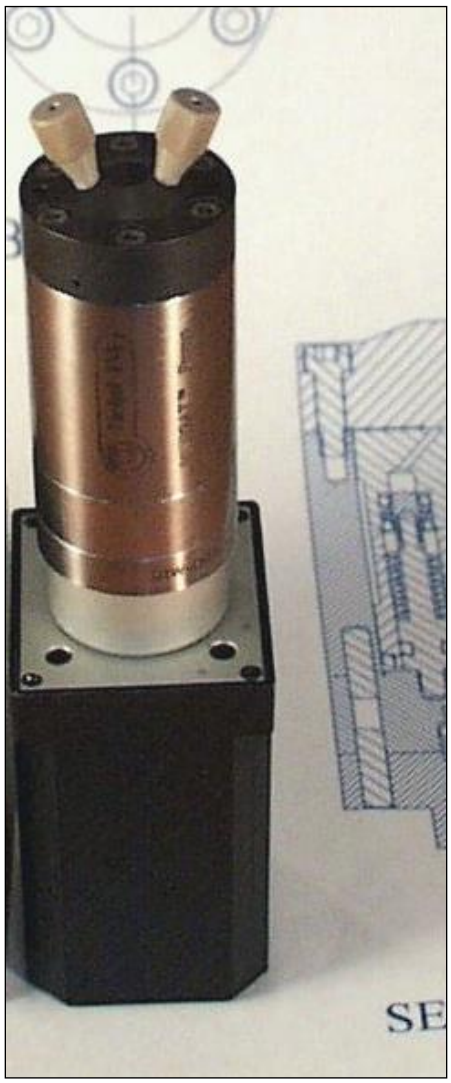
684 Sixth Ave FI
PO Box 480
Fox Island, WA, 98333
253-549-2223
253-549-2283

milliGAT® Pump Manual



The information in this manual has been carefully checked and believed to be accurate; however, no responsibility is assumed for inaccuracies.

Global FIA, Inc. maintains the right to make changes without further notice to products described in this manual to improve reliability, function, or design. Global FIA, Inc. does not assume any liability arising from the use or application of this product.

are trademarks of Intelligent Motion Systems, Inc.

Certain copyrighted figures and diagrams used in this manual are used with the permission of Intelligent Motion Systems, Inc.

milliGAT® is a registered trademark of Global FIA, Inc. Fox Island, WA, USA.

Global FIA, Inc. does not recommend the use of the milliGAT® pump in life support or applications where it may directly or indirectly threaten life or injury. See the Warranty and Disclaimer statement included in the back of this manual.

Contents

List of Figures

List of Tables

1. Product Description

The microprocessor-controlled milliGAT® pump consists of
- a pump head with appropriate fluid line connectors,
- a motor and gearbox assembly,
- a stepper motor controller,
- a switch-mode power supply (100 – 240 VAC to 24 VDC), and
- various cables.

Several models of the pump are available as described in section 3.

1.1 *Principle of operation*

The central component in the pump is a cylindrical rotor that is fitted with four equally spaced pistons (two are shown in Figure 1). This rotor seals against the stator end cap. The stator end cap has an inlet and outlet port. These ports are coupled to an inlet channel in the shape of an arc and a similar outlet channel in the stator cap. As the rotor turns, a cam governs the back and forth displacement of the spring-loaded pistons with a piston stroke of $^1/_8$" (~3mm). The diameter of the pistons is 1/8" (~3mm) for the LF pump and 5/16" (~8 mm) for the HF pump. As the motor turns the rotor, one piston is dispensing into the outlet channel, one piston is filling from the inlet channel and the other two are moving between the inlet and outlet channels. The cam has been engineered to ensure a smooth transition when one piston hands off to the next.

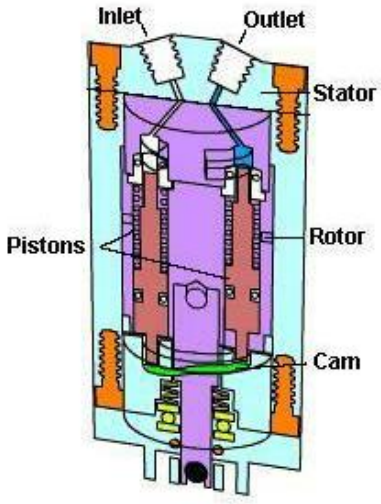


Figure 1: milliGAT pump cross section

A stepper motor governs rotation rate and direction. Flow direction is determined by the direction of rotation. Flow rate is determined by the rate of rotation. The metering capability of the pump is determined by the accuracy of the stepper motor working in micro-step mode. In addition to various levels of gearing, the stepper motor is operated in a mode where every stepper motor step is divided into 256 micro-steps. For the low flow (LF) pump one revolution of the pump displaces 100 μL and for the high flow (HF) pump, one revolution displaces 628 μL. The volume per micro-step is dependent on motor, gearing, and pump used and can be calculated using the formula given in section 3.10 on page 15.

In the event of a deadhead blockage, the backpressure overcomes the spring that holds the rotor against the stator. The rotor of the pump moves away from the stator and fluid leaks into the pump internals

and eventually from one of the pump's leak ports. If this occurs, the leakage must be well flushed from the pump using distilled water and isopropyl alcohol to prevent permanent damage (see section 4.2.1 for more detailed instructions on dealing with a leak).

While care has been taken to ensure a smooth transition from one piston to the next, some users with sensors that are extremely sensitive to flow may notice a small perturbation as one piston hands off to the next.

The pistons are PTFE tipped and the PTFE tip is longer than the piston stroke thereby ensuring that the wetted surface of the piston chamber is not exposed to air. This has a positive implication for wear life of the pistons as crystals of dried dissolved solids cannot form and scratch the seal surface.

The milliGAT® is a self-priming positive displacement pump and can tolerate gas in the fluid lines.

An animated depiction of the operation of the pump is given at
https://www.youtube.com/watch?v=rdXzXQ0KRN0&feature=youtu.be

