# Product Manual

TRICONTINENT
by Gardner Denver

# C-Series
# Syringe Pumps

C3000
C3000MP
C24000
C24000MP

Publication 8694-12 E

TRICONTINENT
by Gardner Denver



**NOTICE**

The information presented in this material is based on technical data and test results of nominal units. It is believed to be accurate and reliable and is offered as an aid to help in the use of TriContinent products. It is the responsibility of the user to determine the suitability of the product for the intended use and the user assumes all risk and liability in connection therewith. TriContinent does not warrant, guarantee or assume any obligation or liability in connection with this information.

Publication 8694-12 E

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# 1 About this manual

## Introduction

This comprehensive manual provides the instructions you need to get the C-Series Syringe Pumps installed and operating as desired, as well as to keep properly maintained. Contact information is also included in case you need to reach TriContinent for assistance. See "Customer support" (page 111).

## Audience

This manual is provided primarily for customers who purchase products from TriContinent. It is expected that the majority of customers are instrument designers and software engineers who are familiar with this type of product and existing software/firmware of similar design. However, this manual is also designed to accommodate those who don't have such familiarity or who simply wish to learn more about the product.

## Products covered by this manual

The following products are covered by this manual:

- C3000
- C3000MP
- C24000
- C24000MP

These are described in "Product overview" (page 11).

## Parts of this manual

The following parts are included in this manual:

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# 2 Safety and standards

## About this chapter

This chapter contains safety notifications used in this manual, cautions about proper use of the equipment, and standards which may be applicable to the C-Series Syringe Pumps.

The C-Series Syringe Pumps are designed to meet recognized technical regulations and are built with state-of-the-art components. Nevertheless, risks to users, property and/or the environment can result when they are used carelessly or improperly. Appropriate warnings in this manual are included to notify of possible hazards.

## Safety notifications used in this manual

⚠CAUTION

**CAUTION:** Alerts you to the possibility of equipment damage and/or improper function if these instructions are not followed.

⚠WARNING

**WARNING!** Indicates a hazardous situation which, if not avoided, could result in injury and/or property damage.

⚠DANGER

**DANGER!** Indicates a hazardous situation which, if not avoided, can result in death or serious injury and property damage. This alert is limited to the most extreme situations.

## ESD precaution

⚠CAUTION

**CAUTION:** ESD-sensitive equipment!

Always use proper ESD practices when handling the C-Series Syringe Pumps. Because it is an electronic device, the pump is vulnerable to ESD (electrostatic discharge). Electrostatic discharge can come from common objects, fixtures, and flooring materials such as carpets, causing the pump to fail prematurely. Proper ESD practices include the use of static-free work areas, wrist or ankle grounding straps, ESD mats, non-static flooring material or treatment, and similar provisions.

# Proper use of equipment

The C-Series Syringe Pumps are designed for pipetting and dispensing operation. Any other use may damage the pump and/or produce unreliable results.

Make sure any liquids used with the equipment are compatible. Refer to the chemical compatibility chart (page 142).

**Note:** It is the responsibility of the purchaser to determine the suitability of an application and material compatibility of the products.

# Syringe shipping precaution

**⚠CAUTION**

**CAUTION:** Avoid shipping pumps with syringes installed. During transport, shock and vibration can be transmitted directly to the syringe. This can lead to glass breakage, loosening of syringes from their threaded ports, and potentially other problems. Syringes should always be shipped separately inside their original packaging for the highest level of protection from damage. Using the pumps' original packaging is insufficient.

For example, when shipping pumps that have been installed in an instrument, syringes should be removed and shipped in their individual packaging as described above.

# Regulatory notices

### FDA

The TriContinent C-Series Syringe Pumps are general laboratory components. Because they are not medical devices, they are not subject to FDA approval.

### CE

The C-Series Syringe Pumps are modular devices intended for incorporation into larger systems, which themselves require independent certification. Therefore, the C-Series Syringe Pumps do not have their own CE mark.

### RoHS

The TriContinent C-Series Syringe Pumps are RoHS compliant. They are constructed of components that meet the requirements set by the European Union's Restriction of Hazardous Substances Directive 2002/95/EC.

# 3 Product overview

## About this chapter

This chapter provides a general introduction to the C-Series Syringe Pumps, including features, facilities, and key specifications.

The following parts are included:



## General description

**Figure 3-1. Typical C-Series Pump**

The C-Series Syringe Pumps are OEM pump modules designed for automated instrumentation.

The module is a self-contained unit that includes the pump, stepper motors, control electronics, drive, and valve. The C-Series pumps utilize a proprietary high-efficiency, direct-drive design instead of belts that can stretch or wear out. The robust drive mechanism has been life tested to several million cycles with no maintenance required during its lifetime.

These pumps are excellent choices for new installations, and for replacements where experienced IVD instrument manufacturers would like to maximize investments they have already made in instrumentation. The C-Series pumps utilize standard communication interfaces and methods for mounting used by other compact syringe pump designs. The pumps are outfitted with TriContinent long-life valves available in various configurations and material combinations. All C-Series pumps can be customized for specific liquid handling needs.

The C-Series hardware and firmware automatically detect the communication interface and communication protocol. The pump can be configured to operate at different communication speeds.

There are currently four models of the C-Series Syringe Pumps: C3000. C3000MP, C24000, and C24000MP.

**C3000.** The C3000 provides all normal aspiration and dispensing operations expected from an OEM syringe pump module. The stepper motor-driven syringe will accurately and precisely handle fluid capacities from a few microliters to 12.5 milliliters. The syringe drive arm can be easily back driven, making syringe installation or replacement extremely quick and easy. The C3000 supports valves with 3 or 4 ports.

**C3000MP (C3000 Multiport).** The C3000MP provides all of the features of the C3000 but is designed to support a 6-way distribution valve.

**C24000.** The C24000 is a high-resolution version of the C3000 that achieves full syringe resolution to 192,000 increments/full stroke. The C24000 is ideal for achieving low flow rate and meeting low pulsation requirements. The C24000 supports valves with 3 or 4 ports.

**C24000MP (C24000 Multiport).** This model has all the features of the C24000 but is designed to support a 6-way distribution valve.

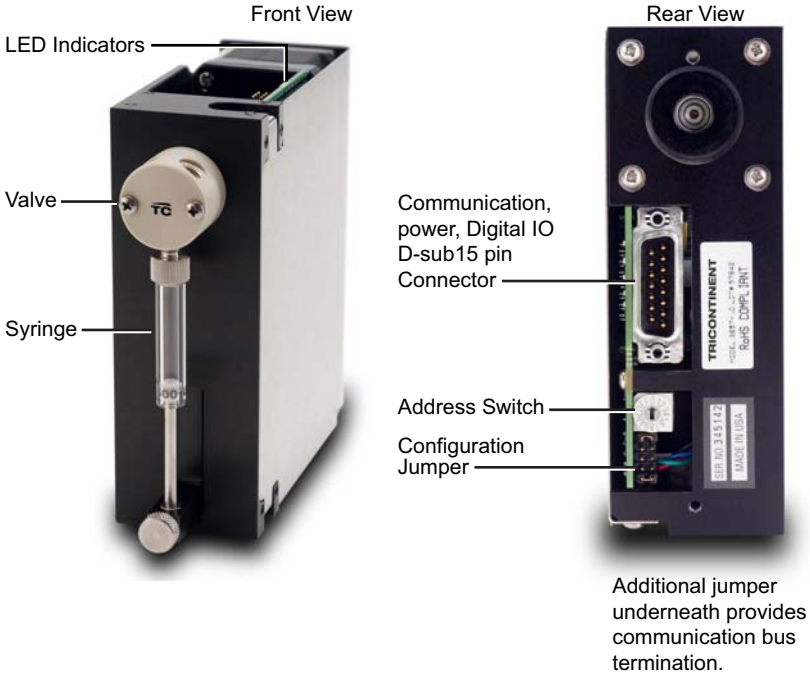
# Features and facilities

Each pump provides two digital inputs and three outputs (digital I/O) that can be used for synchronization with external devices (see Figure 3-2.) Multi-pump communication is possible over an RS485 or CAN bus. The built-in RS232 interface automatically converts to RS485. With an optional converter, USB communication can also be accommodated.

Other features

- Proprietary high-efficiency and maintenance-free direct drive system
- Long-life rotary shear valves (up to 24 times the life of competing valves)
- Valve drive < 250 ms between neighboring ports
- High resolution options available up to 192,000 increments/full stroke
- Up to 15 pumps on a bus; can be addressed individually
- Syringe sizes from 50 µL to 12.5 mL
- LED indicators to assist in monitoring function and provide notification of specific error conditions.

**Figure 3-2. Facilities on C-Series pumps**



# Key specifications

- Interface: RS232, RS485, CAN
- Communication rates: RS232/RS485: 9600 or 38400 baud; CAN: 100K, 125K, 250K, 500K, 1M bps
- Format (RS232/RS485): Data bits 8, Parity None, Stop Bit 1, half duplex
- Operating Temperature 15°C to 40°C (59°F to 104°F)
- Humidity 20 to 95% RH at 40°C (104°F)

More detailed specifications can be seen at http://www.tricontinent.com. Product data sheets can be downloaded from this location.

# 4 Installation instructions

## About this chapter

This chapter describes how to install your C-Series Syringe Pumps.

The following parts are included:



## Unpacking

⚠CAUTION

**CAUTION:** Always use proper ESD practices when handling the C-Series Syringe Pumps.

1. Remove items from shipping carton.
2. Check the contents against the packing slip to make sure that all the components are present. If any components are missing or damaged, see instructions in Customer support (page 111).
3. Dispose of packing material in accordance with local environmental regulations.

# Before starting

## Basic requirements

Basic requirements for installing your C-Series Syringe Pumps are listed below. If you have any difficulty obtaining any of them, you can get assistance from Customer Service. See Customer support (page 111).

- Desired syringe that is compatible with the C-Series Syringe Pumps.
- Tubing appropriate to the pump and valves and the nature of fluid to be moved. For guidance on selecting tubing, refer to "Optimizing tubing performance" (page 147).
- Cabling as needed.
- Computer, Windows® based, to serve as the Host Controller.
- If you are going to use the USB port of your host computer to connect to the C-Series pump, you will need a USB-to-RS485 converter, which can be ordered through TriContinent Customer Service.
- A software interface for communicating with the pump or pumps.
  - For evaluation purposes, the TCS Pump Commander user interface is recommended. See "Obtain and install TCS Pump Commander if needed" (page 18).

    Alternatively, terminal emulator programs such as PuTTY and RealTerm are available. These may be obtained from Customer Service.
  - For instrument development, only an appropriate communications port on the Host Controller PC is needed.

  Details concerning interface selection are included on page 17.

# Protocol and interface options

## Protocol

Three communication protocols are available:

- OEM communications protocol
- Data Terminal (DT) protocol
- CAN protocol

The C-Series firmware automatically detects which protocol is in use.

## Communication standards

The C-Series Syringe Pumps use the following communication standards.

- RS232
- RS485
- CAN

These communication standards are described in detail in Chapter 9, Reference information (page 113).

## Interface Selection

A terminal program or the TCS Pump Commander may be used for direct operator input to the pumps. Note that TCS Pump Commander is especially recommended for use in evaluating pump behavior in response to commands. Other terminal programs such as PuTTY and RealTerm may be used. Customer Service can provide assistance in obtaining these if necessary.

**Table 4-1: Protocol and interface summary**

| Hardware/electrical interface | Communication protocols/ standards | Comments | Connection |
|---|---|---|---|
| RS232 and RS485 | DT or OEM protocol | DT is recommended for use with terminal emulator programs. DT is automatically selected when TCS Pump Commander is used.<br>OEM is recommended for instrument development because of its robust error checking and correction. | Serial or USB computer port<br>Serial connects directly to serial inputs on one pump; RS485 to remaining pumps on bus (daisy-chain).<br>USB goes through an external USB/RS485 converter, which connects directly to the RS485 bus on a pump.<br>Cables are available for these connections. Contact Customer Service (page 111). |
| CAN | CAN (hardware/electrical interface and communication protocol are included in CAN specification.) | If assistance is needed, contact Customer Service (page 111). | |

## Obtain and install TCS Pump Commander if needed

The TCS Pump Commander interface is recommended for evaluation purposes. The TCS Pump Commander displays how commands are structured, and shows the interaction between pumps and commands.

To obtain TCS Pump Commander, email a request to Liquidhandling.TCS@tricontinent.com. You will be provided with further instructions.

## Download and install USB driver if needed

The USB driver is required only when the TriContinent USB converter is being used to communicate with C-Series Syringe Pumps.

If using other third-party USB converters, follow their instructions for downloading and installing drivers.

**Note:** When using the TCS Pump Commander, you will need to know which COM port will be used for communicating with the C-Series pump.

1. Go to this link to download the USB driver for your system: https://www.silabs.com/products/development-tools/software/usb-to-uart-bridge-vcp-drivers.

   This takes you to a web page of Silicon Labs, where the USB drivers for various systems are listed.

   **Note:** It is possible for the link above to change. If this occurs, contact Customer Service for assistance or search elsewhere on the Silicon Labs website for the USB drivers.

2. Click on whichever link is appropriate for your system, and follow directions to download the file.

   **Note:** Do not download files named “VCP with Serial Enumeration.”

3. Extract the zip file.
4. Open the resulting folder, which has the same name as the zip file.
5. Run (double click) the appropriate .exe file for your system:
   - If your system is 64 bit, run CP210xVCPInstaller_x64.exe.
   - If your system is 32 bit, run CP210xVCPInstaller_x86.exe.
6. Follow the prompts to complete the installation.
7. Insert the USB/RS485 converter into the USB port. Windows® should recognize it and load the correct driver for the converter. Once this is done, the USB converter is ready to use.

# Power and electrical considerations

The C-Series pump has the following power requirements:

- Input voltage: 24 VDC ± 10%
- Input current; 1.5 A peak current max., 650 mA average (RMS) current max., and 100 mA typical idle current

### Power supply requirement for single pump

The 24V DC supply for a single C-Series pump should meet the following requirements:

- Output voltage: 24V nominal ±10% with good regulation
- Conformance to required safety and EMI/RFI specifications
- If switching supply, minimum load specification less than pump idle current (above)

### Power supply sizing for multiple pumps

When operating more than one C-Series pump, the power supply should be sized to provide the total peak current for all devices. If pumps are not operating simultaneously, a power supply with a reduced rating may be used. The minimum power supply rating should be confirmed by measurement.

It is suggested that an appropriately designed commercial power supply be used. When using a switching power supply, make sure it has a minimum load specification that is less than the total minimum current draw (idle current, above) from the pumps.

### Cabling

To reduce voltage drops and increase noise immunity, it is good practice to use one power cable for every two pumps. Power lines to the pump should be 24 AWG or heavier, and as short as possible, based on the total current through the wires. Multiple C-Series pumps can be daisy-chained, provided that the wire size and the power supply are adequate for the total current and voltage drop. It is good practice to twist together each pair that connects directly from a power supply to a pump.

Switches should not be located in line with the DC input of the pumps to apply and remove power. This can result in damage to the equipment.

For available evaluation cabling, please refer to "Evaluation cables and accessories" (page 134).

# Place or mount pump(s)

## Before mounting

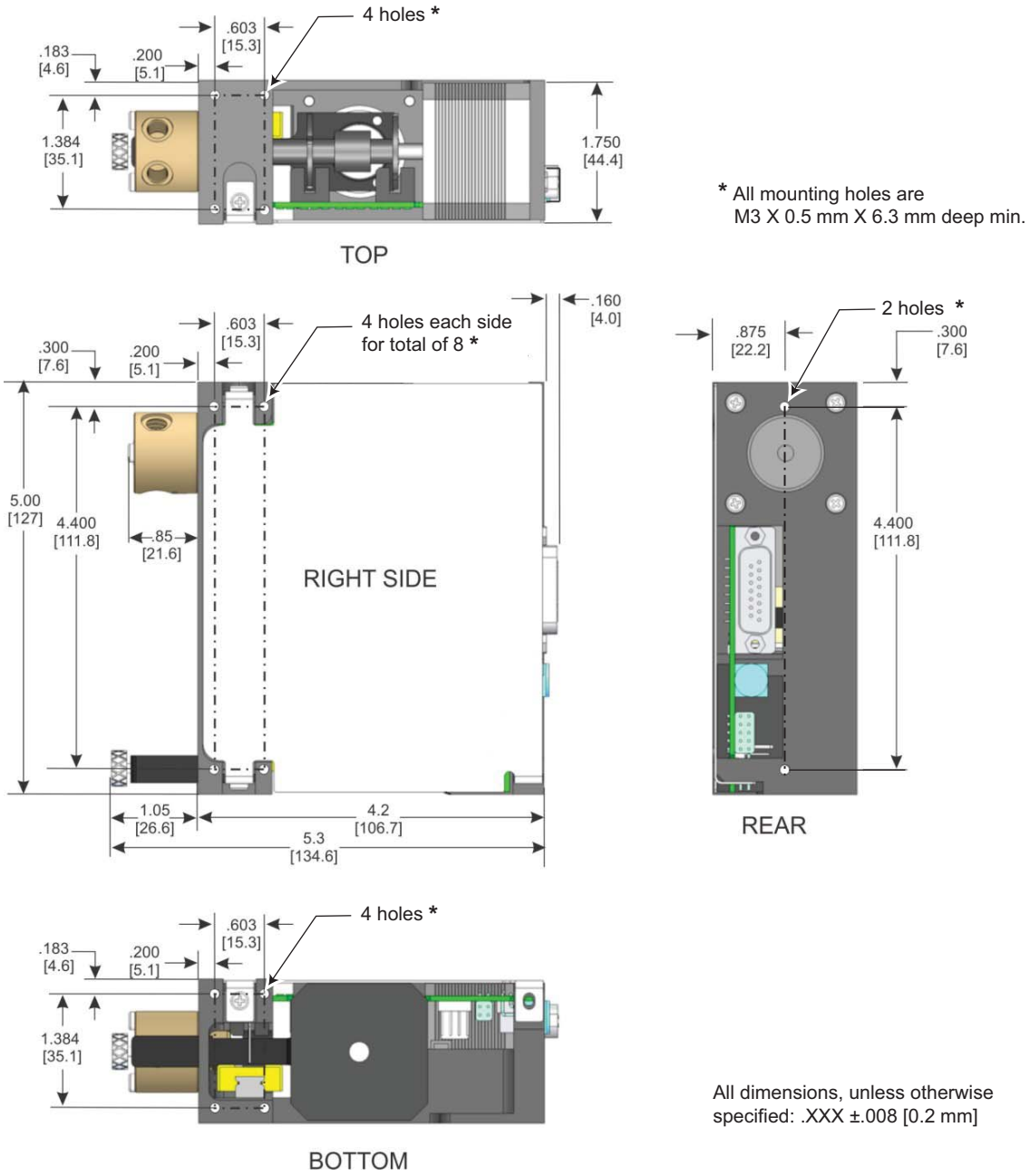
Termination jumper J9 is located on the bottom of the pump. To avoid later inconvenience during installation, make sure it is set correctly for your situation before securing the pump on a surface. Proper terminations are indicated in "Install communication/power cabling" (page 25).

## Mounting

The pumps may be secured at the top, bottom, or either side by four pre-threaded M3 X 0.5mm mounting holes. Refer to Figure 4-1 for mounting hole locations and dimensions.

The upright position is used for best priming. For air displacement applications this is not necessary.

## Figure 4-1. Mounting holes and dimensions



# Set configuration jumpers and address switch

## Configuration jumpers

Before operating the pump, jumpers J2 and J9 must be set for your system. Refer to the following tables and to Figure 4-2.

**Table 4-2: J2, various options**

| Jumper Segment | Function | Action |
|---|---|---|
| 1 | Reserved | None. Spare jumper placed on this segment at factory. |
| 2 | AutoRun | Installed = AutoRun[1]<br>Remove if unused. Recommend removing until operation has been confirmed. AutoRun executes string in EEPROM at power-up. |
| 3 | Overload detection | Installed = disabled |
| 4 | RS232/485 communication rate | Installed = 38,400 baud<br>Removed = 9600 baud |
| 5 | Valve type in use | Installed = 120° 3-port valves<br>Removed = 90° 4-port valves and all other valve types[2] |

1. At power-up, if the AutoRun jumper is installed, the pump will execute the string at the memory location pointed to by the address switch setting.
2. All other valve types are EEPROM configurable. This is described in Table 5-1 (page 48).

**Table 4-3: J9, RS485 and CAN terminations[1]**

| Jumper Segment | Function | Action[2] | Application |
|---|---|---|---|
| 1 | RS485 A termination | Installed = terminated<br>Remove if unused. | Remove all termination jumpers except as shown in cabling diagrams. Cabling diagrams begin on page 26. |
| 2 | RS485 B termination | Installed = terminated<br>Remove if unused. | |
| 3 | CAN termination | Installed = terminated<br>Remove if unused. | |

1. In single-pump installations, the pump is always terminated.
2. Remove, if desired, before mounting pump in a manner in which the termination jumper will be obscured.

## Address switch setting

The address switch is normally used to assign the device address on the RS485/CAN bus (see Figure 4-2). There are 15 possible addresses (0-E hex). The actual device address equals the address switch setting plus one. If the address switch is set to 1, then, the device address is 2.

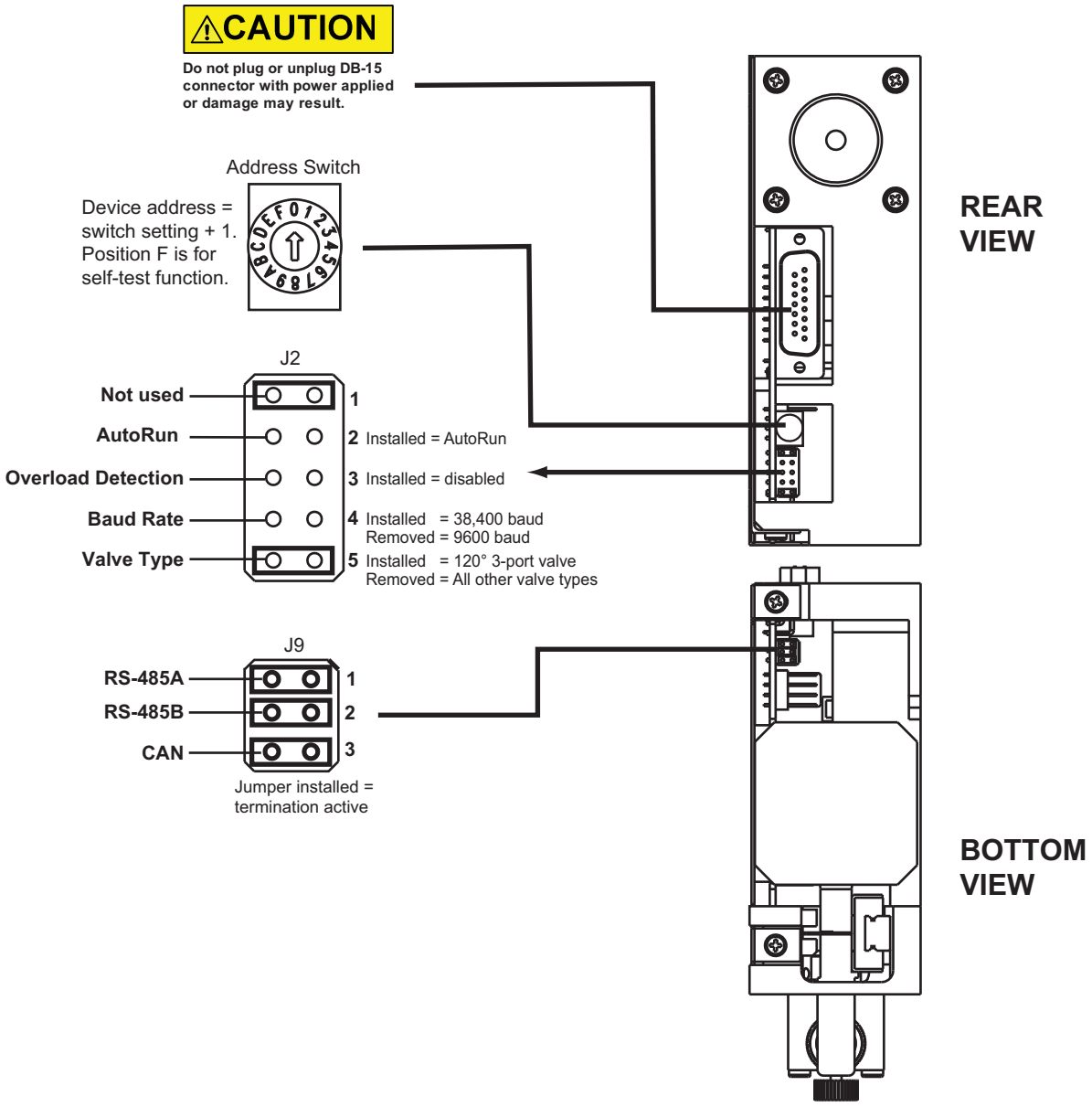
Position F is used for the self test. Use a small flat-bladed screwdriver to rotate the switch. See cabling diagrams for examples.

**Note:** The address switch function changes if AutoRun jumper J2-2 is installed (see Table 4-2, above). For initial setup and confirmation, make sure the AutoRun jumper is not installed.

## CAN baud rate

Default is 100K bps. For initial installation and operation, this should be left unchanged. Once communication has been established, it may be changed as described in Table 5-4 (page 82).

## Figure 4-2. Configuration jumpers and address switch

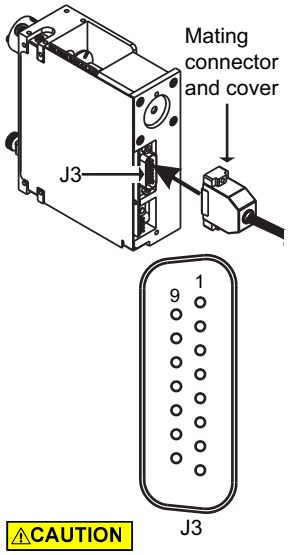


# Make electrical connections

## Connector J3 pin assignments

All electrical connections, including power, communication, and control signal IO are made through 15-pin D-sub connector J3. This connector is located on the back of the pump. Mating connector and shield information is provided in the tables below.

Cables are available for these connections. Contact Customer Service for assistance. Also refer to "Evaluation cables and accessories" (page 134).




**⚠CAUTION**

**CAUTION:** Make sure power is off before making connections to J3. Connecting or disconnecting with power applied may result in damage to equipment.

**Table 4-4: Mating connector and cover for J3**

| Item | Manufacturer | Description | Manufacturer's part number |
|---|---|---|---|
| Mating Connector | TE/TYCO | 15-pin female solder cup, receptacle | 747909-2 |
| Cover | TE/TYCO | Plastic cover (shield) with male screw retainers | 5207908-4 |

**Table 4-5: Pin assignments for J3**

| Pin | Function | Details |
|---|---|---|
| 1 | 24 VDC | 24 VDC nominal, ±10%, 1.5A peak |
| 2 | RS232 TXD line | Output data |
| 3 | RS232 RXD line | Input data |
| 4 | | Not used |
| 5 | CAN HI signal line | |
| 6 | CAN LO signal line | |
| 7 | AUX Input #1 | TTL level (4.7K pullup to +5V) |
| 8 | AUX Input #2 | TTL level (4.7K pullup to +5V) |
| 9 | Ground | Power and logic |
| 10 | Ground | Power and logic |
| 11 | RS485 A line | |
| 12 | RS485 B line | |
| 13 | AUX Output #1 | TTL Level (1K pullup. Max source/sink current = ±20mA) |
| 14 | AUX Output #2 | TTL Level (1K pullup. Max source/sink current = ±20mA) |
| 15 | AUX Output #3 | TTL Level (1K pullup. Max source/sink current = ±20mA) |

# Install communication/power cabling

### Cabling multiple pumps

Make connections as shown in the following diagrams. Each bus can support up to 15 devices in daisy-chain fashion. The diagrams show connections, address switch settings, and termination jumper positions.

### Cabling a single pump

For single-pump installations, refer to the cabling diagrams and follow the instructions for single-pump installations in the diagrams.

**Note:** Terminations must remain installed on the pump.

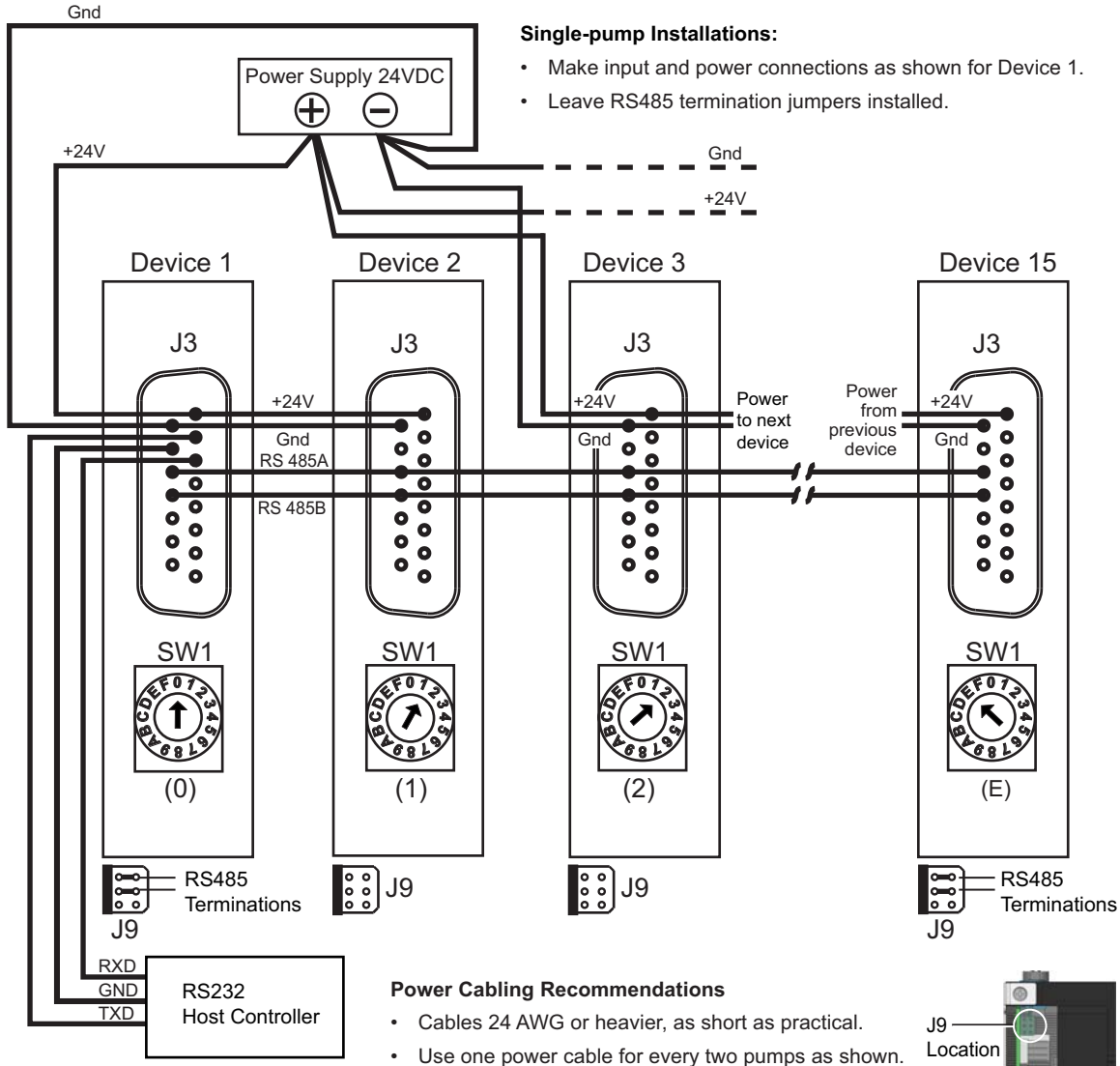
**⚠CAUTION**

**CAUTION:** Make sure power is off while making connections to DB15 connector J3. Connecting or disconnecting with power applied may cause damage to the equipment.

