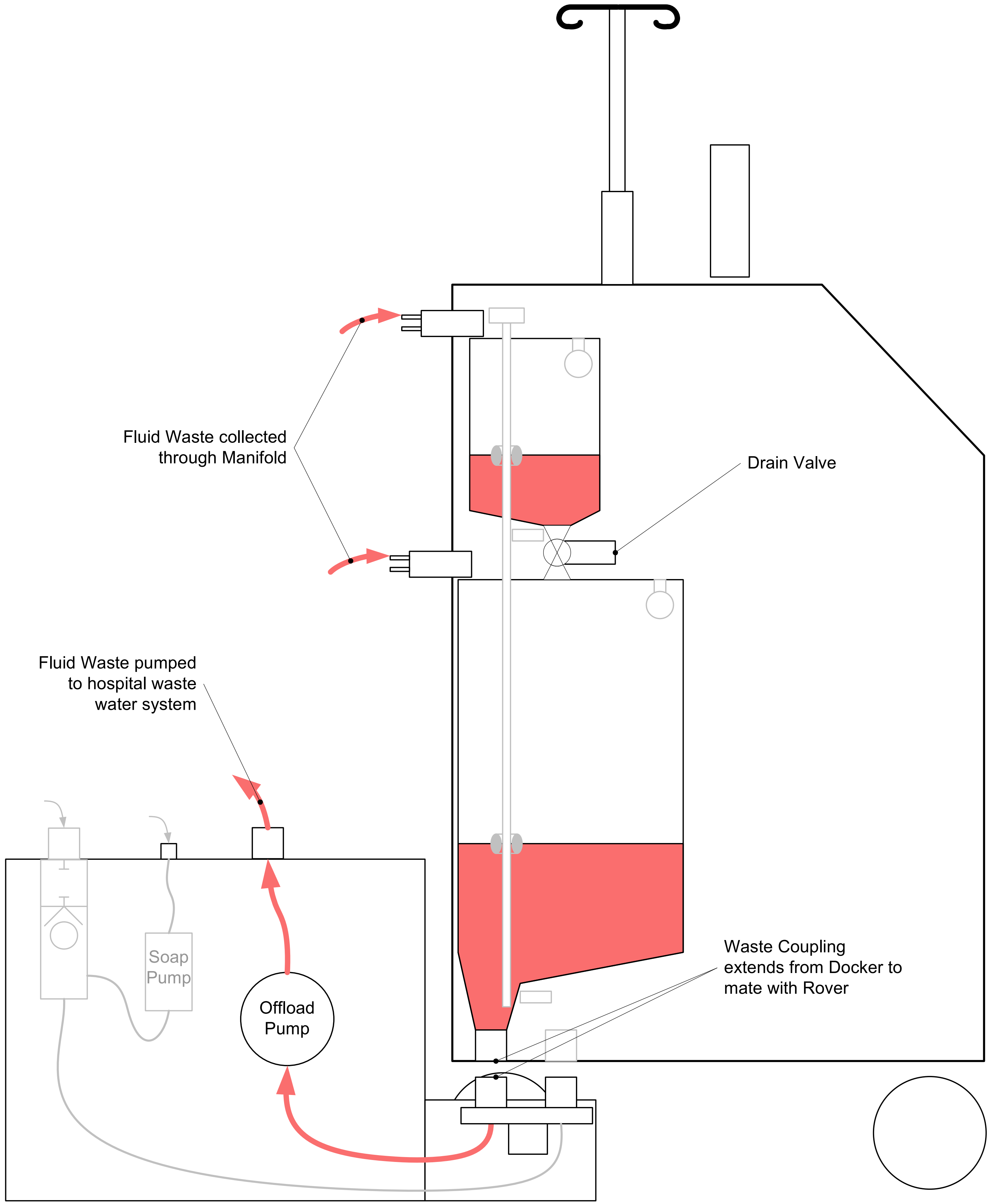
Fluid Waste Handling System
Mechanical



Fluid Waste System Theory of Operation

At the Docking Station, fluid waste is removed from the Rover's Canisters and discarded into the hospitals waste water system. This docking process proceeds automatically when the Rover is pushed into the Docking Station. The general fluid waste transfer steps involved are:

- The Docking Station connects to the dry break Waste Coupling on the bottom of the Rover
- Waste Fluid is pulled from the Large Canister and discarded by the Docker's Offload Pump
- Waste Fluid from the Small Canister is dumped into the Large Canister by opening the Drain Valve
- The Offload Pump continues running until all waste is removed
- Canisters are washed and related water is offloaded in the same manner

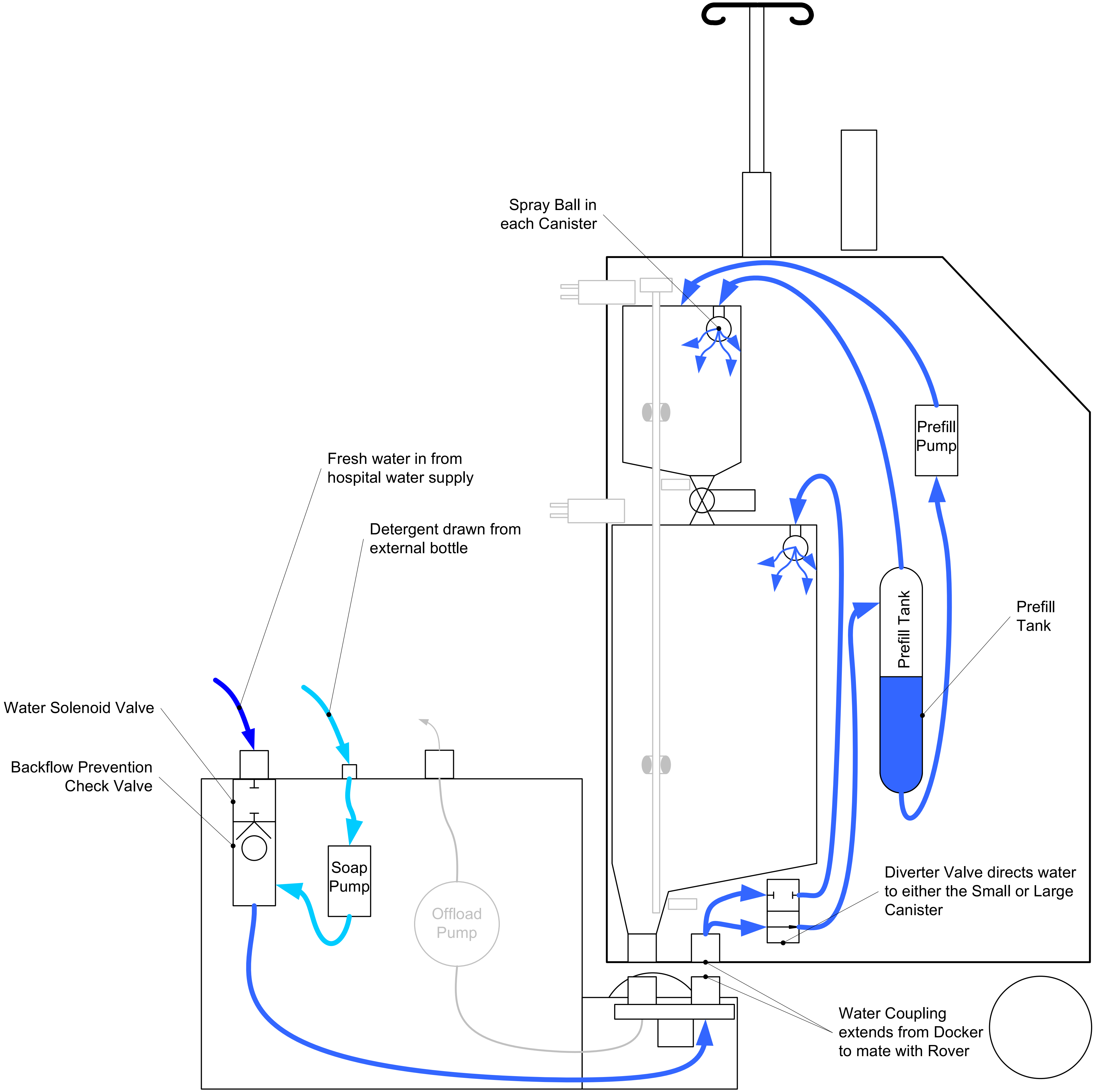
Drain Valve

The Drain Valve between Canisters is a motor actuated Ball Valve connected to a motor control circuit. Its position (open/closed) is determined by a hall sensor mounted to the front of the motor.

Small Canister Clogging

During the docking cycle, clotted blood may not drain from the Small Canister to the Large Canister by the force of gravity alone. To increase the effectiveness of the offload process, the Large Canister is sealed as the Small Canister is drained. This allows the Offload Pump to draw a vacuum (up to ~ 6 in-Hg) on the Large Canister. This vacuum, in addition to the force of gravity, pulls clotted blood from the Small Canister through the Drain Valve.