2. Installation and use

2.1 *Mounting*

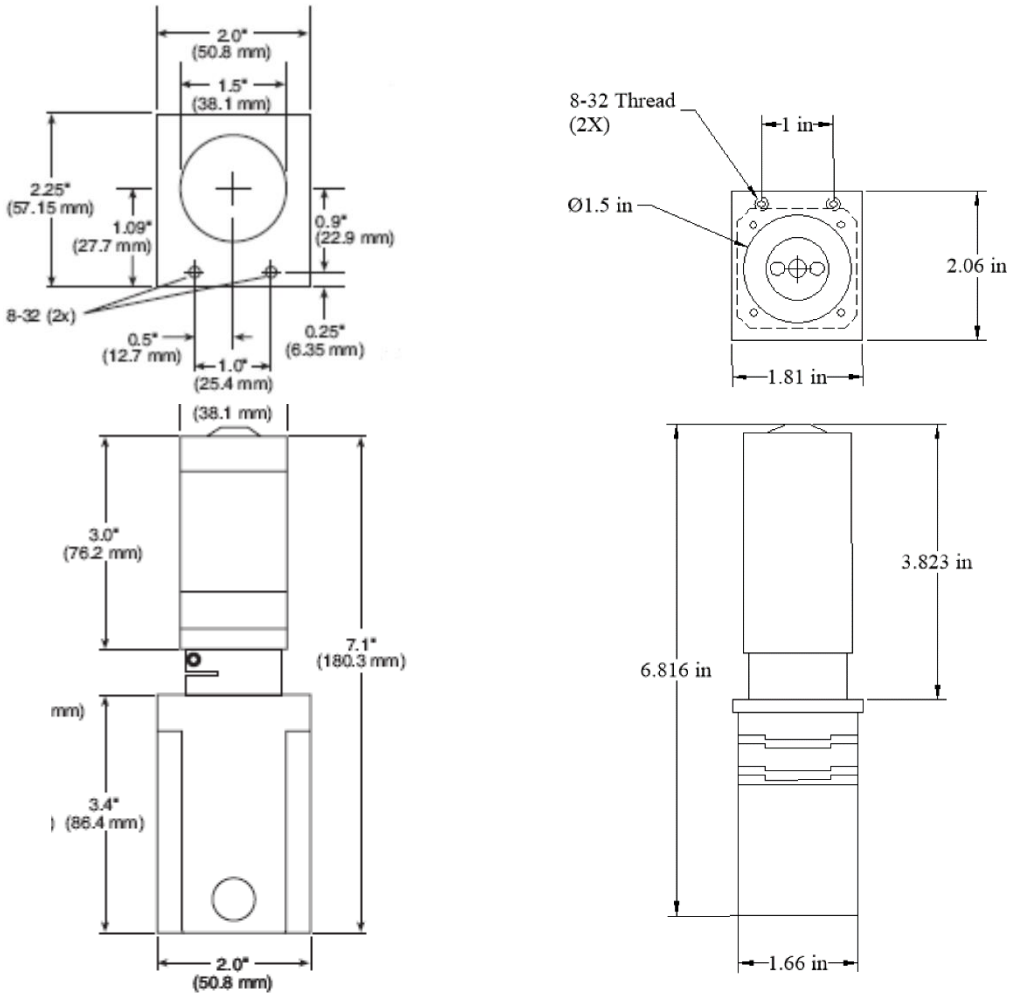
In order to operate the pump you must mount the pump and controller using the provided mounting points or stand it upright on end (skip to section 2.2 on page 8 if not mounting).

For best results, the milliGAT pump must be orientated with its ports facing up. If the pump is orientated in any other direction, bubbles may be trapped in the internal chambers of the pump. This will have an adverse effect on accuracy and smoothness of flow.

The mounting points of the pumps and controllers are given in Figure 2 and Figure 3 together with the external dimensions of each module. Because the high flow pump (HF) makes use of a dual stage gearbox, its motor-gearbox enclosure is 1" (25.4 mm) longer than the low flow pump. An unenclosed motor-gearbox that has an external encoder, will be $^{5}/_{8}$" (16 mm) longer than one that doesn't have an encoder. This applies also for MDrive integrated motor and controller.

The controller should be mounted in such a way to allow adequate cooling and circulation of air around the controller.

Global FIA can provide SolidWorks models.



With Enclosure **Without Enclosure**

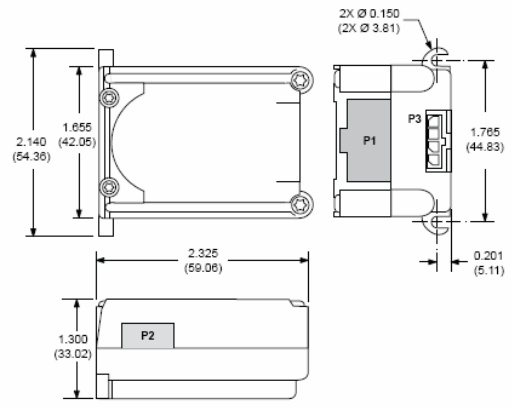


Figure 2: Dimension for milliGAT LF with MForce and no encoder

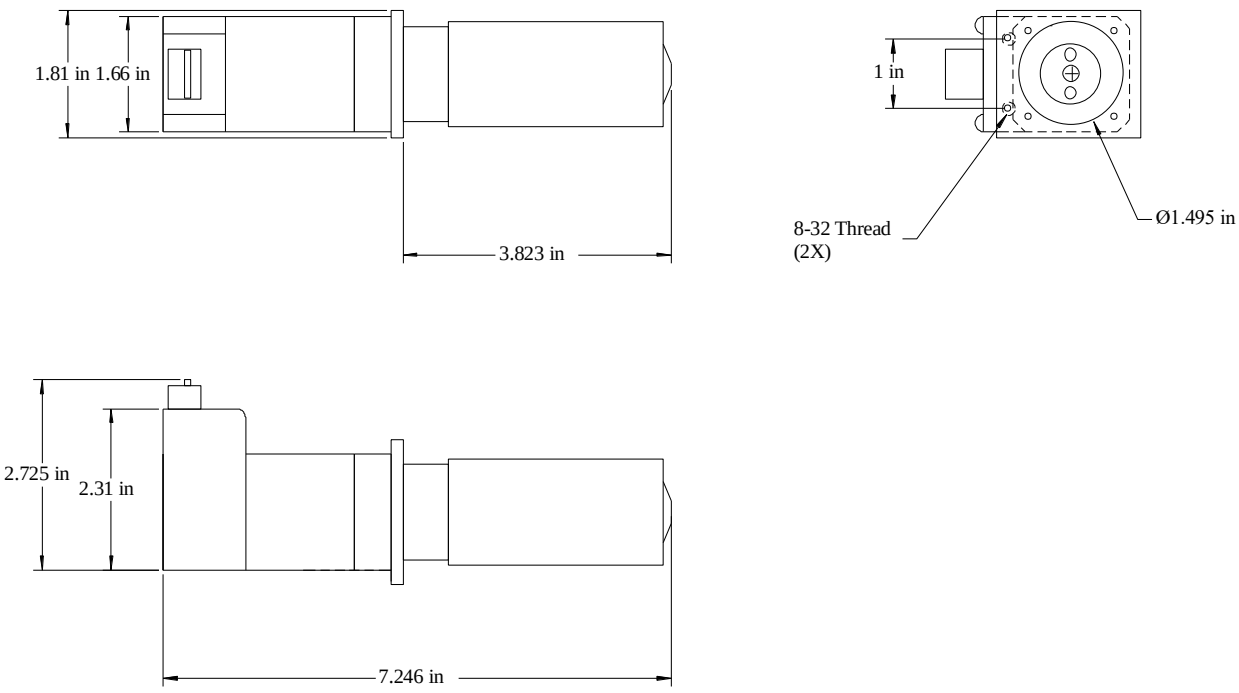


Figure 3: Dimensions for milliGAT LF pump with integrated controller (MG-1M17) no encoder

2.2 *Plumbing*

The low flow milliGAT® pump (MG-1) has two 10-32 threaded female ports. The high flow pump (MG-2) is equipped with two ¼-28 female ports. If you look carefully, you will see that they are labeled A and B. Port A is the inlet and port B is the outlet for positive pump movements.

> **CAUTION!** If you plan on using 1/32" (0.8 mm) OD tubing with the low flow pump, **care must be taken not to insert the tubing too far into the pump and so damage the pump rotor or stator**. A fitting set suited for $^{1}/_{32}$" OD tubing that includes a 6-40 finger-tight fitting and an adapter to the 10-32 female port in the pump is available (see section 7 on page 19 for part numbers).

A set of 10-32 finger-tight fittings and ferrules are supplied with the low flow pump. These fittings are suitable for $^{1}/_{16}$" (1.6 mm) OD tubing. Below is a picture of 10-32 fittings correctly fitted on PFA tubing.

Figure 4: 10-32 fittings on 1/16" (1.6 mm) OD tubing

CAUTION! If you plan on using 1/16" OD tubing with the high flow pump, **care must be taken not to insert the tubing too far into the pump and so damage the pump rotor or stator**. The fittings make-up tool should be used to attach fittings to 1/16" tubing.

