

I. INTRODUCTION

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General Description

The Eldex MicroPro™ Pump has been designed to deliver fluids at low flow rates in a variety of applications, ranging from HPLC, FIA, and various process control applications. The μ Pro Pump combines modularity of design with full component integration for optimized performance at micro flow rates. The modular design allows you to configure your μ Pro Pump in a manner best suited to your use, while component integration minimizes system volume, which is critical in micro flow rate applications.

MicroPro Controls:

- **Operating Mode.** Your μ Pro Pump may be configured for various modes of operation, depending on the number of syringes in your μ Pro system and the plumbing configuration you have chosen. All modes of operation can be controlled directly or at programmable times.
 - ▶ *Single Syringe Mode.* You may control delivery of a single solvent for applications such as isocratic HPLC.
 - ▶ *Multiple, Independent Syringe Mode.* Depending on the number of syringes in your μ Pro system, you may deliver up to four different solvents at any independent rates you choose to a common output.
 - ▶ *Reciprocating Mode.* With two syringes in your μ Pro system, you can program your μ Pro Pump to continuously deliver solvent with the syringes out of phase with each other.
 - ▶ *Gradient Mode.* Depending on the number of syringes in your μ Pro system, up to four solvents may be blended in any proportion from 0 - 100%. You may control solvent composition directly or vary compositions according to patterns you define for automated gradient operation.
 - ▶ *Continuous Flow Gradient Mode.* With a binary or ternary gradient, continuous flow can be achieved by adding a transitional liquid delivery (TLD) pump. When the binary or ternary gradient syringes refill, the TLD syringe, which has pre-pressurized to the system pressure, maintains flow to the system until the gradient syringes are ready for delivery to the system.
- **Flow Rate.** You may set, alter directly or at programmable times, any flow rate, including negative flow rates, within the range of the syringe model you have chosen.
- **Pressure Limits.** If your μ Pro pump is fitted with a pressure transducer, you may set high and low pressure limits.
- **External events.** If your μ Pro pump is fitted with an I/O board, you may control up to 6 external events directly or at programmable times.

MicroPro Features:

- Pulseless fluid delivery.
- Pre-pressurization and compression.
- Constant-pressure operation.
- Interactive menus for easy programming.
- Non-volatile memory for power-off retention of files.

MicroPro Options:

- **Syringe Size.** Two syringe sizes (2mL and 10mL) are available, each tailored to specific flow and pressure ranges.
- **Syringe Temperature Control.** Provides temperature control from 5°C above ambient to 50°C for applications requiring the highest precision at low flow rates.
- **Valves:** Several valves are available:
 - ▶ *Active Low Pressure Valves.* Can be installed on inlet side (for automated priming and purging the syringes) or on inlet and outlet side (for use in low pressure applications) of syringe. Can operate at pressures up to 50 psi.
 - ▶ *Active High Pressure Valves.* Can be installed on outlet side (for the highest level of flow precision) of syringe (active low pressure valve is installed on inlet side). Can operate at pressures up to 5,000 psi.
 - ▶ *Passive Mechanical Valves.* Can be installed in lieu of active valves on inlet and outlet side of syringe (for use in extremely high pressure applications and applications not requiring the highest level of precision). Can operate at pressures up to 10,000 psi.
- **Pressure Transducers:**
 - ▶ *Low Pressure Transducer.* Provides pressure feedback and control at pressures up to 1,000 psi.
 - ▶ *Medium Pressure Transducer.* Provides pressure feedback and control at pressures up to 5,000 psi.
 - ▶ *High Pressure Transducer.* Provides pressure feedback and control at pressures up to 10,000 psi.
- **Mixers:** A micro 5µL static mixer is available. In addition, a dynamic mixer with a volume of 15µL is available. Two other mixer cartridges are available, each of which adds two additional stages of dynamic mixing; one cartridge has a volume of 30µL, the other has a volume of 150µL.
- **Input/Output Control:**
 - ▶ *I/O Board.* Required for use with active low pressure valves. Provides contact closure and TTL inputs and outputs.
 - ▶ *Analog I/O Board.* Required for use with syringe temperature control or pressure transducer. Provides analog outputs.
 - ▶ *RS232.* Provides communication and control between a computer and the µPro Pump system.

About This Manual

This operating manual is intended to help you obtain optimal performance from your μ Pro Pump system.

The remainder of **Section I** provides the basic information necessary for you to operate the system: a description of the location and identity of the control functions, a brief description of the control menus, and the theory of operation and specifications. You should finish reading this section before going on to anything else.

Section II describes the steps involved in setting up your μ Pro Pump.

Section III describes the operation of the μ Pro Pump hardware and the menu system in detail.

Section IV provides examples of file programming for a number of common techniques ranging from isocratic chromatography through process control and automated methods development.

Section V describes troubleshooting and basic maintenance.

Section VI contains appendixes.

A Guided Tour of the MicroPro Pump

The μ Pro Pump system is designed for operational reliability. All of the plumbing connections requiring periodic user attention are located in the front of the unit, away from the electronics. Infrequently accessed connections such as power, fuses, and external event connections (if installed) are located on the rear panel.

Removing the Front Panel

The μ Pro Pump has a removable front cover. To remove the cover:

1. Position your hands so that you can release the bottom of the cover from the spring holding it in place. Press up on the bottom of the cover and swing it out to free it from the chassis.
2. With the bottom of the cover free from the chassis, pull down on the cover to remove the tabs on the cover from their slots in the chassis (see Figure 1.1).

