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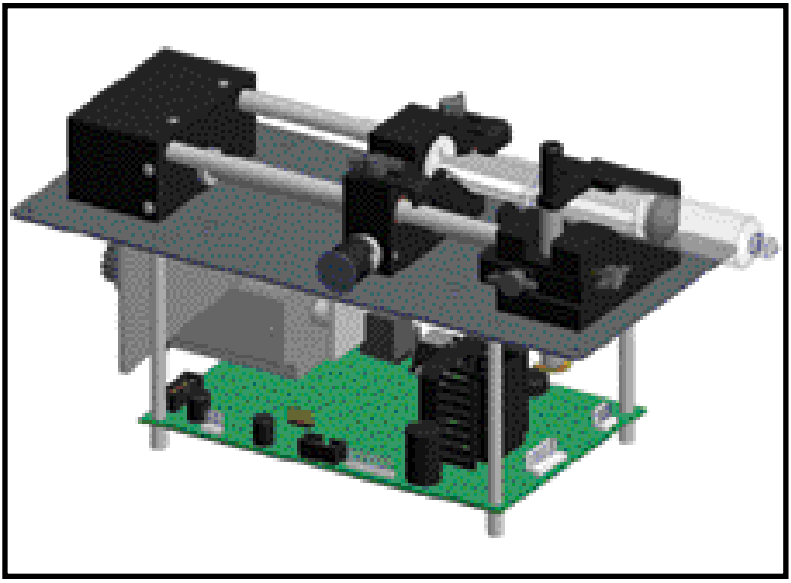
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High Force Modular Pumping Component

User's Manual

MA1 70-2202



HARVARD APPARATUS

Publication 5415-001-REV-C

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WEEE/RoHS Compliance Statement

EU Directives WEEE and RoHS

To Our Valued Customers:

We are committed to being a good corporate citizen. As part of that commitment, we strive to maintain an environmentally conscious manufacturing operation. The European Union (EU) has enacted two Directives, the first on product recycling (Waste Electrical and Electronic Equipment, WEEE) and the second limiting the use of certain substances (Restriction on the use of Hazardous Substances, RoHS). Over time, these Directives will be implemented in the national laws of each EU Member State.

Once the final national regulations have been put into place, recycling will be offered for our products which are within the scope of the WEEE Directive. Products falling under the scope of the WEEE Directive available for sale after August 13, 2005 will be identified with a "wheelie bin" symbol.

Two Categories of products covered by the WEEE Directive are currently exempt from the RoHS Directive – Category 8, medical devices (with the exception of implanted or infected products) and Category 9, monitoring and control instruments. Most of our products fall into either Category 8 or 9 and are currently exempt from the RoHS Directive. We will continue to monitor the application of the RoHS Directive to its products and will comply with any changes as they apply.





- **Do Not Dispose Product with Municipal Waste**
- **Special Collection/Disposal Required**

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Serial Number
All inquires concerning our product should refer to the serial number of the unit. Serial numbers are located on the underside of the mounting plate.

Calibration
All syringe puimps are designed and manufactured to meet their performance specifications at all rated voltages and frequencies.

Warranty
Harvard Apparatus warranties this instrument for a period of two years from date of purchase. At its option, Harvard Apparatus will repair or replace the unit if it is found to be defective as to workmanship or material.

This warranty does not extend to damage resulting from misuse, neglect or abuse, normal wear and tear, or accident.

This warranty extends only to the original customer purchaser.

IN NO EVENT SHALL HARVARD APPARATUS BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES. Some states do not allow exclusion or limitation of incidental or consequential damages so the above limitation or exclusion may not apply to you. **THERE ARE NO IMPLIED WARRANTIES OF MERCHANTABILITY, OR FITNESS FOR A PARTICULAR USE, OR OF ANY OTHER NATURE.** Some states do not allow this limitation on an implied warranty, so the above limitation may not apply to you.

If a defect arises within the two-year warranty period, promptly contact ***Harvard Apparatus, Inc. 84 October Hill Road, Holliston, Massachusetts 01746-1388*** using our toll free number 1-800-272-2775. Outside the U.S. call 508-893-8999. Goods will not be accepted for return unless an RMA (returned materials authorization) number has been issued by our customer service department. The customer is responsible for shipping charges. Please allow a reasonable period of time for completion of repairs, replacement and return. If the unit is replaced, the replacement unit is covered only for the remainder of the original warranty period dating from the purchase of the original device.

This warranty gives you specific rights, and you may also have other rights which vary from state to state.

Repair Facilities and Parts
Harvard Apparatus stocks replacement and repair parts. When ordering, please describe parts as completely as possible, preferably using our part numbers. If practical, enclose a sample or drawing. We offer a complete reconditioning service.

CAUTION:
This pump is not registered with the FDA and is not for clinical use on human or veterinary patients. It is intended for research use only.



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Please read the following safety precautions to ensure proper use of your modular syringe pump. To avoid potential hazards and product damage, use this product only as instructed in this manual. If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

To Prevent Hazard or Injury:

Use Appropriate Power Supply

Use only an SELV approved power supply. Be sure to observe proper polarity of connections when hooking up DC supply voltage.