### RS232 cabling

Cabling for RS232 goes from the host controller serial port to the first pump on the bus. There it is converted by the pump electronics to/from RS485 for the remaining pump connections.

## Figure 4-3. RS232 communication and power cabling




**Single-pump Installations:**

- Make input and power connections as shown for Device 1.
- Leave RS485 termination jumpers installed.

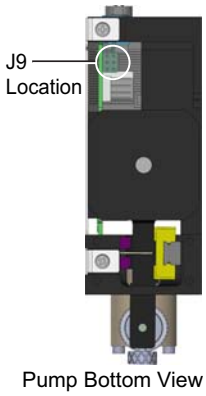
**Power Cabling Recommendations**

- Cables 24 AWG or heavier, as short as practical.
- Use one power cable for every two pumps as shown. However, a single power bus may be used if wire is sized for total current requirements and voltage drops.
- Twist wires together on cable pairs leading from power supply directly to pump.

| Host Serial Port | | Pump Port (J3) | |
|---|---|---|---|
| Function | DB9 Pin | Function | J3 Pin |
| RXD | 2 | TXD | 2 |
| TXD | 3 | RXD | 3 |
| GND | 5 | GND | 10 |

**⚠CAUTION**

**CAUTION:** Do not place switches in line with the DC input of the pumps to apply and remove power.

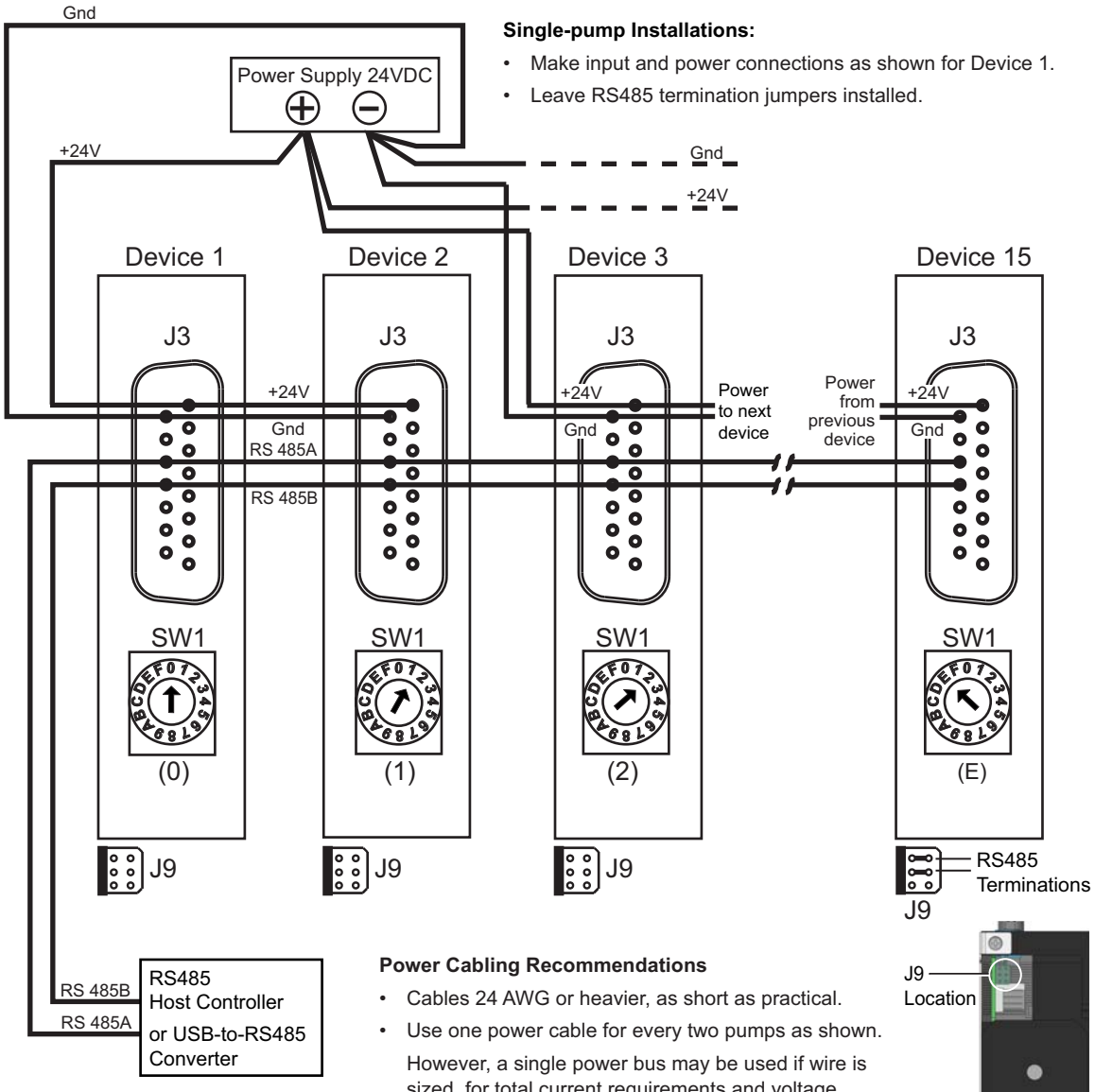



Pump Bottom View

### RS485 cabling

This would typically go from a PC USB port through the optional USB-to-RS485 converter to the RS485 bus. However, it can also come directly from an RS485 host controller.

## Figure 4-4. RS485 communication and power cabling




**Single-pump Installations:**

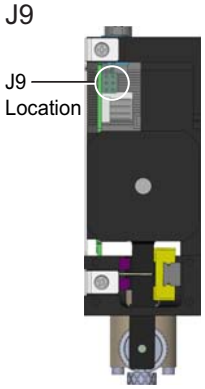
- Make input and power connections as shown for Device 1.
- Leave RS485 termination jumpers installed.

**Power Cabling Recommendations**

- Cables 24 AWG or heavier, as short as practical.
- Use one power cable for every two pumps as shown. However, a single power bus may be used if wire is sized for total current requirements and voltage drops.
- Twist wires together on cable pairs leading from power supply directly to pump.

⚠CAUTION

**CAUTION:** Do not place switches in line with the DC input of the pumps to apply and remove power.

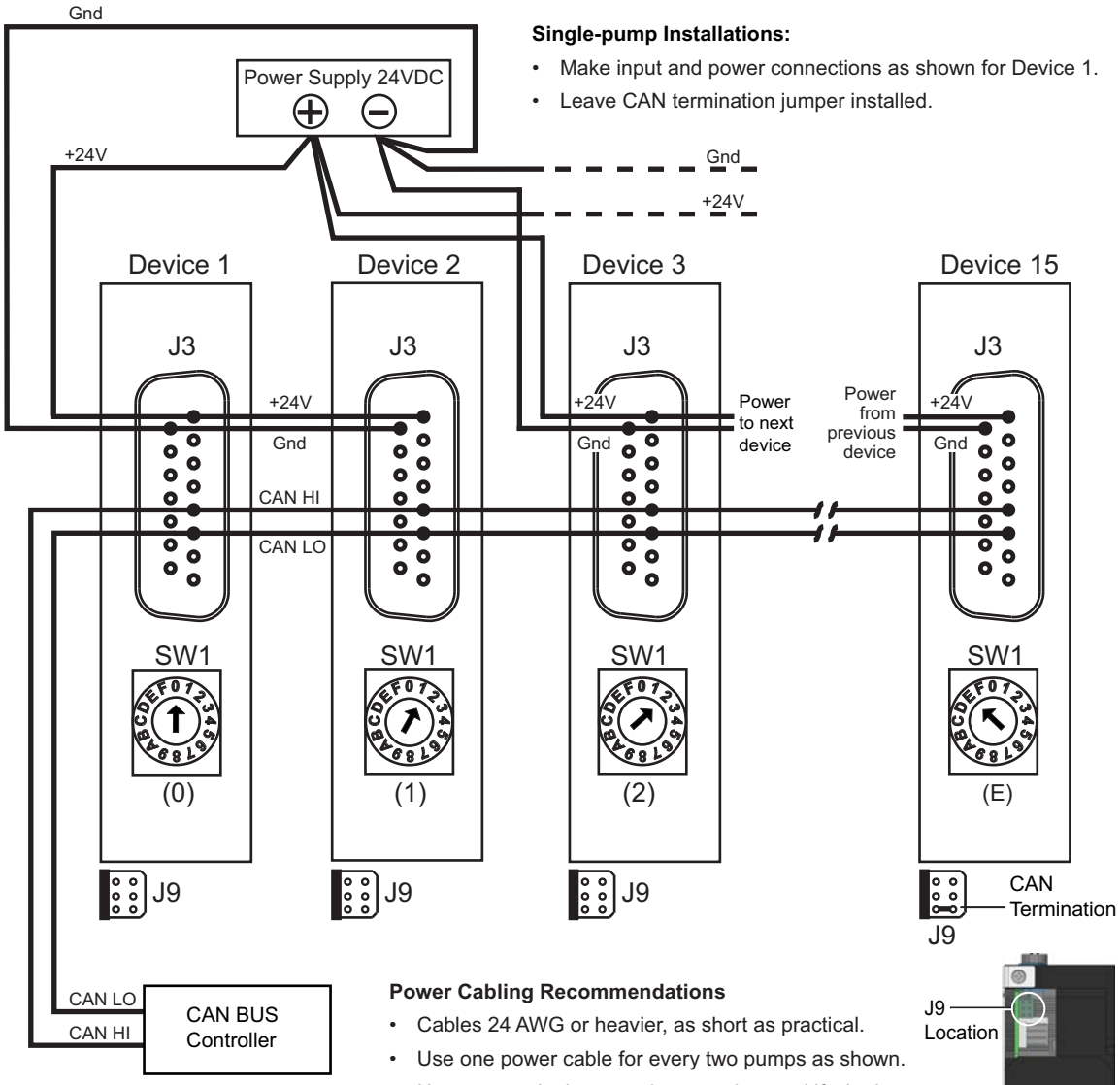



Pump Bottom View

## CAN BUS cabling

CAN cabling is direct from a CAN BUS controller to the CAN bus on the J3 connectors.

### Figure 4-5. CAN BUS communication and power cabling




**Single-pump Installations:**

- Make input and power connections as shown for Device 1.
- Leave CAN termination jumper installed.

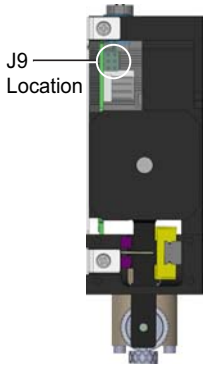
**Power Cabling Recommendations**

- Cables 24 AWG or heavier, as short as practical.
- Use one power cable for every two pumps as shown.

  However, a single power bus may be used if wire is sized for total current requirements and voltage drops.
- Twist wires together on cable pairs leading from power supply directly to pump.

**⚠CAUTION**

**CAUTION:** Do not place switches in line with the DC input of the pumps to apply and remove power.




Pump Bottom View

## Control wiring (auxiliary inputs and outputs)

The C-Series pumps provide two auxiliary inputs and three auxiliary outputs at 15-pin connector J3 (pin assignments are listed on page 24).

- The auxiliary *inputs* can be used to externally trigger or condition command sequences.
- The auxiliary *outputs* may be used for any TTL-compatible interfacing.
- The specific function of each auxiliary input or output is determined by software programming, as described in Operating instructions (begins on page 37).

# Confirm communication with pump

Make sure pump is connected, host controller PC is connected, and power is applied.

## Confirm with TCS Pump Commander (RS232/485)

1. Open TCS Pump Commander and the Pump Communication Setup window. This should open up when you start TCS Pump Commander. If not, press the Setup Communication button on the right side of the screen.
2. Select COM port.
   - If there is only one COM port showing, close the Pump Communication Setup window. Unplug the communication cable to the pump and plug it back in. Open the window again and select the new COM port that appears.
3. Select the Baud Rate and Device Address (position of address switch on pump plus 1).

   **Note:** Baud rate setting must be the same as indicated by baud rate jumper on J2. Refer to Figure 4-2 (page 23) if necessary.

4. Click the Connect button and see the response in the Status window.
   - The response format is OK: C3000 MMDDYY for both the C3000 and C24000 models. Example: OK: C3000 052914, where 052914 represents the date of the firmware.
   - If a “FAILED” response is received, re-check baud rate selection, COM port selection and device address setting. Check power and wiring also if none of these resolves the problem.

For further information about the TCS Pump Commander, see "TCS Pump Commander quick reference guide" (page 131).

## Confirm with terminal emulation programs

1. Open the desired terminal emulation program on the host controller PC.
2. For RS232/RS485, make sure communication settings are as follows:
   - Baud rate: 9600 or 38400, as determined by baud rate jumper on J2. Refer to Figure 4-2 (page 23) if necessary.

     **Note:** Baud rate setting must be the same as indicated by baud rate jumper on J2.

   - Other settings: data bits 8, parity None, stop bit 1, half duplex
3. For CAN bus communication, use default baud rate of 100K bps. This can be changed after communication has been established if desired.
4. Issue the command string [/1&],

   where /1 is the address of the pump (address switch setting plus 1). So if the address switch is set to zero, use /1. This command string requests the firmware version of the pump.

   **Note:** In DT mode, a carriage return/line feed is required after the command string (following the [R] command.

   - The response format is C3000 MMDDYY for both the C3000 and C24000 models. Example: C3000 052914, where 052914 represents the date of the firmware.
   - This confirms communication with the pump has been established.
   - If instead you receive an error message, re-check your communication settings within the communication interface, the COM port selection, and/or communication and power wiring.

# Initialize pump

Initialization verifies correct operation and places the syringe and valve into specific starting positions. Initialization is required before any move commands to the valve or syringe will be accepted.

In this test, default settings specific to the valve provided with your pump are used. In the next chapter, there are instructions for adjusting the settings to your instrument design.

**⚠WARNING**

**WARNING!** Keep fingers out of the syringe slot while the pump is running. Failure to do so can result in injury.

## Initialize with TCS Pump Commander

1. Issue the [Z] command.
2. Observe pump:
   - The plunger arm/holder should move, and the valve will turn. An "OK" message should appear in the Status: Response window at the top of the screen. Most of the LEDs at the top of the pump should be lit. The ERR LED will be off, and the LIFE LED will be blinking slowly.
   - If a "Failed" message is received, check communication settings and power, or for something blocking the mechanism. The message may include suggestions for items to check.
   - Once an "OK" message is received, the pump is ready to accept commands.

## Initialize with terminal emulation programs

**Note:** In DT mode, a carriage return/line feed is required after the command string (following the [R] command).

1. Issue the [Z] command. An example would be [/1ZR], where /1 represents the address of the pump (address switch setting plus 1).
2. Observe pump:
   - The plunger arm/holder should move, and the valve will turn.
   - Most of the LEDs at the top of the pump should be lit. The ERR LED will be off, and the LIFE LED will be blinking slowly.
3. Issue a [Q] command to confirm initialization, for example [/1Q].
   - If initialization was successful, the response will indicate so.
   - If an error occurred during the initialization, an initialization error (error 1) will be returned with the response. Check communication settings and power, or for something blocking the mechanism.
   - Once initialization is successful, the pump is ready to accept commands.

## Check LED indicators

Diagnostic LEDs are provided to assist in monitoring the functioning of the pump. Please refer to Figure 4-6, below.

**Note:**

- Valve sensor LEDs indicate either at home or in other designed position.
- The solenoid LED is not functional.
- If the Error LED is blinking, see Table 7-1 (page 107) for instructions.

### Figure 4-6. C-Series pumps LED indicators

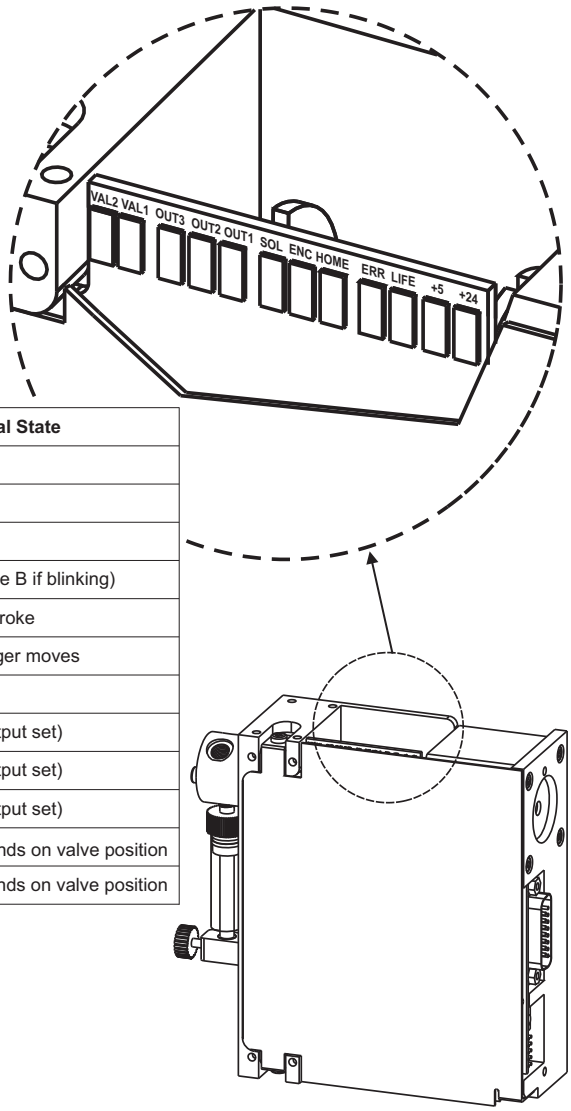



**Table A: LED Functions**

| LED | Function | Normal/Typical State |
|---|---|---|
| +24 | 24 VDC Supply | ON |
| +5 | 5 VDC Regulator | ON |
| LIFE | Processor heartbeat | Blink slowly |
| ERR | Error | OFF (See Table B if blinking) |
| HOME | Top of stroke sensor | ON at top of stroke |
| ENC | Linear encoder sensor | Blinks as plunger moves |
| SOL | Solenoid output | ON |
| OUT1 | Auxiliary output 1 | ON (OFF if output set) |
| OUT2 | Auxiliary output 2 | ON (OFF if output set) |
| OUT3 | Auxiliary output 3 | ON (OFF if output set) |
| VAL1 | Valve sensor | ON/OFF depends on valve position |
| VAL2 | Valve sensor | ON/OFF depends on valve position |

**Table B: ERROR Indications**

| ERR LED | Error |
|---|---|
| OFF | No error |
| 1 blink | Initialization error |
| 2 blinks | EEPROM failure |
| 3 blinks | Plunger overload |
| 4 blinks | Valve overload |

# Install syringe

**Note:** The C24000 pumps must be initialized before the syringe can be installed. This is because these pumps cannot be moved manually. For C24000 pumps, first go to "Initialize pump" (page 31) and return to this procedure after initialization has been performed.

Refer to Figure 4-7 during this procedure.

1. Lower the syringe plunger arm/holder to ensure sufficient room to install the syringe and plunger.
   - C3000 pumps: if the pump is powered off, manually lower the plunger by pushing firmly down on the syringe plunger arm/holder. If the power is on, this can be done by sending the command [A3000R].
   - C24000 pumps: with the power on, send the command [A24000R]. The plunger cannot be manually lowered on the C24000 pump due to the high resolution of the drive system.
2. Make sure the plunger is fully seated in the syringe, to ensure the length is short enough to fit into the available space.

**⚠CAUTION**

**CAUTION:**

- Do not overtighten the syringe or fittings. This can cause damage to the syringe and valve, which can lead to leakage and reduced life. Do not exceed 21 oz-in. torque on either the syringe or fittings.
- Do not use Teflon® tape on syringe or fitting threads. All syringe port seals are face seals (not thread sealing). Use of Teflon® tape can lead to valve damage due to over stress on the valve seat from excessive torque applied to the syringe or fittings.

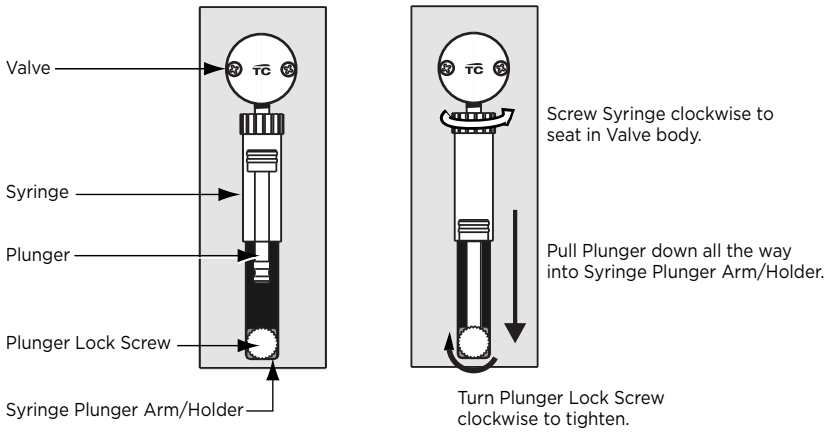
3. Screw the threaded portion of the syringe clockwise into the valve (hold the syringe by the knurled portion when screwing it into the valve).
4. Tighten the syringe until it bottoms in the valve, then tighten another 1/4 turn (this roughly corresponds to 16 oz-in). If a more secure installation is needed, loosen the syringe and repeat the process approximately 24 hours later. *The maximum torque specification is 21 oz-in.*

**⚠CAUTION**

**CAUTION:** Do not exceed the maximum torque specification of 21 oz-in. This can cause damage to the syringe and valve, which can lead to leakage and reduced life.

5. Pull the plunger down and fully seat it into the syringe plunger arm/holder.
6. Securely tighten the plunger lock screw by turning clockwise.

## Figure 4-7. Installing syringe



# Connect tubing

For fluid connections, the standard C-Series valves are equipped with 1/4-28″ ports for the tubing fittings.

**⚠CAUTION**

**CAUTION:** Be sure to check fluid compatibility with the materials in the valve, syringe, and plunger seal. Refer to the Chemical compatibility chart on page 142.

### Procedure

Connect tubing to pump and fluid source and outlet according to your instrument design and the tubing supplier's instructions.

**⚠CAUTION**

**CAUTION:** Do not exceed the maximum torque specification of 21 oz-in. This can cause damage to the valve, causing leakage and reduced life.

**Note:** If more information is needed about valve port options, refer to "Valve movements" (page 48) and the associated illustrations.

The following application information may also be helpful:

- "Optimizing pump performance" (page 145)
- "Optimizing tubing performance" (page 147)
- "Precision and accuracy" (page 143)

# 5 Operating instructions

**⚠CAUTION**

**CAUTION:** After connecting fluids, the initialization command will result in fluid movement. Make sure the pump is properly plumbed and there are no leaks. Otherwise the fluid movement can result in spills.

Always run liquid through the syringe and valve when issuing a move command. Failure to do so will eventually wear out the valve and syringe seal.

## About this chapter

This chapter describes how to operate the C-Series pumps once the following have been done (described in the previous chapter):

- Physical and electrical installation has been completed.
- Tubing has been installed and connections with fluid have been made.

This chapter includes:

# Operation overview

Operation consists of:

- Initializing the pump with input/output ports defined for your application
- Priming syringe and tubing
- Programming the moves and making the settings that are described following "Priming syringe and tubing"

# Interface requirements review

Interface requirements are described in the preceding chapter, Installation instructions. This is a summary. For full information, refer to "Protocol and interface options" (page 17).

### Communication protocols and standards

The C-Series Syringe Pumps use the following communication standards.

- RS232
- RS485
- CAN

CAN is a unique communication standard with a unique protocol. Communication protocols and standards are described in more detail in Chapter 9, Reference information (page 113).

### RS232/485 protocols

Two communication protocols are available for RS232/485:

- OEM communications protocol
- Data Terminal (DT) protocol

The C-Series firmware automatically detects which RS232/485 protocol is in use. There is a built-in RS232-to-RS485 converter, which allows RS232 ports to communicate with pumps on the built-in RS485 bus.

When not using a terminal program for RS232/RS485, the OEM protocol is recommended. It provides robust error checking and recovery.

# Command guidelines

The C-Series features a robust command set which allows a wide range of pump actions. Many of the commands have default arguments; these are frequently-used values that, when used, can help minimize the length of command strings. Take a moment to familiarize yourself with each command in order to obtain the best performance for your application.

For a quick summary of all commands, see "Command summaries" at the end of this chapter.

## Command structure

Each command consists of a pump address, one or more commands, and (with exceptions) a Run command [R].

Example: [/2A3000R] (This example uses DT protocol.)

Breakdown:

| | |
|---|---|
| / | Start of command. |
| 2 | Pump address 2 (see "Addressing" below). |
| A | Move to absolute position. |
| 3000 | The magnitude of the move, which is 3000 position increments. The size of an increment is determined by the N (increment mode) command. |
| R | Run. Execute the command string. [R] is not required for certain classes of commands. |

**Note:** In DT mode, a carriage return/line feed is required after the command string (following the [R] command).

## Addressing

As part of the communications protocol, every command string must begin with an address for the intended pump(s).

Example: [/2A3000R], where 2 is the device address. (This example uses DT protocol.)

- The device address = address switch setting + 1. So if the address switch is set to 1, the address is 2. There are sixteen possible addresses on the bus.
- When using RS232/RS485 protocol, multiple-pump addressing is available. Two pumps, four pumps, or all 16 pumps may be addressed at once.

For more information, refer to "Pump addressing scheme" (page 114).

## Command syntax

The syntax used in this manual for describing commands in the command set is as shown here:

| Convention | Description |
|---|---|
| [command] | The name of the command; the command itself (or a string). Commands are case-sensitive. |
| <n> | Operand (command argument). For example, [A<n>] represents the A (absolute move) command and operand <argument>. The argument must be a value within the valid operand range. |
| 0...6000 | Valid operand range of numerical <argument> |
| (n) | Default <argument>, if no argument is included in command when issued |
| {n} | Power-up default value<br><br>**Note:**<br>• If only a power-up default value is shown for an <argument>, both default values are the same.<br>• If no default value is shown, there is none.<br>• If there is no default value for an <argument>, a value must be included with the command for the command to be valid. |

The symbols [ ], <>, ( ), and { } are not to be sent as part of a command.

## Command execution guidelines

To enter commands properly, keep the following in mind:

- Commands are case-sensitive.
- All commands, except report commands and most control commands, must be followed by an [R] (Run or Execute) command.
- When in DT mode, a carriage return/line feed is needed after each command string, following the [R] command, to send the string to the pump.
- Single or multiple commands can be sent to the pump within a string.

  For example:

  - A single command such as [A3000R] moves the plunger to position 3000.
  - A multi-command string such a [IA3000OA0R] moves the valve to the Input position [I], moves the plunger to position 3000 [A3000], turns the valve to the output position [O], and finally returns the plunger to position 0 [A0].
- The pump's command buffer holds a maximum of 255 characters.
- Once a command is in the process of being executed, the pump is busy and will not accept new commands until the sequence is completed. If a new command is issued while the pump is busy, a command overflow error code will be issued and the command string will be ignored. Exceptions to this rule include the [T] (terminate), [V] (top velocity), and most report commands. The busy/idle status is determined by polling the pump with the [Q] command.
- When a command is sent, the pump answers immediately (except in multi-address mode).
- If an invalid command is sent within a command string, the pump reports an error immediately. The error codes are described in "Status and error codes" (page 88). If there was an invalid parameter, in certain cases the string will execute until the invalid parameter is reached and then stop. In all cases, the [Q] query command is used to read back the error.

## Execution controls

Command strings may contain controls which modify command execution. Examples are the [R] command, halt and wait for an external signal [H], and commands that initiate loops (repeat sequences) [g] [G]. For details on these commands, refer to "Execution control commands" (page 73).

# Initializing pumps

During installation, an initialization was performed using default settings. Your application is likely to require more specific settings than those the defaults provide.

This section describes the initialization sequence, and the commands and options available for customizing the initialization settings to accommodate your application.

Once the valve is initialized with the input/output ports defined for your application, priming can proceed.

**Note:**

- For consistency in initialization, it is recommended that initialization always be performed in the normal increment mode (the default mode). For details on increment modes, see "Set plunger resolution (increment) mode (N)" (page 62).
- The following descriptions mention valve configuration using various [U] commands. These configurations are considered factory-only options, which are set appropriately during manufacture. It is assumed that the user knows what kind of valve the pump has, and that the valve selection setting is correct for that particular valve.
- On power-up, the C-Series pump automatically homes the valve motor. This feature can be disabled if desired.

## Initialization sequence

The typical initialization sequence, in response to the [Z] or [Y] command, is as follows:

1. Valve is homed to output right position with the [Z] command, or output left with the [Y] command.

   Output position is assigned to the right or left by the [Z] or [Y] command.
2. Syringe motor speed and stall force are set by [Z] or [Y] arguments.
3. If pump is at top of stroke, valve moves to input and plunger moves down and out of home opto.
4. Valve moves to output; plunger moves up until home opto is tripped.
5. Plunger is then stalled at the top of the syringe.
6. Valve moves to input; syringe travels downward a fixed number of increments.
7. Valve moves to output; syringe moves up and stops at syringe gap volume <k> increments away from the stall position.

The output position of the valve is assigned to the left or right side, depending upon the Initialization command [Z] or [Y], and all syringe velocity parameters ( [V], [v], [c] and [L] ) are reset to default values. Increment mode [N] retains its value.

The complete set of initialization commands is described on the following pages.

# Initialization commands

### Initialize pump, set valve output to the right (CW polarity) (Z<n1,n2,n3>)

The [Z] command initializes the plunger drive and sets a non-distribution type valve output to the right (as viewed from the front of the pump).

If a distribution valve is configured, <n2> and <n3> select the input and output ports. Valve movement occurs in a CW (clockwise) motion. If a non-distribution valve is configured, <n2> and <n3> are ignored.

The [Z] command resets the velocity settings ([V], [v] and [c]), and acceleration [L] to power-up defaults. The increment mode [N] is preserved after a [Z] command. For consistency in initialization, it is recommended that initialization always be performed in the normal (N0) mode, which is the default.

Arguments:

| | | |
|---|---|---|
| <n1> | 0...40 | Plunger stall force and speed. |
| <n2> | 0...X | Set the initialization input port on distribution valves, numbered clockwise from syringe port. X = number of ports. (Ignored for non distribution valves.) |
| <n3> | 0...X | Set the initialization output port on distribution valves, numbered clockwise from syringe port.X = number of ports. (Ignored for non distribution valves.) |
| (n1) | 0 | Default argument |
| (n2) | 1 | Default argument |
| (n3) | X | Default argument, X = number of ports |

Argument <n1> options:

| <n1> options | Description |
|---|---|
| 0 | Initializes at full plunger stall force at defined speed 11 (default). Recommended for syringes 1.0 mL and larger. |
| 1 | Initializes at half plunger stall force at defined speed 11. Recommended for 250 µL and 500 µL syringes. |
| 2 | Initializes at one third plunger stall force at defined speed 11. Recommended for 50 µL and 100 µL syringes. |
| 3 | Initializes at full plunger stall force at defined speed 16. |
| 4 | Initializes at full plunger stall force at defined speed 18. |
| 5...9 | Same as <n> = 0 |
| 10...40 | Initializes at full plunger force and at defined speed 10...40 |

Defined speeds are explained in the description for the [S] command (page 69). Slower initialization speeds may be useful when working with viscous fluids or small I.D. (inner diameter) tubing.