Fresh Water Handling System
Mechanical



Fresh Water System Theory of Operation

At the Docking Station, the Rover Canisters are washed using the normal hospital water supply pressure. Cleaning water is transferred from the Docking Station to the Rover via dry break couplings. The flow of water within the system is controlled by a Water Solenoid Valve in the Docking Station. The water's destination (Small or Large Canister) is controlled by the Diverter Valve (two solenoid valves) located in the Rover.

Prefill
To enable fluid volume measurement, both Canisters require a small amount of clean water be added after they are offloaded. This prefill water also includes a small amount of detergent to aid in cleaning during the next docking cycle. At the Docking Station, prefill water is added through the spray ball in each Canister

The Small Canister can be emptied into the Large Canister away from the Docking Station. This allows the user to fill the Small Canister multiple times before returning to the Docking Station (i.e. multiple surgical uses between docking cycles). To prefill the small canister away from the Docking Station, the Rover utilizes water stored in its internal Prefill Tank. Water is pulled from the Prefill Tank by the Prefill Pump and added to the Small Canister.

Note that the plumbing configuration within the Rover ensures that the Prefill Tank is filled automatically during Docking.

Detergent Dispensing
Detergent is mixed with rinse water inside the Docking Station to improve Canister cleaning. Detergent is dispensed by the Soap Pump at specific points during the docking cycle to maximize cleaning effectiveness.

Water Temperature and Pressure
Water temperature and the flow rate can significantly affect the ability of the system to clean itself. Since the system does not control either of these parameters, it is important that the hospital plumbing be set up according the the system's installation instructions.

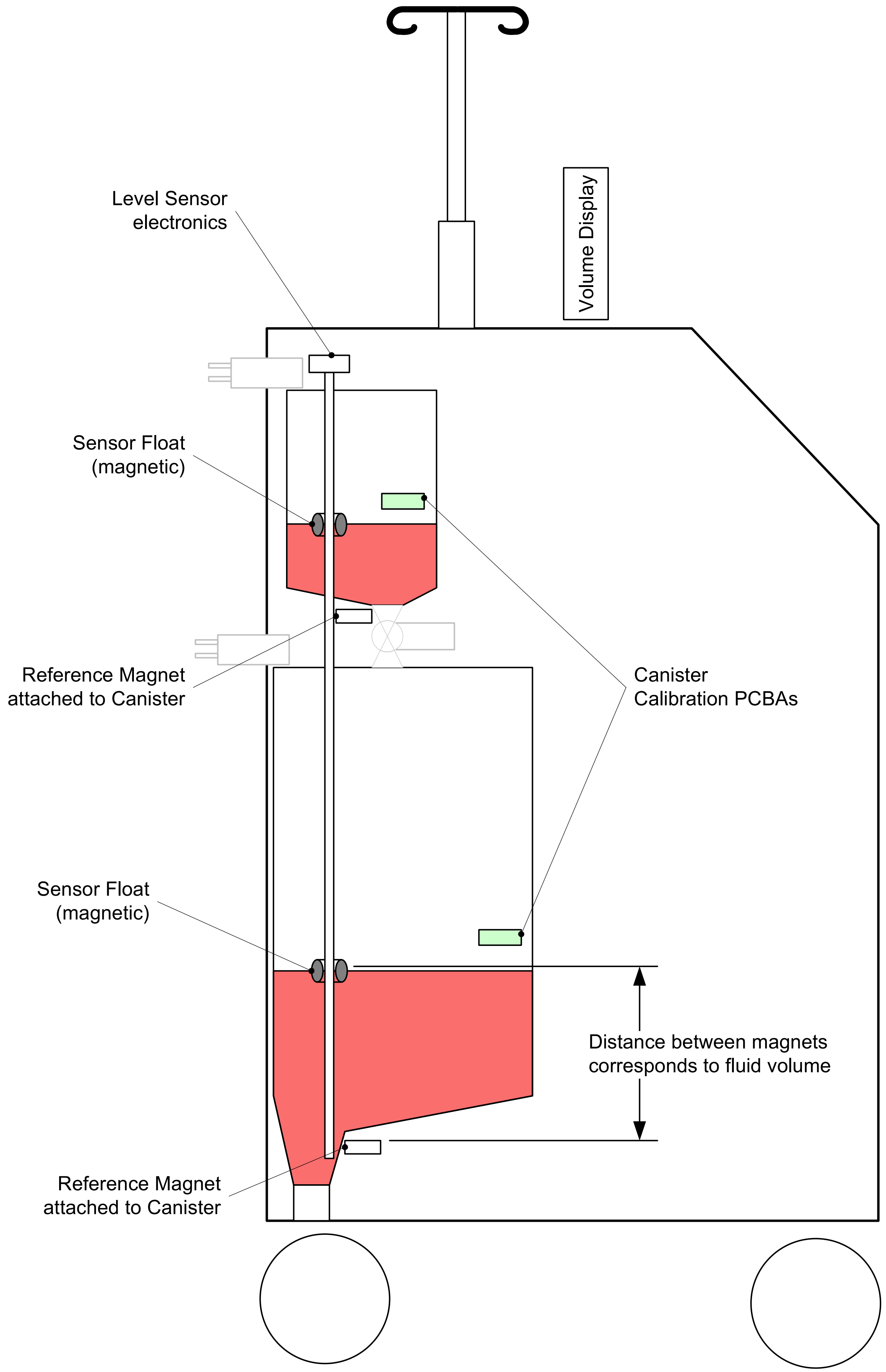
Warm water, up to 110°F, provides the best cleaning. Temperatures above this can 'cook' the blood in the system causing offload problems. High temperatures can also damage internal plumbing components. Low temperatures tend to be less effective at removing fats.

Solenoid Valve Sequencing
To prevent trapping high pressure water in the Rover and Docker Couplings, the solenoid valves are automatically opened and closed in a specific sequence.

- When turning the water on, the proper Diverter Valve is opened first, followed by the Docker Solenoid.
- When turning the water off, the Docker Solenoid is closed first, followed by the Diverter Valve.

When extending or retracting Couplings, the Diverter Valve is opened to prevent pressure in the Couplings from stalling the Coupling Actuator in the Docking Station.

Level Sensor System Mechanical



Level Sensor Theory of Operation

In the Operating Room, the Rover monitors and displays the fluid level of each Canister to the user. Fluid levels are also used to ensure the docking cycle is carried out correctly. The Level Sensing system is comprised of a Level Sensor Rod, two magnetic Sensor Floats, and two Reference Magnets attached to the bottom of the Canisters.

To make a volume measurement, an electrical current **Interrogation Pulse** is sent from the Level Sensor electronics down a wire inside the Level Sensor Rod. When this current pulse passes by each of the four magnets, a mechanical **Return Pulse** is sent back up the Level Sensor Rod. The time between return pulses is used to determine the distance between each Canister's Sensor Float and Reference Magnet. This time is used to calculate the fluid volume. See the timing diagram below for a visual description of this process.

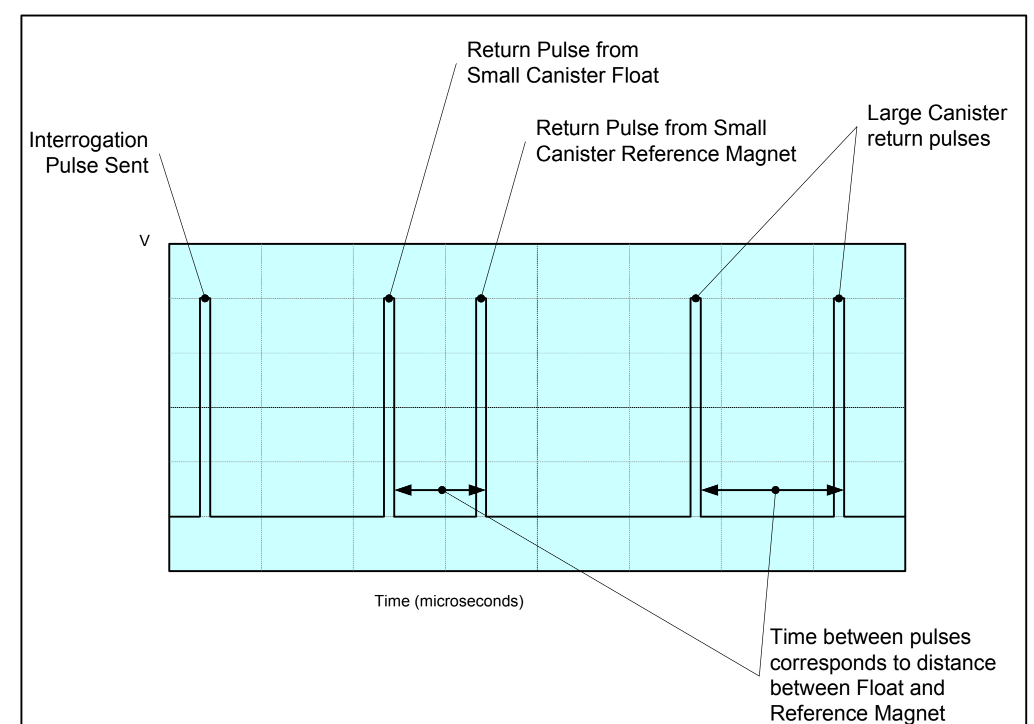
Canister Calibration
Manufacturing variation between Canisters (i.e. canister shape, reference magnet position, etc.) is addressed by factory calibration of each one produced. A Canister's calibration information is stored in a permanently attached Canister Calibration PCBA. This calibration information is read by the Rover's Main Controller at every power up, preventing the need for field calibration when canisters are replaced.