CAUTION: FAILURE TO MAINTAIN POLARITY MAY RESULT IN DAMAGE TO THE UNIT AND WILL VOID THE WARRANTY.

24 Vdc positive–PINS 1 & 2 of connector P1

24 Vdc return–PINS 3 & 4 of connector P1

(see input connections diagram)

Ground the Product

This product is grounded through a ground stud located on the under side of the base plate. To avoid electric shock, the grounding conductor must be connected to earth ground. Before making any connections to the input or output terminals of the product, ensure that the product is properly grounded.

Make Proper Connections

Make sure all connections are made properly and securely.Any signal wire connections to the unit must be no longer than 3 meters.

Avoid Contact with Heatsinks:

Some components normally operate at temperatures exceeding 70 deg C. To avoid injury, do not touch any heatsinks.

Observe all Terminal Ratings

Review the operating manual to learn the ratings on all connections.

Avoid Exposed Circuitry

Do not touch any electronic circuitry inside of the product.

Do Not Operate with Suspected Failures

If damage is suspected on or to the product do not operate the product. Contact qualified service personnel to perform inspection.

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Place Product in Proper Environment

Enviromental Conditions:

- Indoor use only
- Temperature 4˚C to 40˚C (40˚F to 104˚F)
- Humidity 20% to 80% RH
- Well Ventilated Room
- Altitude up to 2000 m
- Mains Voltage Fluctuation not to Exceed +/- 10% of Nominal
- Transient Overvoltage, Category II
- Pump is Rated Pollution Degree 2 in Accordance with IEC 664

Observe all Warning Labels on Product

Read all labels on product to ensure proper usage.



CAUTION
Refer to Manual



Protective Ground
Terminal



Pinch
Hazard



Caution:
Hot
Surface



Caution:
ESD Sensitive
Device

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Specifications

Specifications:

Accuracy:	±1%
Reproducibility:	±0.1%
Syringe Sizes:	0.5µL (min), 140 mL (max)
Flow Rate:	
Min.:	0.001 µL/hr (with 0.5µL syringe)
Max.:	220.82 mL/min (with 140mL syringe)
Linear Force :	200 lbs - *See Appendix E*
Drive:	
Motor:	1.8° Stepper
Control:	Constant Current (Chopper) Drive, 2A per phase (max) Microstepping (from 1/2 to 1/32)
Pulley Ratio:	2:1 (1:2 optional)
Lead Screw Pitch:	24 threads per inch (0.393-24)
Step Rate:	
Min:	27.3 sec/step
Max:	416.7µsec/step
Pusher Travel Rate:	
Min:	0.18 µm/min
Max:	190.676 mm./min
Display:	Optional 2X20 Line VFD (p/n 2400-235)
Keypad:	Optional (p/n 2400-252)
Interface:	RS-232
Connectors:	
DC Power:	4-pin Header (Friction Lock – Molex or AMP)
RS-232:	4-pin RJ-11 Telephone Jack
User I/O:	9-pin D-Sub Female
Power:	+12 to +40VDC, ±5%, 75W * use only a SELV approved power supply
Dimensions:	11.875” X 5.50” X 6.625” (L X W X H) 30.2cm X 14.0cm X 16.8cm
Mounting Dims:	11.375” X 5.00” (Mounting holes for 4 #8 screws) 28.9cm X 12.7cm
Control Board Mounting Dims:	4.50” x 7.00” (Mounting holes for (4) #6 screws)
Weight:	8.5 lbs (3.86kg)
Environmental:	
Operating Temp:	0 to +45°C
Storage Temp:	-20 to +70°C
Humidity:	20% to 80% RH non-condensing

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Theory of Operation

The High Force Modular Pumping Component employs a microcontroller which controls a small step angle stepping motor that drives a lead screw and Pusher Block. Microstepping techniques are employed to further reduce the step angle, eliminating flow pulsation. Data can be entered via an RS-232 connector located on the rear panel. The microcontroller calculates the cross-sectional area of the syringe selected and calibrates the flow rate and volume accumulation. The numerous features of the High Force Modular Pumping Component result from the use of microprocessor technology.

The High Force Modular Programmable Pumping Component model provides full programmability along with Infuse/Withdraw capability. Retaining Brackets and Adjustable Stops are all described in detail on Page 11 of this manual. This unit is designed to operate inside an appropriately rated fire/electrical/mechanical enclosure or cabinet. The board may be removed for "remote" operation. Mounting holes configuration can be found on Pg.10 (Installation) of this manual.

Packing List:

1) Main Unit
2) 6 ft. motor/encoder extension cable
3) 6 ft. DC power extension cable
4) RS232 cable
5) Symphony program disks
6) 6 oz. jar of lubricant

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Pressure and Speed

The High Force Modular Pumping Component can deliver up to 220.82 ml/minute with a single 140 ml syringe. Maximum pressure is dependent on syringe size.

If a syringe is to be used, which is not listed in the syringe table (Pg. 36), enter the inside diameter of the syringe in millimeters.

Infusion and Refill Rates

Specify independent rates for infusing and refilling. This allows a slow infusion rate then a fast refill. If Refill Rate is not set, the software defaults to the set Infuse Rate value.