For the high flow pump, ¼-28 fittings are supplied for either $^1/_{16}$" (1.6 mm) or $^1/_8$" (3.1 mm) OD tubing.

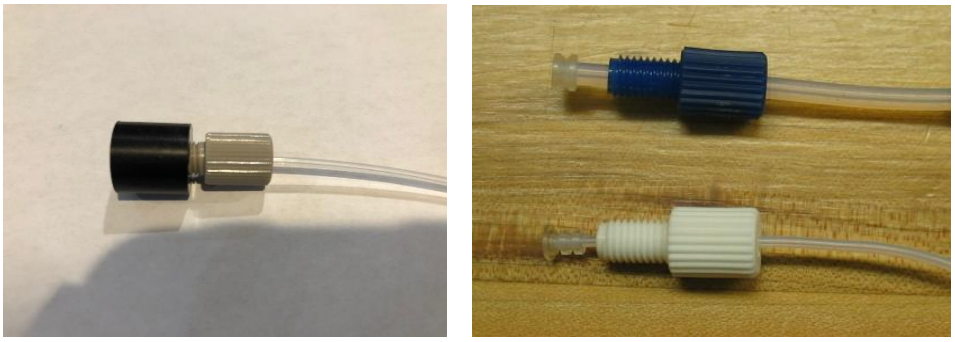


Figure 5: ¼-28 fittings on $^1/_{16}$" (1.6 mm) OD tubing and $^1/_8$" (3.1 mm) OD tubing

The following instructions describe how to make a good fitting connection. The leak-tightness and integrity of the connection is dependent upon tubing preparation and the correct procedure in making up the fitting. **It is important to use the fittings supplied with the pump. Fittings from other suppliers have been known to damage the pump.**

1. To ensure a good seal and avoid unswept volumes, make a square cut of the tubing using a sharp blade or tubing cutter. Make sure that the end of the tube is free of burs or cut debris.
2. Slide the nut and ferrule onto the tubing in the order shown in the pictures above.
3. Insert this tubing into the female port on the pump for the LF pump and on the make-up tool for the HF pump and screw the nut in two or three turns.
4. Push the tubing all the way forward into the detail so that it seats firmly. This is essential for a proper zero dead volume connection.
5. Tighten the nut in the port until it is finger-tight. Do not over tighten the fittings as you could damage the threads of the port.
6. Remove the fitting and inspect it. The tubing should protrude past the ferrule by approximately 2mm for the 10-32 fittings and should be flush with the ferrule for the ¼-28 fittings.
7. When made up properly, the ferrule may be free to spin axially on the tubing, but should have no lateral movement along the tubing. If the ferrule moves laterally, re-install the fitting into the detail and tighten it another $^1/_8$ turn past finger tight.
8. Remove, re-inspect, and repeat, if necessary.

2.3 *Electrical Connections*

1. Connect the USB cable to the computer and MForce or MDrive controller.
2. Connect the motor cable to the MForce controller and pump motor. In the case of and MDrive controller, this connection is internal to the motor and integrated controller.
3. Connect the power and IO cable to the controller. This cable has a white connector on one end that plugs into the controller and the other end has a connector that will supply power. For the MForce controller the power connector is a female 2.5mm barrel connector. For the MDrive controller, the power connector and IO connections are provided via a 7-pin Amp connector that plugs onto the Global FIA FloPro-Uni board. If the pump is equipped with an external encoder this cable will also include the cable that terminates in a 5-pin connector for the encoder (black wire to far-right pin).

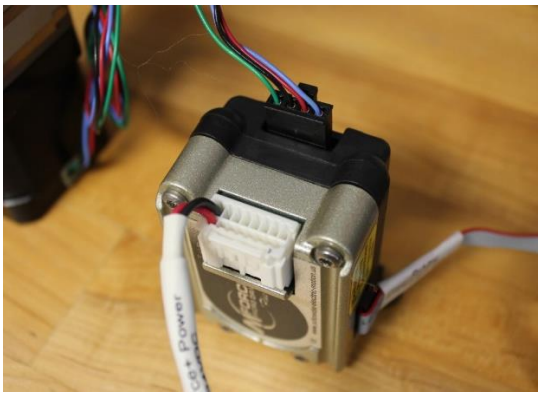


Figure 6: Electrical connections for MForce controller

4. Connect the barrel power connector of the power supply to the power connector on the pump for the MForce controller. For the MDrive controller connect the 7-pin amp connector to the FloPro-Uni. **MAKE SURE TO PERFORM THIS STEP BEFORE APPLYING POWER**. **FAILURE TO DO SO COULD DAMAGE THE CONTROLLER**.
5. Apply power to the system.

2.4 *Serial Communication via Terminal Program*

1. Download CoolTerm from https://freeware.the-meiers.org/ listed under Very useful stuff, unzip the folder, launch the application, and select Connect at the top of the CoolTerm window.
2. Select inside the main terminal window so that there is a flashing cursor visible and press the ESC key on keyboard. A > bracket should be returned if there is communication with the pump and one can skip to step 6 of these instructions.
3. If there is no communication and there are more than one virtual COM port on the computer, select the Options button, and select the COM port associated with pump from the bottom of the Serial Port Options page.
4. If a COM port does not appear, then install the FTDI virtual COM port driver. Download the FTDI USB to serial converter driver from www.globalfia.com/software_downloads/CDM21228_Setup.exe and run this installation program.
5. Ensure that CoolTerm is configured to transmit a Carriage Return (CR) and Line Feed (LF) when the enter key is pressed in the Terminal section of the Option panel. See Terminal Options under the Connection | Options menu or Options button.