Argument <n2> options:

| <n2> options | Description |
|---|---|
| 0 | Set the input initialization port to 1 (default). |
| 1...X | Set the input initialization port to a non-default port. X = number of ports on the valve. |

Argument <n3> options:

| <n3> options | Description |
|---|---|
| 0 | Set the output initialization port to X (default). |
| 1...X | Set the output initialization port to a non-default port. X = number of ports on the valve. |

Distribution valve ports are numbered 1...X starting in a CW direction from the syringe port. See Figures 5-5 (page 57) and 5-6 (page 58).

### Initialize pump, set valve output to the left (CCW polarity) (Y<n1,n2,n3>)

The [Y] command initializes the plunger drive and sets a non-distribution valve output to the left (as viewed from the front of the pump).

If a distribution valve is configured, <n2> and <n3> select the input and output ports, and movement occurs in a CCW (counterclockwise) direction. If a non-distribution valve is configured, <n2> and <n3> are ignored.

The [Y] command resets the velocity settings ([V], [v] and [c]), and acceleration [L] to power-up defaults. The increment mode [N1 or N2] is preserved after a [Y] command.

Arguments:

| | | |
|---|---|---|
| <n1> | 0...40 | Plunger stall force and speed. |
| <n2> | 0...X | Set the initialization input port on distribution valves, numbered counter-clockwise from syringe port. X = number of ports. |
| <n3> | 0...X | Set the initialization output port on distribution valves, numbered counter-clockwise from syringe port. X = number of ports. |
| (n1) | 0 | Default argument |
| (n2) | 1 | Default argument |
| (n3) | X | Default argument, X = number of ports |

Argument <n1> options:

| <n1> options | Description |
|---|---|
| 0 | Initializes at full plunger stall force at defined speed 11 (default). Recommended for syringes 1.0 mL and larger. |
| 1 | Initializes at half plunger stall force at defined speed 11. Recommended for 250 µL and 500 µL syringes. |
| 2 | Initializes at one third plunger stall force at defined speed 11. Recommended for 50 µL and 100 µL syringes. |
| 3 | Initializes at full plunger stall force and at defined speed 16. |
| 4 | Initializes at full plunger stall force and at defined speed 18. |
| 5...9 | Same as <n> = 0. |
| 10...40 | Initializes at full plunger stall force and at defined speed 10...40. |

Defined speeds are explained in the description for the [S] command (page 69). Slower initialization speeds may be useful when working with viscous fluids or small I.D. (inner diameter) tubing.

Argument <n2> options:

| <n2> options | Description |
|---|---|
| 0 | Set the input initialization port to 1. (default) |
| 1...X | Set the input initialization port to non-default value. (X = number of ports on the valve.) |

Argument <n3> options:

| <n3> options | Description |
|---|---|
| 0 | Set the output initialization port to X. (default) |
| 1...X | Set the output initialization port to non-default value. (X = number of ports on the valve.) |

Distribution valve ports are numbered 1...X starting in a CCW direction from the syringe port. This is shown in Figures 5-5 (page 57) and 5-6 (page 58).

### Initialize pump without valve (W<n>)

The [W] command initializes the plunger drive but doesn't initialize the valve drive. The [W] command accepts the same <n1> arguments as the [Z] command.

### Initialize valve only (w<n1,n2>)

The [w] command initializes the valve drive only.

Argument <n1> options:

| <n1> options | Description |
|---|---|
| 0 | Set the input initialization port to 1. (default) |
| 1...X | Set the input initialization port to non-default value. (X = number of ports on the valve.) |

Argument <n2> options:

| <n2> options | Description |
|---|---|
| 0 | Valves homed in CW direction. (default) |
| 1 | Valves homed in CCW direction. |

For <n1> and <n2> to be valid, a distribution valve must be configured. For a 3-way valve, [U11] must be issued to configure appropriately. If the pump is configured for a non-distribution valve, arguments <n1> and <n2> are ignored.

### Specify syringe gap volume (k<n>)

The [k] command sets a gap between the plunger and syringe seal. During initializations, the plunger moves upward until it contacts the top of the syringe, causing a forced stall initialization. The plunger then moves downward 120 full increments, and then upward 120 increments minus the <n> specified amount, leaving a gap between the syringe seal and the top of the plunger. This small gap was designed so that the seal does not hit the top of the plunger each time the syringe moves to the home or zero position. This maximizes the life of the syringe seal.

Arguments:

| | | |
|---|---|---|
| <n> | The offset in increments from the zero or stall position | |
| <n> | 0...120 | increments in N0 mode |
| <n> | 0...960 | increments in N1 or N2 mode (micro-increments) |
| | {24} | Power-up default C3000/C3000MP |
| | {384} | Power-up default C24000/C24000MP |

For example, to offset 10 increments away from the zero position, send the following string:

[k10ZR]

Since [k] only takes effect on initialization, the [k] command is usually followed by an initialization command, [Z] or [Y] as shown on previous pages.

**Note:** Each time the unit is powered down, the [k] value returns to the power-up default setting.

### Perform simulated plunger initialization (z<n>)

The [z] command simulates an initialization of the pump; however, no mechanical movement of either the plunger or valve occurs. The position counter is set to <n>, which becomes home for the plunger.

Arguments for C3000/C3000MP:

| | | |
|---|---|---|
| <n> | 0...3000 | increments in N0 mode |
| <n> | 0...24000 | increments in N1 or N2 mode (micro-increments) |
| <n> | (0) | default argument |

Arguments for C24000/C24000MP:

| | | |
|---|---|---|
| <n> | 0...24000 | increments in N0 mode |
| <n> | 0...192000 | increments in N1 or N2 mode (micro-increments) |

This command can be used to recover from a plunger overload error. Afterwards, the pump must be reinitialized using the [Z] or [Y] commands to set the true home position.

**Note:** Be sure to reinitialize after using the [z] command to ensure correct positioning.

# Priming syringe and tubing

Priming prepares the system for operation by removing air from the syringe and tubing.

1. Run the pump with a full stroke and several cycles to prime the system with the working fluid (e.g. water). The following example is in DT protocol.

   Example priming string:

   [ZV6000gIA3000OA0G3R]

   Initialize [Z]; set priming speed [V6000]; set start of looping sequence [g]; move valve to inlet position and fill, with plunger drawing down to maximum position A3000 [IA3000]; move valve to outlet and dispense, with plunger pushing up to minimum position A0 [OA0]; repeat 3 times [G3].

   - The number of cycles depends on the syringe size and internal volumes of the inlet and outlet tubing connected to the pump.
   - Smaller syringes can be harder to prime due to lower fluid velocity, and require more strokes.

2. Observe for bubbles. If any are observed, run the priming sequence again, perhaps specifying more cycles with the [G] command. Check all connections of tubing and syringe for leaks.

   Surfactants can be added to the working fluid to reduce surface tension and help flush bubbles out of the system. The smallest syringes, 50 µL for example, have been primed with alcohol followed by distilled water to help remove air bubbles.

Once priming has been completed, the pump is ready for comprehensive programming.

# Valve movements

## Valve selection information

The following valve selection instructions are provided for informational purposes, and may be helpful in identifying which pump the instructions in the following section ("Making valve movements") apply to.

No valve selection by the user is needed as this is set by the factory, along with the valve jumper on J2. See "Set configuration jumpers and address switch" (page 22) for J2 details.

Valve characteristics are stored in EEPROM, using the [U] command as shown in Table 5-1, below. In other words, to select a particular valve, one of the [U] command variations shown in the following table are issued.

**⚠CAUTION**

**CAUTION:** This information is provided for informational purposes only. Please contact Customer Service if you would like a different valve for your pump evaluation.

**Table 5-1: Valve selection guide**

| Valve Type | Catalog Number | Material Body/Plug | EEPROM Configuration Command[1] | Reference Figure | Comments |
|---|---|---|---|---|---|
| 3-port 120° Y valve | 10020<br>10021<br>10022<br>10023 | PEEK/UHMWPE<br>PEEK/PTFE<br>PCTFE/UHMWPE<br>PCTFE/PTFE | U1 | 5-1 | Valve jumper[2] installed |
| 4-port 90° valve | 10040<br>10041<br>10042<br>10043 | PEEK/UHMWPE<br>PEEK/PTFE<br>PCTFE/UHMWPE<br>PCTFE/PTFE | U2 | 5-2 | Valve jumper removed |
| 3-way distribution valve | 10062<br>10063 | PCTFE/UHMWPE<br>PCTFE/PTFE | U11 | 5-5 | Valve jumper removed<br>Use with [I]<n> and [O]<n> commands |
| | | | U4 | 5-4 | Valve jumper removed<br>Use with [I],[O],[B] and [E] commands |
| 3-port and 4-port T valves | 10115<br>10125 | PEEK/UHMWPE<br>PEEK/UHMWPE | U5 | 5-3 | Valve jumper removed |
| 6-way distribution valve | 10106 | PCTFE/UHMWPE | U7 | 5-6 | Valve jumper removed |
| 4-port loop valve | Call for availability | | U9 | 5-7 | Valve jumper removed |

1. EEPROM commands require power to be cycled before taking effect. EEPROM commands are non volatile, so they also only need to be issued once.
2. See "Set configuration jumpers and address switch" (page 22).

## Making valve movements

The following pages describe how to make valve movements with the variety of valves available for the C-Series Syringe Pumps.

Descriptions of commands for each type of valve are followed by illustrations which show positions resulting from each command.

**Note:** The illustrations on these pages show valve positions as viewed from the front of the pump.

## Movements for non-distribution valves (3-port and 4-port)

The following commands apply to the 3-port 120° Y valve and the 4-port 90° valve. Refer also to Figures 5-1 and 5-2.

### Move valve to input position (I)

The [I] command moves the valve to the input position. The input position will be either to the left or to the right depending on whether the [Z] or [Y] initialization command was sent first.

For example:

- After [Z] initialization: sets input to left port.
- After [Y] initialization: sets input to right port.

### Move valve to output position (O)

The [O] command moves the valve to the output position. The output position can be either to the right or to the left depending on the [Z] or [Y] initialization commands.

For example:

- After [Z] initialization: sets output to right port.
- After [Y] initialization: sets output to left port.

### Move valve to bypass position (3-port 120° Y valve only) (B)

The [B] command connects the input and output positions, bypassing the syringe. Please see note below.

### Connect flush port to inlet port (4-port 90° valve only) (B)

The [B] command sets the flush port to inlet on left or right, bypassing the syringe. See note below.

- After [Z] initialization: sets the flush port to inlet on left.
- After [Y] initialization: sets the flush port to inlet on right.

### Connect flush port to outlet port (4-port 90°valve only) (E)

The [E] command connects the flush port to an outlet port on the left or right, bypassing the syringe.

- After [Z] initialization: connects the flush port to outlet on right.
- After [Y] initialization: connects the flush port to outlet on left.

**Note:** When the valve is in the [B] or [E] position, the syringe plunger cannot be moved. Sending a plunger move command causes an error 11 (plunger move not allowed).

**Figure 5-1. Positions for 3-port 120° Y valve (U1 config)**

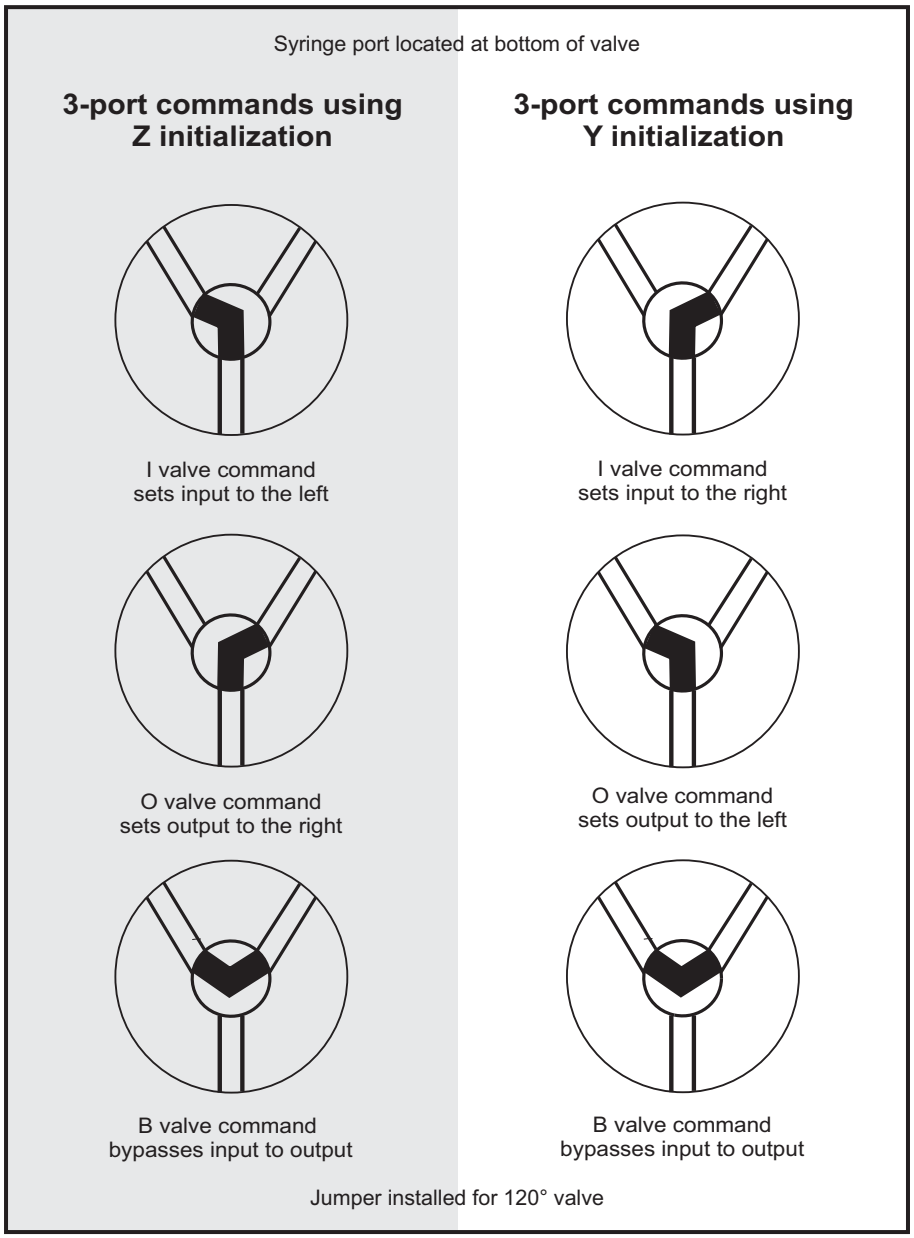
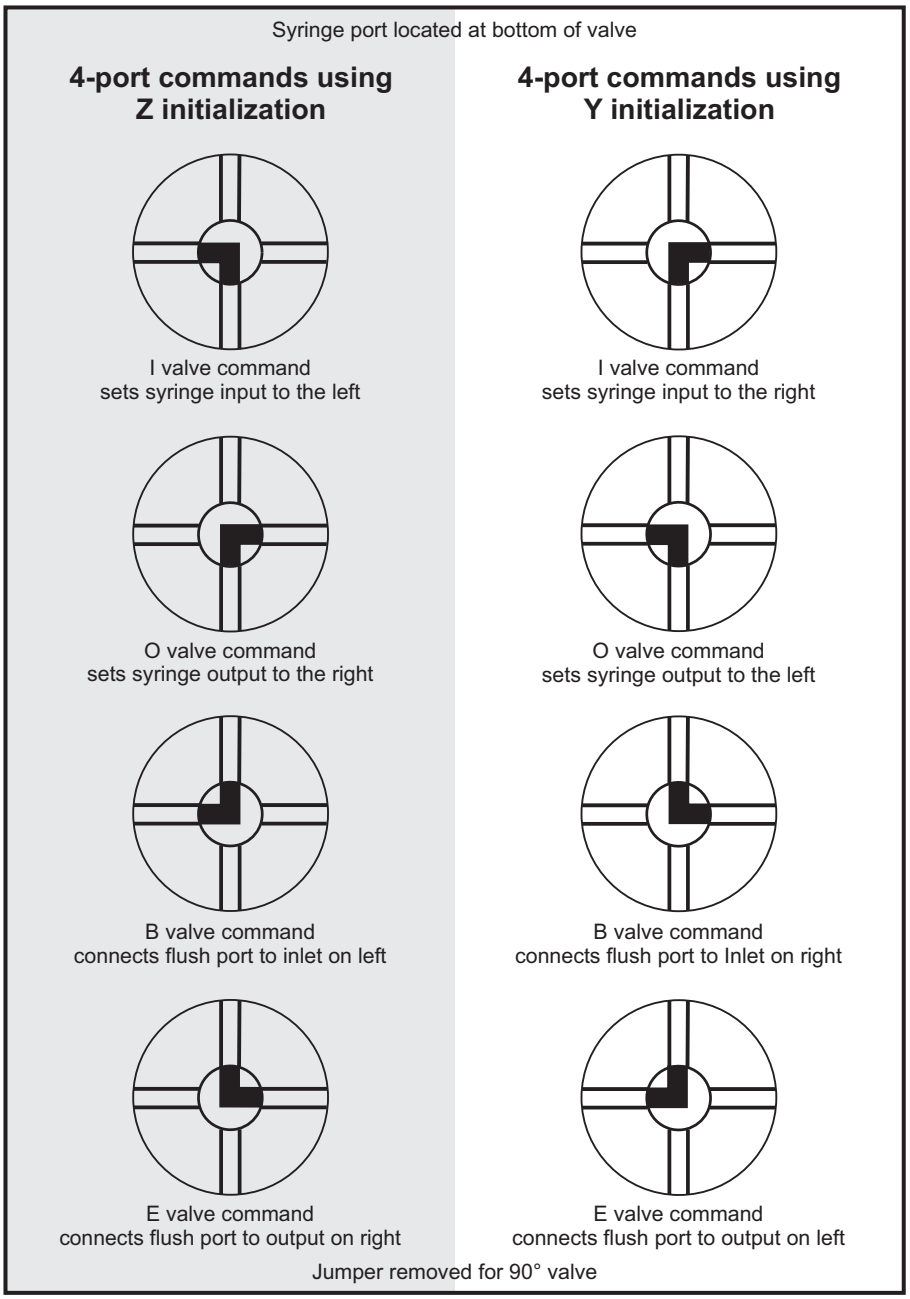


**Figure 5-2. Positions for 4-port 90° valve (U2 config)**



## Movements for T valves (3-port and 4-port)

The following commands apply to the 90° 3-port T and 90°, 4-port T valves. Refer to also to Figure 5-3, which shows valve positions according to valve movement and initialization commands for the 3-port and 4-port T valves.

### Move valve to input position (I)

The [I] command moves the valve to the input position. The input position will be either to the left or the right depending on whether the [Z] or [Y] initialization command was sent first.

- After [Z] initialization: sets input to left port.
- After [Y] initialization: sets input to right port.
- On the 4-Port T valve, the top port is also connected.

### Move valve to output position (O)

The [O] command moves the valve to the output position. The output position can be either to the left or the right depending on the [Z] or [Y] initialization commands.

- After [Z] initialization: sets output to right port.
- After [Y] initialization: sets output to left port.
- On the 4-Port T valve, the top port is also connected.

### Move valve to bypass position (B)

The [B] command connects the input with output and syringe.

Movement is the same regardless of [Z] or [Y] initialization.

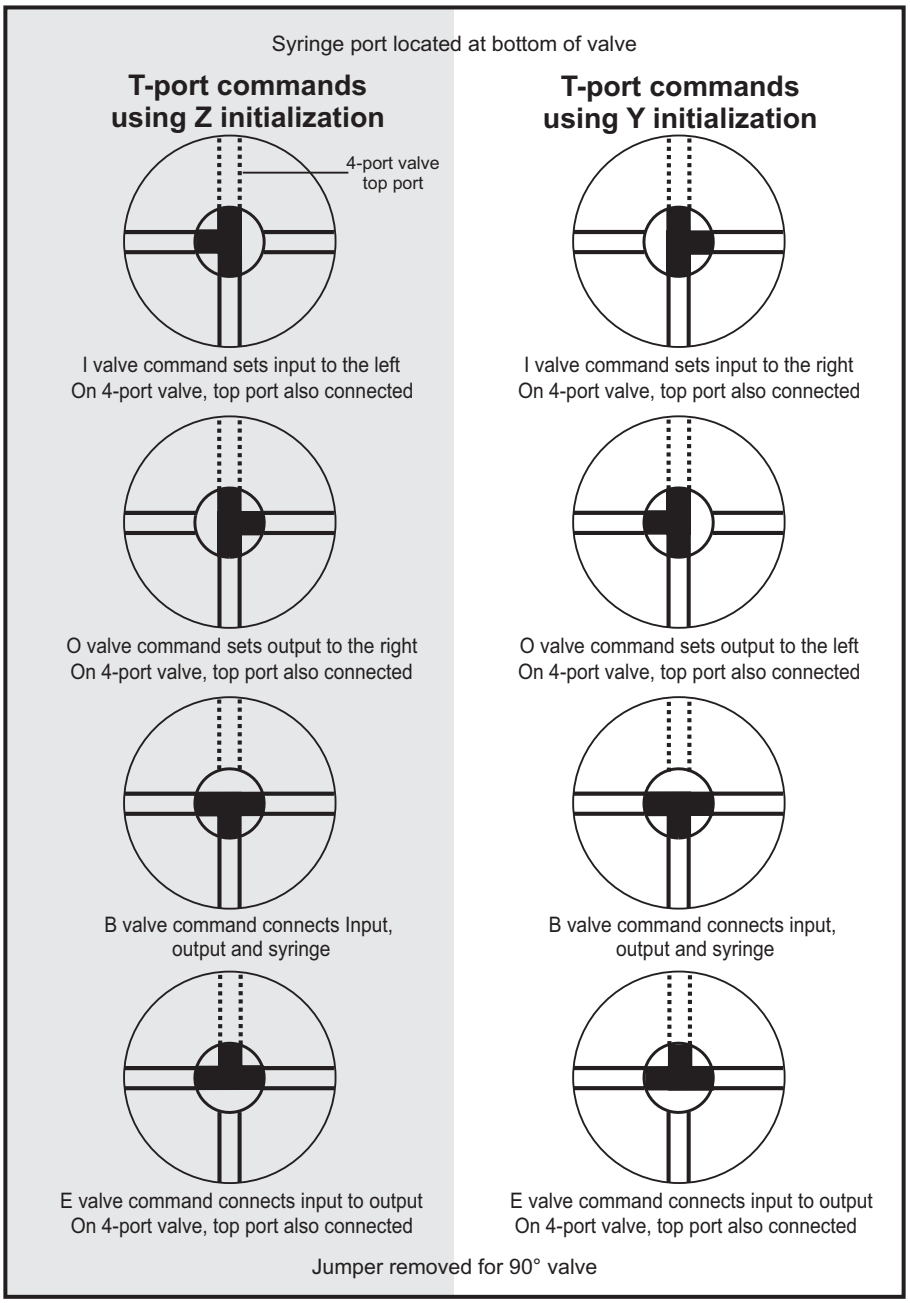
### Bypass input to outlet port (E)

The extra [E] command connects the input and output ports, bypassing the syringe. On the 4-port T valve, the top port is also connected.

Movement is the same regardless of [Z] or [Y] initialization.

**Note:** When the valve is in the extra [E] position, the syringe plunger cannot be moved. Sending a plunger movement command causes an Error 11 (plunger move not allowed).

**Figure 5-3. Positions for 3-port and 4-port T valves (U5 config)**



## Movements for distribution valve (3-way with U4 config)

The following commands apply to the 3-way distribution valve as it behaves when set with the U4 EEPROM configuration command (see "Valve selection information" on page 48.)

In this configuration, the three distribution ports are referred to as left, right, and top. See Figure 5-4 for valve positions vs. commands.

### Set syringe to left/right port (I)

The [I] command sets the syringe to either the left port or the right port, depending on [Z] or [Y] initialization. The positioning is opposite that of the [O] command.

- After [Z] initialization: connects syringe to left port.
- After [Y] initialization: connects syringe to right port.

### Set syringe to right/left port (O)

The [O] command sets the syringe to either the right port or the left port, depending on [Z] or [Y] initialization. The positioning is opposite that of the [I] command.

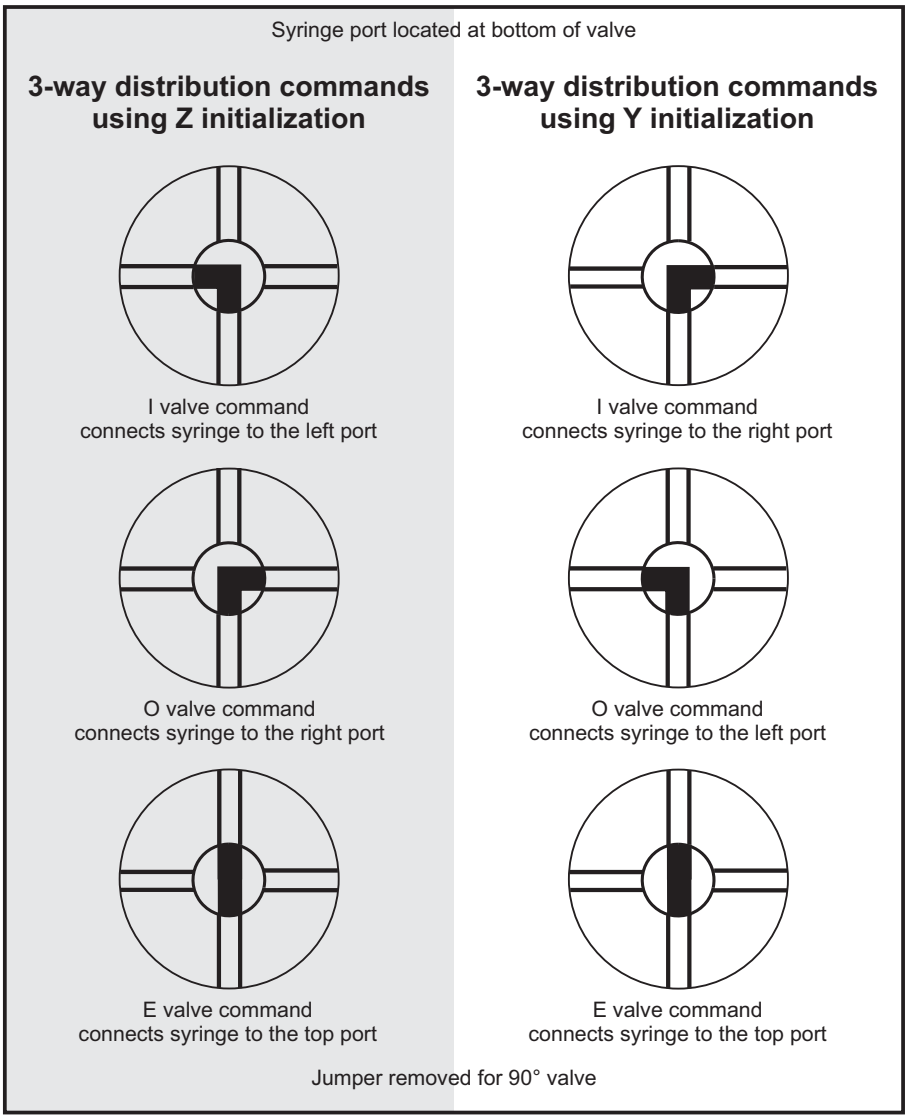
- After [Z] initialization: connects syringe to right port.
- After [Y] initialization: connects syringe to left port.

### Set syringe to top port (E or B)

The [E] and [B] commands both connect the syringe to the top port. Their use is interchangeable.

Movement is the same regardless of [Z] or [Y] initialization.

**Figure 5-4. Positions for 3-way distribution valve (U4 config)**



# Movements for distribution valves (3-way with U11 config; and 6-way)

The commands below apply to two distribution valves:

- The 3-way distribution valve when configured with the U11 command
- The 6-way distribution valve

For these valves, the distribution ports are numbered from the left or right, depending on whether the [Z] or [Y] initialization preceded the positioning commands.

- After [Z] initialization: ports are numbered from left to right (clockwise).
- After [Y] initialization: ports are numbered from right to left (counter clockwise).

Ports are numbered 1 through 3 for the 3-way distribution valve, and 1 through 6 for the 6-way distribution valve.

Refer to Figure 5-5 and Figure 5-6 to view valve positions vs. commands.

## Move valve clockwise to specific distribution port (I<n>)

The [I]<n> command moves the distribution valve to port <n> in a clockwise motion.

| | | |
|---|---|---|
| <n> | 1...X | assigned port, where X = number of distribution ports on valve, and therefore the highest-numbered port. The syringe port is excluded from the count. For a 3-way valve X=3, and for a 6-way valve X=6. |
| | 0 | Sets valve to port 1. |
| | (1) | Default argument |

Example: [I2] moves valve to distribution port 2.

Movement is the same regardless of [Z] or [Y] initialization.

## Move valve counterclockwise to specific distribution port (O<n>)

The [O]<n> command moves the distribution valve to the port <n> in a counterclockwise motion.

| | | |
|---|---|---|
| <n> | 1...X, | assigned port, where X = number of distribution ports on valve, and therefore the highest-numbered port. The syringe port is excluded from the count. For a 3-way valve X=3, and for a 6-way valve X=6. |
| | 0 | Sets valve to port X. |
| | (X) | Default argument |

Example: [O3] moves valve to distribution port 3.

Movement is the same regardless of [Z] or [Y] initialization.

**⚠CAUTION**

**CAUTION:** Due to the smaller internal port diameters of the 6-way distribution valve, it is recommended that fluid velocity does not exceed 1500 µL/sec when using this valve. Use caution when setting velocity with 2.5 mL and larger syringe sizes, to avoid cavitation and excessive syringe back pressure. Refer also to "Calculating flow rates" (page 139).