Float Calibration
Manufacturing variation between Floats (i.e. float weight, internal magnet placement, etc.) must be addressed by field calibration. An especially heavy Sensor Float would sit lower in the canister fluid than a light one. This would result in a different Float-Reference magnet distance for a given fluid volume. The Float Calibration Procedure must be performed any time a Rover's floats are changed.

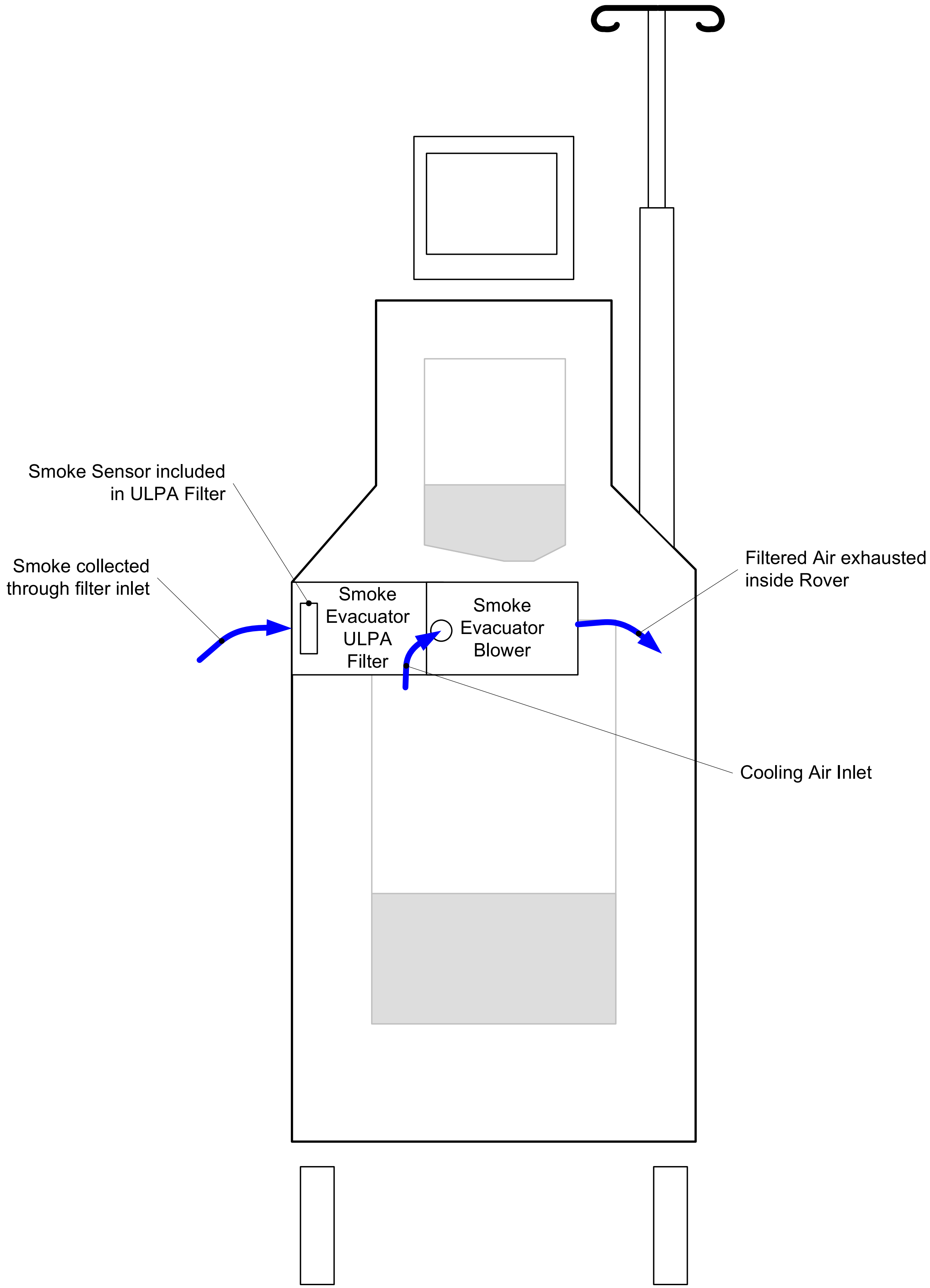
Float calibration information is stored on the Rover Main Controller PCBA. Consequently, the F Float Calibration Procedure must be repeated when this PCBA is replaced.

Since the time between return pulses is not dependent on which sensor is used, the Float Calibration Procedure does not need to be repeated when the Level Sensor Rod is replaced.

Canister Temperature
The diameters of the Fluid Collection Canisters increase or decrease with temperature due to thermal expansion. Because fluid volume calculations take this geometry change into account, the Canister Calibration PCBA's also include sensors to measure Canister temperature.



Smoke Evacuation System Mechanical



Smoke Evacuator Theory of Operation

The Rover's Smoke Evacuation system is activated by pressing a button on the User Interface Panel. The Smoke Blower speed can also be selected to offer the right trade-off between noise and smoke evacuation effectiveness.

Air containing smoke is evacuated from the surgical site and filtered before being discharged back to the room. The Smoke Filter removes smoke particulate using ULPA rated filter media and captures other volatile chemicals with an activated carbon bed.

Manual Mode
When operated in Manual Mode, the Smoke Evacuator Blower runs at a constant speed regardless of the level of smoke present in the OR air.

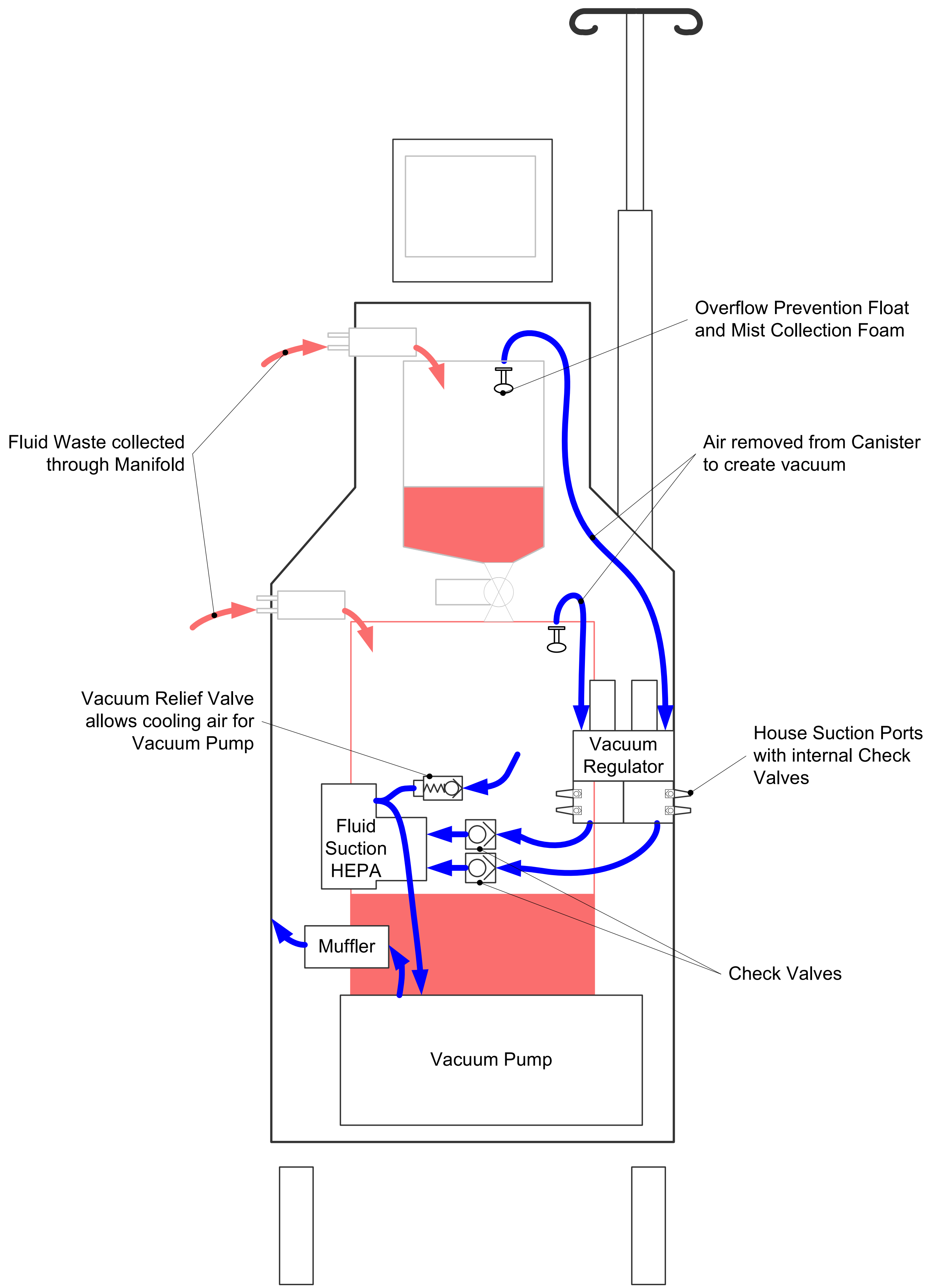
Auto Mode
A Smoke Sensor is built into the ULPA filter for identifying when smoke is actually being generated at the surgical site. When placed in Auto Mode, the Smoke Evacuator Blower defaults to a low speed to 'sniff' for smoke. This 'sniffing' speed was selected to minimize the Blower's audible noise.