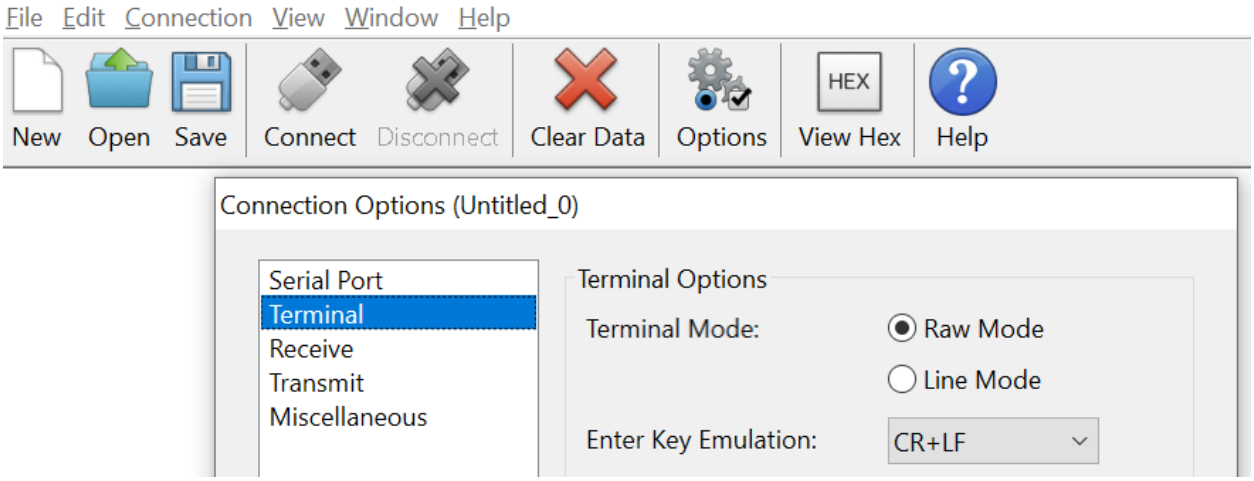


Figure 7: Configure the Enter Key Emulation to CR+LF

6. Each pump controller is pre-configured with certain settings including the device address. This allows the user to communicate with one or more pumps by preceding each command with the address of the pump. The controller address is labelled on the side of the controller. Alternatively, to determine the controller address, with just one controller connected to the COM cable, type ENTER to clear the COM port buffer, then type *PR DN in the terminal window. All commands to the pump are transmitted when the ENTER key is pressed.
7. Another important parameter factory-configured in the controller is the engineering units-conversion factor (EU) to convert stepper motor micro-steps to volume units (micro liters). Determine the present setting for EU by typing APR EU and then the ENTER key in the terminal window (In this command string, A is the address of the device as labeled on the side of the controller. If the address of the controller is different to A then substitute the correct address in the command string before typing it). The window may not show what is initially typed or return a response upon pressing ENTER. However, this will clear the COM port buffer. If no response is returned initially, repeat the command and it should respond. Note the value for EU. This conversion factor allows commands to be given in micro liters instead of micro-steps (see section 3.10 on page 15).
8. Type ASL VM and press ENTER, where VM=flowrate (uL/s)*EU and press ENTER to start the pump flowing. Type ASL 0 followed by ENTER to stop the pump flow. Pressing the ESC key will also stop the pump flow.

2.5 *Pump Commands*

Basic commands for the pump are found in Table 1 and can be sent from a terminal program as in section 2.4 or from computer code (see section 8 on page 20 for additional software interfaces). All commands must be preceded with the pump address and proceeded with the carriage return and line feed <CR><LF>. Terminal programs automatically insert the <CR><LF>.

Table 1: Basic pump commands for the MDrive 17 and MForce

	Description: Pump continuously at the specified flow rate	Min	Max	Units
SL	Example: SL=20*EU	1	167	µL/sec

	Description: Sets the flow rate for pump commands	Min	Max	Units
VM	Example: VM=20*EU	1	167	µL/sec

	Description: Pumps the specified volume, pump direction is determined by the sign	Min	Max	Units
MR	Example: MR=–100*EU	1	± 10^{15}	µL

	Description: Stops pump movement*	Min	Max	Units
SL=0	Example: SL=0			

Table 2 provides a few examples with descriptions given in the first column and the required commands given in the second column.

Table 2: Sample commands for the MDrive 17 and MForce

Description	Command
Aspirate† 10 µL at 5µL/sec	AVM=5*EU AMR=-10*EU
Dispense 1000µL at 100µL/sec	AVM=100*EU AMR=1000*EU
Pump continuously at 50µL/sec	ASL=50*EU
Stop the pump	ASL=0
Re-establish pump factory settings	AEX IZ
Save all present settings to non-volatile RAM	AS

For this example, the MDrive was configured with a device name of A

The MDrive does not have built-in backlash correction. A small program has been installed on the MDrive which compensates for backlash. Backlash comes into play when you change pump direction. There are small tolerances in the drive train and gear box that must be taken up before the pump actually starts to move. So when the direction of flow changes, a small volume equal to the backlash must be added to the desired dispense volume. The embedded program takes care of this but you must use a different command set to aspirate or dispense a particular volume. VL specifies the volume in µL to pump. EX FL runs the embedded program that completes the move with backlash compensation where appropriate. provides the commands to use if you need backlash compensation.

Table 3: Pump commands for the MDrive 17 and MForce with backlash compensation

	Description: Set the desired volume to aspirate or dispense	Min	Max	Units
VL	Example: VL=25	1	±10^{15}	µL

	Description: Execute the pump move	Min	Max	Units
Ex FL	Example: EX FL			

* Pressing the **ESC** key will also halt a pump action

† Switch inlet and outlet ports if flow direction is reversed

VS	Description: Set the desired volume in μsteps	Min	Max	Units
	Example: VS=1216	1	$\pm 10^{15}$	μsteps

Ex FS	Description: Execute the pump move for volume in μsteps	Min	Max	Units
	Example: EX FS*			

3. Pump Configurations

Several pump models are available. The pump part number specifies the pump configuration. Note: these are internal long part numbers (vs. those listed online) and also not all combinations are available.
Pump part number:

MG	**-**	H	P	S	R	O	o	B	**-**	C	G	M	E

H	-	Head type	1-Low flow	2-High flow		
P	-	Pressure range	1-Low pressure	2-High pressure		
S	-	Stator material	1-PTFE	2-Valcon E3	3-PEEK/PTFE	5- Valcon H2
R	-	Rotor material	1-Ceramic	2-Valcon P	3-CTFE	
O	-	Rotor O-ring material	1-Viton	2-Kalrez		
o	-	Piston O-ring material	1-Viton	2-Kalrez		
B	-	Pump body material	1-Stainless steel			
C	-	Controller	1-MForce			
G	-	Gear ratio	1-1:4.75	2-1:9.875	3-1:15	
M	-	Motor resolution	1-1.8°	2-0.9°		
E	-	Equipped with encoder	0-No	1-Yes		

3.1 *Head Type*

The milliGAT is equipped with four spring-loaded pistons mounted in a rotor. The rotor is pressed against a stator with Bellville washers. As the rotor turns, a cam governs the movement of the pistons; one piston is dispensing, one piston is aspirating and the other two are moving between the fill and empty ports. As one piston is emptied it is followed by a piston that is full. As another piston is filled it is followed by an empty piston. Reversing the direction of rotation reverses the flow direction. The speed of rotation and piston volume determines the flow rate.
The low flow (LF) pump head is equipped with four 0.125 inch diameter pistons with a capacity of 25 μL and displaces 100 μL per revolution of the pump. The hold-up volume of the LF pump is 50 uL. LF pumps have 10-32 threaded ports.
The high flow (HF) pump head is equipped with four 8 mm diameter pistons with a capacity of 157 μL and displaces 628 μL per revolution. The hold-up volume of the HF pump is 314 μL. HF pumps have ¼-28 threaded ports.
The flow rate range for each pump is dependent on the head type, motor resolution, and gear box (see section 11 on page 21 for flow ranges).
Faster flow rates will shorten the time before the pump will have to be refurbished (see section 10 on page 21 to return the pump).

3.2 *Pressure Range*

The pressure range of the pump is the back pressure against which the pump can flow (see section 11 on page 21 for pressure range values). When the maximum pump pressure is exceeded, the rotor is forced away from the stator and fluid leaks into the pump internals and out of the leak port. This is undesirable. Install a pressure relief valve (available from Global FIA – see section 6.1 on page 19) with a pressure rating less than the maximum pressure capacity of the pump. **If a leak occurs, the**

* Pumps without encoders and firmware before version 3.4 and pumps with encoders and firmware version 4.1 require that VL also be set to the direction of the flow with either a -1 for aspirate or a 1 for dispense

fluid must be flushed via the leak port from the pump internals with deionized water and isopropyl alcohol.
The pressure against which the pump is pumping will affect the pump life time before the pump will need to be refurbished (see section 10 on page 21 to return the pump).
When considering the pressure capability of the pump, it is also important to consider the pressure drop in the inlet lines to the pump. The maximum pressure drop that the pump can tolerate is 14 psi (atmospheric pressure). Consider using 1/8-inch OD tubing on the inlet side of the pump when high flow rates (HF pump) or viscous solutions or solutions with a low partial pressure are being pumped.

3.3 *Material Selection*

The S, R, O, o, and B fields in the pump part number specify the materials used in the pump construction. A description of the materials is given in section 5.1 on page 17.