Target Volume

Specify the volume that is to be infused or refilled. The pump will run at the rate specified until this volume has been delivered when in the Volume mode.

Auto Fill

Auto Fill automatically activates an externally attached solenoid (refer to Appendix L for part number) and refills the syringe when it is empty. This permits infusions to be virtually independent of syringe capacity.

Modes of Operation

(Set for pump mode, can be changed thru RS232)

Pump:
Runs continuously in the infuse or refill directions until stopped.

Volume:
Runs until a specified volume has been pumped or refilled.

Program:
Pump operates according to a specified sequence of instructions.

(Note: All modes interact with Auto Fill)

CE Mark Approved

The High Force Modular Pump meets all relevant european EMC and safety requirements for laboratory equipment when used in accordance with the guidelines outlined in this manual.

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External Connections

User I/O

Allows pump operations to be synchronized with external devices or by a person at a distance from the pump. Connector pins are available to control direction of pump travel to control an external valve for refilling, and for general use. A simple contact closure to ground or TTL level signals may be used for inputs. (See Section 8 and Appendix I.)

RS-232

Multiple pumps can be 'daisy chained' together and remotely controlled from a computer or any device communicating via RS-232.
A scale can be connected, enabling the pump to infuse by weight instead of by volume. (Section 8).

A printer can be connected to record final volumes or weights whenever the pump stops. In addition the program entered for the program mode can be listed on a connected printer. Both a scale and a printer may be connected simultaneously. (See Section 8).

Nonvolatile Memory

All operational data entered into the pump from a computer will be stored, including the program. On power up, the display will blink until the pump receives its first command and all settings from when it was powered down will be recalled.

Stall Detection

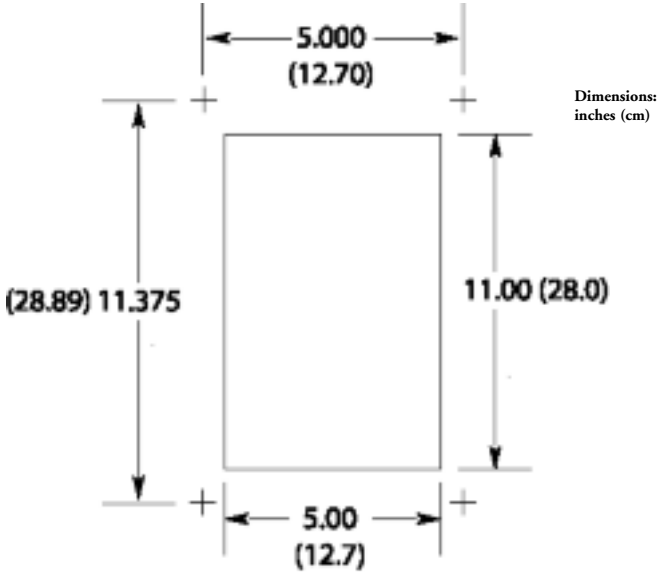
An optical detector is used to verify expected movement of the motor. If the motor is prevented from turning due to jamming or excessive back pressure, the pump will stop. An indication of "PUMP STALLED" will be displayed on the PC and on the optional display (if attached)..

Program Storage

Programmable model can store up to 4 sets of 9 program sequences for later selection.

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- Sturdy, level, clean and dry surface
- Minimum of one inch (2.5 cm) clearance around the pump
- Appropriate environmental conditions
- Well ventilated area
- Mount into an appropriately rated cabinet or enclosure



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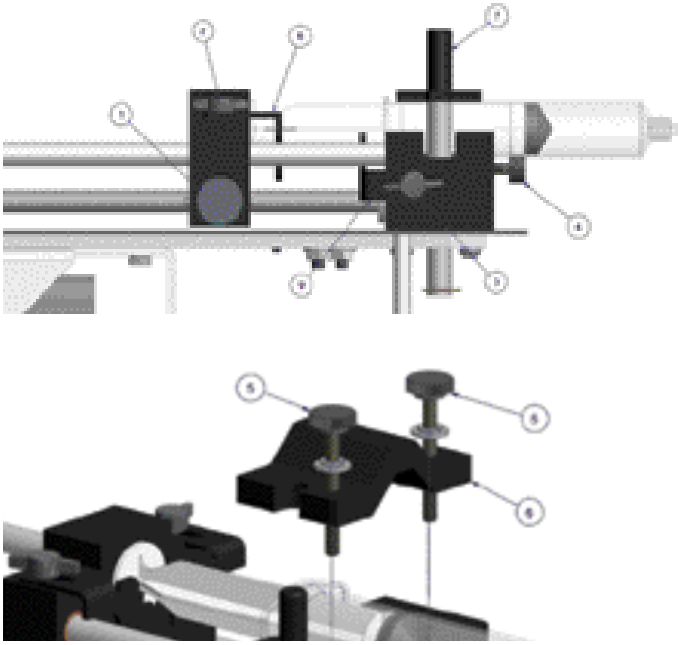