If a smoke plume is generated, it is drawn into the ULPA filter and detected by the Smoke Sensor. The Blower speed is immediately increased to more effectively evacuate the plume. When smoke is no longer detected, the Blower returns to 'sniffing' speed until additional smoke is generated.

Smoke Blower Speed Control
Circuitry controlling the Smoke Blower Motor is designed to ensure its speed is constant over the expected ranges of mains line frequency and voltage. The Rover determines the line frequency (50/60 Hz) at power up and continuously monitors and reacts to line voltage changes while running.

Cooling Air
If run with all of the ULPA Filter inlets closed, the Smoke Evacuator Blower requires cooling air to prevent overheating. This air is provided by a restrictive porous plastic inlet located inside the Rover.

Vacuum System Mechanical



Vacuum Regulator Theory of Operation

The on-board vacuum system is activated by a button on the User Interface and vacuum settings are selected for each canister through dedicated dials. While there is only one Vacuum Pump in the Rover, the actual vacuum level in each canister is controlled by two separate Regulator Valves. Each Regulator Valve attempts to maintain its canister at the user selected vacuum setting by:

- connecting the Canister to the vacuum source (Vacuum Pump) to increase it's vacuum level
- connecting the Canister to the atmosphere to decrease (vent) it's vacuum level
- sealing the Canister to maintain it's current level of vacuum

See the diagrams below for a visual explanation of regulator function.

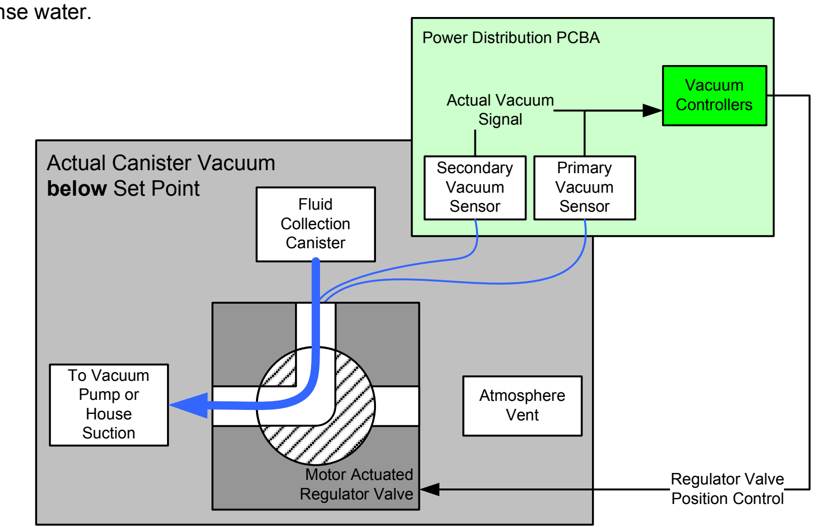
Regulator Valve position is controlled by a DC Motor driven by a Vacuum Control circuit. Valve position is determined by an optical Encoder mounted to each Motor. Since the Encoder does not provide absolute position information, an initialization sequence is performed each time the Rover is powered on. This sequence involves driving the Motor in each direction until a hard-stop is reached.

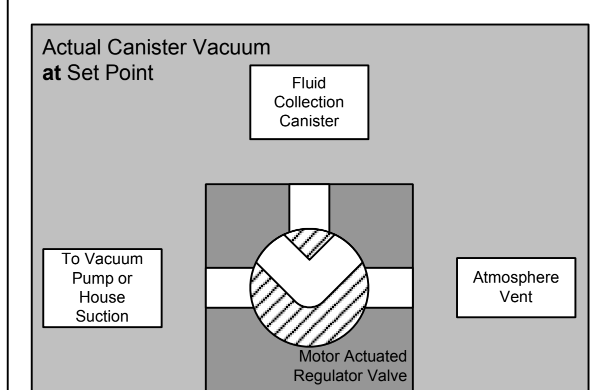
Vacuum Measurement
The actual vacuum level of each Canister is monitored by PCB mounted Vacuum Sensors. Each Canister is monitored by a Primary and Secondary Sensor. The readings from Primary and Secondary Sensors are constantly being compared to each other to ensure accuracy and detect Sensor failure.

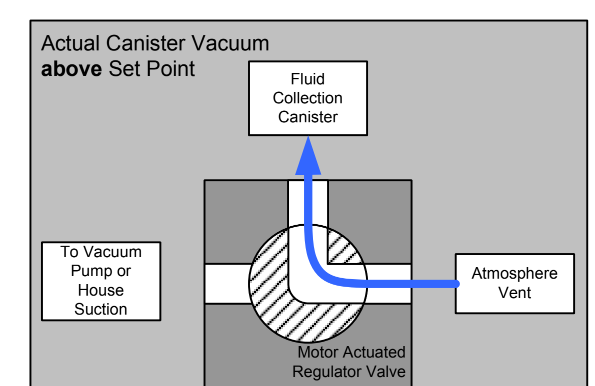
House Suction
The user also has the option of providing suction to the Canisters via the hospital's wall suction. For this mode of use, the Regulators do not attempt to control the Canisters' vacuum level. The Rover must be turned on, however, to ensure the Regulators are in a position that will allow house suction to work (i.e. not vented to atmosphere).

Check Valves in the House Suction Ports eliminate the need for capping these ports when not in use. Additional Check Valves at the inlet to the HEPA filter prevent air from being drawn backward through the Vacuum Pump when House Suction is used

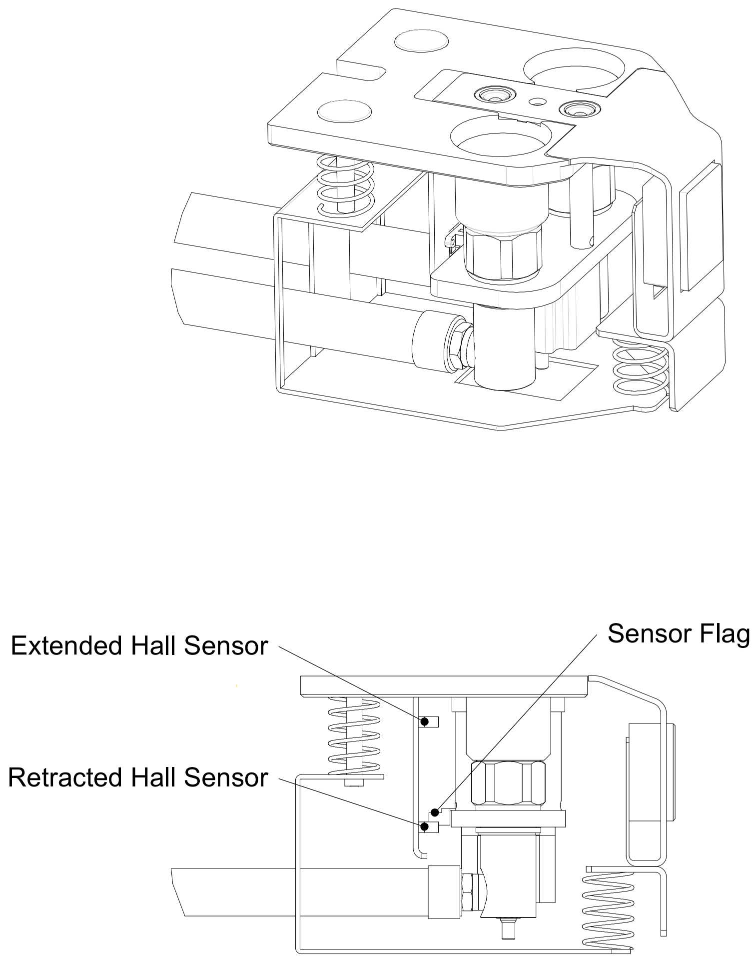
Docking
Regulators are also used during docking to vent or seal Canisters. This facilitates offloading waste and prevents building pressure while spraying rinse water.