3.4 *Stator Material*

S specifies the stator material. Options available depend upon whether it is a LF or HF pump and pressure range. The following table provides the available stator options.

Table 4: Stator options

	1. PTFE	2. Valcon E3	3. PEEK/PTFE	4. Valcon H2
MG-11	✓	Standard	×	×
MG-12	✓	Standard	✓	×
MG-21	✓	×	×	Standard
MG-22	Standard	×	✓	×

3.5 *Rotor Material*

R specifies the rotor material. Options available depend upon whether it is a LF or HF pump and pressure range. The following table provides the available rotor options.

Table 5: Rotor options

	1. Ceramic (ZrO2)	2. Valcon P with o-rings & sapphire liners	3. CTFE
MG-11	×	Standard	×
MG-12	Standard	×	×
MG-21	Standard	×	✓
MG-22	Standard	×	×

3.6 *Rotor O-ring Material*

O specifies the rotor o-ring material. The standard material for o-rings located within the rotor is Viton. These o-rings are not in the wetted path under normal conditions but could be exposed to fluid if the pump is over pressurized. Pumps can also be equipped with Kalrez or Markez if the pumped solution is not compatible with Viton. For these solutions it's also worth considering a ceramic rotor.

3.7 *Piston O-ring Material*

o specifices the piston o-ring material. The standard material for pump pistons located under the PTFE piston tip is Viton. Pumps can also be equipped with Kalrez or Markez if the pumped solution is not compatible with Viton.

3.8 *Body Material*

B specifies the body material. The standard material for the pump body is stainless steel. It is also available in anodized aluminum. Anodized aluminum is lighter and conducts heat better (for a cooler pump head) but is not as chemically resistant as stainless steel.

3.9 *Controller*

The stepper motor controller used with the milliGAT pump is supplied by Schneider electric and equipped with a planetary gearbox and, in most cases, an external encoder. Either a standalone MForce controller and stepper motor (see Figure 7A) or an integrated MDrive stepper motor and controller (see Figure 7B) is used.

3.10 *Motor and Gearbox*

The MForce controller comes standard with 1.8 degree (200 steps) stepper motor but is also available with an 0.9 degree (400 steps) motor
The MDrive controller is only available with 1.8 degree (200 steps) motor

Available gearboxes: 4.75, 9.86X , 15X, and 22.56X
LF - comes standard with 4.75X gearbox

HF- comes standard with 9.86X gearbox

For the milliGAT® pump, EU is calculated as follows:

$$EU = \frac{(\text{step resolution}) * (360/\text{motor step size}) * (\text{gear ratio})}{\text{volume moved by one revolution of the pump}}$$

MSEL sets the pump step resolution. For example, pump units in μL for a pump with a 1:4.75 gear box and a 1.8° stepper motor used in micro stepping mode (MSEL=256) with a pump with an internal capacity of 100μl.

$$EU = \frac{256 * (360/1.8) * (4.75)}{100}$$

Note: all motor commands pertaining to motor velocity (flow rate) and acceleration are expressed in terms of seconds. In the above example, flow rates will be measured in μL/sec and volumes in μl, etc.

3.11 *Encoder*

For the person who absolutely needs to come back to the same place on the cam for added repeatability (enquire with Global FIA if interested in this option).

4. Pump Maintenance and Troubleshooting

4.1 *Maintenance*

There are NO user serviceable parts inside the pump. Opening the pump by removing, or even loosening the hex bolts that hold the pump together will void the pump's Limited Warranty.

To obtain optimum performance and maximum life from the milliGAT® pump, it is important to follow the recommended cleaning and maintenance instructions.

4.1.1 Routine maintenance

- Flush the pump thoroughly with distilled or de-ionized water after each use. Store the pump dry.
- Avoid running the pump dry for extended periods. The pump is self-priming and will dispel entrapped bubbles when orientated vertically.

- Inspect the pump for leaks and correct any problems immediately. Liquid entering the motor housing could damage the motor and gear assembly. The pump is equipped with a leak port. Leakage from this port indicates excessive back pressure and unreliable pumping action.
- Wipe up all spills on and around the pump immediately. If fluid is seen coming from the leak port, flush the internals of the pump through the leak port with distilled water and then isopropyl alcohol (IPA) and allow it to dry before further use.
- If the flow manifold is such that leaks through the leak port are frequent, then it is a good idea to incorporate a pressure relief valve (Part No.: PRV-100) downstream of the pump to allow over pressure situations to leak safely to waste.

4.1.2 Routine cleaning

The pump fluid path can be cleaned with one of the following cleaning solutions

1. Weak detergent wash. We have found Micro-90* to be a good general purpose detergent.
2. Weak acid and base wash: pump 5 mL of 0.1N NaOH followed by 5 mL of water followed by 5 mL of 0.1N HCl, followed by 10 mL of water.
3. Weak bleach wash: pump 5 mL of a 10% beach solution followed by 10 mL of water.

The pump is not amenable to autoclaving. High temperatures compromise pump seals. Chemical cleaning procedures should be employed to ensure sterility.

4.2 *Troubleshooting*

4.2.1 Pump leaks

The most frequent cause of leaks is over pressurization of the pump. The maximum pressure capability of the pump is found in section 11 on page 21. If this pressure is exceed by pumping against a dead head or blockage or by using a high flow rate in very narrow bore tubing, then the rotor moves away from the stator and fluid leaks into the pump internals. There are three leak ports on the pump. One is in the stator and the other two are in the side of the pump housing. If fluid leaks into the pumps internals, eventually it will leak from one of the leak ports. If this occurs it is important to flush out the pump internals through the leak port with distilled water and isopropyl alcohol. This is particular important if the leak fluid is corrosive or has a high dissolved solids content. In most cases, simply flushing out the pump in this way and removing the source of back pressure will get the pump back to good working condition. If the leak fluid has done more permanent damage, then the pump will have to be returned for refurbishment.

4.2.2 Pump stalls

When the torque of the pump exceeds the torque output of the motor, the pump will stall. Depending on the flow rate, a characteristic growling sound or vibration or ticking and no flow of the fluid will indicate that the pump is stalling. There are a few possible causes of this problem:

1. Wires or connections are loose. If the wires between the pump and controller are loose or damaged, the torque output of the motor will be less than optimal. Repair wires or tighten connections to remedy
2. Check the run current. The run current determines the current which is sent to the motor. For the MForce and MDrive the run current (RC) is 40 and 60, respectively. These can be increased to 47 and 70 respectively (RC=47 and RC=70). If it is increased, the motor will run a little hotter than normal but it will not harm the motor or pump. A higher current will give a higher torque.
3. Check the voltage. The controller will accept a voltage between 12 and 48 VDC. The supplied power supply has an output voltage of 24VDC. Slightly higher torque is achievable if a power supply with a higher voltage output is installed. Although the controller will still work with an input voltage of 12 VDC. It is doubtful whether 12VDC will provide enough power to turn the pump.
4. Certain solvents cause the wetted components to swell. Some organic solvents will cause slight swelling of the rotor or stator. A small increase in certain dimensions could cause the pump to stall. Flush out the organic solvent (this may require manual turning of the pump) with distilled water and allow it to dry out and stand for a while. Under certain conditions, the polymers will

* http://www.coleparmer.com/Catalog/product_index.asp?cls=504

shrink back to the correct size and the pump will again begin to function. Under these conditions, the pump is probably not suited to such solvents.