**Figure 5-5. Positions for 3-way distribution valve (U11 config)**

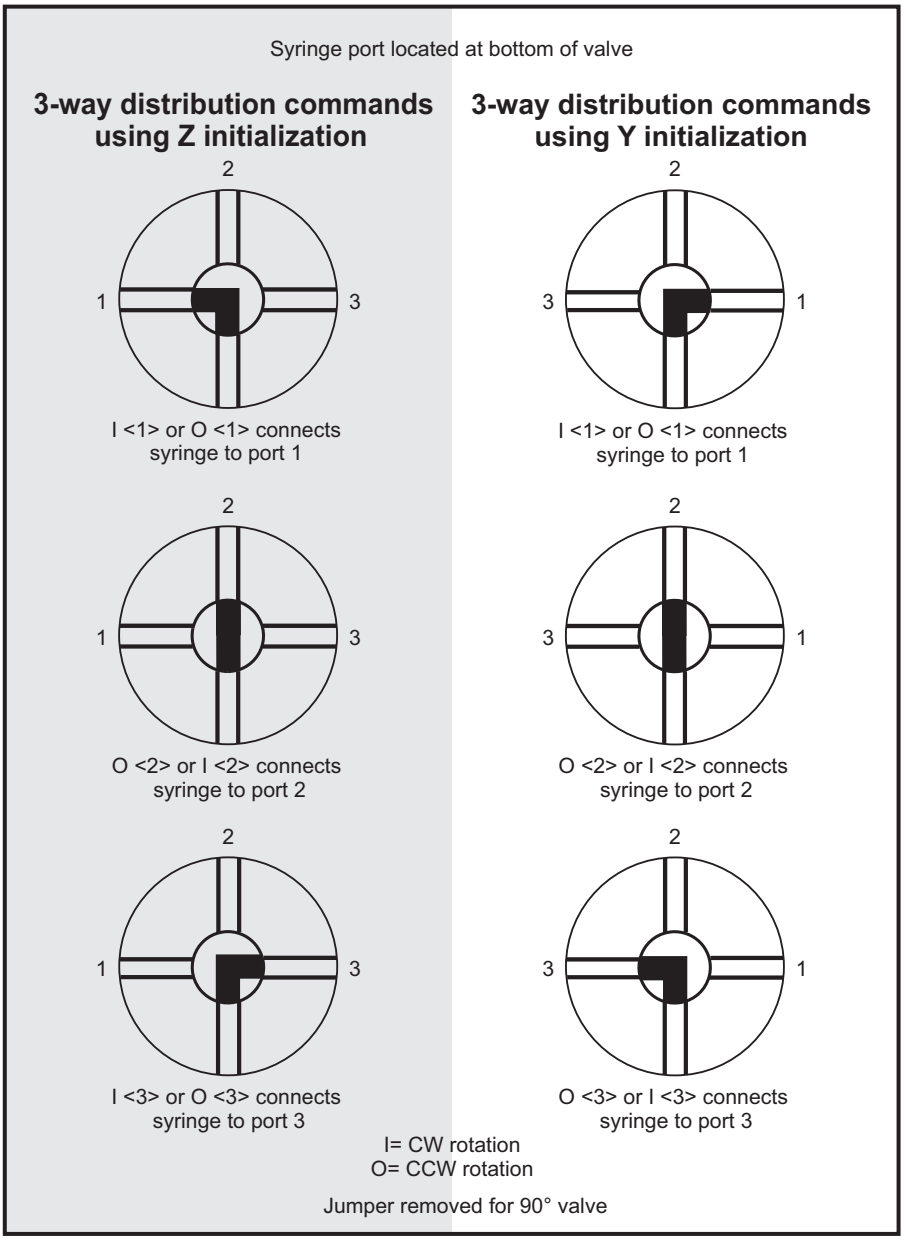
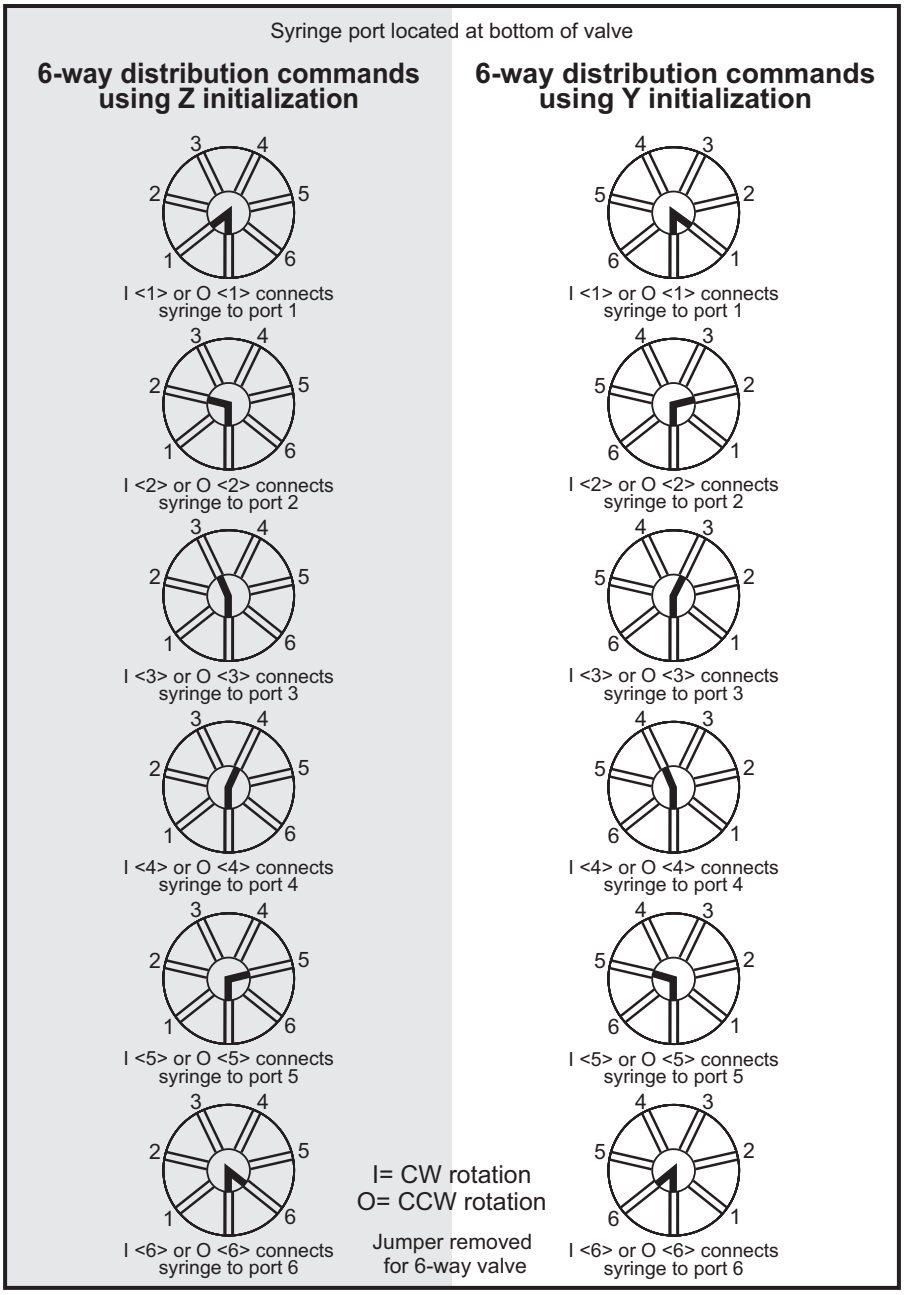


**Figure 5-6. Positions for 6-way distribution valve (U7 config)**



## Movements for 4-port loop valve

The following commands apply to the 4-port loop valves (see "Valve selection information" (page 48).

In this configuration the four ports are referred to as left, right, top, and syringe. Refer also to Figure 5-7 (page 60), which shows valve positions according to valve movement and initialization commands for the 90° 4-port loop valve.

With [Z] initialization the valve rotates 90° CW when transitioning from [I], to [E], to [O], and to [B]. With the [Y] initialization the valve rotates CCW in the same valve position sequence.

### Move loop to input position (I)

The [I] command moves the valve to the input position. The input position will be different depending on whether the [Z] or [Y] initialization command was sent first.

- After [Z] initialization: connects left port to syringe, and top port to right port.
- After [Y] initialization: connects top port to right port, and left port to syringe.

### Move loop to extra port (E)

The [E] command moves the valve to the extra position. The extra position is the same for either the [Z] or [Y] initialization command.

- Connects left port to top port, and right port to syringe.

### Move loop to output position (O)

The [O] command moves the valve to the output position. The output position can be either to the left or the right depending on the [Z] or [Y] initialization commands.

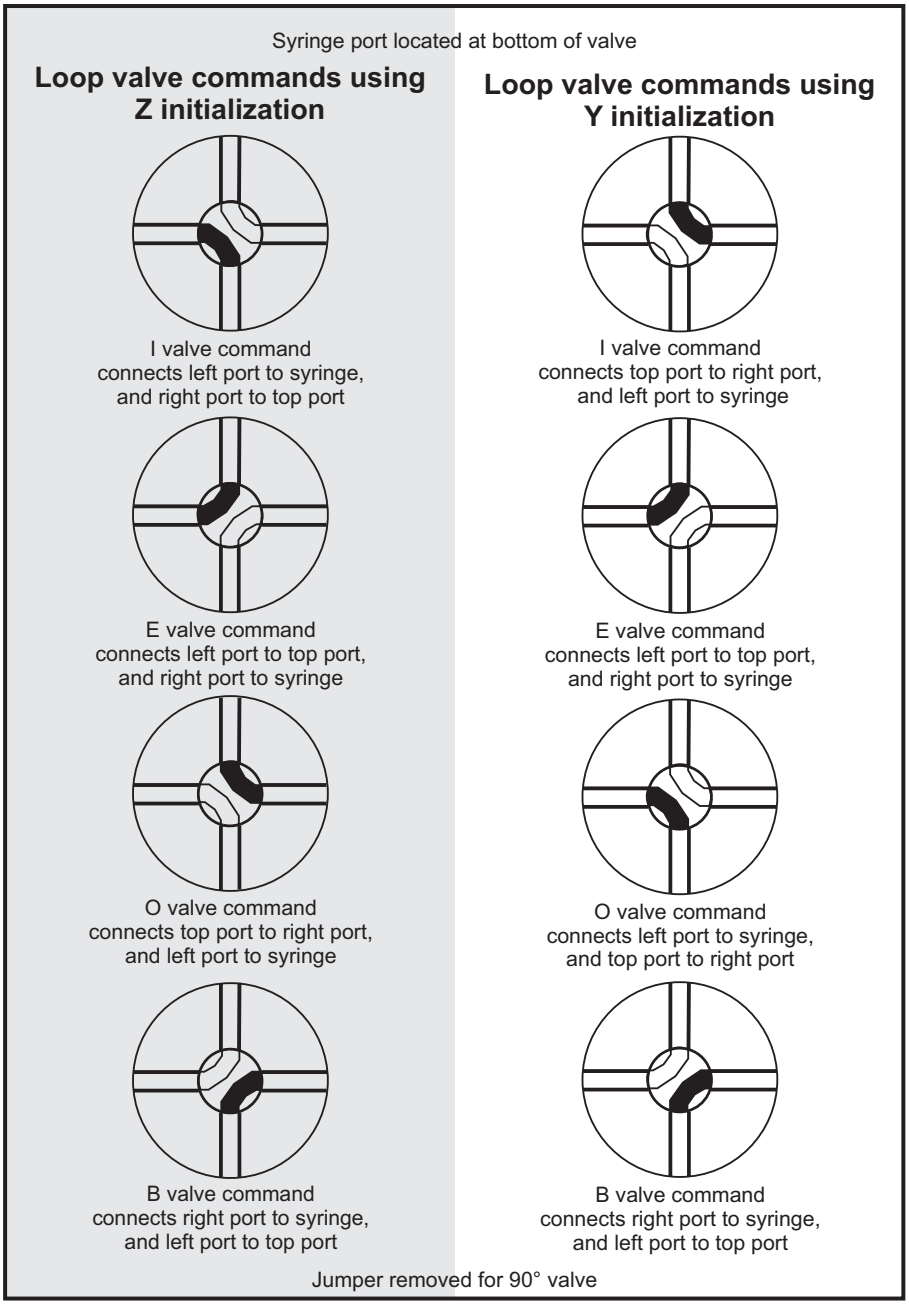
- After [Z] initialization: connects top port to right port, and left port to syringe.
- After [Y] initialization: connects left port to syringe, and top port to right port.

### Move loop to bypass position (B)

The [B] command moves the valve to the bypass position. The bypass position is the same for either the [Z] or [Y] initialization command.

- Connects right port to syringe, and left port to top port.

**Figure 5-7. Positions for 4-port loop valve (U9 config)**



# Plunger movements

The following pages describe how to make plunger movements on the C-Series Precision Syringe Pumps.

The range of the command arguments can vary depending on the specific pump model, e.g., C3000/C3000MP or C24000/C24000MP.

In addition, arguments vary according to the increment (resolution) mode set by the [N] command (described on page 62). For this reason, the increment mode should be decided upon before programming begins.

## Increments and resolution

### Increments

The term “increment” is used in the commands for plunger moves and positions, and for setting velocity/acceleration parameters.

An increment is the smallest available plunger movement, and indicates the available positioning resolution. The size of an increment will vary with the pump model and with the setting of the [N] command (refer to "Set plunger resolution (increment) mode (N)" (page 62). The increments in the higher resolution mode are sometimes referred to as “micro-increments.”

## Set plunger resolution (increment) mode (N)

The resolution should be decided upon and set before programming plunger moves. Normal resolution is adequate for most purposes. Higher resolution is useful when greater precision in movement is required, or very low velocity operation is needed.

The [N] command sets the resolution, that is, increments per stroke. It allows you to select a higher resolution for plunger movement, positioning, and/or velocity in order to obtain finer control.

These settings also apply to position and velocity reporting.

Arguments:

| | | |
|---|---|---|
| <n> | 0 | N0, normal increment mode |
| | 1 | N1, micro-increment mode for plunger positioning only, which is 8X resolution of normal increment mode. Plunger velocity settings remain in normal increment mode. |
| | 2 | N2, micro-increment mode for both positioning and velocity |
| | {0} | Power-up default |

Increment mode vs. full stroke:

| Increment Mode | Increments/full stroke, C3000/C3000MP | Increments/full stroke, C24000/C24000MP |
|---|---|---|
| N0 | 3,000 increments | 24,000 increments |
| N1 | 24,000 (8 * 3,000) | 192,000 (8 * 24,000) |
| N2 | 24,000 (8 * 3,000) | 192,000 (8 * 24,000) |

**Note:**

- Changing between N0 or N1 mode and N2 mode does not automatically scale the existing velocity and acceleration settings to maintain the same velocity/acceleration. Thus, going to N2 from N0 or N1 without changing the velocity/acceleration settings will cause the plunger to move 8 times slower. Also, going from N2 mode to N1/N0 mode without changing velocity/acceleration settings can cause inadvisable settings.
- For initialization consistency, always perform initializations in normal (N0) mode.
- These parameters may be changed with the [u] command. However, it is recommended that Customer Service be consulted before utilizing the [u] command. Otherwise unwanted pump behavior can result.

## Converting increments to volume resolution

To convert increments to volume resolution, divide the syringe volume by the number of increments as determined by the pump model and the [N] command.

Examples

- 1 mL syringe on C3000 in N0 mode:
  volume = 1000 µL/3000 = 0.3333 µL/increment
- 1 mL syringe on C24000 in N0 mode:
  volume = 1000 µL/24000 = 0.0417 µL/increment
- 1 mL syringe on C3000 in N1 or N2 mode:
  volume = 1000 µL/24000 = 0.0417 µL/increment
- 1 mL syringe on C24000 in N1 or N2 mode:
  volume = 1000 µL/192000 = 0.0052 µL/increment

# Plunger move commands

### Move plunger to absolute position (A<n>)

The [A] command moves the plunger to absolute position <n>.

Arguments for C3000/C3000MP:

| | | |
|---|---|---|
| <n> | 0...3000 | increments in N0 mode |
| <n> | 0...24000 | increments in N1 or N2 mode (micro-increments) |
| | (0) | default argument |

Arguments for C24000/C24000MP:

| | | |
|---|---|---|
| <n> | 0...24000 | increments in N0 mode |
| <n> | 0...192000 | increments in N1 or N2 mode (micro-increments) |

For example:

[A300R] moves the syringe plunger to position 300.

[A600R] moves the syringe plunger to position 600.

### Move plunger to absolute position, not busy (a<n>)

This is the same as the [A] command, except the status bit within the reply string, and any subsequent query [Q] commands, indicates that the pump is not busy.

### Make relative pickup (aspirate) move (P<n>)

The [P] command moves the plunger down the number of increments <n> commanded. The new absolute position is the previous position plus <n>.

Arguments for C3000/C3000MP:

| | | |
|---|---|---|
| <n> | 0...3000 | increments in N0 mode |
| <n> | 0...24000 | increments in N1 or N2 mode (micro-increments) |
| | (0) | default argument |

Arguments for C24000/C24000MP:

| | | |
|---|---|---|
| <n> | 0...24000 | increments in N0 mode |
| <n> | 0...192000 | increments in N1 or N2 mode (micro-increments) |

For example:

The syringe plunger is at position 0. The command [P300] moves the plunger down 300 increments. A subsequent [P600] command moves the plunger down 600 additional increments to an absolute position of 900.

The [P] command will return an invalid operand error (error 3) if the final plunger position is greater than 3000 (24000 in N1 or N2 mode) for the C3000/C3000MP.

### Make relative pickup (aspirate) move, not busy (p<n>)

This is the same as the [P] command, except that the status bit of the reply string, and any subsequent query [Q] commands, indicate that the pump is not busy.

### Make relative dispense (D<n>)

The [D] command moves the plunger upward the number of increments <n> commanded. The new absolute position is the previous position minus <n>.

Arguments for C3000/C3000MP:

| | | |
|---|---|---|
| <n> | 0...3000 | increments in N0 mode |
| <n> | 0...24000 | increments in N1 or N2 mode (micro-increments) |
| | (0) | default argument |

Arguments for C24000/C24000MP:

| | | |
|---|---|---|
| <n> | 0...24000 | increments in N0 mode |
| <n> | 0...192000 | increments in N1 or N2 mode (micro-increments) |

For example:

The syringe plunger is at position 3000. [D300] will move the plunger up 300 increments to an absolute position of 2700.

The [D] command will return an invalid operand error (error 3) if the final commanded plunger position would be less than 0.

### Make relative dispense, not busy (d<n>)

This is the same as the [D] command, except that the status bit of the reply string, and any subsequent query [Q] commands, indicates that the pump is not busy.

# Configuring plunger movement

Configuration commands are used to set up pump plunger movement characteristics. These include settings for plunger acceleration/deceleration slope, velocity, acceleration, cutoff, defined speeds, and backlash.

## Velocity and acceleration configuration commands

Velocity and acceleration configuration commands are used to control the motion of the plunger. Plunger movement is structured into three phases:

- Ramping up. Plunger movement begins at the start velocity and accelerates with the programmed slope [L] to the constant or top speed.
- Constant or top speed. The plunger moves at the constant or top speed. Plunger speed or velocity can be programmed in increments/sec or in preset speeds [S]. The actual time the plunger travels depends on the ramping up and down. If the plunger move is short, it may never reach top speed.
- Ramping down. The plunger will decelerate based on the programmed deceleration slope [L]. To enhance fluid break-off, the Cutoff command [c] can be used to define the end velocity of the plunger just before it stops.

For each plunger move, the firmware calculates how many increments the plunger must travel during each phase in order to move the total number of increments commanded.

The top velocity can be changed on the fly (while the plunger is moving) using the [V] command. When the move completes, the speed value reverts back to its original values.

In the N0 and N1 increment modes, velocity and acceleration settings are configured and reported in increments/sec. In the high resolution increment mode (N2), they are set up and reported in micro-increments, which provide 8X the resolution as the N0 mode.

## Difference between C24000/C24000MP and C3000/C3000MP velocity settings

Since the C24000 and C24000MP have a 4 times finer lead screw pitch than the C3000/C3000MP, the linear velocity is 1/4 as fast for a given velocity setting.

Thus, to aspirate/dispense at the same rate, the Top Velocity command [V] needs to be multiplied by 4 for the C24000/C24000MP. For example [V1000] in the C3000/C3000MP is equivalent to [V4000] in the C24000/C24000MP.

The same relationship applies to other velocity and acceleration commands.

### Set acceleration/deceleration slopes (L<n>)

During the beginning and end of a move, the plunger speed ramps up and down respectively. The ramp is programmed using the Set Slope [L] command. It is calculated as <n> x 2,500 increments/sec^2.

Arguments (slope codes):

| | | |
|---|---|---|
| <n> | 1...20 | slope code (see table below) |
| | {14} | power-up default |

Slope codes and corresponding acceleration/deceleration values:

| Slope code | N0 or N1 mode increments/sec^2 | N2 mode micro-increments/sec^2 |
|---|---|---|
| 1 | 2,500 | 20,000 |
| 2 | 5,000 | 40,000 |
| 3 | 7,500 | 60,000 |
| 4 | 10,000 | 80,000 |
| 5 | 12,500 | 100,000 |
| 6 | 15,000 | 120,000 |
| 7 | 17,500 | 140,000 |
| 8 | 20,000 | 160,000 |
| 9 | 22,500 | 180,000 |
| 10 | 25,000 | 200,000 |
| 11 | 27,500 | 220,000 |
| 12 | 30,000 | 240,000 |
| 13 | 32,500 | 260,000 |
| 14 | 35,000 | 280,000 |
| 15 | 37,500 | 300,000 |
| 16 | 40,000 | 320,000 |
| 17 | 42,500 | 340,000 |
| 18 | 45,000 | 360,000 |
| 19 | 47,500 | 380,000 |
| 20 | 50,000 | 400,000 |

### Set start velocity (v<n>)

The [v] command sets the velocity at which the plunger begins its movement.

Arguments:

| | | |
|---|---|---|
| <n> | 1...1000 | increments/sec, N0 or N1 mode |
| <n> | 1...8000 | increments/sec, N2 mode (micro-increments) |
| | {900} | power-up default |

After beginning at the start velocity, the plunger ramps up to the top velocity [V]. The start velocity normally should always be less than the top velocity. If not, the plunger will decelerate from its start velocity [v] to its top velocity [V].

### Set top velocity (V<n>)

The [V] command sets the top velocity in increments/sec.

Arguments:

| | | |
|---|---|---|
| <n> | 1...6000 | increments/sec, N0 or N1 mode |
| <n> | 1...48000 | increments/sec, N2 mode (micro-increments) |
| | {1400} | power-up default, C3000/C3000MP |
| | {5600} | power-up default, C24000/C24000MP |

The top velocity can be changed “on the fly,” that is, while the plunger is moving, using the [V] command. When the move completes, the speed reverts back to its original value. Thus, on-the-fly velocity changes only affect the current move.

On-the-fly velocity changes are limited to a maximum of 2000. Any requested changes greater than 2000 will result in an invalid operand error (error 3).

If the cutoff velocity [c] is higher than the desired top velocity [V], the cutoff velocity [c] is changed to equal the top velocity [V].

The [c] cutoff velocity does not revert back to its original value when the top velocity [V] is changed back.

For assistance in selecting the most appropriate top velocity, refer to "Calculating flow rates" (page 139).

**⚠CAUTION**

**CAUTION:** Due to the smaller internal port diameters of the 6-way distribution valve, it is recommended that fluid velocity does not exceed 1500 µL/sec when using this valve. Use caution when setting velocity with 2.5 mL and larger syringe sizes, to avoid cavitation and excessive syringe back pressure.

### Set cutoff velocity in increments/sec (c<n>)

The [c] command sets the cutoff velocity. The cutoff velocity is the velocity at which the plunger ends its movement. The plunger will slope down [L] from the top velocity [V]. The [c] command overwrites the [C] command.

Arguments:

| | | |
|---|---|---|
| <n> | 1...2700 | increments/sec, N0 or N1 mode |
| <n> | 1...21600 | increments/sec, N2 mode (micro-increments) |
| | {900} | Power-up default |

The cutoff velocity [c] must be less than or equal to the top velocity [V]. If an attempt is made to set the cutoff velocity greater than the top velocity, the cutoff velocity will be automatically set equal to the top velocity.

### Set cutoff in increments (C<n>)

During the last phase of a plunger move, the speed ramps down (as defined by the programmed slope) toward the cutoff velocity [c]. When the cutoff increments [C] are specified, the plunger stops at <n> increments before reaching the cutoff velocity. The total number of increments required by the plunger movement is maintained by adding <n> increments to the second phase (top velocity) of the plunger move.

Arguments:

| | | |
|---|---|---|
| <n> | 0...25 | increments, as determined by the N mode |
| | {0} | power-up default |

For example, [C5] stops the plunger five increments short of the final velocity. The total number of increments is automatically maintained by adding five increments to the second phase of plunger movement. In other words, the deceleration phase of the move is shortened by five increments and the constant speed phase is lengthened by five increments.

### Set a defined speed (S<n>)

The [S] command sets the top velocity [V] to predefined speeds using the codes shown in the table below.

Arguments:

| | | |
|---|---|---|
| <n> | 0...40 | speed code (see table below) |
| | {11} | power-up default |

These speeds do not cover the full range of speeds the plunger can travel. They are commonly used velocities provided for convenience.

The [S] command sets top velocity [V] without changing start velocity [v], slope [L], or cutoff velocity [c] except under the following condition:

If the cutoff velocity [c] is higher than the desired top velocity [V], the cutoff velocity [c] is changed to equal the top velocity [V]. The [c] cutoff velocity does not revert back to its original value when the top velocity [V] is changed back.

**Note:** Speed code is not affected by the [N] command, but increments are, as shown below. The physical speed—and thus the flow rate—stays the same.

**Table 5-2: Defined Speed codes**

| Speed Code [S<n>] | N0 or N1 mode: increments/sec | N2 mode: micro-increments/sec | Speed Code [S<n>] | N0 or N1 mode: increments/sec | N2 mode: micro-increments/sec |
|---|---|---|---|---|---|
| 0 | 6,000 | 48,000 | 21 | 160 | 1,280 |
| 1 | 5,600 | 44,800 | 22 | 150 | 1,200 |
| 2 | 5,000 | 40,000 | 23 | 140 | 1,120 |
| 3 | 4,400 | 35,200 | 24 | 130 | 1,040 |
| 4 | 3,800 | 30,400 | 25 | 120 | 960 |
| 5 | 3,200 | 25,600 | 26 | 110 | 880 |
| 6 | 2,600 | 20,800 | 27 | 100 | 800 |
| 7 | 2,200 | 17,600 | 28 | 90 | 720 |
| 8 | 2,000 | 16,000 | 29 | 80 | 640 |
| 9 | 1,800 | 14,400 | 30 | 70 | 560 |
| 10 | 1,600 | 12,800 | 31 | 60 | 480 |
| 11 | 1,400 | 11,200 | 32 | 50 | 400 |
| 12 | 1,200 | 9,600 | 33 | 40 | 320 |
| 13 | 1,000 | 8,000 | 34 | 30 | 240 |
| 14 | 800 | 6,400 | 35 | 20 | 160 |
| 15 | 600 | 4,800 | 36 | 18 | 144 |
| 16 | 400 | 3,200 | 37 | 16 | 128 |
| 17 | 200 | 1,600 | 38 | 14 | 112 |
| 18 | 190 | 1,520 | 39 | 12 | 96 |
| 19 | 180 | 1,440 | 40 | 10 | 80 |
| 20 | 170 | 1,360 | | | |

### Set backlash increments (K<n>)

The [K] command sets the number of backlash increments <n>.

Arguments:

| | | |
|---|---|---|
| <n> | 0...100 | increments |
| | (10) | default argument, C3000/C3000MP |
| | (80) | default argument, C24000/24000MP |
| | {10} | power-up default, C3000/C3000MP |
| | {80} | power-up default, C24000/24000MP |

When the syringe drive motor reverses direction, the plunger arm will not move until the backlash due to mechanical play within the system is compensated. To provide compensation, during aspiration the plunger moves down additional increments, then backs up the set number of backlash increments. This ensures that the plunger is in the correct position to begin a dispense move.

**Note:** A small volume of fluid will flow out the input side of the valve during this operation.

### Set syringe motor hold current (h<n>)

**Note:** For factory use only.

Sets the syringe's motor hold, or non-moving, current to the value <n> specified in percent of maximum. On power-up, this value is overwritten to the factory set default value.

Arguments:

| | | |
|---|---|---|
| <n> | 0...100 | % of maximum current |
| | {10} | power-up default set at factory |

### Set syringe motor run current (m<n>)

**Note:** For factory use only.

Sets the syringe motor run, or moving current, to the value <n> specified in percent of maximum. On power-up, this value is overwritten to the factory set default value.

Arguments:

| | | |
|---|---|---|
| <n> | 0...100 | % of maximum current |
| | {75} | power-up default set at factory, C3000/C3000MP |
| | {50} | power-up default set at factory, C24000/C24000MP |

# Configuring auxiliary connections

### Set auxiliary outputs (J<n>)

The [J] command sets the three auxiliary TTL outputs high or low.

Arguments:

| | | |
|---|---|---|
| <n> | 0...7 | (see table below) |
| | (0) | default argument |
| | {0} | power-up default |

The C-Series pump provides three TTL outputs on connector JP3 (pins 13, 14, and 15), which correspond to outputs 1, 2, and 3 in the table below. The states of the outputs form a binary equivalent to the J command argument. They are controlled by the [J] command as follows:

Argument <n> options:

| <n> options | Output 3 (pin 15)[1] | Output 2 (pin 14) | Output 1 (pin 13) |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 |
| 2 | 0 | 1 | 0 |
| 3 | 0 | 1 | 1 |
| 4 | 1 | 0 | 0 |
| 5 | 1 | 0 | 1 |
| 6 | 1 | 1 | 0 |
| 7 | 1 | 1 | 1 |

1. (0 = low, Gnd; 1 = high, +5VDC)

### Set auxiliary outputs based on syringe position (j<pppp><n>)

The [j] command sets the three auxiliary TTL outputs to the specified state <n> when the actual syringe position is less than or equal to the specified syringe position <ppppn>.

Arguments:

| | | |
|---|---|---|
| <pppp> | See below | Position value, where auxiliary outputs will be set when the syringe position is less than or equal to this value. The position value is measured from top of stroke, which has a value of zero. Possible argument values are the same as for the [A] command. |
| <n> | 0...7 | Sets TTL output state. Argument works the same as in the [J] command. |

Arguments for C3000/C3000MP:

| | | |
|---|---|---|
| <pppp> | 0...3000 | Position value in N0 mode (increments) |
| <pppp> | 0...24000 | Position value in N1 or N2 mode (micro-increments) |

Arguments for C24000/C24000MP:

| | | |
|---|---|---|
| <n> | 0...24000 | Position value in N0 mode (increments) |
| <n> | 0...192000 | Position value in N1 or N2 mode (micro-increments) |

Typically, this command is used during a dispense operation to provide an early trigger to another pump to begin dispensing. This allows for continuous dispense flow using two pumps.

For example, using the following string:

[J0IA3000j5007OA0GR]

Breakdown:

| | |
|---|---|
| J0 | Set all 3 auxiliary outputs low. |
| I | Move valve to input position. |
| A3000 | Aspirate: move syringe down to bottom of stroke. |
| j5007 | Set all 3 auxiliary outputs high (binary equivalent of the number 7) when syringe position is less than or equal to 500. |
| O | Move valve to output position. |
| A0 | Dispense: move syringe up to top of stroke (position 0). Auxiliary outputs will change state when syringe position is less than or equal to 500. |
| G | Repeat continuously until terminated. |
| R | Execute command string. |

For a complete continuous flow example, see "Dual pump continuous flow application" (page 149).

# Execution control commands

### Execute command or program string (R)

The [R] command tells the pump to execute a new or previously loaded but unexecuted command string. This command will also cause the resumption of a halted [H] command string.

- Commands containing [R] at the end of the string will execute immediately. If the command or program string is sent without the [R], it is placed in the command buffer.
- Sending the [R] alone will execute the last unexecuted command string in the buffer. Sending another [R] will not repeat the program string that was previously executed.

### Execute the last command string (X)

The [X]command repeats the last executed command string.

**Note:** Strings that contain looping commands, [g] and [G], are not valid when using [X].

### Repeat command sequence, or loop (G<n>)

This command repeats a command or program string the specified number of times. The [G] command can be specified to repeat up to 30,000 times. The [G] command can be used with the [g] command to nest up to 10 loops.