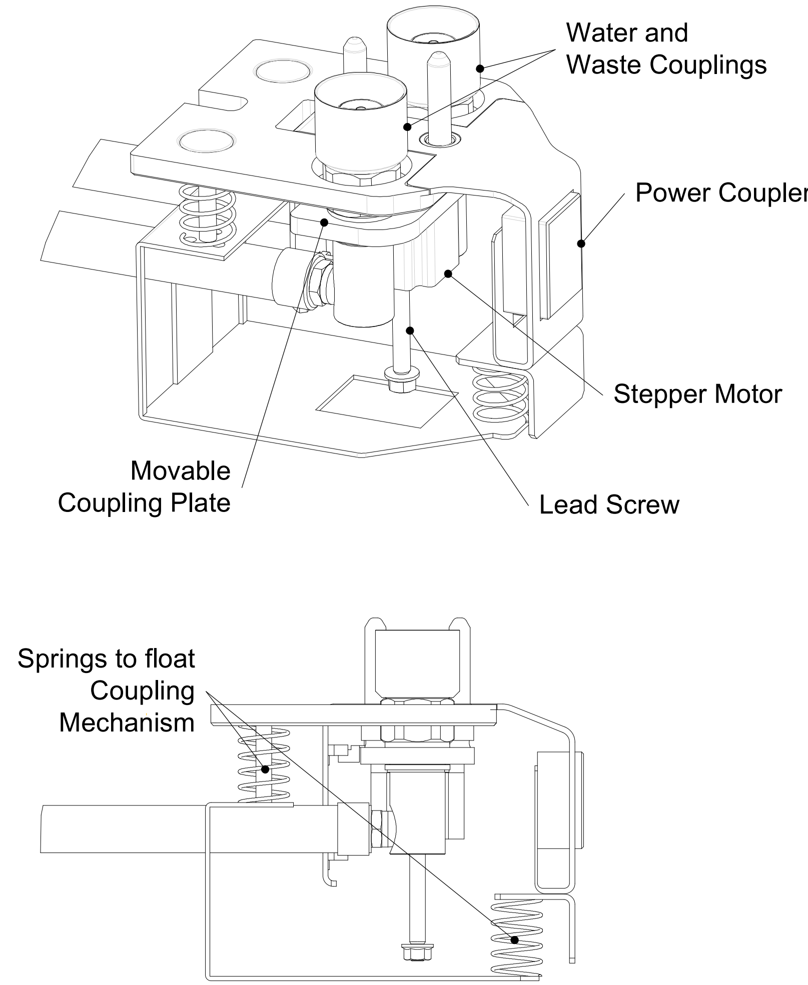




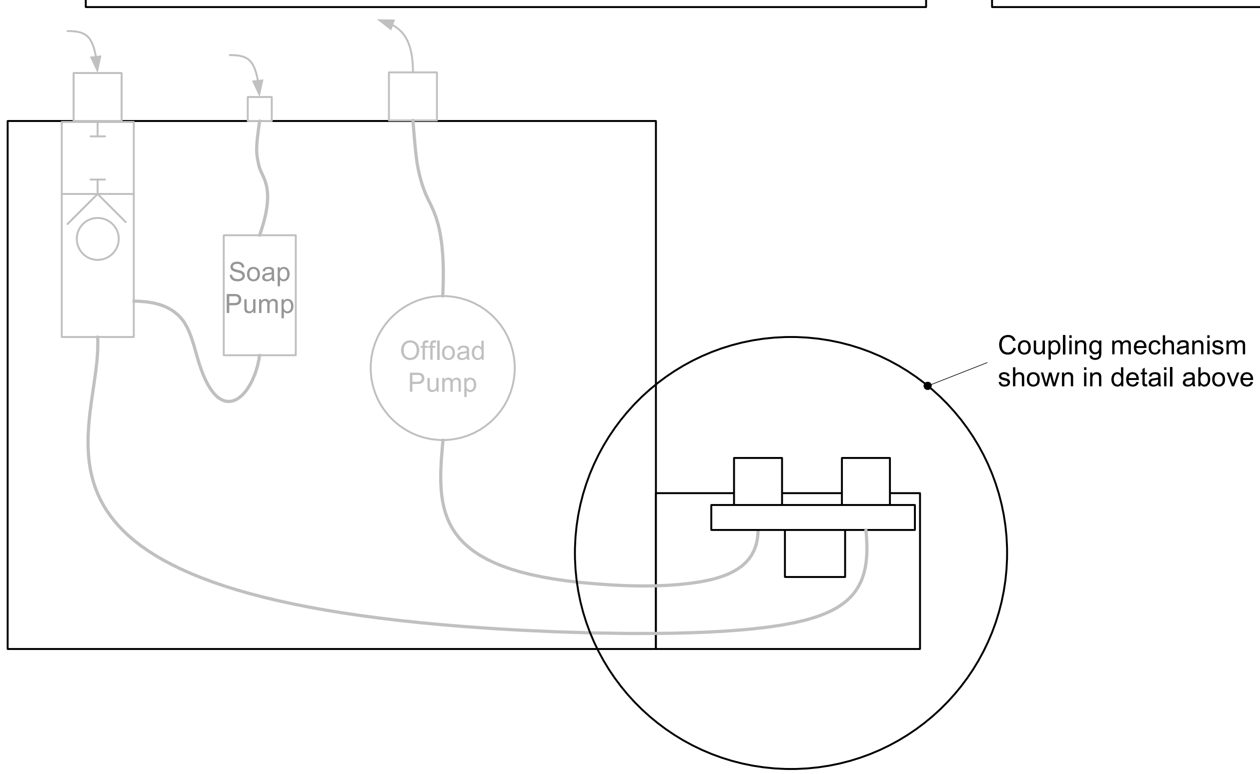
Coupling and Actuation System - Docker Electrical



Couplings shown retracted



Couplings shown extended



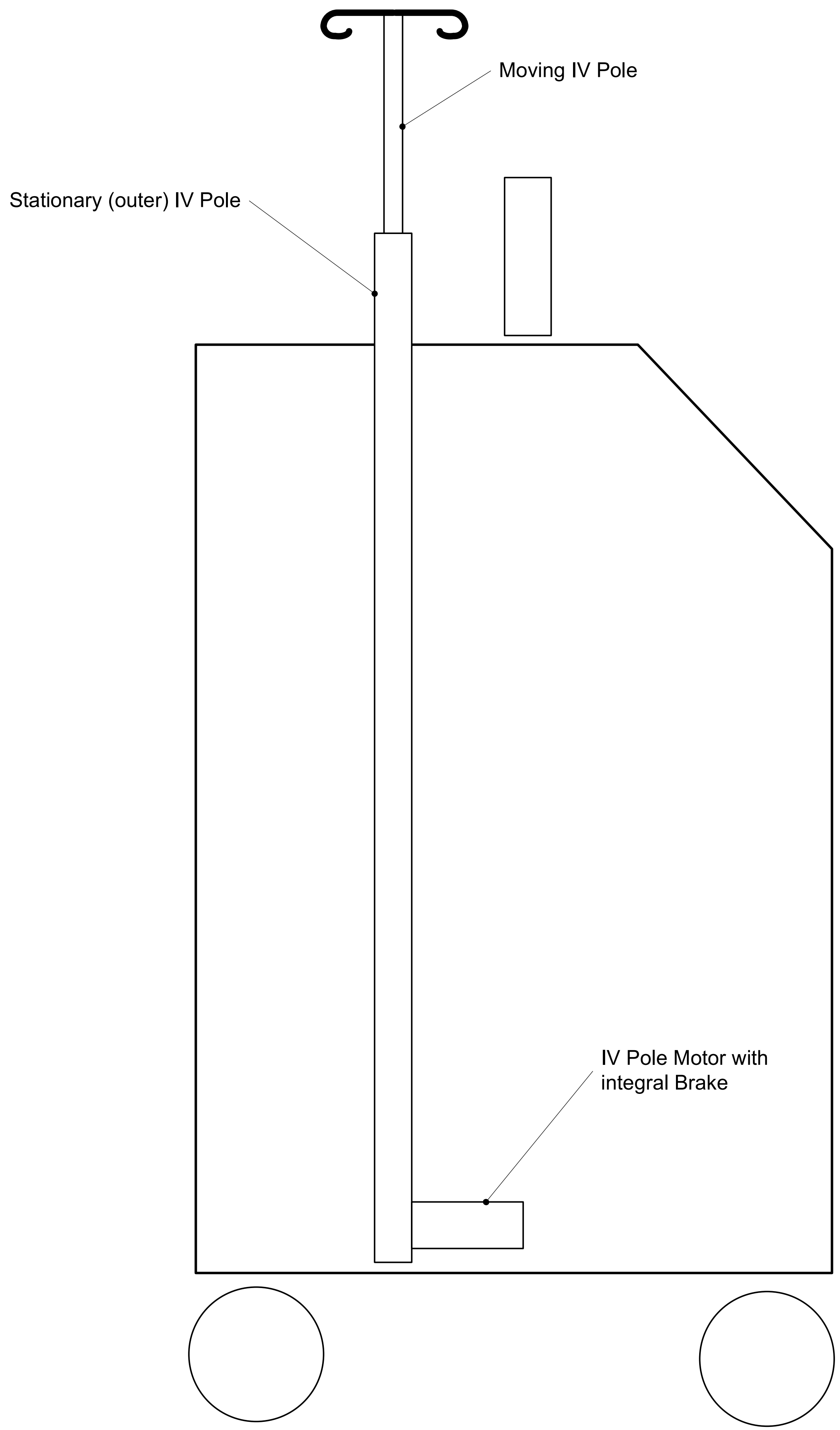
Docker Coupling Actuator Theory of Operation

During docking, fluid connections are bade between the Rover and Docker to transfer fluid waste and fresh water for cleaning. The Water and Waste Couplings on the Rover are stationary and mounted to the bottom surface. In the Docking Station, they are mounted to a movable plate. This plate is raised and lowered by a Stepper Motor riding up and down a stationary lead screw. Diagrams to the left illustrate the components involved, showing them in the fully extended and retracted positions..