4.2.3 Bubbles in output flow

When a continuous stream of bubbles is in the pump outlet but not the inlet, the most likely cause is a poor fluid connection usually in the inlet. Ensure that the tubing is cut square and that the fitting is finger tight. An extra ¼ turn of the fitting beyond finger tight may also help. Bubbles could also occur if there is a negative pressure on the outlet. In this instance, bubbles may be drawn out of solution or the solvent may even vaporize. Reduce the negative pressure on the outlet.

4.2.4 No communication

Sometimes when setting up a new system it is difficult to get communication between a computer and a controller. This problem is exacerbated by the fact that there are so many things that can go wrong with serial communications and it is tedious to identify the defective component. Although time consuming tracking down these problems simply requires a systematic evaluation of each component in the communication system. This includes:

1. If you are using a USB to RS-422 converter, ensure that it is working.
2. Ensure that you have selected the correct communications settings including Port number, baud rate, number of data bits, number of stop bits, and parity checking.
3. In the terminal emulation software ensure that you are connected. Sometimes simply re-starting the Terminal emulation software is helpful.
4. Check the cable that you are using, ensure that all wires are intact and connected and that the pin-outs are correct.
5. Is the controller configured with an address and are you using the address.
6. If in party mode are you using <CR><LF> to send the commands?
7. Is the controller correctly powered?

4.2.5 Flow is not smooth

If a bubble is trapped in the pump, it can cause pulsing flow. To remove the bubble, increase the flow rate to about 50 µL/sec and aspirate 500 µL and then dispense 500 µL (or 3000 µl for the HF pump). You can also displace a small bubble by passing a large bubble (>50 µL) through the pump. It is also a good idea to periodically pump a solution containing a surfactant through the pump. We have found Zonyl FSN* to be a good surfactant for this purpose and have demonstrated that it is compatible with many systems including those involving biochemical elements. In many of our systems we include a few drops of Zonyl FSN in 500 mL of distilled water and use this as a carrier stream. We have also found Micro-90 to be a good cleaning agent for the pump and tubing in general.

5. Material compatibility

5.1 *Materials of construction*

Wetted materials used in the milliGAT® are described below.

5.1.1 PTFE

The piston tips are made from PTFE.

Polytetrafluoroethylene is the generic name for the class of materials such as Teflon®. It offers superior chemical resistance and lends itself to good sealing characteristics. Because it's so easy to handle, it is often used in low pressure devices such as the milliGAT®. Volatile compounds of low molecular weight can permeate PTFE. Fumes of strong acids such as hydrochloric acid can permeate the PTFE and should be constantly purged from the internals of the pump by blowing instrument air in through one of the leak ports. A barbed fitting (Cat No.: P-N) is available to allow convenient hookup of an air line.

5.1.2 PAEK

The pump port end cap makes use of a PAEK-based composite.

* http://www.sigmaaldrich.com/catalog/search/ProductDetail/ALDRICH/421413

Polyaryletherketone is the generic name for the family of polyketone compounds. PAEK includes PEK, PEEK, PEKK, and PEKEKK, which differ in physical properties and, to a lesser degree, in inertness. This composite resists all common HPLC solvents and dilute acids and bases. However, concentrated or prolonged use of halogenated solvents may cause the polymer to swell. Avoid concentrated sulfuric or nitric acids (over 10%) and see guidelines in §5.2.

5.1.3 Valcon P

The low flow pump rotor is made from Valcon P.

This composite, the majority of which is PTFE and carbon, has been used extensively in many analytical applications that use Valco valves. It is routinely used in other applications at 1000 psi, 75°C, and can also be used at temperatures approaching 200°C with decreased sealing tension.

5.1.4 Valcon-E3

The low flow pump port end cap is made of a PAEK-based composite called Valcon-E3.

Polyaryletherketone is the generic name for the family of polyketone compounds. PAEK includes PEK, PEEK, PEKK, and PEKEKK, which differ in physical properties and, to a lesser degree, in inertness. This composite resists all common HPLC solvents and dilute acids and bases. However, concentrated or prolonged use of halogenated solvents may cause the polymer to swell. Avoid concentrated sulfuric or nitric acids (over 10%).

5.1.5 Valcon H2

The high flow pump stator cap is a carbon fiber-reinforced, PTFE-lubricated inert polymer.

5.1.6 Viton®

Viton® O-rings are used to seal the piston chambers in the pump rotor in the low flow pump. Besides its excellent mechanical properties, Viton® provides the best proven fluid and chemical resistance of the commercial non-fluorinated elastomers.

Kalrez has been found to be superior in certain instances and a special pump can be constructed with Kalrez o-rings.

5.1.7 Sapphire

The milliGAT® piston chambers are made of sapphire and are sealed in place with a Viton® o-ring in the low flow pump.

Sapphire has a unique set of properties including high strength, hardness, surface smoothness, and excellent chemical compatibility. It is commonly used in applications where a combination of exceptional mechanical and chemical properties is essential.

5.1.8 Ceramic

In the high flow pump, the rotor and piston chambers are made from ceramic. The ceramic employed in this component comprises of zirconium dioxide.

There are no wetted o-ring seals.

5.2 *Guidelines*

Specific reagent combinations should be tested to ensure compatibility with pump components. Since the least chemically inert component in these composites is PEEK, for optimum component life time, the following guidelines* given for PEEK should be followed:

Acids and bases	No stronger than 1 M
H_2SO_4	Resistant to 10%
HCl	Resistant to 20%

* Corrosion Resistance Tables, Schweitzer, Marcel Dekker, 1991
www.zeusinc.com/product_sheets/resins/peek/chemical_compatibility.html

HF	Not Resistant to 70% (no data on lower conc.)
HNO_3	Resistant to 20%
Dibutylamine in Toluene	Not Rated
TBAH	Not Rated (Dionex uses PEEK as column material at 1 mM)
NaOH	Not recommended for LF pump
H_2S	Resistant
CH_3SH	Not Rated
acetone	Resistant
methyl ethyl ketone	Resistant at Room Temp.
methyl alcohol	Resistant
toluene	Not recommended for LF pump
xylene	Resistant
chloroform	Resistant
chlorobenzene	Resistant at Room Temp.
iodine/iodide in water	Not Rated
sodium hypochlorite (household bleach)	Resistant at Room Temp.
permanganate	Resistant at Room Temp.
hexane	Resistant at Room Temp.

6. Accessories

6.1 *Pressure relief valve (P/N: PRV-100)*

Figure 8: Pressure relief valve

The most frequent failure mode for the milliGAT pump occurs when the pump is over-pressurized. A pressure relief valve installed immediately downstream of the pump ensures that the fluid pumps to waste if there is a blockage that causes the back pressure to exceed 100 psi. In this way, the pump is protected against fluid getting into the pump internals. Any system where there is the possibility of blockage or restriction should be equipped with a pressure relief valve.

6.2 *Right angle drive (P/N: RAD)*

Figure 9: Right angle drive

In some instances it is desirable to orientate the motor horizontally, for example to mount the pump to a vertical plate. The pump must be orientated vertically and so to accommodate such a mounting scenario, a right angle drive can be installed between the motor and pump.

6.3 *IO Switch (P/N: IOS)*

Where only a few pump settings or actions are needed, these can be downloaded as an embedded program to the controller and then selected using a rotary switch coupled to the IO ports of the controller. Contact Global FIA for custom embedded program development.

6.4 *USB to RS-422 converter (P/N: USB-422)*

Most laptop computers are only equipped with USB ports. This adapter provides an RS-422 port that plugs into a USB port. Output connectors are for the MDrive controller.

