 mounted in a front panel assembly of a hemodialysis apparatus in accordance with an embodiment of the present disclosure.

FIG. 62 shows raw and processed signals from the Access Disconnect Sensor system and pumping pressures for a non-dislodgement event.

FIG. 63 shows raw and processed signals from the Access Disconnect Sensor system and pumping pressures for an access disconnect event.

FIG. 64 shows raw and processed signals from the Access Disconnect Sensor system, pumping pressures and the ADS Signal Test for an access disconnect event.

FIG. 65 shows raw and processed signals from the Access Disconnect Sensor system, pumping pressures and the ADS Signal Test for an access disconnect event, with longer duration half cycles than shown in FIGs. 62-64.

DETAILED DESCRIPTION

Various aspects of the invention are generally directed to new systems for hemodialysis and the like, such as hemofiltration systems, hemodiafiltration systems, plasmapheresis systems, etc. Accordingly, 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 plasma.

As discussed below, a hemodialysis system typically includes a blood flow path and a dialysate flow path. It should be noted that within such flow paths, the flow of fluid is not necessarily linear, and there may be any number of "branches" within the flow path that a fluid can flow from an inlet of the flow path to an outlet of the flow path. Examples of such branching are discussed in detail below. In the blood flow path, blood is drawn from a patient, and is passed through a dialyzer, before being returned to the patient. The blood is treated by the dialyzer, and waste molecules (e.g., urea, creatinine, etc.) and water are passed from the blood, through a semi-permeable membrane in the dialyzer, into a dialysate solution that passes through the dialyzer by the dialysate flow path. In various embodiments, blood may be drawn from the patient from two lines (e.g., an arterial line and a venous line, i.e., "dual needle" flow), or in some cases, blood may be drawn from the patient and returned through the same or catheter needle (e.g., the two lines or lumens may both be present within the same needle, i.e., a form of "dual lumen" flow). In still other embodiments, a "Y" site or "T" site is used, where blood is drawn from the patient and returned to the patient through one patient connection having two branches (one being the fluid path for the drawn blood, the second the fluid path for the return blood, i.e., a form of "single needle" flow). The patient may be any subject in need of hemodialysis or similar

1232A to the blood pump pod that was delivering blood when the provisional flag 1218 cleared at time element 1238. After a period of time, the pressure applied to the delivering blood pump pod was reduced to approximately atmospheric pressure 1232B at time 1243. The provisional flag 1216 was reset and an access disconnection 1220 was signaled at time element 1243 because the ADS signal 1210B exceeded the first threshold 1211 and or deltaADS 1216 exceeded the third threshold 1215.

The ADS algorithm may combine some or all of the above thresholds to set the provisional flag and the corresponding tests to clear the flag. Similarly, an access disconnection may be signaled for any of criteria described above. Referring now to FIG 63, in one embodiment, the provisional flag will be set if any of the following conditions occur: the ADS signal 1210 exceeds a first threshold 1212; deltaADS 1216 exceeds a third threshold 1215, the ADS signal drops below a low threshold (not shown) or the derivative of the ADS signal exceeds a fifth predetermined threshold. The provisional flag may be cleared based on conditions that correspond to conditions that set the flag in the first place. For example, if the flag was set by the ADS signal exceeding the first threshold 1211, then the flag only clears when the ADS signal drops below the second threshold 1213, or if the flag was set by deltaADS 1216 exceeding the third threshold, then the flag only clears when the medADS 1212 drops below ADS-exit 1217 (see, e.g., Fig. 62). In another example the flag may be cleared by requiring one or more conditions described above. The ADS algorithm signals the higher software levels or the rest of the controller that a needle has dislodged if the provisional flag has been continuously set for a period of time, while a quantity of blood has been pumped or if a number of blood pump strokes have occurred.

The measured resistance values reported in Figs. 49, 62-64 were made when the binary digital signals 131, 144 in Figs. 37, 38 were alternating at a frequency of approximately 35 kHz. The frequencies of the digital signals 131, 144 were sufficiently high to allow capacitive coupling between the wires in the arterial and venous lines 108, 126 (Fig. 40). The parallel capacitive circuit reduced the measured resistance values throughout the tests, but most significantly during the open circuit conditions, when the venous needle was removed from the first beaker.

In contrast, the measured resistances plotted in Fig. 65 are from an experiment in which the duration of the high half-cycles (Fig. 38) are sixteen times longer than the half-cycles in the experiments plotted in Figs. ~~40~~ 49, 62-64. In the experiment plotted in Fig. 65 the duration of the half cycle is approximately a quarter millisecond. In terms of frequency the