Figure 1. Syringe Loading

Syringe Loading

1. The syringe holder and pusher block are fitted with movable retaining brackets (8 & 9) which hold firmly the syringe barrel and plunger when refilling. When loading the syringe into the pump, it is necessary to adjust these brackets. The pusher block is fitted with a mechanism (1) to release the drive nut from the leadscrew so that the block can be moved freely to facilitate loading the syringe.
2. Loosen the screws on the syringe block (3) and pusher block (2) to free the retaining brackets (8 & 9).
3. To free the pusher block from the leadscrew, turn the knob on the front of the block (1) until the knob slips into the slots.
4. The syringe clamp post's locking screw (4) is located on the right side of the syringe block, & should be loosened so that the syringe clamp post (7) can be rotated to the side.
5. Place the syringe barrel on the syringe holder block and move the pusher block to accommodate the plunger.
6. Make sure the syringe barrel flange and the plunger flange are held by the retaining brackets (8 & 9). Press the retaining brackets firmly against the flanges and tighten the retaining screws.

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7. Rotate the syringe clamp post (7) and press down firmly on the syringe barrel. Secure in place by tightening the "T" knob screw (4).
8. For syringes greater than 50 cc, it may be necessary to use the 'V'-shaped clamp provided (6). Place clamp over the syringe barrel and secure to the holder block with the two long thumbscrews (5).

Note:

If desired, adjustable stops to limit the syringe plunger travel may be purchased from Harvard Apparatus (see Appendix J for part number). Install the stops on the two guide rods at the desired locations.

Infuse Rate

The Infuse Rate is the rate of pumping while infusing in the Pump or Volume modes. Also, the Infuse Rate is used as a starting rate for the program mode if one is not specified in the program, regardless of pumping direction.

Target Volume

The Target Volume is the volume that you desire to deliver at the set Infuse or Refill Rate. The pump must be set for this Volume mode for this feature to work. When entering the Target Volume, enter the volume desired in mls (milliliters).

Auto Fill

When set to 'ON', the syringe is assumed to be empty. Auto Fill continuously monitors the volume of the syringe according to the volume pumped. When the pump determines that the syringe is empty, the operation in progress is suspended and Auto Fill is activated. The pumping direction is then reversed and the pump runs at the refill rate. During the Auto Fill operation, the display will indicate the volume of liquid in the syringe.

When the volume in the syringe reaches the set refill volume, Auto Fill will stop, and the previous operation of the pump will resume. Auto Fill continues to monitor the volume of the syringe. TTL direction output is toggled 'ON' during refill. Refill Rate defaults to Infuse Rate if not set.

Note: Auto Fill will only activate while infusing, (i.e., if the pump direction is set to Refill, the pump will not stop when the syringe is full.) Also, if the syringe plunger is manually moved, the pump will lose track of the true syringe volume.

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Program Description

A program is made up of a set of sequences. Each sequence being a set of operating instructions for the pump to follow. When the pump is started in the PROGRAM run mode, the pump will start at sequence 1 and execute the operating instructions in that sequence. When the pump has completed the instructions for a sequence, it will go to the next, or specified, sequence and execute the instructions in that sequence. The pump continues this process until it either has reached a 'STOP' operation, the pump is manually or remotely stopped, or the last sequence has been completed. 4 programs with up to 9 sequences each may be entered.

A sequence consists of a sequence number, indicating the order of the sequence; a mode, indicating what operation the sequence will be performing; and the actual data for the operation, such as rates and volumes. The necessary data specified for each sequence will depend on the strategy used.

One of two strategies may be chosen for a sequence's target. Strategy 1 (Target Volume) pumps until a target volume is reached, while Strategy 2 (Time Interval) pumps until a target time interval has lapsed. When Strategy 1 is used, enter a time interval of 0:00:00, then you will be prompted for the target volume. See the Programming Tutorial for example programs.

The following is a list of possible data that can be requested when entering a program and instructions on entering the data.

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Sequence of Operation:

Operations that can be selected are:

Profile	Increment (Inc)
Decrement (Decr)	Dispense
Event	Goto
Pause	Pump
TTL Out	Restart
Stop	

Rate:
If the Rate entered is invalid, an error message will not be given at the immediate time of entry. An "Out of. Range" (OOR) error message will be given during the running of the program.

Delta Rate
Enter the rate of Increment or Decrement desired. The units of the rate cannot be specified. Units will be the same as the units of the current pumping rate at the time the sequence is executed.

Target Volume
Enter the required delivered target volume of the sequence. For increment and decrement sequences, the target volume is an incremental target. An incremental target is added to the delivered volume at the start of the sequence.

Time Interval
Enter the time duration of the sequence in the form: 'hours : minutes : seconds'. If sequence Strategy 1 (Target Volume) is used, enter 0:00:00 for the time target. The maximum time interval is 9:99:99.

Number of Repetitions
Enter the number of times the sequence is to be repeated. The repetition number can be from 1 to 99,999.

Pumping Direction
Each sequence that specifies a pumping operation, also specifies a pumping direction.

Pin Level
Select either HI or LOW for the logic level of the programmable output pin 4.

Go to sequence number
Enter the destination sequence to continue operation of the program. Valid sequence numbers are 1 to 10.

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Profile

Runs at specified flow rate until target volume is pumped or a time interval has elapsed. Travel direction is as specified.