7. Spare Parts List

Table 6: Spare parts list

Part No.	Description
ZN1FPK-10	Zero dead volume finger-tight fitting with 10-32 thread(10 pack)
ZF1PK-10	Zero dead volume ferrule (10 pack)
A-1032-640	Zero dead volume 10-32 to 6-40 adapter
640FF-32	Zero dead volume finger-tight fitting with 6-40 thread for 1/32" OD tubing
FF-16W	¼-28 nut and ferrule for $^{1}/_{16}$" (1.6mm) OD tubing
FF-8B	¼-28 nut and ferrule for $^{1}/_{8}$" (3.5mm) OD tubing
SER-232	RS-232 cable (9 pin D-shell to 10 pin ribbon connector)
SER-P-n	Party mode serial cable with "n" slave controllers
PS-2450	24 VDC power supply
I-23688	Pump motor cable
RAD	Right-angle drive
PRV-100	Pressure relief valve (100 psi)
PRV-40	Pressure relief valve (40 psi)

8. Additional Software Interfaces

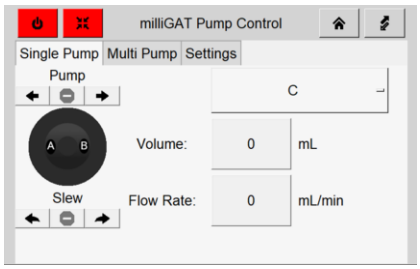
8.1 *FloZF Demo Mode Software (P/N: FLOZF-DEMO)*

FloZF is a device control and data acquisition package developed by Global FIA. A free demo version of this software which you can download from the Global FIA web site allows control of the milliGAT pump and certain Valco valves. The Windows 64-bit compatible version can be downloaded from www.globalfia.com/software_downloads/FloZF_64bit.zip and the 32-bit compatible version from www.globalfia.com/software_downloads/FloZF_32bit.zip .

8.2 *LabView Drivers*

A simple LabView driver for the pump, along with a driver for Valco valves can be downloaded from www.globalfia.com/software_downloads/MDrive_Drivers.zip
In the zipped file is a VI named "Pump and Valve Demo.vi" that is the top-level vi to look at.

8.3 *FLUMI Touch Panel Interface*



The FLUMI touch panel interface is designed to control one or several milliGAT pumps and or Valco valves. A copy of the manual can be downloaded from www.globalfia.com/software_downloads/FLUMI manual.pdf .

9. Technical Support

All technical support for this product is handled by the Global FIA, Inc. facility on Fox Island, WA or through your local distributor.

253-549-2226 (Telephone) 253-549-2283 (Fax) info@GlobalFIA.com (Email)

10. Returning pumps to Global FIA

The following procedure must be followed when pumps are returned to Global FIA for repair:

1. Obtain a Return Merchandise Authorization number (RMA#) from Global FIA.
2. With the RMA number, Global FIA will provide a *Request for Repair* form in pdf format. Complete the form.
3. Describe in detail:
    a. what is wrong with the pump
    b. the environment in which it is used including the fluids used in the pump
    c. your power and communications setup
4. Include contact name, address, telephone number, email address
5. Include the form with the item being returned.
6. Return the pump to:

Global FIA, Inc
Attn: RMA#
684 Sixth Ave
Fox Island, WA, 98333, USA

11. Operational and technical specifications

Specifications for each of the pumps are given in the following tables. These specifications are subject to change from time to time as improvements are made to the pump and the manufacturing and testing procedures.

Physical Specifications	MG-1 milliGAT LF (Low flow)	MG-2 milliGAT HF (High flow)
Dimensions	See Figure 2	See Figure 2
Weight pump	520g	520g
Weight motor and gear assy.	530g	645g
Weight stepper controller	300g	300g
Weight power supply	300g	300g
Volume per rev	100 µL	628 µL
Resolution MSEL=256	243,200 micro steps / 100µL	504,811 micro steps / 630µL
Pump volume range	10 nL – 800 mL in discrete moves or 10^9 L when using SLEW command	100 nL – 8L in discrete moves or 10^9 L when using SLEW command
Flow rate minimum	0.004 µL/sec	0.040 µL/sec
Flow rate maximum	165 µL/sec (standard) or 400,000/EU	700 µL/sec (standard and max) or 562,800/EU
Back pressure	100 psi (standard) 500 psi at 84 µL/sec (hp)	100 psi (standard) 200 psi at 400 µL/sec (hp)
Volume precision (C.O.V.)	<0.08% at 1.25 mL <0.7% at 12.5 µL	<0.1% at 1.25 mL <0.6% at 125 µL
Fittings	10-32 female thread with Valco detail	¼-28 female thread with flat bottom
Fluid contact	See sections 3.5-3.6, piston tips are PTFE	See sections 3.5-3.6, piston tips are PTFE
Power requirement		
Rest current draw	200 mA	200 mA
Operational current draw	1400 mA (Typ.) (peak 1600 mA at acceleration)	1400 mA (Typ.) (peak 1600 mA at acceleration)
Voltage	12-48 VDC, 24 VDC (Typ.)	12-48 VDC, 24 VDC (Typ.)
Motor		
Type	2 Phase Bipolar (1.8º per step)	2 Phase Bipolar (1.8º per step)
Gear Assembly		
Type	Planetary	Planetary
Ratio	1:4.75	1:9.86
Communications		
Type	RS-422	RS-422
Baud rate	9600 (default), 4800 - 38 800 bps	9600 (default), 4800 - 38 800 bps
Parity	None	None
Data bits per character	8	8
Stop bits	1	1
Error checking	None	None
Mode	ASCII	ASCII
Environmental		
Operating Temperature	0 – 50°C	0 – 50°C
Operating Humidity	< 90% non-condensing	< 90% non-condensing
Storage Temperature	-20°C – 70°C	-20°C – 70°C

12. Appendix A – Technical details

12.1 *Stepper motor wiring*

The stepper motor used is a bipolar motor with four leads. This motor is wired as indicated in Table 7.

Table 7: Motor wiring

Phase	Wire Color
Phase A	Black
Phase Bar A	Red
Phase B	White
Phase Bar B	Green

12.2 *Default values for controller variables*

The factory default parameters that may be changed by the user are listed in the following table. All other parameters are set to factory defaults described in the MDrive or MForce manual.

Note: The values of the variables should only be changed by a qualified person as changing some variables may have a drastic impact on the pump's operation.

Table 8: Factory settings for controller variables

Parameter	
Pump units	μSteps
Step resolution	MS=256
Peak flow rate	VM=20*EU
Initial flow rate	VI=10
Acceleration rate	A=500*EU
Deceleration rate	D=500*EU
Motor hold current	HC=0
Motor run current	RC=60 (MDrive) RC=40 (MDrive)
Motor acceleration current	
Backlash enable	BE=1
Backlash mode	
Backlash amount	BL=3740
Holding current delay	HT=100

The present value of any variable can be determined by using the print command **PR**, e.g. **PR VI** will display the present value for VI, the initial flow rate. The present value for all variables can be seen by typing **PR AL**.

To save changes to the default values, use the save command **S**.

12.3 *Backlash correction*

On the MDrive there is no in-built function for compensating for backlash. We have installed a small embedded program on the Drive to allow backlash compensation. To compensate for backlash, you must set the desired volume to aspirate or dispense first, **VL=n**, where n is the desired volume in integer μL. Then issue the command **EX FL**. TO specify the required volume in μ steps, issue the command **VS=n** and then **EX FS (VL=-1 or 1** also for direction if using early versions of controller programs). Remember to precede commands with the address if in party mode. You can change the value of the backlash by changing the variable **BL**, backlash must be specified in μ steps.
The backlash of the pump is compensated for by using the set of commands in Table 3. You can check the backlash of the pump at any time by carrying out the following simple test sequence.