Arguments:

| | | |
|---|---|---|
| <n> | 0...30000 | number of times to repeat loop |
| | (0) | default argument (repeat forever) |

**Note:** With a [GR] or a [G0R], the sequence is repeated continuously until a [T] terminate command is issued.

Example:

[A3000A0G10R] moves the syringe plunger to position 3000, then back to position 0. This sequence is repeated ten times.

### Mark start of a repeat sequence, or loop (g)

The [g] command is used in conjunction with the [G] command. The [g] command marks the beginning of a repeat sequence (loop) that occurs within a program string (i.e., the entire string is not repeated). The [g] command can be used with the [G] command to nest up to 10 loops.

Example of loop nesting:

[A0gP50gP100D100G10G5R]

Breakdown:

| | |
|---|---|
| A0 | Move plunger to position 0 |
| g | Outer loop start |
| P50 | Move plunger down 50 increments |
| g | Inner loop start |
| P100 | Move plunger down 100 increments |
| D100 | Move plunger up 100 increments |
| G10 | Go to inner loop start, repeat 10 times |
| G5 | Go to outer loop start, repeat 5 times |
| R | Execute command string |

### Delay command execution (M<n>)

The [M] command delays execution of a command for <n> milliseconds. This command is typically used to allow time for liquid in the syringe and tubing to stop oscillating, thereby enhancing precision.

Arguments:

| | | |
|---|---|---|
| <n> | 0...30000 | milliseconds |
| | (0) | default argument |

### Halt command execution (H<n>)

The [H] command is used within a program string to halt execution of the string and wait for a specified condition. To resume execution, an [R] command or TTL signal must be sent. Two TTL inputs are available: Input 1 (JP3 pin 7), and Input 2 (JP3 pin 8).

Arguments:

| | | |
|---|---|---|
| <n> | 0...2 | (see table below) |
| | (0) | default argument |

| <n> options | Description |
|---|---|
| 0 | Halt and wait for [R] or falling edge on either Input 1 or 2. |
| 1 | Halt and wait for [R] or falling edge on Input 1. |
| 2 | Halt and wait for [R] or falling edge on Input 2. |

**Note:** Both inputs are pulled up to +5V.

The status of the TTL input lines can be read using [?13] and [?14]. The response of the [H] command to the TTL inputs are set by the EEPROM [u16_X] debounce setting. See details on page 75.

The default configuration is that the inputs are falling-edge sensitive for the [H] command. That is, after the [H] command, if the respective input transitions from high to low, operation will resume.

Example:

[ZgH1IA1000H2OA0G0R]

The pump initializes, halts and waits for the trigger, or low signal on Input 1, then aspirates 1000 increments. It then waits for a low on Input 2 before dispensing.

Breakdown:

| | |
|---|---|
| Z | Initialize pump. |
| g | Start loop. |
| H1 | Halt and wait for falling edge on input 1. |
| I | Move valve to input position (aspirate). |
| A1000 | Move syringe to position 1000. |
| H2 | Wait for falling edge on Input 2. |
| O | Move valve to output position (dispense). |
| A0 | Move syringe to position 0. |
| G0 | Loop back to [g], run continuously until terminated. |
| R | Run |

**Note:** When using H=0 and using only one input with the other input left floating: since the unused input is pulled high, this eliminates the requirement for the active input to go high. The firmware will then respond to the low level on the active input. In this case, then, the inputs will appear to be level sensitive.

### Aux input debounce, EEPROM u16_X, where X<=50.

Default value for this parameter is 1. Units are in ms (milliseconds).

Following the [H] command, the respective input must be high continuously for at least X milliseconds before a high-to-low transition can be recognized. Upon transition from high to low (falling edge), the input must remain low continuously for X milliseconds before the string will resume operation.

The auxiliary input debounce only functions if a specific input is selected. That is, it is only valid using [H]<1> or H<2>. It has no effect if using [H]<0>. If [H]<0> is used, the inputs are level-sensitive, not falling-edge sensitive.

If debounce were set to zero, inputs would be level sensitive also.

**Note:** Debounce is a factory-only adjustment.

### Terminate an executing string (T)

The [T] command immediately terminates any executing command string. All plunger or valve movements are terminated immediately.

### Execute or skip next command based on aux inputs (x)

Execute the next command (or skip) based on the auxiliary inputs.

Arguments:

x<n> 0...3 (see table below)

| <n> options | Input 2[1] | Input 1 | Action |
|---|---|---|---|
| 0 | Low | Low | Will execute next command in the string buffer if Input 2 and Input 1 are held low. |
| 1 | Low | High | Will execute next command in the string buffer if Input 2 and Input 1 are set as indicated. |
| 2 | High | Low | Will execute next command in the string buffer if input 2 and Input 1 are set as indicated. |
| 3 | High | High | Will execute next command in the string buffer if Input 2 and Input 1 are both high. |

1. Input 1 is located on connector JP3 pin 7, and Input 2 is on JP3 pin 8.

**Note:** Auxiliary inputs are internally pulled high. Thus, if left floating, they will be high.

The [x] command, in conjunction with the [e] command, can be used as an IF...ELSE, IF...ELSE statement based on the auxiliary TTL inputs. This is especially useful in standalone operation.

#### Example: switch between strings based on input states

The example below allows a C3000/C3000MP in standalone mode to switch between three modes of operation depending on the states of Input 1 and Input 2. The pump is configured to AutoRun string 0 on power-up. (For more information on storing strings and using AutoRun, see "Using EEPROM" (page 78).)

- If Input 2 is low and Input 1 is high, [e1] will be executed. Thus, the pump will aspirate/dispense cycle 50 increments.
- If Input 2 is high and Input 1 is low, [e2] will be executed. Thus, the pump will aspirate/dispense cycle 1000 increments.
- If none of the above states of Input 2 and Input 1 are realized, [e3] will be executed. The pump will aspirate/dispense cycle a full stroke, 3000 increments.

**Note:** Using the [e] command in a string will force a jump to the specified string. It will not automatically return to the departure point once the “jumped to” string has completed.

The following four strings are programmed into the EEPROM locations 0, 1, 2, and 3 (the commands s0, s1, s2,and s3 store their strings in locations 0, 1, 2, and 3 respectively):

[s0Zx1e1x2e2e3R]

[s1gIA50OA0G0R]

[s2gIA1000OA0G0R]

[s3gIA3000OA0G0R]

Breakdown:

**String 0 [e]:**

| | |
|---|---|
| s0 | Store following in EEPROM location 0 (executed on power-up). |
| Z | Initialize pump. |
| x1 | Execute next instruction if Input 2 is tied low and Input 1 is high (or left open). |
| e1 | Jump to String 1. |
| x2 | Execute next instruction if Input 2 is high (or left open) and Input 1 is tied low. |
| e2 | Jump to String 2. |
| e3 | Else, jump to String 3. |
| R | Run command string. |

**String 1 [e1]:**

| | |
|---|---|
| s1 | Store following in EEPROM location 1. |
| g | Start loop. |
| I | Valve to input position (aspirate). |
| A50 | Move syringe to position 50. |
| O | Valve to output position (dispense). |
| A0 | Move syringe to position 0. |
| G0 | Loop back to [g], run continuously until terminated. |
| R | Run command string. |

**String 2 [e2]:**

| | |
|---|---|
| s2 | Store following in EEPROM location 2. |
| g | Start loop. |
| I | Valve to input position (aspirate). |
| A1000 | Move syringe to position 1000. |
| O | Valve to output position (dispense). |
| A0 | Move syringe to position 0. |
| G0 | Loop back to [g], run continuously until terminated. |
| R | Run command string. |

**String 3 [e3]:**

| | |
|---|---|
| s3 | Store following in EEPROM location 3. |
| g | Start loop. |
| I | Valve to input position (aspirate). |
| A3000 | Move syringe full stroke to position 3000. |
| O | Valve to output position (dispense). |
| A0 | Move syringe to position 0. |
| G0 | Loop back to [g], run continuously until terminated. |
| R | Run command string. |

# Using EEPROM

EEPROM can be used to store up to 15 command strings for later use, including standalone operation using the AutoRun feature. The stored strings can be run individually or linked together to run in sequence using the [e] command.

EEPROM can also be used to configure pump operating characteristics using the [U] and [u] commands. However, this is generally considered to be a factory-only feature.

### Store program string in EEPROM (s<n>)

The [s] command stores a program string to one of 15 EEPROM locations, providing the user with the option of computer-free stand-alone operation.

Argument:

| | |
|---|---|
| <n> | 0...14 EEPROM location 0 through 14 |

The [s] command is placed at the beginning of a program string to load the string into EEPROM.

Example: [s2IA3000OA0R] loads the string beginning with [I] (valve to input) into memory location 2.

Each stored string can contain up to 128 characters.

### AutoRun a stored string (standalone pump operation)

On power-up, if the AutoRun jumper is installed on the back of the pump, the string corresponding to the rotary address switch position will be automatically executed.

Example:

- The following strings store programs into EEPROM locations 0 and 1:

  [s0ZIP1000H0OD1000R]

  [s1ZIP500H0OD500R]
- The AutoRun jumper is installed on the back of the pump.
- At power-up:
  - If the rotary address switch on the back of the pump is set to 0, [s0 . . .] will run automatically.
  - If the rotary switch is set to 1, [s1 . . .valve] will run automatically.

**Note:** An initialization command is required in a stored command string intended for standalone (AutoRun) use.

Table 5-3 shows the relationship between the strings stored with [s<n>] and the address switch settings.

**Table 5-3: Address switch setting vs. stored strings for AutoRun**

| Address switch setting with AutoRun jumper installed | Stored string referenced (memory location) |
|---|---|
| 0 | s0 (string stored in memory location 0, and so forth) |
| 1 | s1 |
| 2 | s2 |
| 3 | s3 |
| 4 | s4 |
| 5 | s5 |
| 6 | s6 |
| 7 | s7 |
| 8 | s8 |
| 9 | s9 |
| A | s10 |
| B | s11 |
| C | s12 |
| D | s13 |
| E | s14 |

Example stored program string for AutoRun:

[s8ZS1gIA3000H0OA0GR]

Breakdown:

| | |
|---|---|
| s8 | Loads following string into location 8 of EEPROM (address switch would be set to position 8). |
| Z | Initializes pump. |
| S1 | Sets plunger speed. |
| g | Marks start of loop. |
| I | Moves valve to input position. |
| A3000 | Moves plunger to position 3000. |
| H0 | Halts operation until either TTL input goes low |
| O | Moves valve to output position. |
| A0 | Moves plunger to position 0. |
| G | Go to [g], repeat continuously until terminated. |
| R | Run command string. |

### Execute program string stored in EEPROM (e<n>)

Execute string stored at EEPROM location <n>.

Argument:

| | | |
|---|---|---|
| <n> | 0...14 | EEPROM location of stored string |

Example:

[e8R] will run the string stored in EEPROM location 8.

### Linking program strings stored in EEPROM

Strings stored in EEPROM can be linked by ending one program string with an [e] command that refers to a second program string stored in another location.

Example program strings:

[sIZgIA3000OA0G5e2R]

[s2gIA3000OgH0D300G10GR]

- The first string loads an initialization and prime sequence into location 1 of EEPROM (address switch position 1). It then links to string 2 in EEPROM.
- The second string loads an aspirate and dispense sequence into location 2 of the EEPROM. This string fills the syringe, then performs 10 dispenses of 300 increments each.

Due to the [H0], the dispenses are triggered by the proper auxiliary input, or an [R] command. This sequence is repeated endlessly until the pump is powered down.

If the AutoRun jumper is installed and the address switch is set correctly, on power-up the pump will automatically initialize, prime, and perform the multiple dispenses until it is again powered down.

**Note:** When linking program strings, a jumped-to string will not automatically return to the calling string. In the example above: [s1] jumps to [e2]. Once [e2] has executed, control will not return to the calling sting [s1]. Thus, [e] commands are normally placed at the end of a string just before the [R].

## Executing long program strings using the [e] command

### Break up commands

If a program string exceeds 128 characters, it can be broken down into parts stored in separate locations. The [e] command can then be used to run the different parts in the appropriate sequence.

For example, if the first part of a string resides in location 3 (s3) and the second part in location 4 (s4), the command [e4] would be placed at the end of s3. This would run the second part of the string (s4) after the first part was finished.

### Virtually embed commands

Another way to limit the length of command strings sent to the pump is to use the [e] command to effectively embed commands in/ strings. For example, If the command [V2000] is used frequently, it could be stored in EEPROM location 0 by issuing [s0V2000]. Afterwards, this command could be called up and executed using [e0], as in the command string [e0AOR]. This would first execute [V2000], then the remaining commands in the string.

### Set pump configuration EEPROM parameters (U<n>)

These parameters are only read on power-up. Thus they will take effect only when the power is cycled.

This command does not require an [R] to execute. Arguments for the [U] command are shown in Table 5-4.

**Table 5-4: Pump configuration set with U<n>**

| <n> value | Description |
|---|---|
| 0 | Reserved for future use. |
| 1 | 3-port 120° Y valve<br>Valve selection jumper on the back of the pump must also be installed. |
| 2 | 4-port 90° valve<br>Valve selection jumper on the back of the pump must also be removed. |
| 3 | Reserved for future use. |
| 4 | 3-way distribution valve that uses [I], [O], [B] and [E] commands. |
| 5 | 3-port and 4-port T valves |
| 7 | 6-way distribution valve |
| 8 | Reserved for future use. |
| 9 | 4-port loop valve |
| 11 | 3-way distribution valves that use [I]<n> and [O]<n> commands |
| 30 | Enable AutoRun mode.<br>This setting performs the same function as the AutoRun jumper on the back of the pump.<br>**Note:** If the AutoRun jumper is installed, it will override the EEPROM setting. |
| 31 | Clear AutoRun mode.<br>**Note:** If the AutoRun jumper is installed, it will override the EEPROM setting. |
| 41 | Reserved for future use. |
| 47 | Reserved for future use. |
| 51 | Set CAN baud rate to 100K bps. |
| 52 | Set CAN baud rate to 250K bps. |
| 53 | Set CAN baud rate to 500K bps. |
| 54 | Set CAN baud rate to 1M bps. |
| 57 | Set CAN baud rate to 125K. |

### Set pump configuration EEPROM parameters (u<n_xxx>)

**⚠CAUTION**

**CAUTION:** For factory use only.

The [u] command loads pump configuration and calibration information into EEPROM. Some of these parameters (AutoRun and CAN baud rate) can also be changed with the [U] command.

This command does not require an [R] to execute.

Table 5-5 shows the full range of settings, and Table 5-6 shows the effect of different settings.

**Note:** These parameters are read only on power-up. Thus they will only take effect when power is cycled.

**Table 5-5: Pump configuration set with u<n_xxx>[1]**

| Command | Description | C3000/ C3000MP factory default | C24000/ C24000MP factory default |
|---|---|---|---|
| u1_XXX | Motor hold current, 0-100% of max. | 10 | 10 |
| u2_XXX | Motor run current, 0-100% of max. | 75 | 50 |
| u3_XXX | Default V max and initialization speed in 100 increments/sec (1...60) | 14 | 56 |
| u4_XXX | Plunger stroke in increments * 100 | 62 | 248 |
| u5_X | 0 = Don't auto initialize valve.<br>1 = Automatically initialize valve on power-up.<br>2 = No valve circuitry installed on PCB. | 1 | 1 |
| u6_X | CAN baud rate<br>0 = CAN bus disabled<br>1 = 100K<br>2 = 125K<br>3 = 250K<br>4 = 500k<br>5 = 1M | 1 | 1 |
| u7_XX | Power-up default backlash in increments, [K] command | 10 | 80 |
| u8_X | Number of increments to jam or stall the plunger into the top of the syringe during plunger initialization. | 10 | 10 |
| u9_XXX | Power-up default gap volume in increments, [k] command | 24 | 384 |
| u10_IOB | 3 way valve position<br>I = Input valve position (0-2)<br>Position 0 = 0 deg.<br>Position 1 = 120 deg.<br>Position 2 = 240 deg.<br>O = Output valve position (0-2)<br>B = Bypass valve position (0-2) | 210 | 210 |

**Table 5-5: Pump configuration set with u<n_xxx>[1] (continued)**

| Command | Description | C3000/ C3000MP factory default | C24000/ C24000MP factory default |
|---|---|---|---|
| u11_ IOBEXYZ | I = Input valve position (0-3)<br>Position 0 = 0 deg.<br>Position 1 = 90 deg.<br>Position 2 = 180 deg.<br>Position 3 = 270 deg.<br>O = Output valve position (0-3)<br>B = Bypass valve position (0-3)<br>E = Extra valve position (0-3)<br>X = Allow plunger movement while valve is in bypass position.<br>X = 1, allow movement<br>X = 0, don't allow movement<br>Y = Allow plunger movement while valve is in extra position.<br>Y = 1, allow movement<br>Y = 0, don't allow movement<br>Z = swap the bypass and extra position on a 4-position valve if a [Y] initialization command is issued.<br>Z = 1, Swap<br>Z = 0, Don't swap | 2130001 | 2130001 |
| u12_X | X = 1, half-step/increment syringe motor resolution<br>X = 0, full step/increment resolution<br>**Note:** If set to half-step and in normal increment mode, stroke = 6000 increments<br>If set to half-step and in micro-increment mode, stroke = 48000 increments (for C3000/C3000MP) | 0 | 1 |
| u13_X | X = 1, AutoRun mode<br>X = 0, Regular mode<br><br>This setting performs the same function as the AutoRun jumper on the back of the pump. If the AutoRun jumper is installed, it will override the EEPROM setting. | 0 | 0 |
| u14_X | X = number of ports on a distribution valve<br>X = 0, Non distribution valve | 0 | 0 |
| u15_X | X = 0, standard lead screw pitch<br>X = 1, 1 mm lead screw pitch, 4X increment resolution<br>X = 2, 2 mm lead screw pitch, 2X increment resolution | 0 | 1 |
| u16_X | De-bounce delay for trigger inputs in ms. Valid arguments are 1...50. After the [H] command, the respective Input must be high for at least X milliseconds before a low transition will be recognized.<br><br>Upon transition from high to low (falling edge), the input must remain low for X milliseconds before the string will resume operation. Only valid for [H]<1> or [H]<2>. Not valid for [H]<0>. | 0 | 0 |
| u17_XX | Default init current in percent for full force initialization | 25 | 30 |
| u18_XX | Default init current in percent for medium force initialization | 20 | 25 |
| u19_XX | Default init current in percent for low force initialization | 15 | 20 |
| u20_XXXXXXX | X = 7, character alpha-numeric | | |

1. Example: u5_0 = Don't auto initialize valve.

**Table 5-6: Example full stroke variations based on [u] command selections**

| Configuration | Full stroke normal mode (N0) | Full stroke (N1 or N2 mode) |
|---|---|---|
| C3000/C3000MP<br>Set to step mode (default settings)<br>(u4_62, u12_0, u15_0) | 3,000 | 24,000 |
| C3000/C3000MP<br>Set to half-step mode<br>(u4_62,u12_1,u15_0) | 6,000 | 48,000 |
| C24000/C24000MP<br>1 mm lead screw pitch and half-step mode (default settings)<br>(u4_248, u12_1, u15_1) | 24,000 | 192,000 |

### Calibrate encoder levels and store in EEPROM (n<x>)

**Note:** For factory use only.

Encoder voltage output levels can calibrated and set into EEPROM.

This command will run the pump through the calibration process, calculate the values, and store them in EEPROM. These values can be read back using the [?21] report command.

# Report commands (query commands)

Report commands report various pump parameters. The response is returned immediately and can be used when the pump is busy executing another command string. The report commands are listed in Table 5-7.

**Note:** Report commands do not require an [R] command.

**Table 5-7: Report commands**

| Report Command | Report description |
|---|---|
| ? or RZ | Reports absolute position of plunger in increments as defined by N mode setting. |
| ?1 | Reports start velocity [v] in increments/sec. |
| ?2 | Reports top velocity [V] in increments/sec. |
| ?3 | Reports cutoff velocity [c] in increments/sec. |
| ?4 or ?5 | Reports absolute position of plunger in increments as defined by N mode setting. Same as [?] or [RZ]. |
| ?6 | For most valves, reports valve position expressed in mnemonics (i = input, o = output, b = bypass and e = extra). For the 3-way distribution valve using [I]<n> and [O]<n> or the 6-way distribution valve, ?6 reports the port number 1..X, where X is the number of ports. |
| ?7 | Reports acceleration slope set using the [L] command, in units of 1,000 increments/sec^2 (increments as defined by N mode setting). |
| ?10 or F | Reports command buffer status. If the buffer is empty, the pump returns status code 0. If the buffer is not empty, the pump returns a 1. If a program string is sent to the pump without an [R] command, the string is loaded into the buffer and the buffer status becomes 1. If an [R] command is sent, the command stored in the buffer will execute.<br>Report values:<br>0 = buffer empty<br>1 = commands in buffer |
| ?12 | Reports backlash setting [K] in increments as defined by N mode setting. |
| ?13 | Reports status of auxiliary input #1 (JP3, Pin 7).<br>Report values:<br>0 = low<br>1 = high |
| ?14 | Reports status of auxiliary input #2 (JP3, Pin 8).<br>Report values:<br>0 = low<br>1 = high |
| ?15 | Non-functional. Always reports 1. |
| ?16 | Non-functional. Always reports 1. |
| ?17 | Non-functional. Always reports 1. |
| ?18 or % | Reports number of valve movements since last [?18] or [%] command). |
| ?19 | Reports whether or not pump has been initialized.<br>Report values:<br>0 = not initialized<br>1 = initialized |
| ?20 or # | Reports firmware checksum. |
| ?21 | Reports calibrate encoder levels. |

**Table 5-7: Report commands (continued)**

| Report Command | Report description |
|---|---|
| ?22 | Non-functional. Always reports 255. |
| ?23, &, or RV | Reports firmware version. Format is “C3000: MMDDYY”<br>where:<br>MM = month<br>DD = day<br>YY = year<br>**Note:** C3000 is the response regardless of whether the actual pump is a C3000/C3000MP or C24000/C24000MP configuration. |
| ?24 | Reports gap volume set with [k]. |
| ?25 | Reports syringe motor hold current [h] in % of max. |
| ?26 | Reports syringe motor run current [m] in % of max. |
| ?27 or ?76 | Reports the EEPROM configuration data set by the [u] command. |
| ?28 | Reports state of the 3-port valve jumper (J2, segment 5).<br>3 = 3-port valve; jumper installed.<br>4 = other valves, jumper not installed |
| ?29 or Q | Reports system status. Reports error codes and pump status (idle or busy). Also see "Status and error codes"below. |
| ?30 | [s0] string. Reports command string stored in EEPROM location 0. |
| ?31 | [s1] string. Reports command string stored in EEPROM location 1. |
| ?32 | [s2] string. Reports command string stored in EEPROM location 2. |
| ?33 | [s3] string. Reports command string stored in EEPROM location 3. |
| ?34 | [s4] string. Reports command string stored in EEPROM location 4. |
| ?35 | [s5] string. Reports command string stored in EEPROM location 5. |
| ?36 | [s6] string. Reports command string stored in EEPROM location 6. |
| ?37 | [s7] string. Reports command string stored in EEPROM location 7. |
| ?38 | [s8] string. Reports command string stored in EEPROM location 8. |
| ?39 | [s9] string. Reports command string stored in EEPROM location 9. |
| ?40 | [s10] string. Reports command string stored in EEPROM location 10. |
| ?41 | [s11] string. Reports command string stored in EEPROM location 11. |
| ?42 | [s12] string. Reports command string stored in EEPROM location 12. |
| ?43 | [s13] string. Reports command string stored in EEPROM location 13. |
| ?44 | [s14] string. Reports command string stored in EEPROM location 14. |

# Status and error codes

The [Q] command reports error codes and pump status (idle or busy). The user should send a [Q] command before sending a program string or individual command to ensure that the pump has completed the previous command successfully.

The response to the [Q] command is the status byte. This byte provides two items of information: pump status (bit 5) and error code (bits 0-3).

**⚠CAUTION**

**CAUTION:** All errors reported by the pump should be captured by the user's software and the physical cause corrected before continuing operation. Failure to do so may result in damage to the pump or adversely affect pump performance, and void the warranty.

### Pump status bit

Bit 5 is the status bit. It indicates whether the pump is busy or not busy. The designations for bit 5 are listed below.

Bit 5 values:

| | |
|---|---|
| 1 | Pump is idle. It is ready to accept new commands. |
| 0 | Pump is busy and will only accept report, terminate [T] or velocity [V] commands. |

In response to uppercase move commands ([A], [P] and [D]), the [Q] command reports that the pump is busy. In response to lowercase move commands ([a], [p], and [d]), the [Q] command reports that the pump is Idle. Additionally, commands addressed to multiple pumps at once cannot be used to obtain pump status; each pump must be queried separately.

**Note:** Although the answer block for other commands contains a status bit, it should not be used for determining pump status. A [Q] command is the only valid method to determine if the pump is busy. The error information in the status byte of the answer block is always valid.

### Error codes (bits 0-3)

Error codes describe problem conditions that may be detected when operating the C-Series Syringe Pumps. The error codes are listed in Table 5-8 (page 90).

- Error codes are returned in the least significant four bits of the status byte (0-3). If an error occurs, the pump stops executing commands, clears the command buffer, and inserts the error code into the status byte.
- Some errors, such as plunger overloads, continue to appear until they are cleared by an initialization command. On a plunger overload, the device will not execute another plunger move command until it is reinitialized.
- The most recent error has precedence in the status byte. For example, if a command overflow occurs, an error 15 results. If the next command causes an error 3 (invalid operand), the status byte reflects the error 3.

## Error types

The pump handles errors differently depending on the error type. There are four error types, described below and listed in Table 5-8 (page 90).

### Immediate errors

These include:

- Invalid command (error 2)
- Invalid operand (error 3)
- Invalid checksum (error 4)
- Plunger move not allowed (error 11)
- Device not initialized (error 7)

When a command is sent, the answer block immediately returns an error. Any subsequent [Q] command will not report the error.

**Note:** There is no need to reinitialize the pump following this type of error.

### Initialization errors

These include:

- Initialization error (error 1)
- Device not Initialized (error 7)

To ensure that the pump initialized successfully, send a [Q] command after the initialization [Z], [Y] or [W] command.

- If an error occurs during initialization, an initialization error (error 1) will be returned in response to the [Q] command. The pump must be reinitialized until the [Q} command indicates successful initialization.
- If the response indicates both a successful initialization and that the pump is ready, subsequent move commands can be sent.
- If initialization is not successful, or if any plunger move command is sent prior to an initialization command, a device not initialized error (error 7) is returned in response to the command.

### Overload errors

These include:

- Plunger overload (error 9)
- Valve overload (error 10)

If the pump returns either of these errors, the pump must be reinitialized before continuing.

If another plunger or valve movement command is sent without reinitializing the pump, the initialization error (error 1) will be returned.

### Command overflow error

This error (error 15) occurs when certain commands are sent to the pump while it is busy executing another command string. The pump ignores the new command and issues a command overflow error.

Any move, setting (except [V]), or valve commands that are sent while the pump is busy will cause this error to be issued.

Report, top velocity [V], and terminate [T] commands will not return a command overflow error. These commands are considered valid even when the pump is busy.

The [Q] command is used to determine when the command is complete and the pump is ready to accept new commands.

**Note:** There is no need to re-initialize the pump following this type of error.

**Table 5-8: Error codes, status byte with ASCII and hexadecimal values**

| Status Byte | Hex if Status Bit 5 = | | ASCII if Status Bit 5 = | | Error Code Description | |
|---|---|---|---|---|---|---|
| 7 6 5 4 3 2 1 0 | X= 0 (Busy) | X=1 (Idle) | X= 0 (Busy) | X=1 (Idle) | Number | Error type |
| 0 1 X 0 0 0 0 0 | 40h | 60h | @ | ` | 0 | No error |
| 0 1 X 0 0 0 0 1 | 41h | 61h | A | a | 1 | Initialization failure |
| 0 1 X 0 0 0 1 0 | 42h | 62h | B | b | 2 | Invalid command |
| 0 1 X 0 0 0 1 1 | 43h | 63h | C | c | 3 | Invalid operand |
| 0 1 X 0 0 1 0 0 | 44h | 64h | D | d | 4 | Invalid checksum |
| 0 1 X 0 0 1 0 1 | 45h | 65h | E | e | 5 | Unused |
| 0 1 X 0 0 1 1 0 | 46h | 66h | F | f | 6 | EEPROM failure |
| 0 1 X 0 0 1 1 1 | 47h | 67h | G | g | 7 | Device not initialized |
| 0 1 X 0 1 0 0 0 | 48h | 68h | H | h | 8 | CAN bus failure |
| 0 1 X 0 1 0 0 1 | 49h | 69h | I | i | 9 | Plunger overload |
| 0 1 X 0 1 0 1 0 | 4Ah | 6Ah | J | j | 10 | Valve overload |
| 0 1 X 0 1 0 1 1 | 4Bh | 6Bh | K | k | 11 | Plunger move not allowed |
| 0 1 X 0 1 1 1 1 | 4Fh | 6Fh | O | o | 15 | Command overflow |

## Error reporting examples

| | |
|---|---|
| [A4000R] | Since <4000> is greater than the stroke of the C-Series, this returns an error immediately in the command response. When queried with the [Q] command, does not return error. |
| [A3000P3500R] | Moves to position 3000 then stops. The [P3500] is past the stroke of the C-Series; a [Q] command returns an error. |
| [e200R] | <14> is the maximum argument for [e]. It returns an invalid command error immediately in the command response. The pump status is Idle. |
| [BA1000R] | Since valve is in the bypass position, plunger movements are not allowed. This returns an error immediately. When queried with the [Q] command, an error is not returned. |

# Non-functional commands

The following commands have been included in the C-Series command set to make the pump backward compatible with other pumps. These commands are non-functional.

### Set threshold value for fluid detection (^<n>)

Always returns 255.

### Clear run from EEPROM (b)

# Command summaries

The following tables contain summaries of the commands for RS232/RS485 and CAN Bus communications as a convenient quick reference.