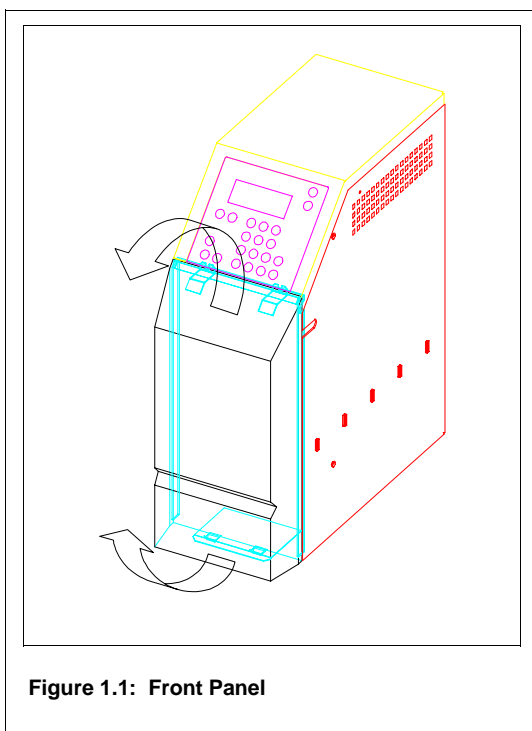


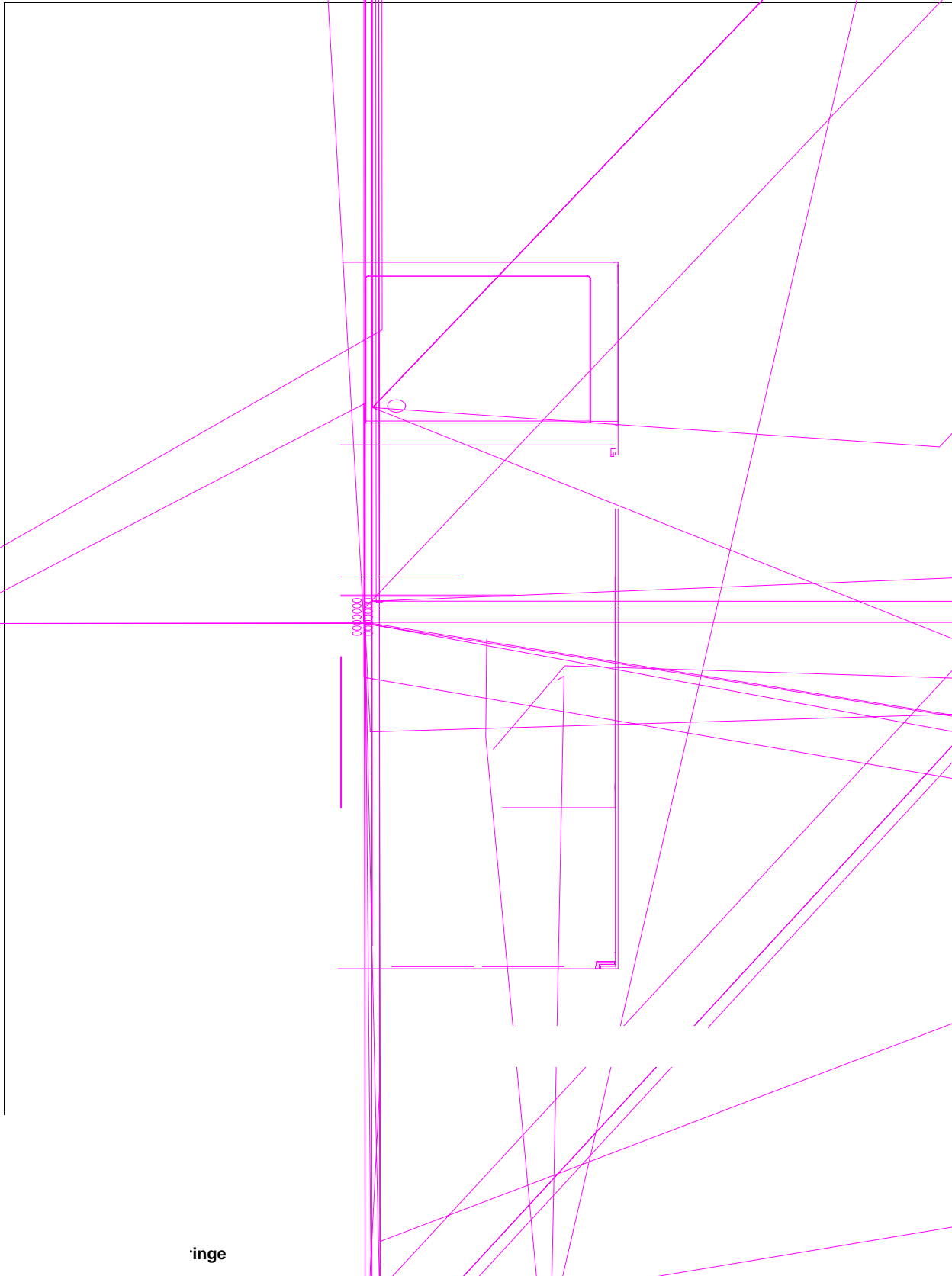
Figure 1.1: Front Panel



CAUTION: The μ Pro pump is designed to be operated with the cover on. The cover will contain any damage which may result from over-pressurizing the system. In addition, if your pump is fitted with temperature control, the cover helps to keep the temperature stable.