1. Prime the pump making sure that all bubbles have been purged from the pump. Aspirate a small 5 µL bubble into the outlet line of the pump so that you can visually observe movement of the liquid.
2. Set BL=0. This will disable backlash compensation.
3. Aspirate 5 µL. This will cause the fluid in the outlet to move towards the pump.
4. Dispense 1.0 µL. This will cause the fluid in the outlet to move away from the pump and represents a change in direction. Because you have disabled backlash compensation, the fluid in the outlet line will not actually move – the backlash has not been taken up yet.
5. Repeatedly issue dispense 0.1 commands until you observe movement of the liquid.
6. The backlash is equivalent to 1.0 plus the number of 0.1 increments necessary before movement was observed.
7. You can determine the backlash more accurately by incrementing smaller volumes. If you do this, it is useful to use narrow bore tubing with an ID of 250 µm or less so that you can physically see the movement.
8. Set BL to the new determined value for backlash.
9. Verify correct operation by moving the fluid back and forth the same volume. You should end up at the same spot.

Of course, whenever you change direction, even though the pump is moving, for the first short period of time, you will not see movement of the fluid as the pump takes up the backlash. With backlash enabled, this is handled automatically.

12.4 *Embedded programs*

The MForce and MDrive have powerful *Program Modes*. Using these modes, sequences and programs can be downloaded to the controller to add functionality. All pumps that use the MForce or MDrive are shipped with a small memory resident program installed. This program can be viewed by sending the command **L**. If this program becomes corrupted or is lost, contact Global FIA for instructions and how to re-instate the embedded program.

Global FIA can also develop custom embedded programs to suit customer needs.

12.5 *Upgrading the firmware*

Periodically Intelligent Motion Systems releases a new version of the Controller Firmware for the MForce and MDrive controllers. The present version of your firmware can be determined by typing **PR VR**. To update the firmware, download the latest version of IMS terminal from https://motion.schneider-electric.com/dloads/user-interface-software/ and the latest version of the firmware from https://motion.schneider-electric.com/dloads/firmware/.

13. Appendix B: MDrive and MForce commands

Command	Description	Factory
A=n	Peak acceleration value, microsteps/sec^2	1000*EU
D=n	Peak deceleration rate, microsteps/sec^2	1000*EU
SL=n	Slew the motor at a constant velocity in microsteps/sec	
VI=n	Initial pump velocity, microsteps/sec (also creep velocity with HM command)	0.01*EU
VM=n	Maximum velocity of pump during a pump action, microsteps/sec (also seek velocity with HM command)	20*EU
MA n	Move to absolute motor position, n is microstep position, sign indicates direction	
MR n	Move motor relative to present position, n is no of microsteps, sign indicates direction	
MV	"Read only" flag that indicates if the pump is moving. Use the PR command to see the value of this flag. 1 = moving, 0 = stopped.	
P=n	Set or print the motor position counter in microstep units	
HC=n	Motor holding current used when the pump is stationary, n=% of 2A	0
HT=n	Hold current delay time, msec	0
RC=n	Motor run current used when the pump is running, n=% of 2A	60
MS=n	Micro stepping resolution, n=2,4,8,16,32,64,128,256	256
AL	Variable used with PR instruction	
ER	"Read only" variable that gives the error code of the most recent error	
IP	Initialize all motion control parameters to their stored values	
FD	Returns all variables to factory defaults	
S1	Setup IO point 1 (available for S2, S3, and S4) (see MDI manual for details)	1,1
O1=n, O2=n, O3=n, O4=n	Switch digital output on and off (n=1 – on n=0 – off)	
I1, I2, I3, I4	Present state of digital input, 1=on, 0=off	
D1	Input 1 digital filtering (available for D2, D3, and D4 as well)	1
PG	Keyword to place controller into program mode	
PR n	Print to screen selected data or text	
CL n,m	Call subroutine, n label of subr, m – conditional statement	
RT	Return from sub routine	
BR n,m	Branch to sub routine, n label of subr, m – conditional statement	
DC	Decrement variable	
IC	Increment variable	
H=n	Hold program operation for time n in msec if blank or 0 till motion stops	
LB	Create program address label, SU will run on startup	
E	End program execution	
S	Instruction to save ALL variables to non-volatile memory	
VA	Create a user variable in program mode	
R1, R2, R3, R4	32 bit user registers	
VR	"Read only" firmware version	
CP	Clears the program space	
L n	List the program stating at address n or label n	
<ESC>	Terminate all active operations and running programs	
BD=n	Sets the baud rate	96
DN="n"	Set the device address for PARTY mode operation	"!"
EM=n	Specifies whether commands will be echoed back over communication line, n=0 Full duplex, n=1 Half duplex, n=2 Only respond to PRINT and LIST commands	0
BY	Flag that indicates whether a program is running	
PY	Enables / disables PARTY mode for multi drop applications	

All variables are integers, no floating point capabilities
All commands are preceded by the address if DN has been set (default A) and terminated with a carriage return and line feed <CR><LF>

14. WARRANTY AND DISCLAIMER

This Limited Warranty gives the Buyer specific legal rights.

For a period of 365 calendar days from the date of shipment, Global FIA Inc. (hereafter Seller) warrants the goods to be free from defect in material and workmanship to the original purchaser. During the warranty period, Seller agrees to repair or replace defective and/or non-conforming goods or parts without charge for material or labor OR at Seller's option demand return of the goods and tender repayment of the price. Buyer's exclusive remedy is repair or replacement of defective and nonconforming goods OR at Seller's option return of the goods and repayment of price.

SELLER EXCLUDES AND DESCLAIMS ANY LIABILITY, WHETHER ARISING IN CONTRACT, TORT OR OTHERWISE, FOR LOSS OF USE, REVENUES OR PROFITS, PERSONAL INJURY, INTERRUPTION OF SERVICE, OR FOR CONSEQUENTIAL INCIDENTAL OR SPECIFIC DAMAGES ARISING OUT OF, RESULTING FROM, OR RELATING IN ANY MANNER TO THESE GOODS.

There are NO user serviceable parts inside the pump. Opening the pump by removing, or even loosening, the hex bolts that hold the pump together will void this Limited Warranty.

This Limited Warranty does not cover defects or nonconformity resulting from abuse, misuse, neglect, lack of reasonable care, modification or the attachment of improper devices to the goods. This Limited Warranty does not cover expendable items. This warranty is VOID when repairs are performed by a non-authorized service center or representative. At Sellers option, repairs or replacements will be made on site or at the factory. If repairs or replacements are to be made at the factory, Buyer shall return the goods prepaid and bear all the risks of loss until delivered to the factory. If Seller returns the goods, they will be delivered prepaid and Seller will bear all risks of loss until delivery to the Buyer. Buyer and Seller agree that this Limited Warranty shall be governed by and construed with the laws of the State of Washington.

The warranties contained in this agreement are exclusive and in lieu of all other warranties, obligations and liabilities, express or implied, arising by law or otherwise, including: (a) any implied warranty of merchantability or fitness for a particular purpose; (b) any implied warranty arising from course of dealing or usage of trade; and (c) any right, claim or remedy in tort, whether or not arising from the sellers negligence.

This Limited Warranty supersedes all prior proposals or representations oral or written and constitutes the entire understanding regarding the warranties made by Seller to Buyer. This Limited Warranty may not be expanded or modified except in writing signed by the parties hereto.