Data Specified:

Strategy 1:	Flow rate
(Volume)	Time Interval = 00:00:00
	Target volume
	Pumping direction
Strategy 2:	Flow rate
(Time)	Time interval
	Pumping direction

Incr

Increments current rate by specified value and pumps until the target volume is pumped or a time interval has elapsed. Units of rate will be that of the current rate of the pump or the infusion rate's units, if first sequence.

Sequence is repeated the specified number of times. Travel direction is as specified.

Data Specified:

Strategy 1:	Delta flow rate
(Volume)	Time Interval = 00:00:00
	Volume increment
	Number of repetitions
	Pumping direction
Strategy 2:	Delta flow rate
(Time)	Time interval
	Number of repetitions
	Pumping direction

Decr

Same as INCR except rate is decremented.

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Dispense

Repeatedly dispense specified volume. Runs at specified flow rate until a volume is pumped or a time interval has elapsed, then pump will stop. If no time interval was specified (Strategy 1), the display will show 'TRIGGER' and the next dispense will begin after an external or keyboard run command. Otherwise, the sequence will pause for specified time interval. Sequence is repeated the specified number of times. Travel direction is as specified.

Data Specified:

Strategy 1: (Volume)	Flow rate Time Interval 00:00:00 Target volume Number of repetitions Pumping direction
Strategy 2: (Time)	Flow rate Target volume Time interval Number of repetitions Pumping direction

Event

Program Events – A program event is an external event defined as a high to low transition on TTL pin-9. Within a program, a one time event trigger can be set which watches for and acts upon the external event. The triggered event causes an immediate continuation of the program at the specified sequence and the operation of the pump will be according to this sequence.

Data Specified:

Go To sequence number

Go To

Causes the program to immediately continue operation at the sequence specified.

Data Specified:

Go To sequence number

Pause

Pump stops for specified time then continues with next programmed sequence. Current program rate set to 0, with no change in units.

Data Specified:

Time interval

Pump

Runs the pump continuously at the specified flow rate without any pumping target. This mode can provide a background flow rate while waiting for an external event to trigger a new sequence specified by the EVENT operation.

Data Specified:

Flow rate
Pumping direction

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TTL Out

Programmable TTL Pin. TTL output Pin 4 of the user I/O connector can be set to a HIGH or LOW level from within a program.

Data Specified:

TTL pin level

Restart

Immediately restart program from the first sequence.

Data Specified:

None

Stop

Stops pump and the program terminates.

Data Specified:

None

Program Runtime Error Messages (using optional keypad & display)

If while running a program an operation is requested that cannot be performed, the pump will stop and an error message will be displayed. Error messages will be displayed with the following format:

Program N SEQ n: message

Where 'N' is the Program number and 'n' is the sequence number when an error was detected, and 'message' is the indicated error as follows:

INFINITE LOOP

A GO TO sequence cannot specify the current sequence.

INVALID GO TO

The target of the GO TO specified an invalid sequence number.

RATE UNDERFLOW

A decrement sequence decremented a rate to less than or equal to 0.

RATE OVERFLOW

An increment sequence caused an arithmetic overflow.

OUT OF RANGE

Specified or calculated rate is beyond the pumps capabilities with the specified syringe.

VOL TGT ERROR

A sequence with a volume target cannot follow a sequence with a time target, unless the volume delivered is zero or the pump is stopped at the start of the sequence entering it, select Program Mode using the SELECT MODE key and press the RUN/STOP key.

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RS-232 Devices

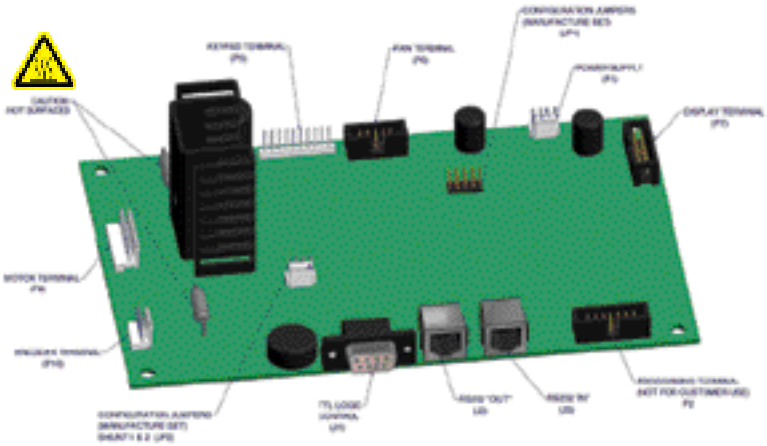


Figure 2. External Connections

External devices that can be attached to the High Force Modular Pumping Component are categorized into either RS-232 devices or user I/O devices. Pump Chains, Scales and Printers are RS-232 devices, all other devices are user I/O devices. See the Appendix G for specification details on attaching RS-232 devices and Appendix I for user I/O specifications.