## RS232/RS485 command summary

**Table 5-9: RS232/RS485 command summary**

| Command | Operand <n> range ( ) = C24000/ C24000MP only | Default Operand | Power-up default | Command description | Operand description |
|---|---|---|---|---|---|
| **Control commands** | | | | | |
| R | N/A | N/A | | Execute command string. | |
| x<n> | 0...3 | N/A | | Execute next command in buffer based on auxiliary inputs. | 0 = Execute if input 2 is low and Input 1 is low.<br>1 = Execute if input 2 is low and input 1 is high.<br>2 = Execute if input 2 is high and input 1 is low.<br>3 = Execute if input 2 is high and input 1 is high. |
| X | N/A | N/A | | Re-execute last executed command string. | |
| G<n> | 0...30000 | 0 | | Repeat command sequence (loop). | Number of loops to repeat<br>0 = Loop forever |
| g | N/A | N/A | | Mark the start of a repeat sequence (loop). | |
| M<n> | 0...30000 | 0 | | Delay command execution. | Milliseconds |
| H<n> | 0...2 | 0 | | Halt command execution and wait for [R] command, input state, or negative-going transition. | 0 = Wait for [R] or either input 1 or 2 to go low.<br>1 = Wait for [R] or input 1 to go low.<br>2 = Wait for [R] or input 2 to go low. |
| T | N/A | N/A | | Terminate command. | |
| **Initialization commands** | | | | | |
| Z<n1> | 0...40 | 0 | | Initialize plunger. Set valve to the right on non-distribution valves. | 0 = initialize at full plunger force.<br>1 = initialize at half plunger force.<br>2 = initialize at one third plunger force.<br>3 = initialize at speed 16.<br>4 = initialize at speed 18.<br>5-9 = same as 0.<br>10-40 = initialize at defined plunger speed. |
| <n2> | 0...X | 0 | | Set input port at initialization on distribution valves. | 0 = port 1, counting clockwise<br>X=number of output ports<br>(Ignored on non-distribution valves.) |
| <n3> | 0...X | 0 | | Set output port at initialization on distribution valves. | 0 = port 1, counting clockwise<br>X=number of output ports<br>(Ignored on non-distribution valves.) |

**Table 5-9: RS232/RS485 command summary (continued)**

| Command | Operand <n> range ( ) = C24000/ C24000MP only | Default Operand | Power-up default | Command description | Operand description |
|---|---|---|---|---|---|
| Y<n1,n2, n3> | 0...40 | 0 | | Initialize plunger. Set valve to the left on non-distribution valves. | <n1> same as [Z<n1>]<br><n2> same as [Z<n2>] except counterclockwise<br><n3> same as [Z<n3>] except counterclockwise |
| W<n> | 0...40 | 0 | | Initialize plunger without valve. | Same as [Z<n1>] |
| z<n> | 0...3000 N0<br>0...24000 N1/N2<br>(0...24000 N0<br>0...192000 N1/N2) | 0 | | Set pump's internal position counter to value specified. | |
| k<n> | 0...120 N0<br>0...960 N1/N2 | 24 (384) | 24 (384) | Set syringe gap volume. | |
| **Plunger movement commands** | | | | | |
| A<n> | 0...3000 N0<br>0...24000 N1/N2<br>(0...24000 N0<br>0...192000 N1/N2) | 0 | | Move plunger to absolute position. | |
| a<n> | | 0 | | Move plunger to absolute position, not busy. | |
| P<n> | | 0 | | Relative pickup | |
| p<n> | | 0 | | Relative pickup, not busy | |
| D<n> | | 0 | | Relative dispense | |
| d<n> | | 0 | | Relative dispense, not busy | |
| **Valve commands** | | | | | |
| I | N/A | N/A | | Move valve to input position. | |
| O | N/A | N/A | | Move valve to output position. | |
| B | N/A | N/A | | Move valve to bypass position. | |
| E | N/A | N/A | | Move valve to extra position. (Valid for 4-position valves only.) | |
| **Set commands** | | | | | |
| K<n> | 0...100 | 10 (80) | 10 (80) | Set backlash increments. | |
| L<n> | 1...20 N0/N1<br>8...160 N2 | | 14 | Set acceleration/deceleration slope. | Slope code |
| v<n> | 1...1000 N0/N1<br>1...8000 N2 | | 900 | Set start velocity in increments/sec. | |
| V<n> | 1...6000 N0/N1<br>1...48000 N2 | | 1400 (5600) | Set top velocity in increments/sec. | |
| S<n> | 0...40 | 11 | 11 | Set a defined speed. | Speed code |
| c<n> | 1...2700 N0/N1<br>1...21600 N2 | | 900 | Set cutoff velocity in increments/sec. | |
| C<n> | 0...25 | | 0 | Set cutoff in increments. | |

**Table 5-9: RS232/RS485 command summary (continued)**

| Command | Operand <n> range ( ) = C24000/ C24000MP only | Default Operand | Power-up default | Command description | Operand description |
|---|---|---|---|---|---|
| N<n> | 0...2 | 0 | 0 | Set resolution/increment mode for positioning and velocity. | 0 = Both position and velocity in normal increment mode.<br>1 = Micro-increment mode for positioning, and normal increment mode for velocity.<br>2 = Both position and velocity in micro-increment mode (8X normal mode). |
| J<n> | 0...7 | 0 | 0 | Sets the three TTL auxiliary outputs. | 0 = all outputs low<br>7 = all outputs high<br><n> operand represents equivalent binary number created from resulting states of the three outputs 1 through 3. |
| j<pppp> <n> | <pppp><br>0...3000 N0<br>0...24000 N1/N2<br>(0...24000 N0<br>0...192000 N1/N2)<br><br><n> 0...7 | | | Set auxiliary outputs based on syringe position. | Outputs are set to <n> value when syringe position < = <pppp>.<br><n> arguments same as for J<n>. |
| h<n> | 0...100 | | 10 | Set motor hold current in % of max. | For factory use only. |
| m<n> | 0...100 | | 75 (50) | Set motor run current in % of max. | For factory use only. |
| ^<n> | 0...255 | | | Non-functional command; always returns 255. | |
| b | N/A | N/A | | Non-functional command | |
| **EEPROM commands** | | | | | |
| s<n> | 0...14 | | | Load program string into specified EEPROM location. | |
| e<n> | 0...14 | | | Execute EEPROM string. | |
| U | | | | Set pump configuration parameters. | |
| u | 1...16 | | | Set system configuration parameter into EEPROM. | For factory use only. |
| **Report commands** | | | | | |
| Q | N/A | N/A | | Reports system status. | |
| ? | N/A | N/A | | Reports absolute plunger position. | |
| ?0 | N/A | N/A | | Same as [?]. | |
| ?1 | N/A | N/A | | Reports start velocity in increments/sec. | |
| ?2 | N/A | N/A | | Reports top velocity in increments/sec. | |
| ?3 | N/A | N/A | | Reports cutoff velocity in increments/sec. | |
| ?4 | N/A | N/A | | Reports absolute plunger position; same as [?]. | |
| ?5 | N/A | N/A | | Same as [?]. | |

**Table 5-9: RS232/RS485 command summary (continued)**

| Command | Operand <n> range ( ) = C24000/ C24000MP only | Default Operand | Power-up default | Command description | Operand description |
|---|---|---|---|---|---|
| ?6 | N/A | N/A | | Reports valve position (i, o, b and e). | |
| ?7 | N/A | N/A | | Reports acceleration/deceler-ation slope. | |
| ?10 | N/A | N/A | | Reports command buffer sta-tus, same as [F]. | |
| ?12 | N/A | N/A | | Reports number of backlash increments as set by the [K] command. | |
| ?13 | N/A | N/A | | Reports status of auxiliary 1 input. | |
| ?14 | N/A | N/A | | Reports status of auxiliary 2 input. | |
| ?15 | N/A | N/A | | Non-functional, will always report 1. | |
| ?16 | N/A | N/A | | Non-functional, will always report 1. | |
| ?17 | N/A | N/A | | Non-functional, will always report 1. | |
| ?18 | N/A | N/A | | Reports number of valve movements since last [?18]; same as [%]. | |
| ?19 | N/A | N/A | | Reports whether pump is initialized. | 0 = not initialized<br>1 = initialized |
| ?20 | N/A | N/A | | Reports firmware checksum; same as [#]. | |
| ?21 | N/A | N/A | | Reports calibrate encoder levels. | |
| ?22 | N/A | N/A | | Non-functional; will always return 255. | Non-functional command to maintain backward firmware compatibility. |
| ?23 | N/A | N/A | | Reports firmware version, same as [&]. | |
| ?24 | N/A | N/A | | Reports syringe gap volume as set by the [k] command. | |
| ?25 | N/A | N/A | | Reports motor hold current in % of max. | |
| ?26 | N/A | N/A | | Reports motor run current in % of max. | |
| ?27 | N/A | N/A | | Reports configuration EEPROM data as set using the [u] command | |
| ?28 | N/A | N/A | | Reports 3-port valve jumper installation. | 3 = 3-port valve; jumper installed.<br>4 = Other valve types; jumper not installed |
| ?29 | N/A | N/A | | Reports current status; same as [Q] command. | |
| ?30...?44 | | | | Reports program string stored in specified EEPROM location. ?30 = s0, ?31 = s1 and so on. | |

**Table 5-9: RS232/RS485 command summary (continued)**

| Command | Operand <n> range ( ) = C24000/ C24000MP only | Default Operand | Power-up default | Command description | Operand description |
|---|---|---|---|---|---|
| ?76 | N/A | N/A | | Same as [?27]. | |
| F | N/A | N/A | | Reports command buffer status; same as [?10]. | |
| & | N/A | N/A | | Reports firmware version; same as [?23]. | |
| # | N/A | N/A | | Reports firmware checksum; same as [?20]. | |
| RZ | N/A | N/A | | Reports absolute plunger position; same as [?]. | |
| RV | N/A | N/A | | Reports firmware version; same as [?23]. | |
| % | N/A | N/A | | Reports number of valve movements since last report; same as [?18]. | |

## CAN Bus command summary

### Table 5-10: C-Series CAN Bus command summary

| Command | Operands | Command Description |
|---|---|---|
| **On-the fly commands frame type = 0** | | |
| V | Same as RS232/ RS485 | Top velocity |
| T | N/A | Terminate |
| **Action commands frame type = 1** | | |
| All RS232/RS485 commands, with the exception of Report commands, are valid action commands in CAN bus mode. | | |
| **Common commands frame type = 2** | | |
| 0 | N/A | Reset mode |
| 1 | N/A | Start loaded command in buffer. |
| 2 | N/A | Clear loaded command in buffer. |
| 3 | N/A | Repeat last command; like [X]. |
| 4 | N/A | Stop action immediately; same as [T] command. |
| **Report commands frame type = 6** | | |
| 0 | N/A | Reports plunger position. |
| 1 | N/A | Reports position; like [?4]. |
| 2 | N/A | Same as report command [0]. |
| 3 | N/A | Reports valve position; like [?6]. |
| 4 | N/A | Reports top velocity; like [?2]. |
| 6 | N/A | Reports start velocity; like [?1]. |
| 7 | N/A | Reports cutoff velocity; like [?3]. |
| 10 | N/A | Reports buffer status; like [F]. |
| 12 | N/A | Reports backlash increments; like [?12]. |
| 13 | N/A | Reports input 1 status; like [?13]. |
| 14 | N/A | Reports input 2 status; like [?14]. |
| 15 | N/A | Non-functional; will always report 1. |
| 16 | N/A | Non-functional; will always report 1. |
| 17 | N/A | Non-functional; will always report 1. |
| 18 | N/A | Reports number of valve movements since last report; like [?18]. |
| 19 | N/A | Reports whether pump is initialized. 1 = initialized, 0 = not initialized. |
| 20 | N/A | Reports firmware checksum; like [?20]. |
| 22 | N/A | Non-functional command to maintain backward firmware compatibility. Will always return 255. |
| 23 | N/A | Reports firmware version; like [&]. |
| 24 | N/A | Reports syringe gap volume; like [?24]. |
| 29 | N/A | Reports current status; like [Q]. |

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# 6 Maintenance

## About this chapter

This chapter provides maintenance information for the C-Series Syringe Pumps.

The following parts are included:



## Routine maintenance

**Table 6-1: Maintenance Activities**

| Frequency | Activity | Comments |
|---|---|---|
| Daily | Inspect syringe seals and valves for leaks and proper operation. Look for fluid dripping from the fittings, syringe port, or syringe seal. Also look for air bubbles in the syringe, which would indicate leaking at these interfaces. | Replace as required. |
| Daily | Inspect tubing fittings for leaks. | Tighten or replace as required. |
| Daily | Inspect for any fluid or material on outside of pump. | Clean as required. |
| As needed | Park inactive syringes. | Flush with distilled water at end of use, and place syringe full of system fluid in full down position. |

# Replacing components

## Replacing syringe

### Before starting

Prime with air to remove all fluid from the syringe.

### Remove syringe

Refer to Figure 6-1 for this procedure.

1. Lower the syringe plunger arm/holder to ensure sufficient room to remove the syringe.
   - C3000 pumps: if the pump is powered off, manually lower the plunger by pushing firmly down on the syringe plunger arm/holder. If the power is on, this can be done by sending the [A3000R] command.
   - C24000 pumps: with the power on, send the [A24000R] command. The plunger cannot be manually lowered on the C24000 pump due to the high resolution of the drive system.
2. Twist the plunger lock screw counterclockwise at least two full turns (do not completely remove the plunger lock screw).
3. Turn the syringe counterclockwise and remove from the valve.
4. Push the syringe down over the plunger.
5. Remove the syringe with plunger from syringe plunger arm/holder.
6. To install the replacement syringe, follow the steps in "Install new syringe" below.

### Install new syringe

**Note:** The C24000 pumps must be initialized before the syringe can be installed. This is because these pumps cannot be moved manually. For C24000 pumps, first go to "Initialize pump" (page 31) and return to this procedure after initialization has been performed.

Refer to Figure 6-1 during this procedure.

1. Lower the syringe plunger arm/holder to ensure sufficient room to install the syringe and plunger.
   - C3000 pumps: if the pump is powered off, manually lower the plunger by pushing firmly down on the syringe plunger arm/holder. If the power is on, this can be done by sending the command [A3000R].
   - C24000 pumps: with the power on, send the command [A24000R]. The plunger cannot be manually lowered on the C24000 pump due to the high resolution of the drive system.
2. Make sure the plunger is fully seated in the syringe, to ensure the length is short enough to fit into the available space.

**⚠CAUTION**

**CAUTION:**

- Do not overtighten the syringe or fittings. This can cause damage to the syringe and valve, which can lead to leakage and reduced life. Do not exceed 21 oz-in. torque on either the syringe or fittings.
- Do not use Teflon® tape on syringe or fitting threads. All syringe port seals are face seals (not thread sealing). Use of Teflon® tape can lead to valve damage due to over stress on the valve seat from excessive torque applied to the syringe or fittings.

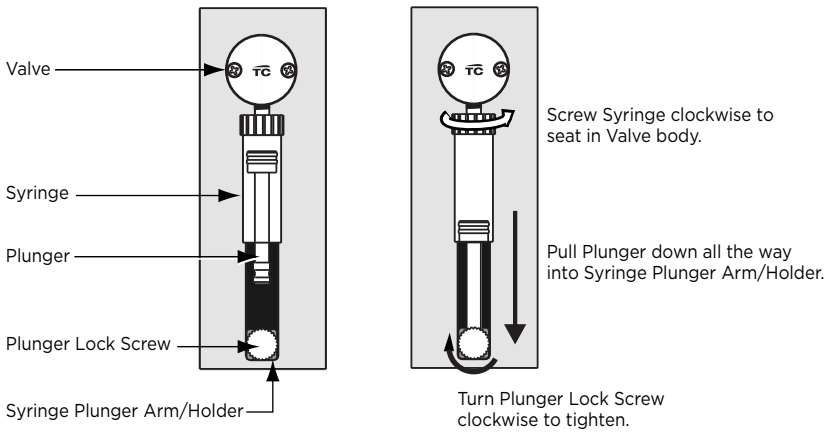
3. Screw the threaded portion of the syringe clockwise into the valve (hold the syringe by the knurled portion when screwing it into the valve).
4. Tighten the syringe until it bottoms in the valve, then tighten another 1/4 turn (this roughly corresponds to 16 oz-in). If a more secure installation is needed, loosen the syringe and repeat the process approximately 24 hours later. *The maximum torque specification is 21 oz-in.*

**⚠CAUTION**

**CAUTION:** Do not exceed the maximum torque specification of 21 oz-in. This can cause damage to the syringe and valve, which can lead to leakage and reduced life.

5. Pull the plunger down and fully seat it into the syringe plunger arm/holder.
6. Securely tighten the plunger lock screw by turning clockwise.

**Figure 6-1. Installing syringe**



## Replacing valve

**⚠CAUTION**

**CAUTION:** If you would like to replace your current valve with a valve of a different kind or type, please first contact Customer Service for assistance. There are some important factors to consider in order to avoid damaging the equipment.

### Before starting

Prime with air to remove all fluid from the syringe.

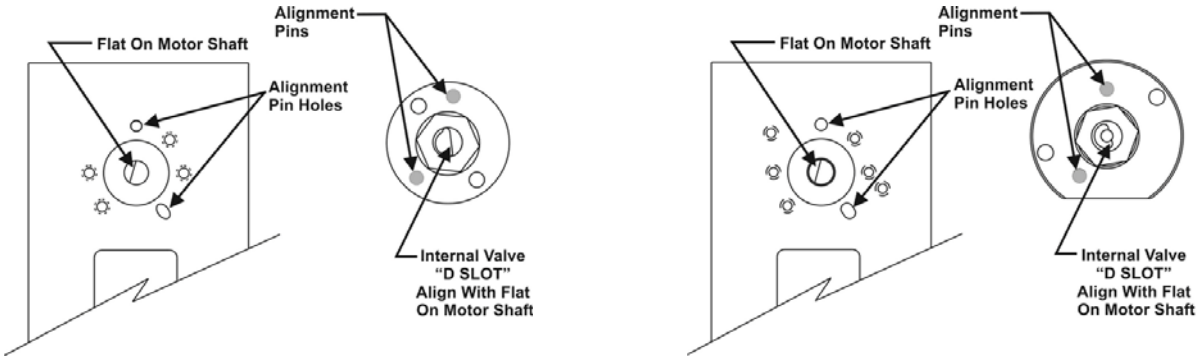
### To remove the valve

1. Remove syringe as described on page 100.
2. Disconnect the tubing from the valve.
3. Remove the two screws used to secure the valve to the panel.
4. Remove the valve from the pump by pulling directly away from the pump's front face.

### To install the new valve

1. Align internal valve "D" slot with the flat on the motor shaft.
2. Gently push and rotate the valve into the correct position to align the pins with the holes in the panel.
3. Securely tighten (clockwise) the plunger lock screws.

### Figure 6-2. Common valve interfaces




4. Replace syringe and tubing as follows:

- Replace tubing fittings and tubing according to your instrument design and the tubing supplier's instructions. Verify fittings are fully seated and finger tight.

**⚠CAUTION**

**CAUTION:** When replacing syringe and tubing, do not exceed the maximum torque specification of 21 oz-in for both the tubing fittings and the syringe. Exceeding this maximum torque can cause damage to the syringe and valve, which can lead to leakage and reduced life.

5. Replace syringe as described on page 100.

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# 7 Troubleshooting

## About this chapter

This chapter provides diagnostic and troubleshooting information for the C-Series Syringe Pumps.

The following parts are included:

# Performing diagnostic self test

During the self test, the pump initializes, then cycles repeatedly through a series of plunger movements. If an error condition occurs, the pump stops moving.

To perform the self test:

1. Turn power off.
2. Turn the address switch to the F position.


3. Install the AutoRun jumper on J2. For location of the AutoRun jumper, see Figure 4-2 (page 23).
4. Turn power on.
5. If errors are experienced, refer to "Status and error codes" (page 88).
6. Return address switch and AutoRun jumper to their normal position when finished.

# Symptoms and solutions

See Table 7-1 for common symptoms and their remedies. Also see Table 7-2 for any error codes that are received.

**Table 7-1: Troubleshooting**

| Symptom | Possible cause(s) | Corrective action |
|---|---|---|
| Unit runs automatically | Address switch and jumpers set incorrectly | • Verify proper address switch setting. See "Set configuration jumpers and address switch" (page 22).<br>• Verify AutoRun jumper on J2 is removed. See Figure 4-2 (page 23). |
| No response to host commands | Pump not receiving power | • Check 24VDC power supply.<br>• Verify LEDs lit on pump.<br>• Check cables (broken or unconnected wires, connectors properly seated, proper connections per pinout diagram). For pinout, refer to "Connector J3 pin assignments" (page 24). |
| | No communications to pump | • Verify proper COM port is selected on host computer.<br>• Verify any external RS485 converter is working properly.<br>• Verify proper pump address is selected. See "Address switch setting" (page 22).<br>• Verify proper baud rate setting is selected. See "Configuration jumpers" (page 22) and "CAN baud rate" (page 22) and Table 5-4 (page 82).<br>• Verify that execute command [R] is being sent at end of command strings.<br>• If DT mode is in use, verify that carriage return/line feed is inserted at end of command string following [R] command.<br>• If OEM mode is in use, make sure STX and ETX characters are in the string, and checksum is generated correctly. See "OEM communication protocol" (page 115). |
| Pump does not complete initialization command.<br><br>⚠CAUTION<br><br>When replacing syringe and tubing, do not exceed the maximum torque specification of 21 oz-in for both the tubing fittings and the syringe. Exceeding this can damage the syringe and valve, causing leakage and reduced life. | Syringe not installed correctly and obstructs motion | • Verify pump initializes without syringe installed.<br>• Reinstall syringe. See "Replacing syringe" (page 100). |
| | Damaged PCBA (motor connection or sensor issues) | Contact Customer Service. |
| | Fluid obstruction | Check fittings, look for kinked or obstructed tubing, and probe for other obstructions. |

**Table 7-1: Troubleshooting (continued)**

| Symptom | Possible cause(s) | Corrective action |
|---|---|---|
| Fluid leaking | Syringe not installed correctly | Reinstall syringe.<br>See "Replacing syringe" (page 100). |
| | Fittings not installed correctly | Verify fittings are fully seated and finger tight. |
| | Tubing damaged or broken | Replace tubing. |
| | Excessive back pressure | Remove/reduce restriction in fluid path (e.g., kinked or blocked tubing). |
| | Syringe or valve has exceeded its useful life.<br>(Some valves have a “weep hole” located at bottom of valve behind the syringe port. Fluid coming from this location indicates valve failure.) | Replace syringe or valve.<br>See "Replacing syringe" (page 100) or "Replacing valve" (page 102). |

# Error code listing

Table 7-2 lists the error codes and corrective action for each.

**Table 7-2: Error Codes**

| Error Code | Error LED pattern | Error | Error name/possible cause | Corrective Action |
|---|---|---|---|---|
| 1 | 1 blink | Initialization error | Failure occurred during initialization. | See “Pump does not complete initialization command” in Table 7-1. |
| 2 | NA | Invalid command | An unrecognized command was issued. | Correct the command. Refer to "Operating instructions" beginning on page 37. |
| 3 | NA | Invalid operand | An invalid argument (<n>) was included with a command. Command parameters out of valid range. | Correct the argument and pump operation will continue normally. Refer to "Operating instructions" beginning on page 37. |
| 4 | NA | Invalid checksum | Checksum generation is incorrect. In OEM mode, the checksum did not match the received string. | Verify checksum calculation. |
| | | | Noise on communication lines. | Check communication signals; use repeat and resend command. |
| | | | Damaged cable | Check all cables and connections. |
| 6 | 2 blinks | EEPROM failure | Data is faulty on PCBA, indicating faulty EEPROM. | Contact Customer Service. |
| 7 | NA | Device not initialized | Initialization command not sent before using the pump | Initialize the pump. |
| | | | Pump failed previous initialization command | See “Pump does not complete initialization command” in Table 7-1. |
| 8 | NA | CAN bus failure | Cabling issue | Verify cables, and that all connectors are fully seated. See "Cabling" (page 19). |
| | | | Incorrect communication rate | Verify communication rate settings match on pump and host computer. See "Set pump configuration EEPROM parameters (U<n>)" (page 82). |
| 9 | 3 blinks | Plunger overload | Plunger movement is restricted | Verify syringe is installed properly. See "Replacing syringe" (page 100). Reinitialize pump to allow normal operation to resume. |
| | | | Excessive back pressure | Remove/reduce restriction in fluid path (kinked tubing, etc.). Reinitialize pump to allow normal operation to resume. |
| | | | Damaged or dirty encoder sensor | Contact Customer Service. |
| | | | Damaged PCBA (printed circuit board) or faulty motor connection | Contact Customer Service. |
| 10 | 4 blinks | Valve overload | Valve drive has lost steps for unknown reason | Reinitialize pump and send new valve command. |
| | | | Excessive torque required to move valve | Remove valve, re-install, and retry. |
| | | | Valve failure | Contact Customer Service. |
| | | | Damaged PCBA (motor connection or sensor failure) | Contact Customer Service. |
| 11 | NA | Plunger move not allowed. | Valve is in the bypass position | Move valve to a position where syringe is not blocked. |

**Table 7-2: Error Codes (continued)**

| Error Code | Error LED pattern | Error | Error name/possible cause | Corrective Action |
|---|---|---|---|---|
| 15 | NA | Command overflow | Command string is too long. (command buffer limit is 255 characters) | Reduce length of command string. Also see "Executing long program strings using the [e] command" (page 81). |
| | | | Host computer sends command before pump is ready. (pump may be busy executing another command) | Before sending, verify pump is ready by polling with the [Q] command. |

# 8 Customer support

## About this chapter

This chapter provides the instructions you need to obtain Customer Service assistance, order parts and accessories, and return equipment for warranty service.

## Contacting Customer Service

You may obtain assistance with the operation or repair of the C-Series Syringe Pumps by contacting us at any of the following locations:

| | |
|---|---|
| Americas | 12740 Earhart Avenue<br>Auburn, CA 95602<br>USA<br>Tel: +1 530-273-8888<br>Fax: +1 530-273-2586<br>LiquidHandling.TCS@gardnerdenver.com |
| Europe | Livry-Gargan-Str. 10<br>Fürstenfeldbruck nearby Munich<br>82256<br>Germany<br>Tel: 49 8141 2280 0<br>Fax: 49 8141 8892136<br>thomas.de@gardnerdenver.com |
| Asia Pacific | Gardner Denver Hong Kong, Limited<br>Unit 1317-1318 Delta House, 3 On Yiu Street<br>Siu Lek Yuen, Shatin, New Territories<br>Hong Kong<br>Tel: +852 26903502<br>Fax: +852 27924598<br>thomas.hk@gardnerdenver.com |
| Website: | http://www.tricontinent.com |

# Ordering parts and accessories

To view and/or download detailed product and accessory information and literature, please go to the product page for the C-Series Syringe Pumps at www.tricontinent.com. Typical Information at this location includes the following:

- Specifications (data sheets)
- Dimensions
- Models and eDrawings
- Product and accessory ordering information
- Warranty and return instruction details
- Product literature and drawings
- Links to associated drivers, etc. as appropriate

To order parts and accessories, contact TriContinent using any of the methods listed on the previous page.

# Warranty and return information

C-Series Syringe Pumps are warranted against manufacturing defects for a period of one year. For detailed warranty and return instruction, please go the product page for C-Series Syringe Pumps at www.tricontinent.com.

**Please observe:**

DO NOT ship the instrument back for repair until you are advised to do so by Customer Service and have been issued an RMA number.

DO NOT attempt to repair the instrument. Removing the case will nullify the warranty.

There is no warranty expressed for syringes and plungers.

**⚠CAUTION**

**CAUTION:** Avoid shipping pumps with syringes installed. During transport, shock and vibration can be transmitted directly to the syringe.

This can lead to glass breakage, loosening of syringes from their threaded ports, and potentially other problems. Syringes should always be shipped separately inside their original packaging for the highest level of protection from damage. Using the pumps' original packaging is insufficient.

For example, when shipping pumps that have been installed in an instrument, syringes should be removed and shipped in their individual packaging as described above.

# 9 Reference information

## About this chapter

This chapter contains reference information to support use of the C-Series Syringe Pumps.

The following subjects are included:

# Pump addressing scheme

As part of the communications protocol, every command string begins with an address for the intended pump(s), e.g., [/2A1000R] in DT protocol, where 2 is the address.

The address corresponds to a device number set by the address switch on the pump plus one. There are sixteen possible addresses on the bus. For RS232, RS485, and CAN, the overall hexadecimal addressing scheme is shown in Table 9-1. For RS232 and RS485 only, device settings with corresponding hex and ASCII values are shown in Table 9-2.

**Table 9-1: Hexadecimal addressing scheme, RS232/485 and CAN**

| Address (hex) | | |
|---|---|---|
| **RS232/RS485** | **CAN** | **Device** |
| 30 | 0 | Master address (master controller, host, personal computer, etc) |
| 31...3F | 1...F | Addresses single device. |
| 41...4F | N/A | Addresses two devices at a time (dual device). |
| 51...5D | N/A | Addresses four devices at a time (quad device). |
| 5F | N/A | Addresses all devices on the bus. |

**Table 9-2: Device addressing values for RS232/485**

| Device number[1] | Single Device | | Dual Device | | Quad Device | | All Devices | |
|---|---|---|---|---|---|---|---|---|
| | Hex Address | ASCII Address | Hex Address | ASCII Address | Hex Address | ASCII Address | Hex Address | ASCII Address |
| 0 | 31 | 1 | 41 | A | 51 | Q | 5F | - |
| 1 | 32 | 2 | | | | | | |
| 2 | 33 | 3 | 43 | C | | | | |
| 3 | 34 | 4 | | | | | | |
| 4 | 35 | 5 | 45 | E | 55 | U | | |
| 5 | 36 | 6 | | | | | | |
| 6 | 37 | 7 | 47 | G | | | | |
| 7 | 38 | 8 | | | | | | |
| 8 | 39 | 9 | 49 | I | 59 | Y | | |
| 9 | 3A | : | | | | | | |
| A | 3B | ; | 4B | K | | | | |
| B | 3C | < | | | | | | |
| C | 3D | = | 4D | M | 5D | ] | | |
| D | 3E | > | | | | | | |
| E | 3F | ? | 4F | O | | | | |
| F | 40 | @ | | | | | | |

1. Assigned by switch on pump.

**Note:** Multiple-device addresses (Dual, Quad, All) cannot be used to query device status or to issue report commands. Each device must be queried separately. Were it not so, all the addressed devices would attempt to respond at once.

Notice in Table 9-2 that the RS232/485 protocols allow multiple-device addressing. A user can address not only single pumps, but also two pumps (Dual Device), four pumps (Quad Device), or all 16 pumps (All Devices). Address 5Fh (All Devices), for example, can be used to perform a simultaneous initialization on all pumps. Afterwards, each pump can be addressed individually using 31h through 40h.

# OEM communication protocol

OEM communication is a robust protocol that includes automatic recovery from transmission errors. Table 9-3 describes each setting within the OEM communication protocol.

**Table 9-3: OEM Protocol communication details**

| Parameter | Setting |
|---|---|
| **Character Format** | |
| Baud Rate | 9600 or 38400 |
| Data Bits | 8 |
| Parity | None |
| Stop Bit | 1 |
| **Command Block**<br>(see "OEM protocol command block characters" for details) | |
| 1 | SYNC (FFh) |
| 2 | STX (Ctrl B or 02h) |
| 3 | Pump address |
| 4 | Sequence Number/Repeat flag |
| 5+n | Data block (length n bytes) |
| 6+n | ETX (Ctrl C or 03h) |
| 7+n | Checksum |
| **Answer Block**<br>(see "OEM protocol answer block characters" for details) | |
| 1 | STX (Ctrl B or 02h) |
| 2 | Master address (0 or 30h) |
| 3 | Status/error code |
| 4+n | Data block (length n bytes) |
| 5+n | ETX (Ctrl C or 03h) |
| 6+n | Checksum |

## OEM protocol command block characters

The command block characters in the OEM communication protocol are described below. All characters outside the command block are ignored.

When developing a parsing algorithm, the programmer should key on the STX as the beginning of the answer block and the checksum (character after ETX) as the end of the answer block.

### SYNC (FFh)

Used for backward compatibility with older model pumps.

### STX (Ctrl B or 02h)

The STX character indicates the beginning of a command string.

### Pump address

The pump address is specific, selected on each individual pump, as described in the instructions for that pump.

### Sequence number/repeat flag

The sequence number is a single byte that conveys both a sequence number (legal values: 0 through 7) and a bit flag indicating that the command block is being repeated due to a communications breakdown. The sequence number is used as an identity stamp for each command block. Since it is only necessary that every message carry a different sequence number from the previous message (except when repeated), the sequence number may be toggled between two different values (e.g., 1 and 2) as each command block is constructed. During normal communication exchanges, the sequence number is ignored. If, however, the repeat flag is set, the pump compares the sequence number with that of the previously received command block to determine if the command should be executed or merely acknowledged without executing.