Front Panel, Single Syringe

As you look at the front panel (Figure 1.2) of a typical single μ Pro Pump, you will see:



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Component Details

Local Interface:

1. **Liquid Crystal Display (LCD).** Displays current menu information, allowed functions and softkey definitions and indications, or current status of flow rate, pressure, and other operating conditions. Not present on “slave” pumps.
2. **Softkeys.** These control keys are defined by the menu-driven software for menu selection and instrument control. Key functions at each menu are displayed or indicated on the LCD display screen. Not present on “slave” pumps.
3. **Permanent Function Keys.** These control keys are permanently defined for direct control of major instrument functions. Not present on “slave” pumps.
4. **Numeric Keypad.** Allow entry of numeric information. Not present on “slave” pumps.

Syringe and Options:

5. **Syringe.** The syringe pump design provides precise, pulseless solvent delivery at low flow rates. Two syringe sizes are available; 2 mL and 10 mL. The size of your μ Pro Pump is indicated by the etched number on the surface of the syringe where the syringe input/output is located.
6. **Syringe Input/Output.**
7. **Heater.** The μ Pro Pump may be fitted with a heater which will regulate the syringe temperature.
8. **Solvent Bottle.** The μ Pro Pump is shipped with a solvent bottle fitted with a screw cap and plumbing to provide solvent delivery.

Valves and Transducers:

9. **Outlet Valve:** (three options)
 - High Pressure Valve.** The μ Pro Pump may be fitted with a high pressure active valve for regulating flow to the output of the μ Pro Pump system.
 - Mechanical Valve** (not shown, see Figure 3.2). An option in position 9. The μ Pro Pump may be fitted with mechanical valves which allow both input to the syringe and output to the system.
 - Low Pressure Valve** (not shown, see Figure 3.1). An option in position 9. The μ Pro Pump may be fitted with a low pressure active valve for output to the system.
10. **Transducer.** The μ Pro Pump may be fitted with one of three pressure transducers. The high pressure transducer is capable of 10,000 psi output, the medium pressure transducer is capable of 5,000 psi output, and the low pressure transducer is capable of 1,000 psi output.
11. **Low Pressure Valve.** The μ Pro Pump may be fitted with a low pressure active valve for purging and priming the syringe.

Rear Panel, Dual and Single

As you look at the rear panel (Figure 1.3) of a μ Pro Pump, you will see:

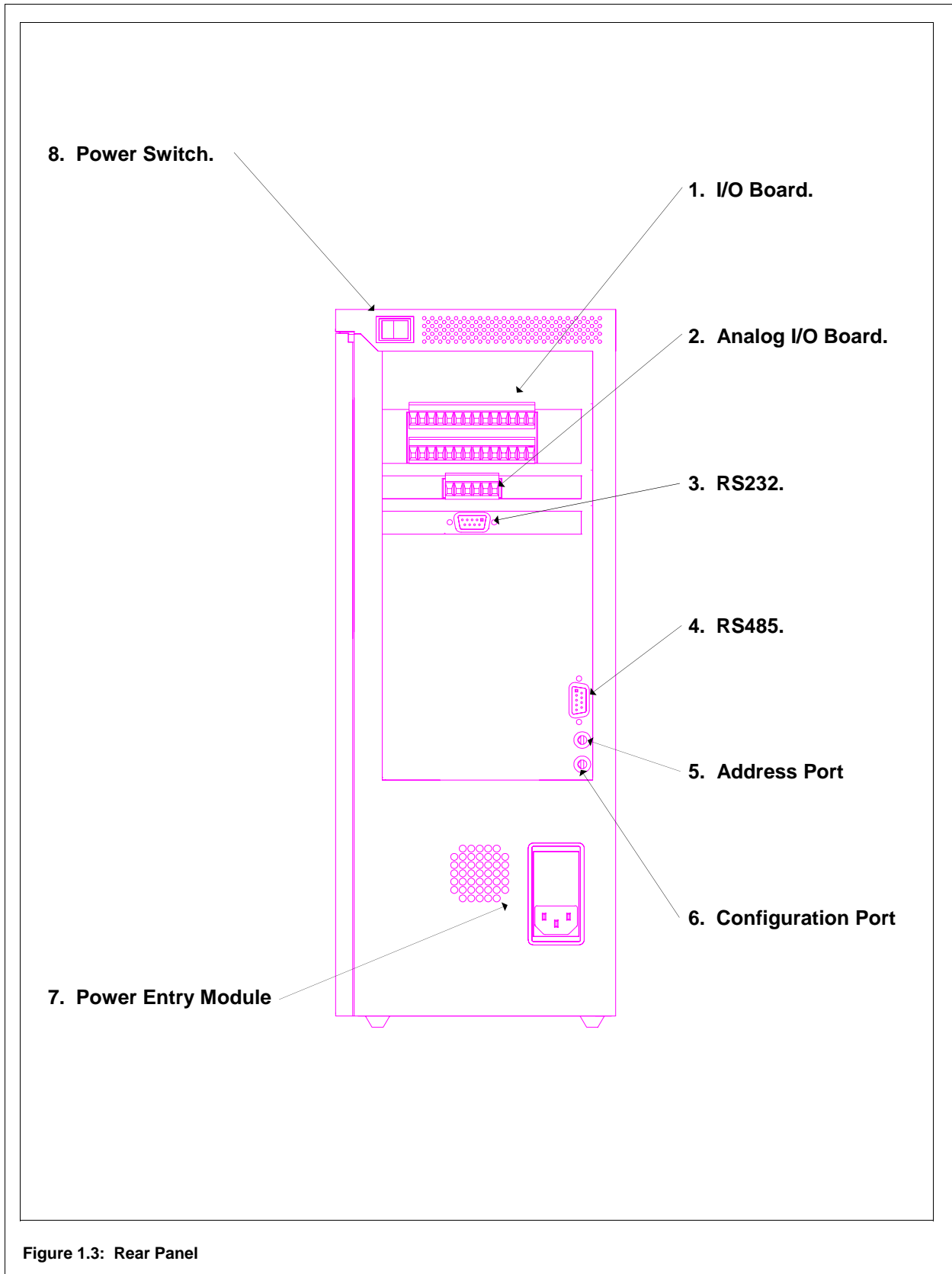


Figure 1.3: Rear Panel

Component Details

I/O Connections:

1. **I/O Board.** The μ Pro Pump may be fitted with an input/output board which provides connection to external devices for event control by the μ Pro Pump, and remote control of the μ Pro Pump.
2. **Analog I/O Board.** The μ Pro Pump may be fitted with an analog input/output board which provides external monitoring of pressure, composition, etc.

Remote Communications:

3. **RS232.** The μ Pro Pump may be fitted with a board which provides for communication between a computer and the μ Pro Pump system.
4. **RS485.** Provides for communication between several μ Pro Pump systems. Up to four μ Pro Pump systems can be daisy-chained together.

System Settings:

5. **Address Port.** Sets the address of each μ Pro Pump system in the daisy chain.
6. **Configuration Port.** Sets the configuration of the syringe size and transducer of your μ Pro Pump.

Power:

7. **Power Entry Module.** Provides for voltage selection and accepts a standard 3-conductor modular power cord.
8. **Power Switch.** Switches system power ON/OFF. CAUTION: Rapid toggling of the power switch may result in component failure.

Front Panel, Dual Syringe

As you look at the front panel (Figure 1.4) of a dual μ Pro Pump, you will see:

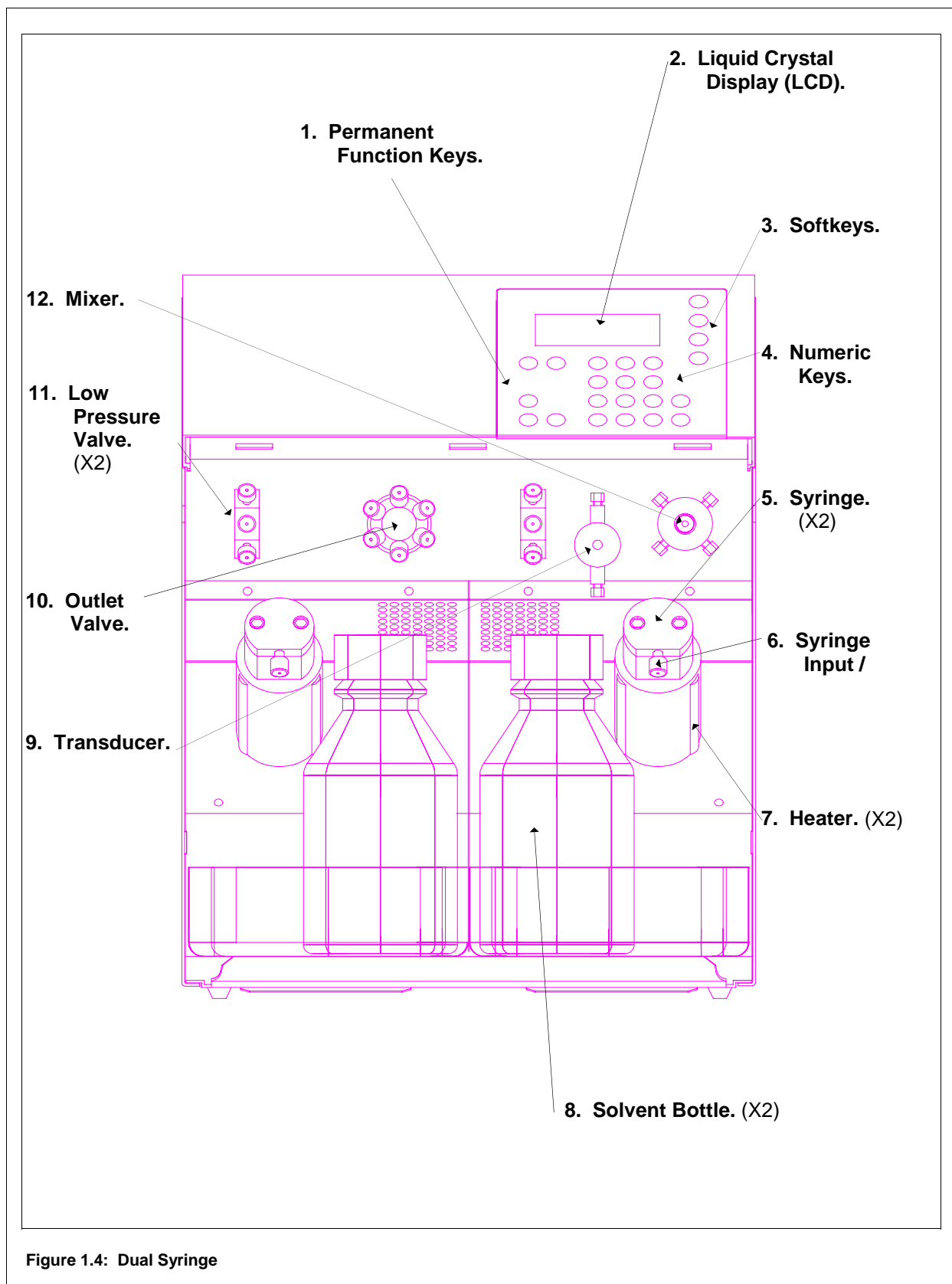


Figure 1.4: Dual Syringe

Component Details

Local Interface:

1. **Permanent Function Keys.** These control keys are permanently defined for direct control of major instrument functions.
2. **Liquid Crystal Display (LCD).** Displays current menu information, allowed functions and softkey definitions and indications, or current status of flow rate, pressure, and composition.
3. **Softkeys.** These control keys are defined by the menu-driven software for menu selection and instrument control. Key functions at each menu are displayed or indicated on the LCD display screen.
4. **Numeric Keypad.** Allow entry of numeric information.

Syringe and Options:

5. **Syringe.** The syringe pump design provides precise, pulseless solvent delivery at low flow rates. Two syringe sizes are available; 2mL and 10mL. The size of your μ Pro Pump is indicated by the etched number on the surface of the syringe where the syringe input/output is located. Syringe #1 (A in gradient mode) is on the right, syringe #2 (B in gradient mode) is on the left.
6. **Syringe Input/Output.**
7. **Heater.** The μ Pro Pump may be fitted with a heater which will regulate the syringe temperature.
8. **Solvent Bottle.** The μ Pro Pump is shipped with a solvent bottle fitted with a screw cap and plumbing to allow solvent delivery.

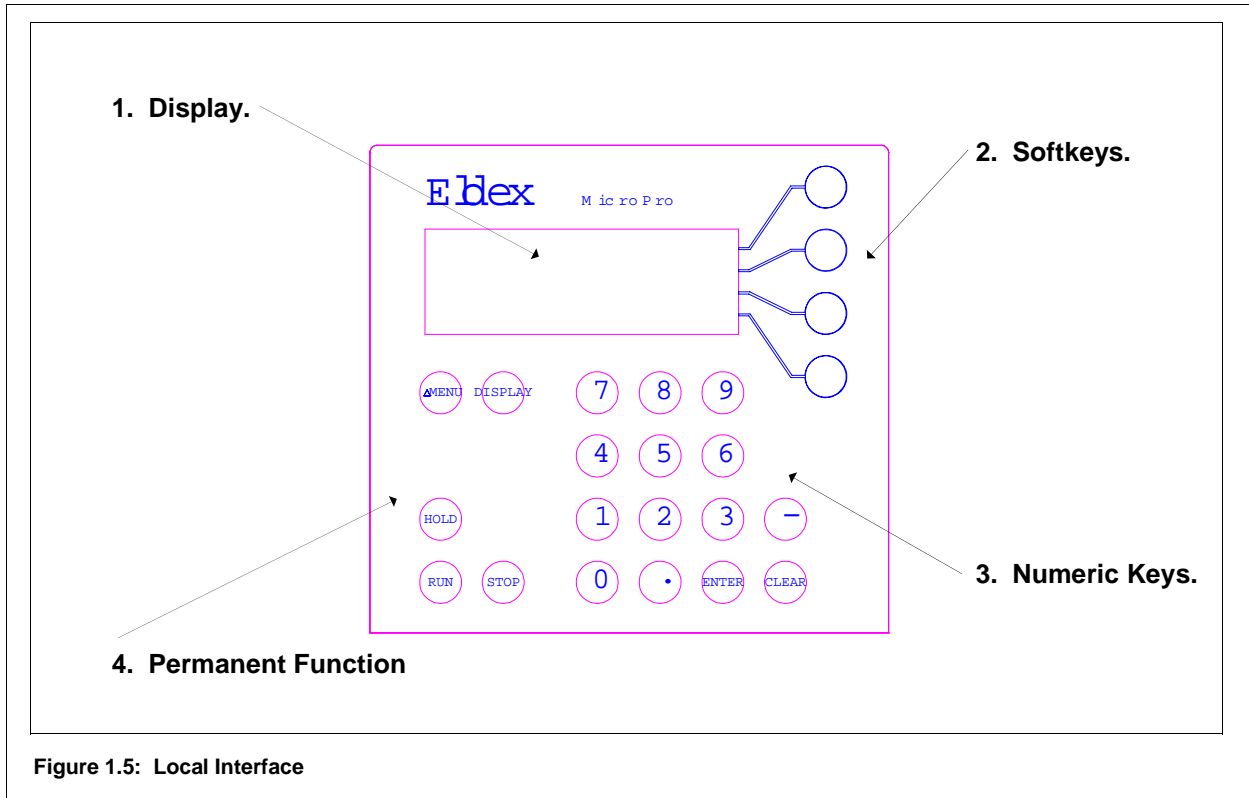
Valves and Transducers:

9. **Transducer.** The μ Pro Pump may be fitted with one of three pressure transducers. The high pressure transducer is capable of 10,000 psi output, the medium pressure transducer is capable of 5,000 psi output, and the low pressure transducer is capable of 1,000 psi output.
10. **Outlet Valve:** (three options)
 - High Pressure Valve.** The μ Pro Pump may be fitted with a high pressure active valve for regulating flow to the output of the μ Pro Pump system.
 - Mechanical Valve** (not shown, see Figure 3.2). An option in position 10. The μ Pro Pump may be fitted with mechanical valves which allow both input to the syringe and output to the system.
 - Low Pressure Valve** (not shown, see Figure 3.1). An option in position 10. The μ Pro Pump may be fitted with a low pressure active valve for output to the system.
11. **Low Pressure Valve.** The μ Pro Pump may be fitted with a low pressure active valve for purging and priming the syringe.
12. **Mixer.** The μ Pro Pump may be fitted with a micro mixers.

An Overall Look at the Local Interface

Operation of the μ Pro Pump system is controlled from a series of menus and there is no need to remember esoteric control codes or command sequences. All of the options available to you at any given time are visible on the LCD display. A detailed description of the menu sequence is given in Section III, and examples illustrating a variety of specific programs are covered in Section IV.

As you look at the keyboard (Figure 1.5), you will see:



Component Details

- 1. Display.** Current menu information, allowed functions and softkey definitions and functions are displayed on the 4 line by 20 character LCD display. The menu screens referenced in this manual are identified at the top by a unique alpha-numeric designation (e.g., Main Menu, A, B2.2, etc.).
- 2. Softkeys.** These control keys are defined by the menu-driven software for menu selection and instrument control. Key functions at each menu are displayed or indicated on the LCD display screen. The softkeys are referred to as “A”, “B”, “C”, and “D” (from the top to the bottom) in the text of this manual.
- 3. Numeric Keys.** Allow entry of numeric information, as well as Enter, Clear, and “-” (negative).
- 4. Permanent Function Keys.** These control keys are permanently defined for direct control of major instrument functions.

Key Definitions

Δ MENU: The Δ MENU (Change Menu) key returns to the previous menu level.

DISPLAY: The DISPLAY key returns to the display screen (function and purpose of the display screen is described on page 3.8), repeated use of the DISPLAY key toggles between display screen and last used screen.

HOLD: The HOLD key stops the clock and freezes the file (time) running, while the pump continues to run; this key is only active when running a file.

RUN: The RUN key has four functions. First, it starts the pump in either real time, or a file/cycle or file/sequence. Second, the RUN key starts the refill and purge cycle. Third, the RUN key starts the system characterization. Fourth, the RUN key continues after a hold or stop. The key is active from screens A, C1, C2, D1.2, and D1.1.2 (individual screens are referred to in this manual using a shorthand designation such as A, C1, etc.; each screen is discussed in detail in Section III of the manual).

STOP: The STOP key stops the clock and pump, whether in file execution, real time or refill and purge.

ENTER: The ENTER key enters a value or accepts displayed value.

CLEAR: The CLEAR key either clears invalid entries, or clears the field of entries, or, when in the flow field, moves cursor to the next field without affecting the flow or gradient.

- : The - key (minus key) moves cursor (non-destructively) one character to the left or begins the entry of a negative flow rate (when preceded by CLEAR).

DISPLAY then Δ MENU: Pressing the DISPLAY key followed by the Δ MENU key returns to the main menu, regardless of the level in the menu tree.

Theory of Operation

General

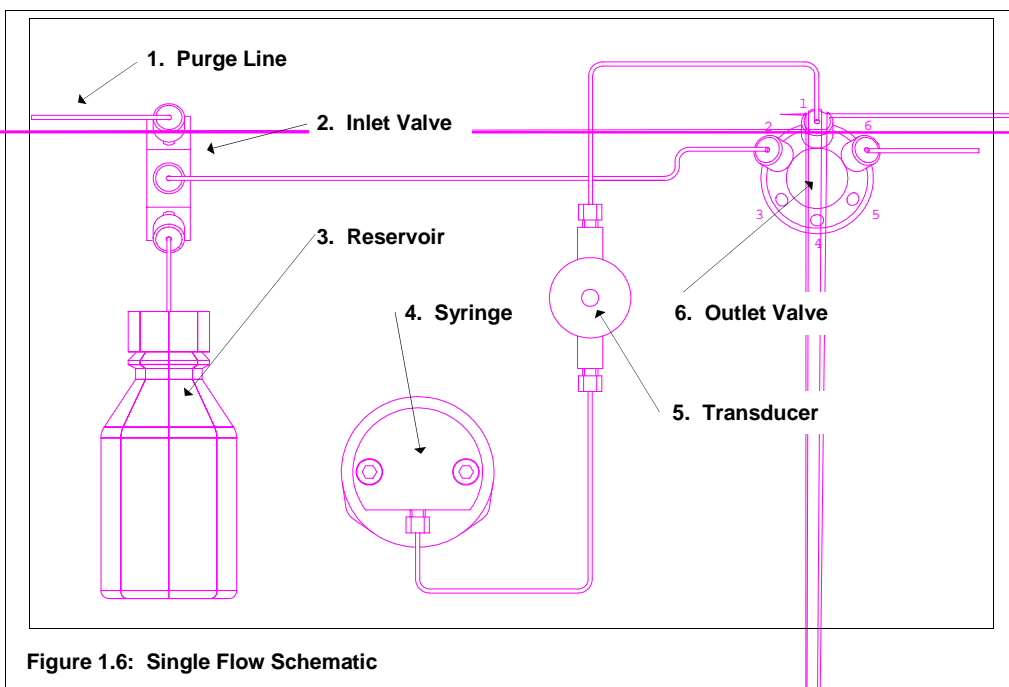
The heart of the μ Pro Pump is the syringe. The syringe is filled with fluid from the solvent reservoir through an inlet valve at a rate you define. The syringe dispenses fluid through an outlet valve at rates you define within the limits of the specific syringe installed. Negative flow rates are also accepted values. Syringe motion is controlled by a stepper motor.