Coupling position is determined using two digital hall sensors. The Extended Hall Sensor is triggered by a metal Sensor Flag when the couplings are fully extended. The Retracted Hall Sensor is triggered by the Flag when the couplings are fully retracted.

The entire coupling mechanism is floated on springs to accommodate misalignment between the Rover and Docking Station.

Power Coupler
An inductive Power Coupler transfers power wirelessly from the Docking Station to the Rover during Docking. The Power Coupler functions much like a transformer with a primary winding located in the Docking Station and a secondary winding in the Rover. The two transformer halves are brought together when the Rover is pushed into the Docking Station, which allows for power transfer.



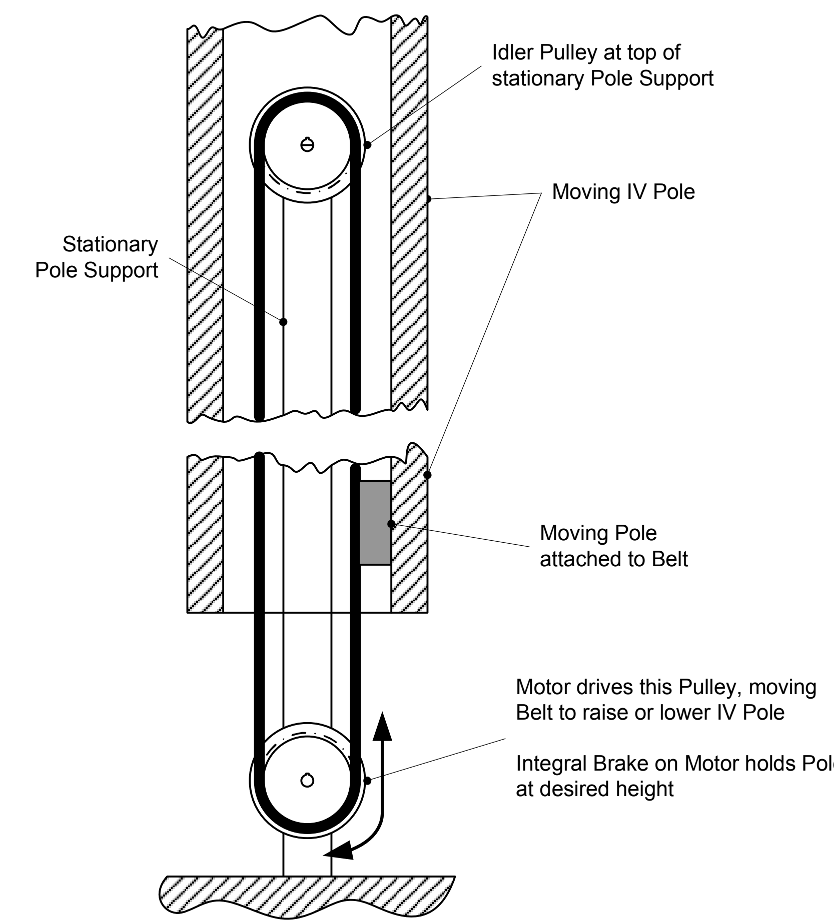
IV Pole Theory of Operation

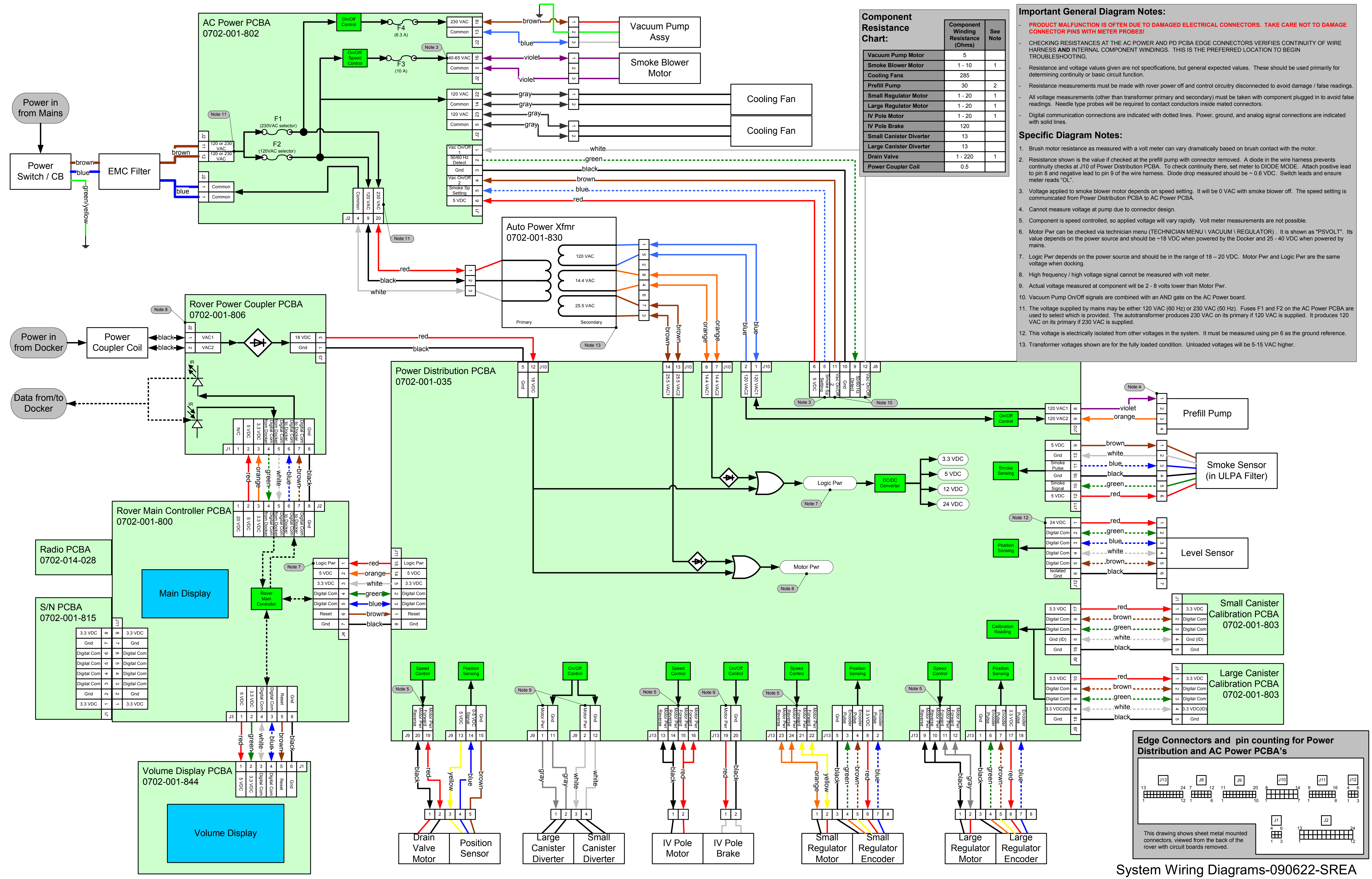
The Rover's IV Pole is raised and lowered in response to buttons pressed on the User Interface Panel. The Pole is driven by a DC motor and associated control circuitry. The Motor contains an integral Brake, which when powered, holds the Pole at the desired height. The mechanism connecting the IV Pole Motor to the IV Pole is illustrated in the diagram below.

Auto Down Feature

When power is removed from the Rover, the IV Pole Brake releases automatically. As the pole begins to drop under its own weight (and the force of an internal Return Spring), the Motor is mechanically back-driven by the falling Pole. In this instance, the Motor acts as electrical generator and provides power to run a speed control circuit. The speed control circuit electronically brakes the Motor to limit the speed of the descending Pole.

Since the speed of Pole descent is controlled by the Motor, if it is electrically disconnected from the rest of the system, the Pole will fall rapidly.