**Note:** If the operator chooses not to use the error detection option, the sequence number can be set to a fixed value of 1 (31h).

The following two scenarios clarify this error detection mechanism.

#### Scenario 1

1. The computer sends a command block stamped with sequence number 1 to the pump.
2. The pump receives the command, sends an acknowledgment to the PC, and executes it.
3. Transmission of the acknowledgment message is imperfect; the PC does not receive it.
4. The PC waits 100 ms for the acknowledgment, then retransmits the command block with the sequence number left at 1 and the repeat bit set to indicate a retransmission.
5. The pump receives the transmission, identified as such by the repeat bit.
6. The pump checks the sequence number against that of the previously received command block. Noting a match, the pump sends an acknowledgment to the PC, but does not execute the command (since it has already been executed as indicated by the repeat bit).
7. The PC receives the acknowledgment and continues with normal communications.
8. The next command block is stamped with sequence number 2 to indicate a new command.

#### Scenario 2

1. The computer sends a command block stamped with sequence number 1 to the pump.
2. The pump never receives the command due to a communication error and thus does not send an acknowledgment to the PC.

3. The PC waits 100 ms for the acknowledgment then retransmits the command block with the sequence number left at 1 and the repeat bit set to indicate a retransmission.
4. The pump receives the retransmission, identified as such by the repeat bit.
5. The pump checks the sequence number against that of the previously received command block. Noting a mismatch, the pump recognizes this as a new command block and sends an acknowledgment to the PC. It then executes the command.
6. The PC receives the acknowledgment and continues with normal communications.
7. The next command block is stamped with sequence number 2 to indicate a new command.

The sequence number/repeat byte is constructed as follows:

| **Bit #** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| **Value** | 0 | 0 | 1 | 1 | REP | SQ2 | SQ1 | SQ0 |

REP: Value is 0 for non-repeated command, 1 for repeated.

SQ0 - SQ2: Sequence value, as shown below:

| **Sequence Value** | **SQ2** | **SQ1** | **SQ0** |
|---|---|---|---|
| 1 | 0 | 0 | 1 |
| 2 | 0 | 1 | 0 |
| 3 | 0 | 1 | 1 |
| 4 | 1 | 0 | 0 |
| 5 | 1 | 0 | 1 |
| 6 | 1 | 1 | 0 |
| 7 | 1 | 1 | 1 |

### Data block (length n bytes)

The data block consists of an ASCII string of data or commands sent to the pump or host Certain commands, [Q] for example, have a data block length of 0. That is, no data string exists.

### ETX (Ctrl C or 03h)

The ETX character indicates the end of the command string.

### Checksum

The checksum is the last byte of the message string. All bytes (excluding line synchronization and checksums) are XORed to form an 8-bit checksum. This is appended as the last character of the block. The receiver compares the transmitted value to the computed value. If the two values match, an error-free transmission is assumed. otherwise, a transmission error is assumed.

## OEM protocol answer block characters

The answer block characters in the OEM communication protocol are described below.

### STX (Ctrl B or 02h)

The STX character indicates the beginning of a response string.

### Master address

The master address is the address of the host system. This should always be “0” or 30h.

### Status and error codes

The status and error codes define pump status and notify of error conditions. For a complete listing of error codes, see the instructions for the particular pump.

### Data block (length n bytes)

This is the response from all report commands except the [Q] command.

### ETX (Ctrl C or 03h)

The ETX character indicates the end of the response string.

### Checksum

The checksum is the last byte of the message string. All bytes (excluding line synchronization and checksums) are XORed to form an 8-bit checksum. This is appended as the last character of the block. The receiver compares the transmitted value to the computed value. If the two values match, an error-free transmission is assumed; otherwise, a transmission error is assumed.

# Data Terminal (DT) protocol

The DT protocol can be used easily from any terminal or terminal emulator capable of generating ASCII characters at 9600 or 38400 baud, 8 bits, and no parity. Table 9-4 lists each setting of the DT protocol.

**Table 9-4: DT Protocol communication details**

| Parameter | Setting |
|---|---|
| **Character Format** | |
| Baud Rate | 9600 or 38400 |
| Data Bits | 8 |
| Parity | None |
| Stop Bit | 1 |
| **Command block** (see "DT protocol command block characters" below, for details) | |
| 1 | Start character (ASCII “/” or 2Fh) |
| 2 | Pump address |
| 2+n | Data block (length n) |
| 3+n | End character (carriage return, “CR” or 0Dh) |
| **Answer block** (see "DT protocol answer block characters" below, for details) | |
| 1 | Start character (ASCII “/” or 2Fh) |
| 2 | Master address (ASCII “0” or 30h) |
| 3 | Status character |
| 3+n | Data block (if applicable) |
| 4+n | ETX (Ctrl C or 03h) |
| 5+n | Carriage return (“CR” or 0Dh) |
| 6+n | Line feed (0Ah) |

## DT protocol command block characters

The command block characters in the DT communication protocol are described below.

### Start character

The start character (ASCII “/” or hex 2Fh) indicates the beginning of a message.

### Pump address

The pump address is an ASCII character specific to each pump.

### Data block (length n)

The data block consists of the ASCII data or commands sent to the pump or host.

### End character

The end character (carriage return, ASCII “CR” or ODh) indicates the end of the message.

## DT protocol answer block characters

The answer block characters comprising the DT communication protocol are described below.

### Start character

The start character (ASCII “/” or hex 2Fh) indicates the beginning of the response.

### Master address

The master address is the address of the host system. This should always be “0” or 30h.

### Status character

The status and error codes define pump status and signal error conditions. See the description of the [Q] command in the main part of the product manual.

### Data block

This is the response from all report commands with the exception of the [Q] command.

### ETX

The ETX character (Ctrl C or 03h) indicates the end of the response string.

### End character(s)

The carriage return (“CR” or 0Dh) and/or line feed (“LF” or 0Ah) terminates the reply block.

# CAN interface communications

CAN (Controller Area Network) is a two-wire, serial communication bus. It eliminates polling sequences that verify task completion. Using CAN, the pumps asynchronously report to the master host when they have finished the current task.

**Note:** The pumps use a CAN controller chip compatible with Philips Semiconductor CAN bus specification, version 2.0. This is also compatible with the CANOpen standard.

## CAN messages

Standard CAN messages consist of 18-bit frames. Each frame has a 12-bit *arbitration* field and a 6-bit *control* field. These are all the bits that must be considered at the programming level. On the physical CAN hardware there are additional bits that occur in a message, such as the start bit and CRC Field bits; but these are not discussed here, since they are implemented at the hardware level.

Within the arbitration field, there is an 11-bit message identifier (MID), and within the control field a 4-bit data length identifier.

The eleven MID bits are used to:

- Indicate which device on the bus the message involves.
- Identify the message type.
- Show the direction of the message (either to or from the master device).

The 4-bit data length identifier within the control field represents the length of the data block.

Data blocks can be from zero to eight bytes in length. Any message that requires more than eight bytes must be sent in a series of multi-frame messages. The receiving unit then assembles the data in the separate frames into one long string.

### CAN message construction

The CAN messages format used to communicate between a host and the pump are described in this section.

Each message frame begins with the message identifier (MID). The CAN data block (up to 8 bytes in length) follows the MID and length information. The MID makes up three nibbles that are transmitted first in a message frame. The bits are grouped as shown below:

| **CAN arbitration field** | | | | | **CAN control field** | | | |
|---|---|---|---|---|---|---|---|---|
| MID | | | | RTR | IDE | r0 | Data Length (DLC) | **CAN data block** |
| Direction | Group | Device | Frame | | | | | |
| X | 010 | XXXX | XXX | 0 | 0 | 0 | XXXX | 0-8 Bytes |

### Direction bit (1)

| CAN arbitration field | | | | | CAN control field | | | |
|---|---|---|---|---|---|---|---|---|
| MID | | | | RTR | IDE | r0 | Data Length (DLC) | **CAN data block** |
| Direction | Group | Device | Frame | | | | | |
| X | 010 | XXXX | XXX | 0 | 0 | 0 | XXXX | 0-8 Bytes |

The Direction bit lets the devices on the bus know whether the current message is to or from the master. “0” means that the message is from master to slave; “1” means the message is from the slave to the master.

**Note:** Peer-to-peer messaging is not supported.

### Group bits (3)

| CAN arbitration field | | | | | CAN control field | | | |
|---|---|---|---|---|---|---|---|---|
| MID | | | | RTR | IDE | r0 | Data Length (DLC) | **CAN data block** |
| Direction | Group | Device | Frame | | | | | |
| X | 010 | XXXX | XXX | 0 | 0 | 0 | XXXX | 0-8 Bytes |

The three group bits specify the group number (0-7). Each device on the CAN bus has a group assignment. The pump is assigned to group 2 (010). Group 1 is reserved for the boot request procedure.

### Device address bits (4)

| CAN arbitration field | | | | | CAN control field | | | |
|---|---|---|---|---|---|---|---|---|
| MID | | | | RTR | IDE | r0 | Data Length (DLC) | **CAN data block** |
| Direction | Group | Device | Frame | | | | | |
| X | 010 | XXXX | XXX | 0 | 0 | 0 | XXXX | 0-8 bytes |

The device address bits specify the address of the pump in the indicated group. There can be up to 16 devices in the group, with addresses from 0 to 15. Expressed in binary, these would be b0000 through b1111. In hexadecimal, they would be 0h through 0Fh.

### RTR, IDE, r0

| CAN arbitration field | | | | | CAN control field | | | |
|---|---|---|---|---|---|---|---|---|
| MID | | | | RTR | IDE | r0 | Data Length (DLC) | CAN data block |
| Direction | Group | Device | Frame | | | | | |
| X | 010 | XXXX | XXX | 0 | 0 | 0 | XXXX | 0-8 bytes |

The RTR, IDE, and r0 bits are not used in the TriContinent CAN implementation and should always be set to 0.

### Data length code (DLC)

| CAN arbitration field | | | | | CAN control field | | | |
|---|---|---|---|---|---|---|---|---|
| MID | | | | RTR | IDE | r0 | Data Length (DLC) | CAN data block |
| Direction | Group | Device | Frame | | | | | |
| X | 010 | XXXX | XXX | 0 | 0 | 0 | XXXX | 0-8 bytes |

This is the length of the data block in the message. Data blocks can be from zero to eight bytes in length.

### CAN data block

| CAN arbitration field | | | | | CAN control field | | | |
|---|---|---|---|---|---|---|---|---|
| MID | | | | RTR | IDE | r0 | Data Length (DLC) | CAN data block |
| Direction | Group | Device | Frame | | | | | |
| X | 010 | XXXX | XXX | 0 | 0 | 0 | XXXX | 0-8 bytes |

The data block contains the information to be transmitted (pump commands), up to eight bytes. For command strings that are more than eight bytes in length, multi-frame messages are used. This permits long program strings to be sent, just as when other communications interfaces are used.

Pump commands are sent in ASCII just as in RS-232 or RS-485.

### CAN frame bits (3), and frame types

| CAN arbitration field | | | | | CAN control field | | | |
|---|---|---|---|---|---|---|---|---|
| MID | | | | RTR | IDE | r0 | Data Length (DLC) | CAN data block |
| Direction | Group | Device | Frame | | | | | |
| X | 010 | XXXX | XXX | 0 | 0 | 0 | XXXX | 0-8 bytes |

The frame type (specified by the three bits in the Frame portion of the MID) allows a device to know what type of command is coming in and enables faster processing of commands. Pumps respond to the frame types as follows:

### Type 0: On-the-Fly commands ([V] and [T]). Frame bits = 000

Normal commands use a frame type of 1 (i.e., action commands). Since commands sent over the CAN bus with a particular frame type must complete before a subsequent command using the same frame type can be issued, a different ID must be used when issuing an “on-the-fly” command. For this reason, on-the-fly commands must be issued with a frame type of 0 (zero).

Commands issued with frame type 0 do not generate completion messages, and thus no pairing code is needed (these commands are simply acknowledged immediately).

### Type 1: Action commands. Frame bits = 001

This frame type is used for action commands such as initialization commands [Z], movement commands ([A],[D],[P]), or for setting pump operating parameters. All task-type commands are sent in this type of message frame. When multi-frame messages are used to send an action command, this frame is the end message sent to the pump.

### Type 2: Common commands. Frame bits = 010

This frame type is used for commands that are common to every device on the bus. The command is a single ASCII character in the data block. The ASCII command characters with hexadecimal equivalents are described below.

| Command | Description |
|---|---|
| 0 (0x30 in hex) | Reset mode. This resets the pump and begins the boot request procedure. |
| 1 (0x31 in hex) | Start loaded command. Just like sending a run [R] command after a string has been loaded. |
| 2 (0x32 in hex) | Clear loaded command. This clears out the command buffer. |
| 3 (0x33 in hex) | Repeat last command. This command does the same thing as the arbitration field command (execute last command in string). |
| 4 (0x34 in hex) | Stop action immediately. This acts like the terminate [T] command. |

### Type 3: Multi-frame start message. Frame bits = 011

This frame type lets the pump know that the next message will be longer than the 8-byte maximum for each frame. Subsequent frames will follow to complete the message. The frame will contain 8 bytes of data.

### Type 4: Multi-frame data. Frame bits = 100

This frame type is used to identify a frame that is within a multi-frame message. It will contain 8 bytes.

**Note:**

- The last frame of a multi-frame message for action commands must be type 1. The last frame of a multi-frame message response from the pump for report commands must be type 6.
- There is no type 5 frame.

### Type 6: Report/answer commands. Frame bits = 110

This frame type is used to get information back from the pump. It is similar in operation to the query commands (e.g. [?]) used in the OEM and DT protocols. The report command is one or two bytes long since the command is sent as ASCII characters in the data block.

When the pump responds to a query, the first byte of the data block is the status byte. It is defined like the status byte in the RS485 and RS485 protocols. The next byte is a null character. The remaining six bytes are for the response in ASCII. If the pump is only reporting current status, the message is only two bytes long. If the reply consists of more than six bytes, multi-frame messages are used.

## Handling of pump boot requests

When the pump is first powered up or receives a system reset command (frame type 2, command 0), the pump notifies the host of this condition by sending a boot request message at intervals of 10-12 seconds until it receives a boot request response. The group number is 1 for the boot request message. The frame type is 2 when the pump sends messages to the host, and the frame type must be 0 when the host replies to the boot request.

### Example 1. The pump is set to address 0.

1. Pump sends boot request (Group=1, Frame=2):

| Direction | Group | Device | Frame | RTR/IDE/r0 | Length |
|---|---|---|---|---|---|
| 1 | 001 | 0000 | 010 | 000 | 0000 |

2. Host acknowledges:

| Direction | Group | Device | Frame | RTR/IDE/r0 | Length | Data bytes[1] | |
|---|---|---|---|---|---|---|---|
| | | | | | | Node ID[2] | Slave ID |
| 0 | 001 | 0000 | 000 | 000 | 0010 | 0010 0000 | 0010 0000 |

1. Node ID = Group ID (2) high nibble, + pump address (0) low nibble = 0010 0000
   Slave ID = Same as Node ID
2. The pump will save the Node ID to use for message filter Group ID.

Acknowledgment details:

| | |
|---|---|
| Direction = 0 | Host to slave |
| Group = 1 | Boot request response group |
| Device = 0 | Always 0 in boot response |
| Frame = 0 | Boot request response frame |
| RTR/IDE/r0 = 0 | All three always 0 |
| Length = 2 | Two data bytes in return message |

**Note:** Boot MID is the same for all nodes.

### Example 2. The pump is set to address 6.

1. Pump sends boot request:

| Direction | Group | Device | Frame | RTR/IDE/r0 | Length |
|---|---|---|---|---|---|
| 1 | 001 | 0110 | 010 | 000 | 0000 |

2. Host acknowledges:

| Direction | Group | Device | Frame | RTR/IDE/r0 | Length | Data bytes[1] | |
|---|---|---|---|---|---|---|---|
| | | | | | | Node ID[2] | Slave ID |
| 0 | 001 | 0000 | 000 | 000 | 0010 | 0010 0110 | 0010 0110 |

1. Node ID = Group ID (2) high nibble, + pump address (0) low nibble = 0010 0000
   Slave ID = Same as Node ID
2. The pump will save the Node ID to use for message filter Group ID.

Acknowledgment details:

| | |
|---|---|
| Direction = 0 | Host to slave |
| Group = 1 | Boot request response group |
| Device = 0 | Always 0 in boot response |
| Frame = 0 | Boot request response frame |
| RTR/IDE/r0 = 0 | All three always 0 |
| Length = 2 | Two data bytes in return message |

**Note:** Boot MID is the same for all nodes.

## CAN host and pump message exchanges

### Pump response

When a pump receives a command, finishes a command, encounters an error condition, or responds to a query, it sends an answer frame to the host using the same frame type as the command it received. Generally, it will have the following format:

<MID><RTR/IDE/r0><DLC><Answer>

Where:

| | |
|---|---|
| <MID> | 11-bit message identifier. The direction bit is 1. The group number and the frame type are the same as received. Device is the current device address. |
| <RTR/IDE/r0> | Always zero. |
| <DLC> | 4-bit data length code |
| <Answer> | Data bytes. The first byte of the data block is always the status byte. It is defined as in the table with this title: “Error codes, status byte with ASCII and hexadecimal values” in the main part of the product manual. The second byte is a null character. The remaining bytes contain the response in ASCII format. If the reply consists of more than six bytes, multi-frame messages are used. |

**Note:** Only one command of a given frame type can be in progress at any time: e.g., after issuing a command to a pump with frame type = 1, the master

must wait for the answer with frame type = 1 before issuing the next command with frame type = 1. If a second command of the same type is sent without waiting, a command overload status results. Several commands with different frame types can be in progress at the same time (e.g., an action command and a query command).

## Example host/pump exchanges

The following are typical exchanges between the host and pump for action commands, multi-frame commands, common commands, and query commands.

### Action command example

The host sends a [ZR] command to a pump, where the pump is set to address 0.

1. Host sends:

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC | Data bytes |
|---|---|---|---|---|---|---|
| 0 | 010 | 0000 | 001 | 000 | 0010 | 0x5A 0x52 (“ZR”) |

2. Pump acknowledges:

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC |
|---|---|---|---|---|---|
| 1 | 010 | 0000 | 001 | 000 | 0000 |

3. After executing the command, pump reports status:

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC | Data bytes |
|---|---|---|---|---|---|---|
| 1 | 010 | 0000 | 001 | 000 | 0010 | 0x60 0x00h (“`0”) |

**Note:** “`0“ decodes as first byte status = idle, followed by a null character (hex zero).

### Multi-frame command example

The host sends the command string [Z2S31A3000gHD300G10G5R] to a pump, where the pump is set to address 0.

1. Host sends in three consecutive messages:

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC | Data bytes |
|---|---|---|---|---|---|---|
| 0 | 010 | 0000 | 011 | 000 | 1000 | 0x5A 0x32 0x53 0x33 0x31 0x41 0x33 0x30 (“Z2S31A30”) |

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC | Data bytes |
|---|---|---|---|---|---|---|
| 0 | 010 | 0000 | 100 | 000 | 1000 | 0x30 0x30 0x67 0x48 0x44 0x33 0x30 0x30 (“00gHD300”) |

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC | Data bytes |
|---|---|---|---|---|---|---|
| 0 | 010 | 0000 | 001 | 000 | 0110 | 0x47 0x31 0x30 0x47 0x35 0x52 (“G10G5R”) |

**Note:** The last frame type of a multi-message command is the type of command being sent. This example is an action command. Therefore the last frame type is type 1. The first message in a multi-message command is type 3 and messages between the first and last are type 4.

2. Pump acknowledges:

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC |
|---|---|---|---|---|---|
| 1 | 010 | 0000 | 001 | 000 | 0000 |

3. After executing the command, the pump reports status:

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC | Data bytes |
|---|---|---|---|---|---|---|
| 1 | 010 | 0000 | 001 | 000 | 0010 | 0x60 0x00h (“`0”) |

**Note:** “`0” decodes as first byte status = idle, followed by a null character (hex zero). For multi-frame commands, the pump only sends an acknowledgment for the last frame.

### Common command example

After the host has sent command [A1000A0] to the pump, it can send command 0 of frame type 2 to a pump and initiate execution of the buffered command string. The pump here has been set to address 0.

1. Host sends:

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC | Data bytes |
|---|---|---|---|---|---|---|
| 0 | 010 | 0000 | 010 | 000 | 0001 | 0x30 (“0”) |

2. Pump acknowledges:

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC |
|---|---|---|---|---|---|
| 1 | 010 | 0000 | 010 | 000 | 0000 |

3. After executing the command, pump reports status:

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC | Data bytes |
|---|---|---|---|---|---|---|
| 1 | 010 | 0000 | 010 | 000 | 0010 | 0x60 0x00h (“`0”) |

### Query command examples

Example: the host sends report command 29 of frame type 6 to a pump, with the pump set to address 1.

1. Host sends:

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC | Data bytes |
|---|---|---|---|---|---|---|
| 0 | 010 | 0001 | 110 | 000 | 0010 | 0x32 0x39 (“29”) |

2. Pump reports:

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC | Data bytes |
|---|---|---|---|---|---|---|
| 1 | 010 | 0001 | 110 | 000 | 0010 | 0x60 0x00h (“`0”) |

**Note:** For query commands, no acknowledge frame is needed.

Example: the host sends report command 23 of frame type 6 to a pump, and the pump is set to address 1.

1. Host sends:

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC | Data bytes |
|---|---|---|---|---|---|---|
| 0 | 010 | 0001 | 110 | 000 | 0010 | 0x32 0x33 (“23”) |

2. Pump reports:

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC | Data bytes |
|---|---|---|---|---|---|---|
| 1 | 010 | 0001 | 011 | 000 | 1000 | 0x60 0x00h 0x49 0x50 0x5A 0x3A 0x20 0x30 (“`0IPZ: 0”) |

| Direction | Group | Device | Frame Type | RTR/IDE/r0 | DLC | Data bytes |
|---|---|---|---|---|---|---|
| 1 | 010 | 0001 | 110 | 000 | 0101 | 0x38 0x32 0x39 0x31 0x36 (“82916”) |

**Note:** For a multi-frame reply, the start frame is type 3, the middle frame is type 4, and the last frame is type 6 since type 6 indicates a report command.

# TCS Pump Commander quick reference guide

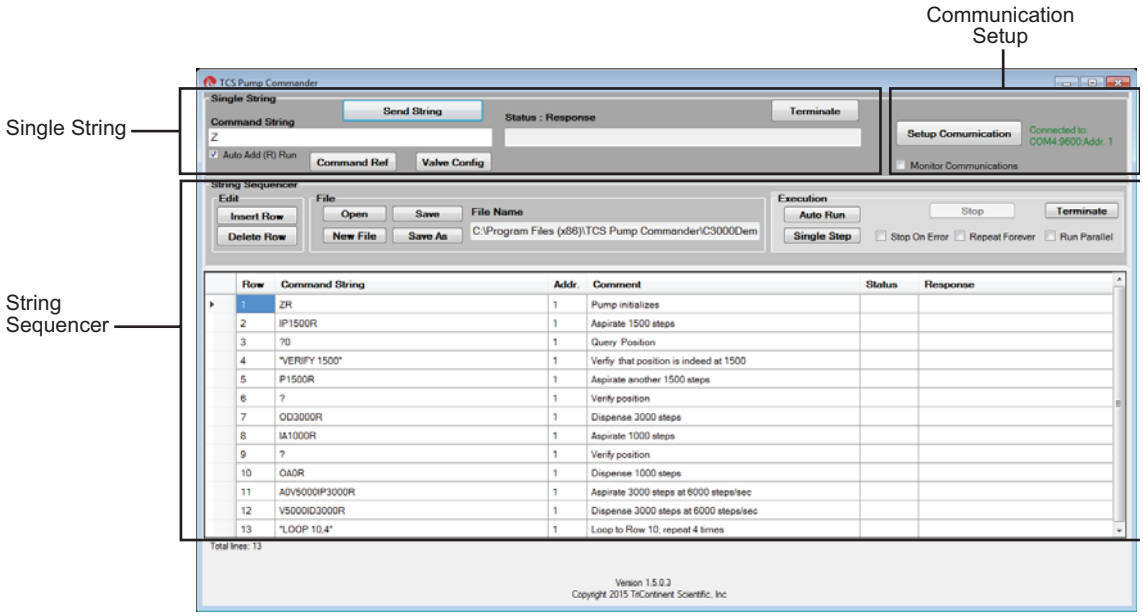
This is a quick reference to the TCS Pump Commander user interface.

**Note:** TCS Pump Commander defaults to the DT protocol mode.

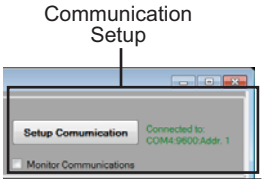
## User Interface overview

The areas shown in Figure 9-1 are each discussed below.

**Figure 9-1. TCS Pump Commander User Interface**




## Communication Setup area

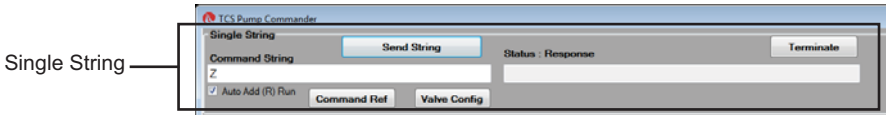



Displays connection status; allows you to monitor communications.

Pressing Setup Communication button allows you to select communication COM port, baud rate, and device address. Includes an auto scan function to detect and set these items automatically.

Checking Monitor Communications opens a dialog box for viewing and logging pump communication activity.

## Single String area




Allows you to enter command sequences and send them by clicking the Send String button. Command sequences can either be typed or entered using the Command Ref button (see below).

- **Status: Response** field: displays response from pump.
- **Auto Add (R) Run** checkbox: Inserts [R] command automatically at end of command string when sent.
- **Terminate** button: Terminates executing command.
- **Command Ref** button: Add commands to string by clicking buttons in a new screen.
- **Valve Config** button: Read current valve type configuration or program new valve configuration.

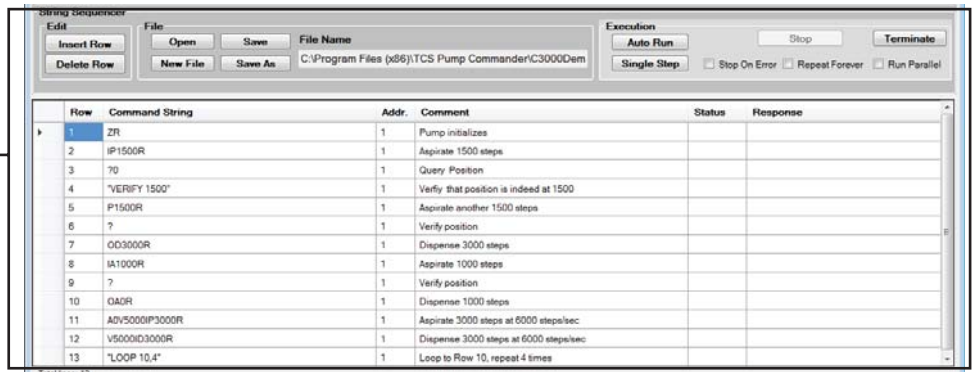
**⚠CAUTION**

**CAUTION:** (**Valve config** is factory use only; can cause malfunction.)

## String Sequencer area

Allows you to build a table of command strings that can be sent individually or in an automated sequence. Each row is a string.

String Sequencer




- **Addr** field: For pump address (required) and may be changed.
- **Comment** field: Manually populated with desired information.
- **Status** and **Response** fields: Display response from pump.
- **Command String** field: Double-clicking will send the string.
- **Insert Row** button: Add new empty row below selected row.
- **Delete Row** button: Delete selected row.
- **File** area: Populate table with existing text file, save existing table as a recallable text file, or save changes to table based on an existing file.
- **Execution** area
  - **Auto Run** executes commands row by row in order as numbered.
  - **Single Step** executes commands row by row as button is clicked.
  - **Stop** interrupts the sequence.
  - **Terminate** stops during command execution.
  - **Stop on Error** stops sequence if error is detected.
  - **Repeat Forever** continues sequence until terminated or stopped.
  - **Run Parallel.** If more than one address is in the ADDR. fields, commands are sent to the different addresses in numbered order. e.g., if two addresses first Addr1, then Addr2, then Addr1, etc.

# Evaluation cables and accessories

This section identifies the cables and accessories needed for evaluating Tri-Continent pumps/devices that include a DSUB 15-pin connector for power and communication. Several scenarios are described.

**Obtaining needed items.** Items listed here can be obtained through Customer Service or as otherwise described. Refer to Customer support (page 111).

**GUI Interface.** For the best evaluation experience, use TCS Pump Commander. TCS Pump Commander is user-friendly and easy to set up to get going quickly. It does not require the user to write any protocol software.

Alternatively, terminal emulator programs such as PuTTY and RealTerm may be used to send commands using DT protocol.

**USB driver.** Some applications use a USB interface. The correct driver may be obtained at https://www.silabs.com/products/development-tools/software/usb-to-uart-bridge-vcp-drivers. If more detail is needed, refer to "Download and install USB driver if needed" (page 18).

**⚠CAUTION**

**CAUTION:** Observe the following to avoid damage to the equipment.

- Always use proper ESD practices when handling these products.
- Keep power OFF while connections are being made.

**Evaluation kits.** For some products, a kit is available for evaluating a single device. The kit contains all hardware needed for product evaluation: USB to RS485 converter, cables, power supply, and instructions.

In addition, it is necessary to download the USB driver for the kit, and to obtain TCS Pump Commander or a terminal emulator program as described above.

To order a kit or to determine whether there is one available for your product, inquire with Customer Service.

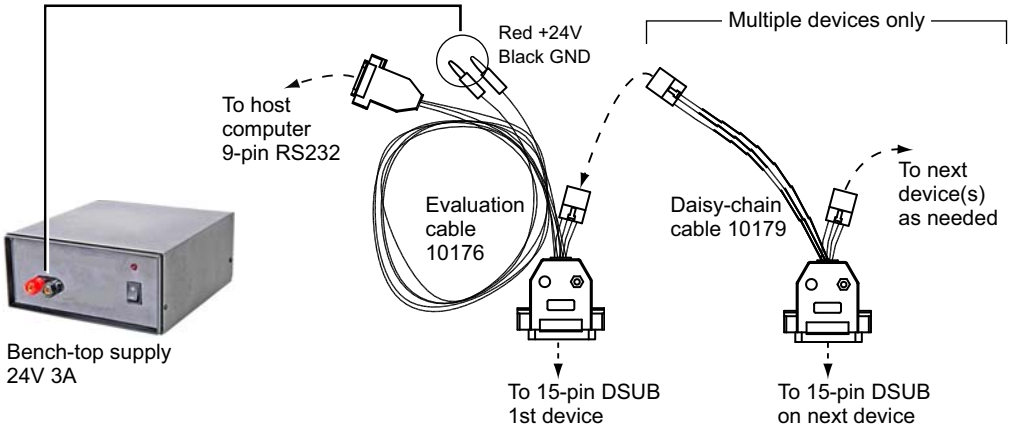
# RS232 to single or multiple devices evaluation

### Items needed

- Evaluation cable 10176, approx. 24” length
- Daisy-chain cable 10179, if multiple devices; one per additional device approx. 6” length
- Bench-top power supply, 24V 3A (user supplied)
- TCS Pump Commander or terminal emulator program (obtain as described at the beginning of this section)

**Note:** The daisy-chain cables provide about 6” of wire between devices. Ensure devices are mounted close together to accommodate this length.