Flow Schematic

Several flow schematics are possible with the μ Pro Pump, depending on the options installed. Two common flow schematics are shown below. Section IV shows the wide variety of flow schematics available.

Single Syringe Schematic:

A flow schematic for a single syringe with active high pressure valving is shown in Figure 1.6. Fluid is transferred from the solvent reservoir (3) through the low pressure inlet valve (2) to the syringe (4) via the high pressure active valve (6). The low pressure inlet valve is also used to divert flow to waste (1) for purging the syringe. The syringe dispenses the fluid to the system through a flow-through pressure transducer (5) and an active high pressure outlet valve (6).



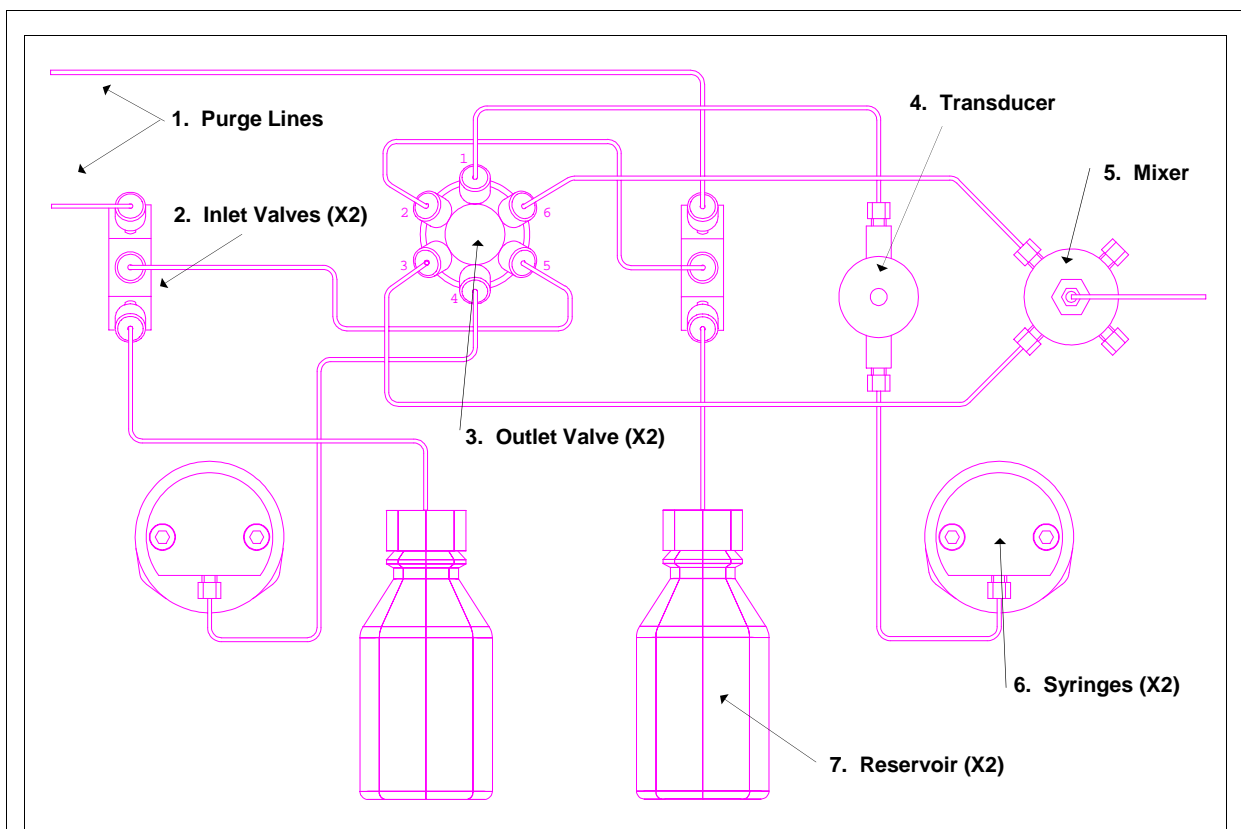


Figure 1.7: Dual Flow Schematic

Dual Syringe Schematic:

A flow schematic for a dual gradient syringe with active high pressure valving is shown in Figure 1.7. Fluid is transferred from the solvent reservoirs (7) through the low pressure inlet valves (2) to the syringes (6) via the high pressure active valve (3). The low pressure inlet valves are also used to divert flow to waste (1) for purging the syringes. The syringes dispense the fluid to the mixer (5) through active high pressure valve (3). One of the syringes has a flow through pressure transducer (4) installed between the syringe and the high pressure active valve. A micro-mixing chamber (5) combines and mixes the output of the two syringes.

Electronic Control

Control of the entire system is maintained by a microprocessor system which continuously controls flow rates, system pressure (if a pressure transducer is installed), solvent composition (if multiple syringes are installed and being used in the gradient mode) and external events (if the I/O board is installed). All functions may be varied in a time-based manner.

