CLAIMS

1. A manifold module for controlling a pneumatically actuated diaphragm pump comprising:

a manifold base reversibly connectable via a first pressure line inlet port to a first pressure line containing positively pressurized gas and a second pressure line inlet port to a second pressure line containing negatively pressurized gas;

first, second, third and fourth valve assemblies, each mounted to a valve assembly receiving station on the manifold base;

a controller mounted to the manifold base and connected to the four valve assemblies;

the manifold base configured to fluidically connect the first pressure line inlet port of the manifold base to a first inlet respectively of the first, second and third valve assemblies, to fluidically connect the second pressure line inlet port of the manifold base to a second inlet respectively of the first, second and fourth valve assemblies, to fluidically connect a cavity of each of the third and fourth valve assemblies to a respective pressure sensing port of the manifold base, to fluidically connect an outlet of each of the valve assemblies to a respective outlet of the manifold base, and to fluidically connect the first and second pressure line inlet ports of the manifold base to respective first and second pressure line outlet ports of the manifold base;

each of the first and second valve assemblies configured to be electrically actuated by the controller to establish communication between the cavity of said first or second valve assemblies and the first inlet of said first and second valve assemblies, or establish communication between the cavity of said first or second valve assemblies and the second inlet of said first and second valve assemblies;

the third valve assembly configured to be electrically actuated by the controller to open or close communication between the cavity of said third valve assembly and the first inlet of said third valve assembly;

the fourth valve assembly configured to be electrically actuated by the controller to open or close communication between the cavity of said fourth valve assembly and the second inlet of said fourth valve assembly;

wherein the first valve assembly is configured to fluidically connect to a fluid inlet valve of the diaphragm pump, the second valve assembly is configured to fluidically connect to a fluid outlet valve of the diaphragm pump, and the third and fourth valve assemblies are configured to fluidically connect to a control chamber of the diaphragm pump;

wherein the controller comprises first and second pressure sensors mounted on a control board, the pressure sensors configured to form a reversible sealed connection respectively with the pressure sensing ports of the manifold base connected to the cavities of the third and fourth valve assemblies;

wherein the controller is configured to coordinate actuation of the four valve assemblies to open the inlet valve, close the outlet valve and generate a fill stroke in the diaphragm pump, or close the inlet valve, open the outlet valve and generate a deliver stroke in the diaphragm pump;

wherein the first and second valve assemblies each comprises first and second opposing inlet orifices and a single outlet, a magnetic shuttle configured to travel within the cavity between the opposing inlet orifices, the inlet orifices associated with an electromagnetic coil, so that activation of the electromagnetic coil by the controller moves the shuttle toward the associated inlet orifice and occludes said inlet orifice;

wherein the shuttle comprises an elastomeric layer on opposing sides facing the first and second inlet orifice and configured to be sized such that the shuttle is only displaced ~5% or less of the length of the interior valve cavity; and

the manifold module further comprising a capacitor connected to the controller and configured to hold a charge sufficient to power the first or second valve assemblies to a fail-safe state when power or communications to the controller is impaired, the fail-safe state causing either or both fluid inlet and fluid outlet valves to close.

2. The manifold module of claim 1, wherein the controller is configured to activate the electromagnetic coil of the first inlet orifice of the first valve assembly to deliver negative gas pressure to the fluid inlet valve to open the valve, and is configured to activate the

electromagnetic coil of the second inlet orifice of the first valve assembly to deliver positive gas pressure to the fluid inlet valve to close the valve.

3. The manifold module of claim 1, wherein the controller is configured to activate the electromagnetic coil of the first inlet orifice of the second valve assembly to deliver negative gas pressure to the fluid outlet valve to open the valve, and is configured to activate the electromagnetic coil of the second inlet orifice of the second valve assembly to deliver positive gas pressure to the fluid outlet valve to close the valve.

4. The manifold module of any one of claims 2 - 3, wherein the cavity includes cup-shaped inserts positioned against each inlet orifice, so that the shuttle is configured to move within the inserts between the inlet orifices.

5. The manifold module of claim 4, wherein each insert includes a valve seat surrounding an inlet fluid pathway leading to the inlet orifice to form a seal against the shuttle.

6. The manifold module of claim 4, wherein each insert comprises a sealing flange, so that the sealing flanges are configured to abut each other.

7. The manifold module of claim 4, wherein each insert includes an inlet fluid pathway adjacent the corresponding inlet orifice to permit communication between the inlet orifice and the cavity of the valve assembly, and an outlet fluid pathway to permit communication between the outlet and an internal volume of the insert.