### Figure 9-2. RS232 evaluation hookup




### Instructions

1. Start with power OFF to avoid damaging the equipment while connections are being made.
2. Connect evaluation cable 10176 as indicated by dashed lines/arrows in illustration above. Wait to connect power.
3. Multiple devices: Connect daisy-chain cable 10179 as indicated by dashed lines/arrows in illustration above. Repeat for each additional device.
4. Connect power plugs of evaluation cable 10176 to the bench supply. Red is for +24V; black is for ground.
5. Install TCS Pump Commanderor terminal emulator on the host computer.
6. Apply power, and follow instructions beginning with "Confirm communication with pump" (page 29).

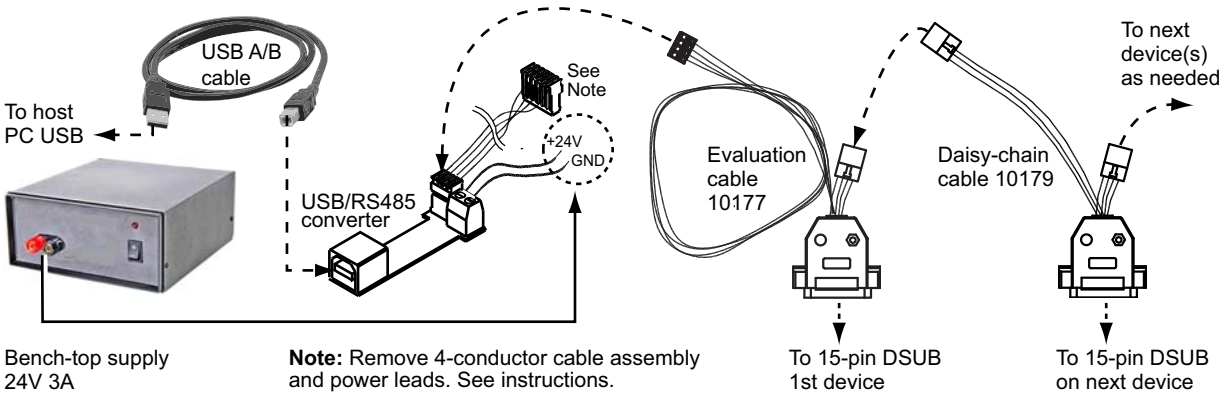
## USB to multiple device evaluation

### Items needed

- Evaluation cable 10177, approx. 18” length
- Daisy-chain cable 10179, approx. 6” length (one needed for each additional device)
- USB/RS485 converter kit, 0960
- USB A/B cable (order as needed: part number 8698-03, approx. 6’ 6” length).
- Bench-top power supply, 24V 3A (user supplied)
- USB driver for host PC (download as described at the beginning of this section)
- TCS Pump Commander or terminal emulator program (obtain as described at the beginning of this section.)

**Note:** The daisy-chain cables provide about 6” of wire between devices. Ensure devices are mounted close together to accommodate this length.

### Figure 9-3. USB to multiple device hookup




### Instructions

1. Start with power OFF to avoid damaging the equipment while connections are being made.
2. Unplug and discard the 4-conductor ribbon cable assembly from the USB/RS485 converter kit. This uncovers a 4-pin header.
3. Make cable and converter connections as indicated by the dashed lines/arrows above. Evaluation cable 10177 will be plugged into the header on the USB/RS485 converter.
4. Connect power lines from the USB/RS485 converter to the power supply. Observe polarities shown in the illustration.
5. Install the USB driver and TCS Pump Commander or terminal emulator program on the host computer. See instructions at beginning of this section.
6. Apply power, and follow instructions beginning with "Confirm communication with pump" (page 29).

## Single device evaluation with direct USB input

Some products (such as the MC6000) include a direct USB input. The USB input may be used for single-device evaluation if desired. The following items are needed:

- USB A/B cable 8698-03 (if none already available)
- Bench-top power supply, 24V 3A (user supplied)
- USB driver (obtain as described at the beginning of this section)
- TCS Pump Commander or terminal emulator program (obtain as described at the beginning of this section)

Connect the USB A/B cable between the host computer and the device, and provide power as described in the Installation instructions chapter of this manual. Then download and install the USB driver. Obtain and install the TCS Pump Commander or terminal emulation program.

# PTFE vs. UHMWPE for syringe seals and valve plugs

Valve plugs and syringe seals may be PTFE or UHMWPE. Each of these materials has its advantages and disadvantages. These are summarized in Table 9-5.

**Table 9-5: PTFE vs. UHMWPE**

| Material | Advantages | Disadvantages |
|---|---|---|
| PTFE | • Best chemical resistance. Very inert.<br>• Very soft (good for sealing)<br>• Very low seal drag due to its low friction properties | • Not well suited for crystalline reagents such as buffers.<br>• Easily scored/damaged.<br>• Can shed over time (although we specify the best PTFE available to avoid this potential issue). |
| UHMWPE | • Very good chemical resistance.<br>• Best abrasion resistance.<br>• Extremely durable material yet fairly soft so well suited for long-lasting seals.<br>• Longest life.<br>• Will not shed over time.<br>• Well suited for crystalline reagents such as buffers. | • Higher seal drag. |

# Calculating flow rates

In syringe pump applications, flow rate is defined as the amount of fluid being dispensed in a given time frame (total syringe volume divided by dispense speed). Typically, this is in microliters per second (µL/sec). However, depending on the application it could also be stated using a different volume, such as milliliter (mL) or in time (minutes, hours, etc).

While you may or may not ever want to calculate precise flow rates, knowing the ranges of flow rates for each of the C-Series pumps will help guide you in your selection of a C-Series pump and syringe.

Refer to the following table to help determine which syringe/pump will meet your requirements. The table shows flow rate ranges for each of the C-Series pumps, according to the size of the syringe in use.

**Table 9-6: C-Series flow rate guide**

| Syringe size (µL) | C3000/C3000MP | | C24000/C24000MP | |
|---|---|---|---|---|
| | Highest flow rate @1.2 sec/full stroke (µL per sec) | Lowest flow rate @ 48000 sec/full stroke (µL per second) | Highest flow rate @ 4.2 sec/full stroke (µL per second) | Lowest flow rate @192000 sec/full stroke (µL per second) |
| 50 | 41.67 | 0.001042 | 11.90 | 0.0002604 |
| 100 | 83.33 | 0.002083 | 23.81 | 0.0005208 |
| 250 | 208.33 | 0.005208 | 59.52 | 0.0013021 |
| 500 | 416.67 | 0.010417 | 119.05 | 0.0026042 |
| 1000 | 833.33 | 0.020833 | 238.10 | 0.0052083 |
| 2500 | 2083.33 | 0.052083 | 595.24 | 0.0130208 |
| 5000 | 4166.67 | 0.104167 | 1190.48 | 0.0260417 |
| 12500 | 10416.67 | 0.260417 | 2976.19 | 0.0651042 |

**Note:**
- This guide is intended to provide a snapshot of potential flow rates and does not imply specific performance at those rates.
- Higher flow rates may not be achievable due to flow rate restrictions in the fluid path.
- Extremely low flow rates may be accompanied by pulsation.

The flow rate formula is simply total syringe volume divided by dispense speed. For example, with a C3000/1000 µL syringe combination at top speed of 1.2 seconds/full stroke, the maximum flow rate is 833.33 µL/sec. (1000/1.2 = 833.33); and the minimum is 0.0208 µL/sec (1000/48000 = 0.0208).

In the minimum case, because the slowest rated speed for the C3000 is stated in minutes, you need to multiply by 60 to get seconds (800 X 60 = 48000). Keep in mind that, as syringe volume goes up and pump speed decreases, pulsation increases. Running smaller syringes at higher speeds decreases pulsation.

### Converting velocity to flow rate

To convert velocity in increments/sec to flow rate in volume/sec: Divide the syringe volume by the velocity resolution, then multiply by the [V] command setting, as shown by the following examples.

Examples

- 1 mL syringe on C3000 in N0 or N1 mode at velocity [V] of 6000 increments/sec: flow rate = (1000 µL/6000) * 6000 = 1000 µL/sec (see note below)
- 1 mL syringe on C3000 in N2 mode at velocity [V] of 6000 increments/sec: flow rate = (1000 µL/48000) * 6000 = 125 µL/sec
- 1 mL syringe on C24000 in N0 or N1 mode at velocity [V] of 6000 increments/sec: flow rate = (1000 µL /24000) * 6000 = 250 µL/sec
- 1 mL syringe on C24000 in N2 mode at velocity [V] of 6000 increments/sec: flow rate = (1000 µL/192000) * 6000 = 31.25 µL /sec

**Note:** Velocity resolution is twice the position resolution for the C3000 product.

**⚠CAUTION**

**CAUTION:** Due to the smaller internal port diameters of the 6-way distribution valve, it is recommended that fluid velocity does not exceed 1500 µL/sec when using this valve. Use caution when setting velocity with 2.5 mL and larger syringe sizes.Take these precautions to prevent cavitation and excessive syringe back pressure.

# Chemical compatibility chart information

Please refer to the chemical compatibility chart on the following page for questions concerning compatibility of the materials in your pump, valves, tubing and interconnections.

Be aware that TriContinent has obtained this information from reputable sources, and cannot be responsible for the accuracy of its content. Therefore it should only be used as a guideline. Actual testing of the materials should be performed before permanently implementing any application.

For further questions, please contact Customer Service as described in Customer support, beginning on page 111.

This chart is also available for download from the TriContinent website.

## Chemical Compatibility
Fluid Contact Materials

| | Acids | | | | | | | | | | Alcohols | | | | | | Bases | | | Esters | | | | | | Ethers | | | Glycols | | | Aromatic Hydrocarbons | | | Halogenated Hydrocarbons | | | | Ketones | | | | Miscellaneous | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acetic acid, glacial | Acetic acid 90% | Acetic acid 30% | Acetic acid 10% | Hydrocloric acid. conc. (35%) | Hydrocloric acid. 6N. (20%) | Hydrocloric acid. 1N (3.3%) | Nitric acid, conc. (67%) | Nitric acid, 6N (27%) | Sulfuric acid, conc. (96%) | Sulfuric acid, 6N (16%) | Amyl Alcohol | Benzyl alcohol | Butanol | Ethanol | Isopropanol | Methanol | Ammonium hydroxide, 6N (11.4%) | Potassium hydroxide, 3N (15%) | Sodium hydroxide, 6N (22%) | Amyl acetate | Butyl acetate | Cellosolve acetate | Ethyl acetate | Isopropyle acetate | Methyl acetate | Ethyl ether | Tetrahydrofuran | Tetrahydrofuran/water (50/50,v/v) | Ethylene glycol | Glycerol | Propylene glycol | Benzene | Toluene | Xylene | Carbon Tetrachloride | Chloroform | Ethylene dichloride | Methylene chloride | Tetrachloroethylene | Acetone | Cyclohexanone | Methy ethyl ketone | Methyl isobutyl Ketone (MEK) | Acetonitrile | Dimethyl formamide (DMF) | Dimethyl sulfoxide (DMSO) | Formaldehyde, 37% | Formaldehyde, 4% |
| Acetal Copolymer | N | N | L | L | L | L | - | N | N | - | N | R | R | R | R | R | R | L | R | R | R | R | R | N | R | R | R | L | R | R | R | L | R | R | R | R | R | R | R | L | R | R | N | - | R | R |
| Borosilicate Glass | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R |
| Buna -N | N | N | L | L | L | L | L | N | N | N | N | L | N | R | L | L | R | N | R | R | N | N | N | N | N | N | N | N | N | R | R | R | N | N | N | N | N | N | N | N | N | N | N | N | N | R | R |
| Ceramic (Al203) | R | R | R | R | L | L | L | R | R | R | R | R | R | R | R | R | R | R | R | N | R | - | - | R | - | - | - | R | R | R | R | R | R | R | R | R | R | R | - | - | R | - | R | - | - | - | - | - | - |
| Nylon | R | R | R | R | N | N | - | N | N | N | N | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R |
| PCTFE | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | - | R | R | R | R | R | - | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | - | - | R | R | R |
| PEEK | R | R | R | R | R | R | R | N | R | N | N | R | R | R | R | R | R | R | R | R | R | R | - | R | R | - | - | R | R | R | R | R | R | R | R | R | R | R | R | R | - | R | R | R | - | - | R | L | - | - |
| Platinum Iridium | R | - | R | R | R | R | R | R | R | L | R | - | - | - | R | R | R | R | L | L | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Polycarbonate | L | L | R | R | N | R | R | N | N | N | R | R | N | R | R | R | N | N | N | R | N | N | - | N | N | N | - | N | N | R | R | R | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N | N |
| Polypropylene | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | L | - | R | R | R | L | L | L | L | L | N | L | R | R | R | R | R | R | R | R | R | R |
| PPS | R | R | R | R | N | N | - | L | L | R | R | R | - | R | R | R | R | R | R | R | - | - | R | - | - | R | R | - | R | - | - | R | R | R | R | R | R | - | R | R | R | - | - | R | - | R | R |
| PTFE | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R |
| PVC | N | N | N | N | L | R | R | L | R | N | R | R | N | R | L | R | R | R | R | R | N | N | N | N | N | N | N | N | - | R | R | R | N | N | N | N | N | N | N | N | L | L | L | L | L | R | L | L | - |
| Santoprene® | N | L | R | R | R | R | R | N | N | L | R | R | N | L | R | - | R | - | L | R | N | - | - | R | - | - | - | N | N | R | N | - | L | N | N | - | N | N | N | - | R | - | N | N | - | R | - | R | R |
| Silicone Lubricant | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Silicon-Nitride Ceramic | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Stainless Steel 304 Series | N | N | L | L | N | N | N | R | R | N | N | R | L | R | R | L | R | R | L | L | R | L | L | L | N | R | L | R | R | L | - | L | L | R | L | L | R | L | R | - | R | R | R | L | R | R | - | R | R |
| Stainless Steel 316 Series | R | L | L | R | N | N | N | R | R | N | N | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | - | R | R | R | R | R | R | L | R | L | R | R | R | R | R | R | R | R | R | R | R | R |
| UHMWPE | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | - | R | R | R | - | - | - | R | R | R | R | L | L | L | L | L | L | L | R | R | R | R | - | - | - | - | R | R |
| Viton® | N | N | L | L | R | R | R | R | R | R | R | R | R | R | R | R | N | R | R | R | N | N | N | N | N | N | N | N | R | R | R | R | R | R | R | R | R | R | L | R | N | N | N | N | R | L | N | R | R |

R = Resistant
L = Limited Resistance
N = Not Resistant
- = Insufficient Data

1 Completely or alomost comletely inert
2 Partially attacked
3 Severely attacked

TRICONTINENT
by Gardner Denver

WEB90107 B

# Precision and accuracy

## Overview

**Precision** is defined as shot-to-shot repeatability. This is typically quantified as “imprecision” and expressed as *Coefficient of Variation (C.V.)*.

The precision of the pump is mechanically controlled through a consistent interface between the stepper motor/leadscrew. A correctly manufactured syringe has little impact on precision.

TriContinent assures precision by measuring the repeated movements of the pump mechanism with a custom designed fixture.

**Accuracy** is defined as the agreement of desired volume with actual volume. The difference between the two is quantified as “inaccuracy” and expressed as a percentage.

The accuracy of the pump is mechanically controlled through proper lead-screw pitch and motor step angle. Correct syringe barrel I.D. also assures accuracy. Consistency of I.D. over the entire barrel length is necessary.

TriContinent assures accuracy by mechanically measuring syringe barrels for proper I.D. using air bore gauges. The pump mechanism is verified by the use of manufacturing test fixtures.

When precision and accuracy data is based on results from gravimetric testing with fluids, the test setups and environmental conditions have been optimized. Tubing sizes, probe configurations, protocols and speeds have been selected to provide optimum results. The fluid measured is distilled water. Whenever any of these factors are changed, you can expect deviations from published performance data.

You can use your pump’s specifications as a benchmark to determine how close to optimum your instrument’s fluid path is.

Performance of a liquid handling system will depend on many factors. As a rule, empirical testing will be required to resolve all pertinent issues.

## Important variables

Below are some typical variables to be considered when developing an application-specific fluid handling system. All these items must reach a balance before optimization is achieved.

- **Syringe size**, while important, is not as critical as you might imagine. A significant shift of volume (either up or down) must be made before any measurable difference in precision and accuracy will be noted in most applications.
- **Pump speed** needs to be adjusted to deliver fluids at rates agreeable with desired throughput but not so fast as to stall the motor when pumping through restrictive tubing. It is used for “fine tuning.”
- **Tubing selection** can have a major impact on fluid handling performance. Keep tubes as stiff and as short as possible. Inside diameters should be as large as possible without causing the smallest sample/air gap to break up. See "Optimizing tubing performance" (page 147) for more details.
- **Orifices** of all valves, connectors, fittings, etc. must be of appropriate size (see tubing). Transitions must be smooth and free from unswept volume.

- **Priming and preloading** to remove air and charge fluid paths is critical to fluid handling system performance. See "Optimizing pump performance" (page 145) for more detail.
- **Probes** for aspirating and dispensing are often the most critical component in a fluid handling system. Good probe design should follow the same general guidelines as tubing and orifices (see above). Additional probe-specific criteria include:
  - Contour: make all transitions in I.D. smooth and step-free.
  - Surface area: the end of the probe should have as little surface area as possible. Keep probe end perpendicular to probe and wall thickness minimized to help prevent drops from clinging.
  - Finish: both inside and outside surfaces should be free from burrs.

# Optimizing pump performance

There are two types of movements in a syringe pump, *measured* and *preliminary*. Both are equally important in achieving optimum performance.

- **Measured** movements provide accurate and precise fluid volumes to a specified location.
- **Preliminary** movements prepare the fluid path for measured movements.

While most pump users are only concerned with the results of their measured movements, it is imperative to understand and fully utilize preliminary movements if optimum pump performance is to be achieved. One way to visualize the effect of preliminary movement in the fluid path is to imagine trying to push or pull two bricks with an inflated toy balloon between them. In order to get equal movement between the bricks, you must either expand or compress the balloon to its fullest point through preliminary movements. Once you have accomplished this, you have a charged fluid path and measured movements will be optimized.

Air gaps are useful in minimizing mixing of aspirated and primed fluids but must be handled carefully. Their introduction into a positive displacement system can severely degrade precision and accuracy unless countered with appropriate preliminary movements. Air gaps must be kept as small as possible.

Even with air gaps between sample and priming fluids, some mixing will take place in probes and tubes. In one-step sample dilutions, this has no effect; but in multiple aliquoting and sample transfers, some dilution of the measured sample closest to the air gap will occur. Make preliminary allowances for some waste if absolute sample integrity is required. Aspirate an additional amount of the sample to act as a buffer.

Discard this amount as part of the probe cleaning process. Typically 10% can be used as a guideline, but variables such as speed, type of fluids, volumes, and allowable error will determine final adjustments. Optimum waste allowances can only be determined through testing.

Repetitive functions, such as multiple dispenses and aliquoting, are best done when all measured movements are done in a like manner and speed. preliminary movements to ensure a charged fluid path are critical to achieving optimum precision. The best method for accomplishing this task is to make a preliminary dispense, roughly equal to the desired measured movement, of the aspirated fluid into a waste cup or even into the same receptacle aspirated from, if possible.

Backstepping or anti-backlash routines built into most commercial syringe drive software typically eliminate only the inherent looseness of the drive mechanism. They do not charge the fluid path.

Priming, the most common preliminary movement, is important. All air should be expelled from the syringe, valves, tubes, and other wetted surfaces to achieve optimum performance.

Bubbles and air pockets may cause inconsistencies. Small bubbles located directly on the surface of the syringe seal often do not cause problems. However, should they break free and enter the fluid path, a measured movement could be affected. It is best to try and remove these through adequate priming. Surfactants in priming fluids make priming easier and more effective. If the priming fluid is outgassing during fill, evidenced by recurring bubbles in the syringe, either slow down the fill stroke or increase the diameter of the tubing.

The guidelines and tips offered here are generally effective in optimizing performance of syringe pumps. They are not, by any means, an all-inclusive list of methods and procedures. Every application requires specific techniques, tailored to that application, to achieve optimum performance.

# Optimizing tubing performance

There are two types of liquid transfer lines in a typical system: *suction* and *delivery*.

- **Suction** lines transfer liquid from a vessel to the input port of the pump.
- **Delivery** lines transfer liquid from the output port of the pump to another location (i.e., cuvette or test tube).

When selecting liquid lines, the parameters to pay attention to are tubing I.D, length, material, secure port connection, and smooth ID transitions.

### Tubing I.D.

- Suction line I.D.
  - Too small will restrict flow causing the pump to cavitate.
  - Too large will generate additional priming requirements.
- Delivery line I.D.
  - Too small will cause additional back pressure and excessive liquid velocity.
  - Too large may slow liquid velocity excessively and generate additional priming requirements.

### Tubing length

- Suction line: excessive length may prevent the pump from priming and introduce pressure drop that will restrict flow to the pump.
- Delivery line: excessive length will introduce back pressure, increasing pressure at the pump.

### Tubing material

- Suction line: soft tubing will collapse and pulse causing flow restriction, blockage, and pump cavitation.
- Delivery line: soft tubing will expand and pulse causing flow fluctuations, undermining the system's C.V.

  Semi-rigid tubing such as Teflon® or L.D.P.E. is preferred for consistent performance of the liquid transfer system.

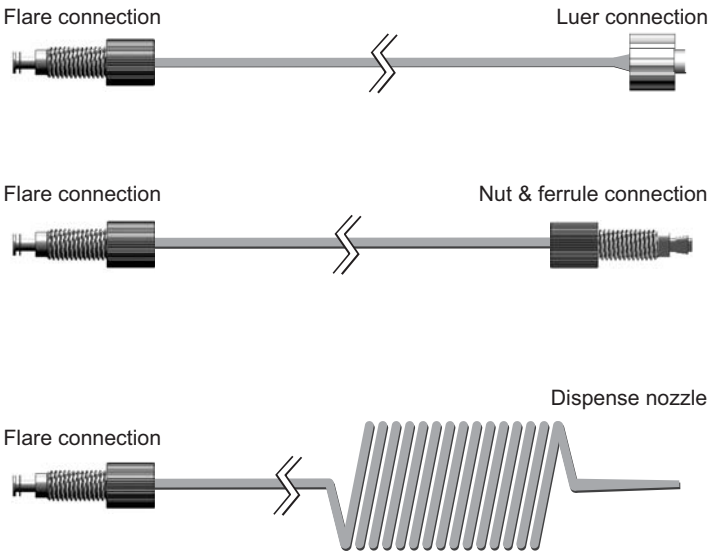
### Port connection

- Suction line: should be bubble tight to prevent introduction of micro air bubbles into the pump input port.
- Delivery line: should be bubble tight to prevent leakage of liquid from the pump output port.

### Smooth ID transitions (contour)

Configurations should be used to prevent particle entrapment and minimize flow turbulence. Particle entrapment may cause material carry-over contamination. Flow turbulence may introduce additional back pressure, affecting system performance.

## Typical tubing configurations



# Dual pump continuous flow application

## Introduction

This section describes how two C-Series pumps can be used to provide continuous flow in a standalone application.

The [j] command is a unique feature of the C-Series pumps that allows a change in state of auxiliary outputs based on the position of a syringe. This enables one pump to trigger the other before it is finished dispensing, causing the other in turn to begin dispensing. Consequently there is no gap in the flow.

The fluid outputs of the pumps are combined, an auxiliary output of each pump is wired to the input of the other, and program strings utilizing the [j] command are written to the pumps. To achieve standalone operation, these strings are pre-written to the EEPROMs of the pumps.

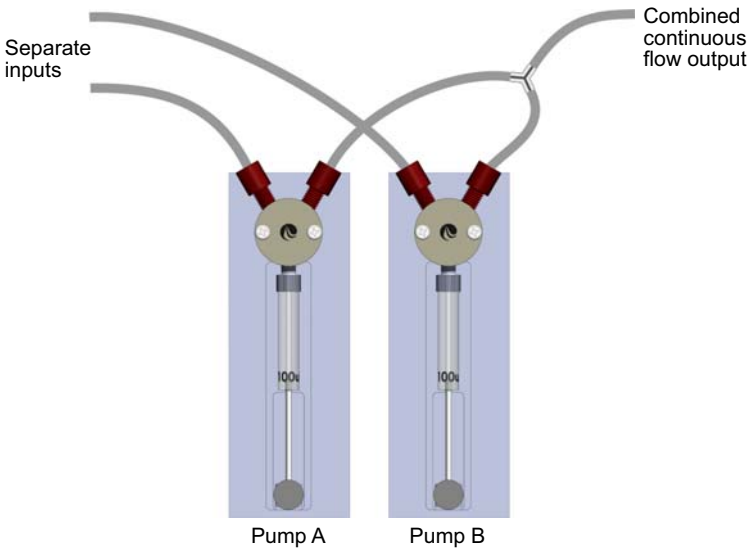
## Sequence of operation

The two pumps are named A and B, respectively.

1. At power-up, Pump A and B are both initialized, and they both aspirate a full syringe.
2. Pump A starts dispensing, while Pump B remains idle.
3. As Pump A nears the end of its stroke, Pump A triggers Pump B to start dispensing.
4. Pump B is now dispensing. When Pump A has finished dispensing its syringe, it aspirates a full stroke.
5. When Pump B nears the end of its stroke, it triggers Pump A to start dispensing.
6. The sequence returns to step 3 and repeats continuously.

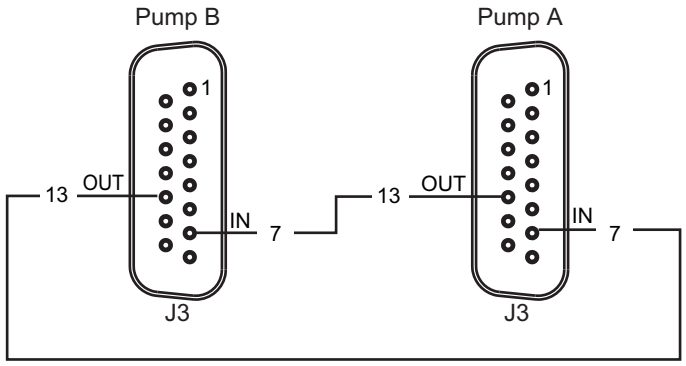
## Tubing hookup

The fluid outputs of the two pumps are connected together with a “Y” fitting. The inputs are independent.




## Wiring

Special cable is required (TCS 8246-73). As shown below, this cable connects an auxiliary output of each pump to an auxiliary input of the other pump.




## Jumper and address switch settings

Pump A is set to address 1, and Pump B is set to address 2 using the address switches on the back of the two pumps (address 1 = switch position 0, address 2 = switch position 1).

After programming has been completed, the AutoRun jumper is installed on J2. This causes strings to run automatically from EEPROM on power-up. It

also changes the function of the address switch. Its position now indicates which EEPROM location contains the string to be run at power-up.

**Note:** These are in addition to any other settings that may be required. See "Set configuration jumpers and address switch" (page 22) for details.

# Programming

## Overview

The following example provides full stroke continuous flow, in standalone (AutoRun) mode.

- Special command strings are issued to each pump. Because this is a standalone application, the program strings are loaded into the pumps' EEPROMs using the [s] command. Strings run automatically at power-up when the AutoRun jumper is installed on the pumps after programming. The address switch indicates which string (memory location) will be run.
- Aspirate velocity must be faster than dispense velocity to provide time for the pump to be ready for triggering after aspiration.
- The [j] command trigger position parameters may require adjustment based on pump dispense velocity and syringe size.

## C3000 example program strings

C3000 Pump A (sent to address 1):

s0J7ZV2000IA3000OV1000j100A0IV2000A3000J7OV1000j100g

H0A0IV2000A3000J7OV1000j100GR

C3000 Pump B (sent to address 2):
s1J7ZV2000IA3000OV1000j100gH0A0IV2000A3000J7OV1000

j100GR

## C24000 example program strings

**Note:** Velocity may need to be scaled to account for the fact that the C24000 plunger moves 1/4 as fast as the C3000 at the same velocity [V] setting.

Pump A (sent to address 1):

s0J7ZV2000IA24000OV1000j100A0IV2000A24000J7OV1000

j100gH0A0IV2000A24000J7OV1000j100GR

Pump B (sent to address 2):

s1J7ZV2000IA24000OV1000j100gH0A0IV2000A24000J7OV1000

j100G

## Command string breakdown for Pump A

| | |
|---|---|
| s0 | Store following string in EEPROM location 0 [s0]. |
| J7ZV2000IA3000 | Initial setup: set outputs high [J7], initialize pump [Z], set velocity to 2000 increments/sec [V2000], move valve to input position [I], aspirate a full syringe [A3000] at set velocity.<br>**Note:** for C24000 pumps, A3000 would be A24000 instead. This applies below also. |
| OV1000 | Prepare for dispense: move valve to outlet [O], set dispense velocity to 1000 increments/sec [V1000]. |
| j100 | When syringe position during dispense gets close to top of stroke (10 in this case) [j10], set outputs low [0]. This will trigger Pump B to begin its dispense. |
| A0 | Dispense full stroke (trigger is sent to Pump B when position is at 10, as stated above). |
| IV2000A3000J7O V1000j100 | When finished dispensing, move valve to input position [I], refill [V2000A3000], and reset for next dispense [J7OV1000j100]. |
| g | Start of continuous loop. |
| H0 | Wait for trigger from Pump B. |
| A0 | Dispense full stroke (trigger is sent to Pump B when position is at 10, as stated above). |
| IV2000A3000J7O V1000j100 | When finished dispensing, move valve to input position [I], refill [V2000A3000], and reset for next dispense [J7OV1000j100]. |
| G | Repeat forever (back to [g]). |
| R | Run command string. |

## Command string breakdown for Pump B

| | |
|---|---|
| s1 | Store following string in EEPROM location 1 [s1]. |
| J7ZV2000IA3000 | Initial setup: set outputs high [J7], initialize pump [Z], set velocity to 2000 increments/sec [V2000], move valve to input position [I], aspirate a full syringe [A3000] at set velocity.<br>**Note:** for C24000 pumps, A3000 would be A24000 instead. This applies below also.) |
| OV1000 | Prepare for dispense: move valve to outlet [O], set dispense velocity to 1000 increments/sec [V1000]. |
| j100 | When syringe position during dispense gets close to top of stroke (10 in this case) [j10], set outputs low [0]. This will trigger Pump A to begin its dispense. |
| g | Start of continuous loop. |
| H0 | Wait for trigger from Pump A. |
| A0 | Dispense full stroke (trigger is sent to Pump A when position is at 10, as stated above). |
| IV2000A3000J7O V1000j100 | When finished dispensing, move valve to input position [I], refill [V2000A3000], and reset for next dispense [J7OV1000j100]. |
| G | Repeat forever (back to [g]). |
| R | Run command string. |

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# 10 Revision history

## Revision history table

Revision information for this manual is shown in Table 10-1.

**Table 10-1: Revision History**

| Date | Revision Level | Description |
|---|---|---|
| 6/22/2017 | C | Thorough revision and expansion to create comprehensive product manual. |
| 10/25/2017 | D | Updated company logo, made minor corrections and edited to maintain consistency with other product manuals and improve clarity. Added cautions about shipping with syringes installed, and about the capture of errors received during operation. |
| 12/14/17 | E | Corrections to RS232 pin assignments, affecting RS232 cabling diagram on page 26 and J3 pin assignment table on page 24. Other minor text changes. |

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