Five Operating Modes:

The μ Pro Pump system can be programmed to operate in one of four different modes: single syringe operation, multiple independent syringe operation, reciprocating syringe operation, and gradient operation.

Single syringe operation of the μ Pro is straightforward programming of a single syringe's system parameters.

Multiple independent syringe operation involves programming parameters for each of several syringes installed in the μ Pro system. Programming of each syringe flow rate is independent of the other syringes programmed.

Reciprocating syringe operation involves two syringes operating out of phase with each other to provide continuous flow output.

Gradient operation involves two or more syringes being operated in varying ratios of the total system flow.

Continuous Flow Gradient operation uses a binary or ternary gradient system. Continuous flow is achieved by adding a transitional liquid delivery (TLD) pump. When the binary or ternary gradient syringes refill, the TLD syringe, which has pre-pressurized to the system pressure, maintains flow to the system until the gradient syringes are ready for delivery to the system.

Real Time and File Operation:

The μ Pro Pump system can be controlled in “real-time” or by running a file.

Real-time control of the syringes operates the system at the set parameters immediately upon pressing the RUN key. The real-time screen specifies the flow rate to be run, the syringe being programmed (if being used in the multiple syringe mode), the devices ON (if an I/O board is installed), the solvent composition (if being used in the gradient mode), and the high and low pressure limits (if a pressure transducer is installed).

A file is a time program of pump parameters and may best be thought of as a series of screens defining the pump’s parameters at specific times. Up to 10 files with up to 20 steps in each file can be stored in memory. By default, before running a file the μ Pro pump refills; then it executes user programmed equilibration conditions, including pre-pressurization of the syringe (if a pressure transducer has been installed and pre-pressurization is ON). Each screen specifies the elapsed time, the syringe being programmed (if being used in the multiple syringe mode), the flow rate, the devices ON (if an I/O board is installed), and the solvent composition (if being used in the gradient mode).

Pre-Pressurization:

A key parameter when operating the μ Pro syringe pump concerns the pre-pressurization routine. When operating at pressure it will be useful to characterize your system, using the pre-pressurization screens built into the user interface (screens D1.1, D1.1.1, D1.1.2). Pre-pressurization and characterization are only operative when the μ Pro has been fitted with a pressure transducer. Running the characterization allows the μ Pro to measure the resistance of your system.

You can enter up to three parameters in gradient mode, and two parameters in other modes. In screen D1.1.1 you can enter a target pressure (the pressure you believe the system will be at in a state of equilibrium), a maximum flow (usually a minimum of 100 μ L/min, or 5 to 10 times the flow rate - as your desired flow increases, usually a lower multiplier will work better), and if operating in gradient mode, %B. A more complete explanation of pre-pressurization is detailed in the explanations of the individual user screens in section III.

TIP: Equilibrating your system just prior to entering the pre-pressurization and characterization screens will result in a more accurate measurement of your system’s resistance by the μ Pro Pump. For details on equilibrating your system, see pages 2.17-2.19.

Specifications

General Features:

# syringes controlled:	4 (1 master up to 3 slaves)
Modes of Operation:	single syringe, reciprocating syringe, multi-syringe, gradient, constant pressure
Wetted Parts:	316 ss, u.h.m.w. polyethylene, PEEK
Syringe Sizes:	2mL or 10mL
Position Sensors:	2

Pump Features:

Flow Rate:	
2mL syringe:	.01 - 2000 μ L/min. (.01 - 500 μ L/min in reciprocating)
10mL syringe:	.05 - 10000 μ L/min (.05 - 2500 μ L/min in reciprocating)
Flow Reproduce:	\pm .5% typically
Set increment:	.01 μ L
Refill time:	minimum: 30 sec; rate and time programmable
Maximum Pressure:	
2mL syringe:	10,000 psi (to limit of valves)
10mL syringe:	5,000 psi (to limit of valves, at flows below 900 μ L/min)
Minimum Gradient flow rate:	
2mL syringe:	1 μ L/min
10mL syringe:	5 μ L/min
Gradient resolution:	\pm 1%
Gradient reproducibility:	\pm .5% typically

Program Features:

# of steps	200 (20 per file)
# of files	10
# of cycles	999

General:

dimensions: (M31(.3(i)5.8f)-7.30(ri) 7h/-7.3ei):(i)5.8

Temperature: 5-35°C
Maximum Humidity: 85%, non-condensing
Maximum Altitude: 2,000 meters

Transducer:

type: none, low pressure (0-1k psi), medium pressure (0-5k psi), high pressure (0-10k psi)
pressure limit: high (in the range of the transducer) and low (applies to flows above 10 μ L/min)
pressure gradient: yes
press. gradient resolution: 1 psi
press. gradient accuracy: $\pm 2\%$ full scale
press. gradient reproducibility: $\pm 1\%$ full scale

Valves:

mechanical valves: pressure limit of valve is 10,000 psi
low pressure active valves: pressure limit of valve is 50 psi
high pressure active valves: pressure limit of valve is 5,000 psi

Mixers: dynamic or static, several sizes

Temperature Control: 5°C above ambient to 50°C

I/O Board: remote start, stop, program hold, 6 contact closures (30V maximum 3VA), and 24V

Remote Connections: RS232 for remote computer control; RS485 for daisy chain control of slave pumps