8. A fluid flow control system for controlling a pump cassette, the fluid flow control system comprising:

a pump cassette including a diaphragm pump having an inlet valve and an outlet valve;

a system controller;

a manifold base reversibly connectable via a first pressure line inlet port to a first pressure line containing positively pressurized gas and a second pressure line inlet port to a second pressure line containing negatively pressurized gas;

first, second, third and fourth valve assemblies, each mounted to a valve assembly receiving station on the manifold base;

an on-board controller mounted to the manifold base and connected to the four valve assemblies;

the manifold base configured to fluidically connect the first pressure line inlet port of the manifold base to a first inlet respectively of the first, second and third valve assemblies, to fluidically connect the second pressure line inlet port of the manifold base to a second inlet respectively of the first, second and fourth valve assemblies, to fluidically connect a cavity of each of the third and fourth valve assemblies to a respective pressure sensing port of the manifold base, to fluidically connect an outlet of each of the valve assemblies to a respective outlet of the manifold base, and to fluidically connect the first and second pressure line inlet ports of the manifold base to respective first and second pressure line outlet ports of the manifold base;

each of the first and second valve assemblies configured to be electrically actuated by the on-board controller to establish communication between the cavity of said first or second valve assemblies and the first inlet of said first and second valve assemblies, or establish communication between the cavity of said first or second valve assemblies and the second inlet of said first and second valve assemblies;

the third valve assembly configured to be electrically actuated by the on-board controller to open or close communication between the cavity of said third valve assembly and the first inlet of said third valve assembly;

the fourth valve assembly configured to be electrically actuated by the on-board controller to open or close communication between the cavity of said fourth valve assembly and the second inlet of said fourth valve assembly;

wherein the first valve assembly is configured to fluidically connect to the inlet valve of the diaphragm pump, the second valve assembly is configured to fluidically connect to the outlet valve of the diaphragm pump, and the third and fourth valve assemblies are configured to fluidically connect to a control chamber of the diaphragm pump;

wherein the on-board controller comprises first and second pressure sensors mounted on a control board, the pressure sensors configured to form a reversible sealed connection

respectively with the pressure sensing ports of the manifold base connected to the cavities of the third and fourth valve assemblies; and

wherein the on-board controller is configured to coordinate actuation of the four valve assemblies to open the inlet valve, close the outlet valve and generate a fill stroke in the diaphragm pump, or close the inlet valve, open the outlet valve and generate a deliver stroke in the diaphragm pump, the system controller being configured to provide commands to the on-board controller including a start pumping command, a stop pumping command, or a command to pump a pre-determined quantity of liquid;

wherein the first and second valve assemblies each comprises first and second opposing inlet orifices and a single outlet, a magnetic shuttle configured to travel within the cavity between the opposing inlet orifices, the inlet orifices associated with an electromagnetic coil, so that activation of the electromagnetic coil by the controller moves the shuttle toward the associated inlet orifice and occludes said inlet orifice;

wherein the shuttle comprises an elastomeric layer on opposing sides facing the first and second inlet orifices and configured to be sized such that the shuttle is only displaced ~5% or less of the length of the interior valve cavity; and

the fluid flow control system further comprising a capacitor connected to the controller and configured to hold a charge sufficient to power the first or second valve assemblies to a fail-safe state when power or communications to the controller is impaired, the fail-safe state causing either or both fluid inlet and fluid outlet valves to close.

9. The fluid flow control system of claim 8, wherein the controller is configured to activate the electromagnetic coil of the first inlet orifice of the first valve assembly to deliver negative gas pressure to the fluid inlet valve to open the valve, and is configured to activate the electromagnetic coil of the second inlet orifice of the first valve assembly to deliver positive gas pressure to the fluid inlet valve to close the valve.

10. The fluid flow control system of claim 8, wherein the controller is configured to activate the electromagnetic coil of the first inlet orifice of the second valve assembly to deliver negative gas pressure to the fluid outlet valve to open the valve, and is configured to activate the

electromagnetic coil of the second inlet orifice of the second valve assembly to deliver positive gas pressure to the fluid outlet valve to close the valve.

11. The fluid flow control system of any one of claims 8 - 10, wherein the cavity includes cup-shaped inserts positioned against each inlet orifice, so that the shuttle is configured to move within the inserts between the inlet orifices.

12. The fluid flow control system of claim 11, wherein each insert includes a valve seat surrounding an inlet fluid pathway leading to the inlet orifice to form a seal against the shuttle.

13. The fluid flow control system of claim 11, wherein each insert comprises a sealing flange, so that the sealing flanges are configured to abut each other.

14. The fluid flow control system of claim 11, wherein each insert includes an inlet fluid pathway adjacent the corresponding inlet orifice to permit communication between the inlet orifice and the cavity of the valve assembly, and an outlet fluid pathway to permit communication between the outlet and an internal volume of the insert.