Component Resistance Chart:

	Component Winding Resistance (Ohms)	See Note
Vacuum Pump Motor	5	
Smoke Blower Motor	1 - 10	1
Cooling Fans	285	
Prefill Pump	30	2
Small Regulator Motor	1 - 20	1
Large Regulator Motor	1 - 20	1
IV Pole Motor	1 - 20	1
IV Pole Brake	120	
Small Canister Diverter	13	
Large Canister Diverter	13	
Drain Valve	1 - 220	1
Power Coupler Coil	0.5	

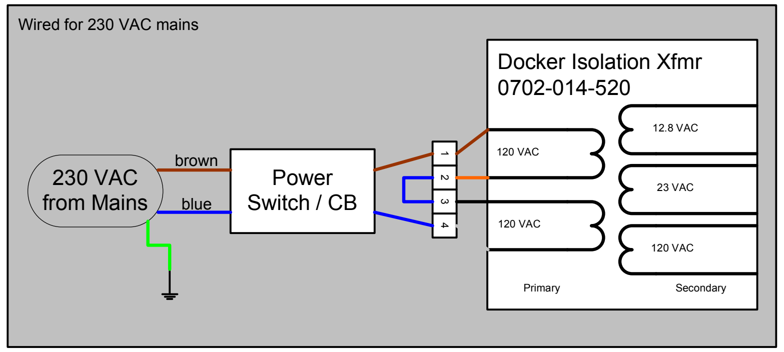
Important General Diagram Notes:

- **PRODUCT MALFUNCTION IS OFTEN DUE TO DAMAGED ELECTRICAL CONNECTORS. TAKE CARE NOT TO DAMAGE CONNECTOR PINS WITH METER PROBES!**
- CHECKING RESISTANCES AT THE AC POWER AND PD PCBA EDGE CONNECTORS VERIFIES CONTINUITY OF WIRE HARNESS **AND** INTERNAL COMPONENT WINDINGS. THIS IS THE PREFERRED LOCATION TO BEGIN TROUBLESHOOTING.
- Resistance and voltage values given are not specifications, but general expected values. These should be used primarily for determining continuity or basic circuit function.
- Resistance measurements must be made with rover power off and control circuitry disconnected to avoid damage / false readings.
- All voltage measurements (other than transformer primary and secondary) must be taken with component plugged in to avoid false readings. Needle type probes will be required to contact conductors inside mated connectors.
- Digital communication connections are indicated with dotted lines. Power, ground, and analog signal connections are indicated with solid lines.

Specific Diagram Notes:

1. Brush motor resistance as measured with a volt meter can vary dramatically based on brush contact with the motor.
2. Resistance shown is the value if checked at the prefill pump with connector removed. A diode in the wire harness prevents continuity checks at J10 of Power Distribution PCBA. To check continuity there, set meter to DIODE MODE. Attach positive lead to pin 8 and negative lead to pin 9 of the wire harness. Diode drop measured should be ~ 0.6 VDC. Switch leads and ensure meter reads “OL”.
3. Voltage applied to smoke blower motor depends on speed setting. It will be 0 VAC with smoke blower off. The speed setting is communicated from Power Distribution PCBA to AC Power PCBA.
4. Cannot measure voltage at pump due to connector design.
5. Component is speed controlled, so applied voltage will vary rapidly. Volt meter measurements are not possible.
6. Motor Pwr can be checked via technician menu (TECHNICIAN MENU \ VACUUM \ REGULATOR) . It is shown as "PSVOLT". Its value depends on the power source and should be ~18 VDC when powered by the Docker and 25 - 40 VDC when powered by mains.
7. Logic Pwr depends on the power source and should be in the range of 18 – 20 VDC. Motor Pwr and Logic Pwr are the same voltage when docking.
8. High frequency / high voltage signal cannot be measured with volt meter.
9. Actual voltage measured at component will be 2 - 8 volts lower than Motor Pwr.
10. Vacuum Pump On/Off signals are combined with an AND gate on the AC Power board.
11. The voltage supplied by mains may be either 120 VAC (60 Hz) or 230 VAC (50 Hz). Fuses F1 and F2 on the AC Power PCBA are used to select which is provided. The autotransformer produces 230 VAC on its primary if 120 VAC is supplied. It produces 120 VAC on its primary if 230 VAC is supplied.
12. This voltage is electrically isolated from other voltages in the system. It must be measured using pin 6 as the ground reference.
13. Transformer voltages shown are for the fully loaded condition. Unloaded voltages will be 5-15 VAC higher.

System Wiring Diagrams-090622-SREA



Docker Main Controller Software Status LEDs: (See Notes 11, 12)

	System Condition / Defect		
LED Label	Expected	Questra Com Lost	Power Coupler PCBA Com Lost
D25	ON	OFF	ON
D26	ON (dim)	FLASH (10s / 10s)	FLASH (0.25s / 0.25s)
D27	ON	ON	ON

Questra Controller Software Status LEDs:

(See Notes 11, 13)

	System Condition	
LED Label	Expected (no ethernet connection)	Expected (with ethernet connection)
D21	OFF	OFF
D20	ON	ON
D18	ON	FLASH

Hardware LED Indicators:

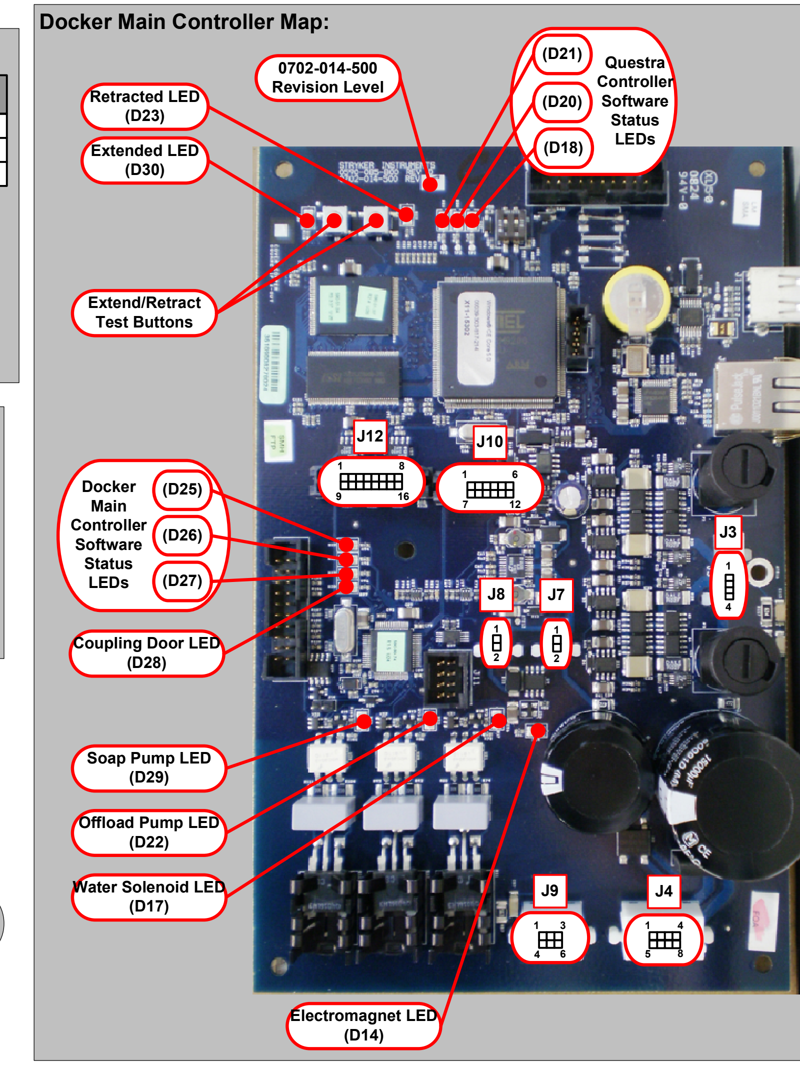
(See Note 10)

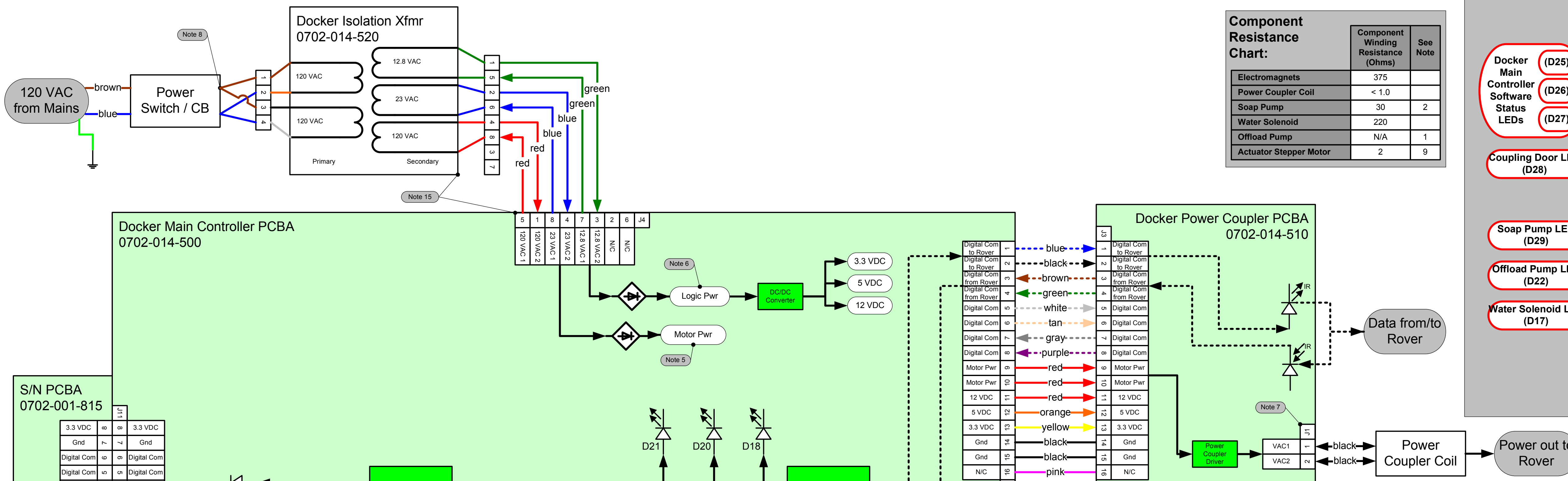
LED	LED Label	Triggered Condition	LED State if Triggered	Signal if Triggered
Coupling Door	D28	Door Closed	OFF	0 VDC
Couplings Extended	D30	Extended	ON	3.3 VDC
Couplings Retracted	D23	Retracted	ON	3.3 VDC

