CLAIMS

1. A system for measuring an amount of liquid in a pumping chamber of a pneumatically actuated diaphragm pump comprising:

a fluid inlet and fluid outlet valve connected to the pumping chamber;

a diaphragm separating a pneumatically actuated control chamber from the pumping chamber, the control chamber fluidly connected to a reference chamber of known volume via a conduit that includes a reference chamber valve;

the control chamber fluidly connected via one or more actuation valves to a source of positive or negative pneumatic pressure;

a controller configured to control the fluid inlet and outlet valves, the reference chamber valve, and the one or more actuation valves, and to receive pressure data from a first pressure sensor connected to the control chamber and a second pressure sensor connected to the reference chamber;

wherein the controller is configured to isolate the pumping chamber by closing the fluid inlet and outlet valves, charge the control chamber with a first control chamber pneumatic pressure; vent the reference chamber or fix a first reference chamber pneumatic pressure in the reference chamber that is different from the first control chamber pneumatic pressure; measure the first control chamber pneumatic pressure and the first reference chamber pneumatic pressure, connect the control chamber to the reference chamber by opening the reference chamber valve, measure a third equalized pneumatic pressure in the control and reference chambers, and

compute a control chamber volume based on an ideal gas model that assumes an adiabatic pressure equalization process in the reference chamber and a polytropic pressure equalization process in the control chamber that has a variable polytropic coefficient.

2. The system of claim 1, wherein the ideal gas model further assumes an isothermal process in the conduit as a gas moves from the control chamber to the reference chamber during the equalization process.

3. The system of claim 1, wherein the ideal gas model applied to the control chamber uses a polytropic coefficient in the ideal gas model, wherein the controller is programmed to vary the polytropic coefficient as a pre-defined function of the control chamber volume.

4. The system of claim 3, wherein the controller is programmed to compute the polytropic coefficient based on an estimated volume of the control chamber using a model that assumes an adiabatic pressure equalization process in the control chamber.

5. A system for measuring an amount of liquid in a pumping chamber of a pneumatically actuated diaphragm pump comprising:

a fluid inlet and fluid outlet valve connected to the pumping chamber;

a diaphragm separating a pneumatically actuated control chamber from the pumping chamber, the control chamber fluidly connected to a reference chamber of known volume via a conduit that includes a reference chamber valve;

the control chamber fluidly connected via one or more actuation valves to a source of positive or negative pneumatic pressure;

a controller configured to control the fluid inlet and outlet valves, the reference chamber valve, and the one or more actuation valves, and to receive pressure data from a first pressure sensor connected to the control chamber and a second pressure sensor connected to the reference chamber;

wherein the controller is configured to isolate the pumping chamber by closing the fluid inlet and outlet valves, charge the control chamber with a first control chamber pneumatic pressure; vent the reference chamber or fix a second reference chamber pneumatic pressure in the reference chamber that is different from the first control chamber pneumatic pressure; measure the first control chamber pneumatic pressure and the second reference chamber pneumatic pressure, connect the control chamber to the reference chamber by opening the reference chamber valve and equalizing pressures between the control chamber and the reference chamber, measure a third equalized pneumatic pressure in the control and reference chambers, and

compute a control chamber volume based on an ideal gas model under a polytropic process, wherein the controller is configured to select a polytropic coefficient for the model using a pre-determined function in which a value of the polytropic coefficient depends on and varies with the control chamber volume.

6. The system of claim 5, wherein the pre-determined function is determined by fixing the control chamber volume at a known volume, and calculating a polytropic coefficient corresponding to the known volumes of the control and reference chambers, and the measured first, second and third pressures before and after equalization of pressures;

wherein said calculation is repeated a plurality of times, each said time corresponding to fixing the control chamber volume at a different known volume.

7. The system of claim 6, wherein the function corresponds to a stored look-up table from which the controller selects a polytropic coefficient corresponding to the volume of the control chamber being computed.

8. The system of claim 6, wherein the function corresponds to an equation that has been fitted to a plurality of calculated polytropic coefficients corresponding to a series of known control chamber volumes.