There are two telephone jack type connectors on the back of the unit (See Figure 2). These are the RS-232 ports. Looking at the back of the pump, the connector on the right is IN and the left is OUT. Attach the RS-232 connectors in the appropriate port according to the following chart:

Device	Port
Pump Chain computer side	IN
Pump Chain pump side	OUT
Scale	IN
Printer	OUT

Configuring the Pump for RS-232 Devices - (Set at "44" Protocol)

The High Force Modular Pumping Component is factory set at pump chain address 00, baud rate 9600. Other configurations can be made upon request of customer.

Pump Chain - (Only with keypad)

Enter the 2-digit address assigned to the pump. Note: Each pump in the chain needs a unique address. After entering the address (up to 99), the baud rate will be requested. Use the RS-232 key to toggle between the supported baud rates: 1200, 2400 , 9600 and 19200. Note: Each pump in the chain must have same baud rate. See the Section 10, Pump Chain Commands for pump chain control information.

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User I/O Devices

The pump does not need to be configured to attach a user I/O device. Simply plug the device into the 9-pin connector on the rear of the pump. See Appendix I for wiring specifications.

Foot Switch or Relay

Used to start and stop the pump. Pressing the foot switch performs the same function as pressing the RUN/STOP key on the keyboard. The foot switch connector allows remote or automated operation of the pump.

Timer

Opening the timer input starts the pump. Closing the timer input stops the pump. The timer input allows for an externally controlled pumping interval.

Pumping Direction

Sets the direction of pumping. Opening the directional input sets the pump to infuse. Closing the directional input sets the pump to refill. The pumping direction input is recognized only in the situations that the INFUSE/REFILL key would be recognized, i.e., when the pump is stopped or running in the Pump Mode.

Valve Control

The valve control output is an indicator of the direction of pump travel. When the output is high, the pump is set to Refill. A low output indicates Infuse.

In the following examples, the diameter is 26.7 mm and the infuse rate is 50 ml/mn. To run a program after entering it, select Program mode using the SELECT MODE key and press the RUN/STOP key. The examples on the following pages include: Multiple Infusions, Ramping Up Infusion Rate, Multiple Dispensing, Periodic Dispense Loop, Combination Infuse and Withdraw Profile, Use of Events and Use of Signal.

OEM Configuration (Factory Set)

44 Protocol

No Alarms

Standby - Mode - On power up

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The following examples are laid out for inputing data thru the optional keypad. This same data can be entered thru the RS-233 connection. (See pump chain commands starting on page 27)

Multiple Infusion Example

The following program will instruct the pump to infuse according to the above graph. The program instructs the pump to infuse 10 ml at 75.000 ml/mn then infuse another 5 ml at 25 ml/mn then stop, for a total of three sequences. Since this graph is Rate vs. Volume, Strategy 1 will be used when entering the program.

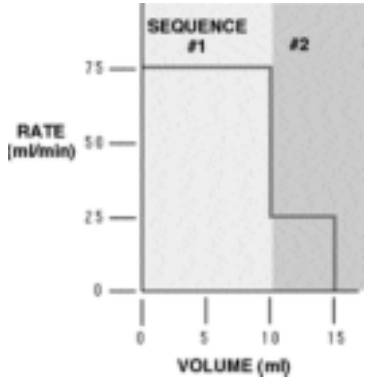


Figure 3. Multiple Infusions.

SEQUENCE 1:	Key Presses	Explanation
	SET	Allows selection of Programming mode
	PROGRAM	Press until PROFILE selected
	ENTER	Enters selection
	75	Enter rate of 75.000 ml/mn
	INFUSE RATE	Press until units are ml/mn
	ENTER	Enters rate
	0 ENTER	Enter 0 for the time, this indicates Strategy 1
	10 ENTER	10 ml is the first target volume
	INFUSE/REFILL	Toggles direction to infuse
	ENTER	Enters sequence's pumping direction
SEQUENCE 2:	**Key Presses**	**Explanation**
	PROGRAM	Press until PROFILE selected
	ENTER	Enters selection
	25	Enter rate of 25.000 ml/mn
	INFUSE RATE	Press until units are ml/mn
	ENTER	Enters rate
	0 ENTER	Enter 0 for the time, this indicates Strategy 1
	5 ENTER	5 ml is the second target volume
	INFUSE/REFILL	Toggles direction to infuse
	ENTER	Enter sequence's pumping direction
SEQUENCE 3:	**Key Presses**	**Explanation**
	PROGRAM	Press until STOP selected
	ENTER	Enters selection and ends program entry

PROGRAM PRINTOUT

PROG1 SEQ 1: PROFILE	25.000 ml/mn
75.000 ml/mn	5.0000 ml
10.000 ml	INFUSE
INFUSE	PROG1 SEQ 3:
PROG1 SEQ 2: PROFILE	STOP

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Ramping Up Infusion Rate Example

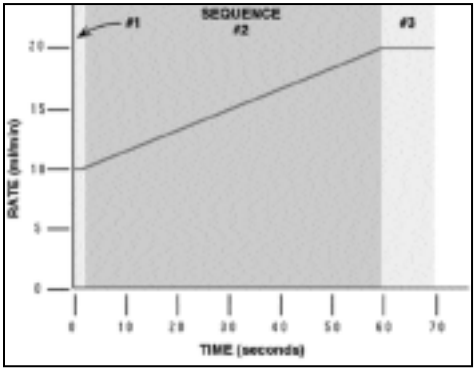


Figure 4. Ramping Up Infusion Rate

PROGRAM PRINTOUT

```
PROG1  SEQ 1: PRO-
FILE
10.000 ml/mn
0:00:01 INTERVAL
INFUSE
PROG1  SEQ 2: INCR
0.1695 INCR
0:00:01 INTERVAL
INFUSE
59 REPEAT
PROG1  SEQ 3: PRO-
FILE
20.000 ml/mn
0:00:10 INTERVAL
INFUSE
PROG1  SEQ 4: STOP
```