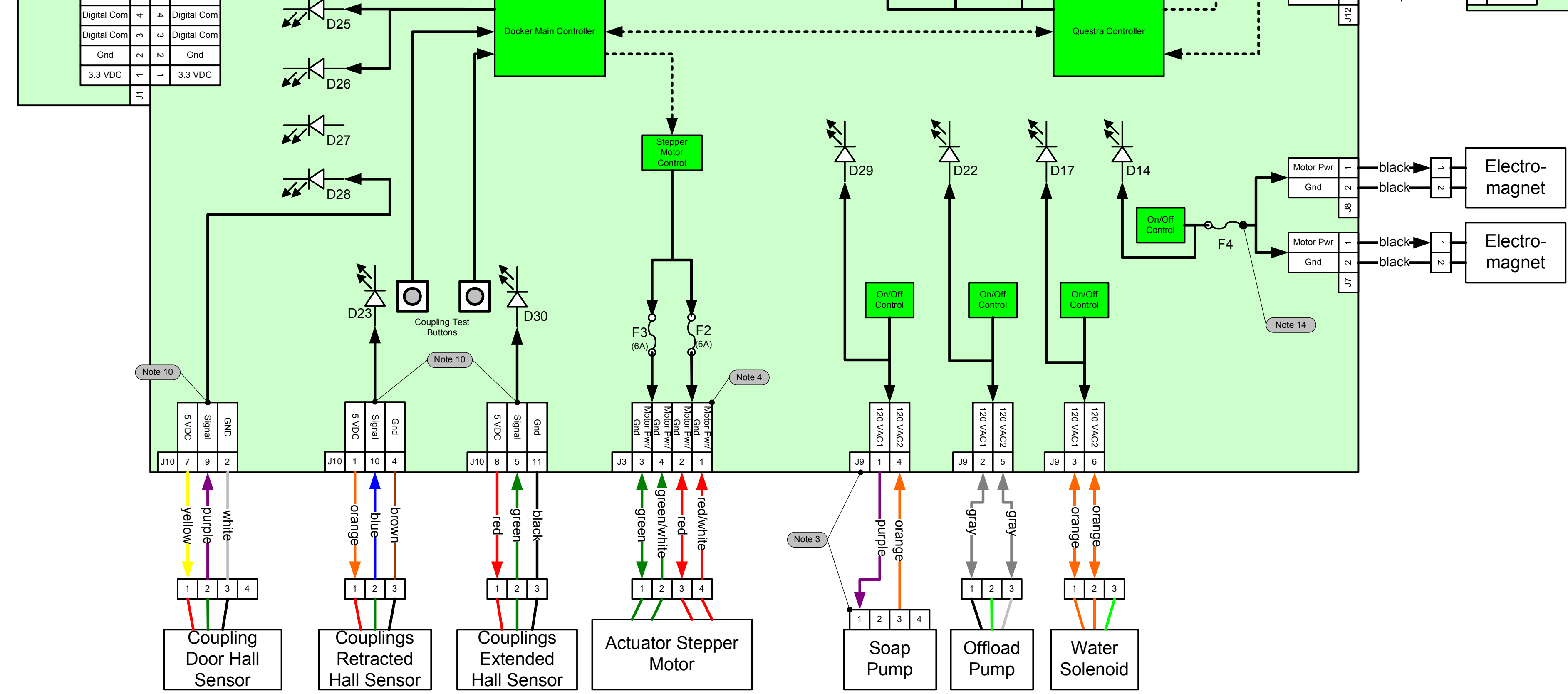
		Docker Main Controller PCBA Revision Level	
LED	LED Label	A - F	H
Soap Pump State	D29	ON = ON	
Offload Pump State	D22	ON = ON	
Water Solenoid State	D17	ON = ON	
Electromagnet State	D14	ON = OFF	ON = ON

Component Resistance Chart:

	Component Winding Resistance (Ohms)	See Note
Electromagnets	375	
Power Coupler Coil	< 1.0	
Soap Pump	30	2
Water Solenoid	220	
Offload Pump	N/A	1
Actuator Stepper Motor	2	9







Important General Diagram Notes:

- PRODUCT MALFUNCTION IS OFTEN DUE TO DAMAGED ELECTRICAL CONNECTORS. TAKE CARE NOT TO DAMAGE CONNECTOR PINS WITH METER PROBES!
- BOTH THE DOCKER MAIN CONTROLLER AND POWER COUPLER PCBA'S HAVE LARGE CAPACITORS THAT RETAIN CHARGE FOR EXTENDED PERIODS OF TIME. POWER MUST BE REMOVED FROM THE DOCKER FOR 3 MINUTES PRIOR TO CONNECTING OR DISCONNECTING ANYTHING FROM THESE PCBA'S!
- CHECKING RESISTANCES AT THE CONNECTORS TO THE DOCKER CONTROLLER PCBA VERIFIES CONTINUITY OF WIRE HARNESS **AND** INTERNAL COMPONENT WINDINGS. THIS IS THE PREFERRED LOCATION TO BEGIN TROUBLESHOOTING.
- Resistance and voltage values given are not specifications, but general expected values. These should be used primarily for determining continuity or basic circuit function.
- Resistance measurements must be made with docker power off and control circuitry disconnected (unplug wire harness from PCBA) to avoid damage / false readings.
- All voltage measurements (other than transformer primary and secondary) must be taken with component plugged in to avoid false readings. Needle type probes will be required to contact conductors inside mated connectors.
- Digital communication connections are indicated with dotted lines. Power, ground, and analog signal connections are indicated with solid lines.

Specific Diagram Notes:

1. The offload pump has an internal rectifier that prevents making resistance measurements. To check continuity, put meter in DIODE MODE. Measured voltage drop through the pump should be ~ 1.1 VDC when checked in both directions.
2. Resistance shown is the value if checked at the prefill pump with connector removed. A diode in the wire harness prevents continuity checks at the Main Controller end of the wire harness. To check continuity there, set meter to DIODE MODE and remove connector from J9 of the PCBA. Attach positive lead to purple wire and negative lead to orange wire. Diode drop measured should be ~0.6 VDC. Switch leads and ensure meter reads "OL".
3. Cannot measure voltage at pump due to connector design. Voltage can be measured at Docker Controller PCBA. With pump off, measured voltage will be < 100 VAC. With pump on, measured voltage will be ~120 VAC.
4. Component is current controlled, so applied voltage will vary rapidly. Volt meter measurements are not possible.
5. Motor Pwr depends on power source and should be in the range of 25 - 40 VDC.
6. Logic Pwr depends on the power source and should be in the range of 18 – 20 VDC.
7. High frequency / high voltage signal cannot be measured with volt meter.

Specific Diagram Notes (continued):

8. The voltage supplied by mains may be either 120 VAC (60 Hz) or 230 VAC (50 Hz). Input voltage is selected by installing the appropriate wire harness P/N between the power switch and transformer. The main diagram shows the Docker wired for 120 VAC mains.
9. The resistance of both stepper motor phases should be checked. Check resistance from green wire to green/white. Check resistance from red wire to red/white.
10. Hall signal indicator LED's are ON when hall sensors are un-plugged.
11. The software status LED states specified in this table apply after the Docker power up sequence is complete and when no Rover is attached. The Docker power up sequence is complete 90 seconds after power is applied.
12. Questra Com Lost condition requires replacing Docker Controller PCBA. Power Coupler Com Lost condition requires troubleshooting of Power Coupler PCBA (check for power and continuity of communication lines).
13. Conditions other than those shown may require replacing Docker Controller PCBA.
14. Fuse and fuse holder was not included in PCBA revisions prior to H.
15. Transformer voltages shown are for the fully loaded condition. Unloaded voltages will be 5-15 VAC higher.

System Control Overview
Electrical