In this example, the pump will ramp up from 10 ml/mm to 20 ml/mn over 60 seconds, then continue to run at 20 ml/min for another 10 seconds. This is a Strategy 2 Program requiring four sequences:

1. Specify the initial rate as a profile of 10 ml/mn for one second.

2. Specify the ramp up to 20 ml/mn. Since the minimum resolution of an increment is one second, it will take 59 steps to reach the target rate. Sequence 2 starts at time 1 second and ends at time 60 seconds, giving it a duration of 59 seconds.

   At one second a step, 59 seconds divided by one second per step equals 59 steps. The increase per step will by 20 ml/mn minus 10 ml/mn, divided by 59 steps or 0.1695 rounded to four decimal places.

3. Continue running at 20 ml/mn for 10 seconds with a profile operation.

4. Stop the pump.

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Multiple Dispensing Example

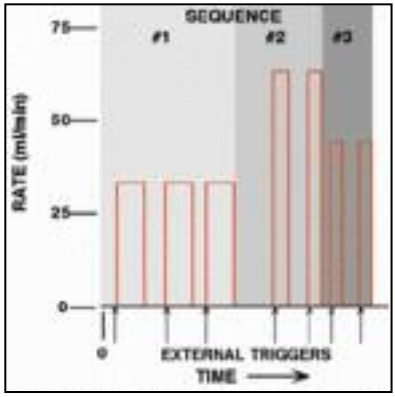


Figure 5. Multiple Dispensing

PROGRAM PRINTOUT

```
PROG1  SEQ 1:  DISPENSE
35.000 ml/mn
15.000 ml
3.  REPEAT
INFUSE
PROG1 SEQ 2:  DISPENSE
65.000 ml/mn
25.000 ml
2. REPEAT
INFUSE
PROG1 SEQ 3:  DISPENSE
45.000 ml/mn
17.000 ml
2. REPEAT
INFUSE
PROG1 SEQ 4:  STOP
```

Here, a series of dispenses are programmed. Each dispense is started by a trigger, such as pressing the RUN/STOP key or pressing an attached foot switch. Seven dispenses are programmed: three of 15 ml at 35 ml/mn, two of 25 ml at 65 ml/mn, and two of 17 ml at 45 ml/mn. The pump's display will show 'TRIGGER' when it is waiting for a run trigger and < or > will not be displayed.

This is a Strategy 1 dispense. A time interval of 0 is specified when entering a Strategy 1 dispense. Since the total volume to be dispensed is 129 ml and the syringe volume is 50 ml, the Auto Fill feature would be very useful with this program.

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Periodic Dispense Loop Example

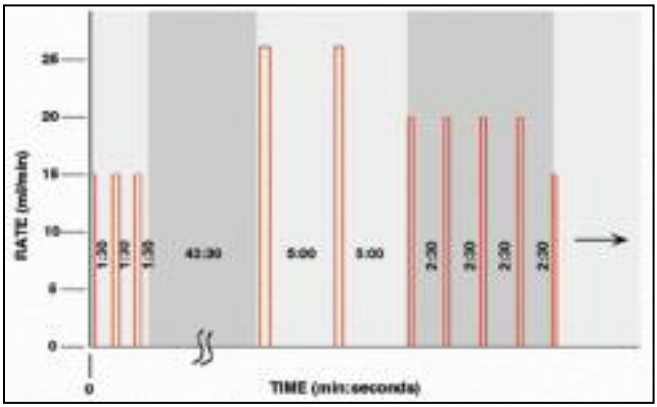


Figure 6. Periodic Dispense Loop

This is an example of a series of periodic dispenses of varying volumes and intervals. For this application, Strategy 2 dispenses are used. Note that between the third and fourth dispenses is a 45 minute interval. Each dispense in the first sequence is separated by a pause interval of 1:30. Since after the third dispense there already will be a 1:30 pause, an additional pause of 43:30 is used to extend the pause to the desired 45:00. Sequence 5 is a RESTART command, causing the series of dispenses to be continuously repeated until the pump is stopped.

PROGRAM PRINTOUT

```
PROG1 SEQ 1:  DISPENSE
15.000 ml/mn
3.5000 ml
0:01:30 INTERVAL
3. REPEAT
INFUSE
PROG1   SEQ 2:  PAUSE
0:43:30 INTERVAL
PROG1 SEQ 3:  DISPENSE
25.700 ml/mn
6.7500 ml
0:05:00 INTERVAL
2.  REPEAT
INFUSE
PROG1   SEQ 4:  DIS-
PENSE
20.000 ml/mn
4.3000 ml
0:02:30 INTERVAL
4.  REPEAT
INFUSE
PROG1 SEQ 5:  RESTART
```


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Combination of Infusion and Withdraw Profiles Example

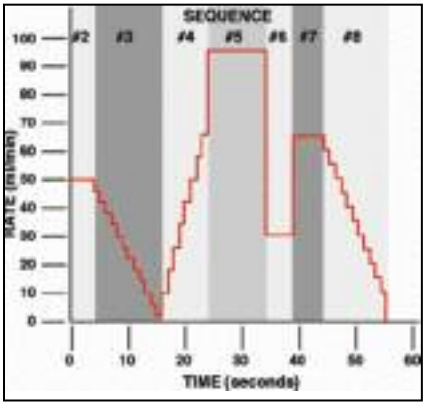


Figure 7. Combination Infusion and Withdraw Profiles

Here is an example of a more complex profile program. Each 'run' of the infusion has been determined to pump 43.155 ml. The first sequence refills the syringe with the volume to be infused then the infusion profile is started, after which the syringe is refilled and the infusion is repeated until the pump is stopped.

PROGRAM PRINTOUT

PROG1 SEQ 1: PROFILE 75.000 ml/mn 43.155 ml REFILL PROG1 SEQ 2: PROFILE 50.000 ml/mn 0:00:04 INTERVAL INFUSE PROG1 SEQ 3: DECR 4.0000 DECR 0:00:01 INTERVAL 12. REPEAT INFUSE PROG1 SEQ 4: INCR 5.0000 DECR 8.0000 INCR 0:00:01 INTERVAL 8. REPEAT INFUSE	PROG1 SEQ 5: PROFILE 95.000 ml/mn 0:00:10 INTERVAL INFUSE PROG1 SEQ 6: PROFILE 30.000 ml/mn 0:00:05 INTERVAL INFUSE PROG1 SEQ 7: PROFILE 65.000 ml/mn 0:00:05 INTERVAL INFUSE PROG1 SEQ 8: DECR 5.0000 DECR 0:00:01 INTERVAL 11. REPEAT INFUSE PROG1 SEQ 9: RESTART

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Use of Events

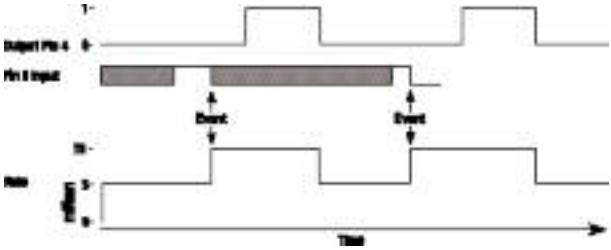


Figure 8. Use of Events

This is an example of the High Force Modular Pumping Component working interactively with other laboratory equipment. The pump will continuously pump at 300 ml/hr until an external event, a high to low transition at pin 9, possibly produced by another High Force Modular Pumping Component , causes the pump to deliver a 15 ml bolus at 75 ml/mn. After delivering 5 ml of the bolus, output pin 4 is set to a logic high for the duration of the bolus after which it is dropped. This output pin can be attached to the timer input of another pump, such as a Harvard Pump 22 or 44, to create a precise mixture during the bolus. After the bolus is completed, the Pump 22 would be stopped and the High Force Modular Pumping Component would return to delivering its background rate of 300 ml/hr, waiting for another external event.

PROGRAM PRINTOUT

PROG1 SEQ 1: TTL OUT OFF PROG1 SEQ 2: EVENT GO TO 4 PROG1 SEQ 3: PUMP 300.00 ml/hr INFUSE PROG1 SEQ 4: PROFILE 75.000 ml/mn	5.0000 ml INFUSE PROG1 SEQ 5: TTL OUT ON PROG1 SEQ 6: PROFILE 75.000 ml/mn 10.0000 ml INFUSE PROG1 SEQ 7: RESTART

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Figure 9. Use of TTL Signal

Before the pumping flow begins, the pump sends a TTL signal to another piece of equipment for 5 seconds, but first verifies that the TTL line is low by turning it off for 1 second, then turns it on. The pumping process consists of an alternation of pumping 3 ml's at 53 ml/mn and 5 ml's at 75 ml/mn. It uses the TTL output to signal to another device whose sequence it is executing by lowering the TTL line before sequence 5 and raising it before sequence 8.

PROGRAM PRINTOUT

PROG1 SEQ 1: TTL OUT OFF Prog1 SEQ 2: PAUSE 0:00:01 INTERVAL PROG1SEQ 3: TTL OUT ON PROG1 SEQ 4: PAUSE 0:00:01 INTERVAL PROG1 SEQ 5: TTL OUT OFF PROG1SEQ 6: PROFILE	53.000 ml/mn 3.0000 ml INFUSE PROG1 SEQ 7: TTL OUT ON PROG1 SEQ 8: PROFILE 75.000 ml/mn 5.0000 ml INFUSE PROG1SEQ 9: GO TO 5

This is an example of the High Force Modular Pumping Component being operated from a remote location. When the pump is powered on, the position of the pusher block is unknown and must be homed to a known position.

At the syringe full position, a limit switch is placed such that it is tripped by the pusher block when the syringe is full. The limit switch is connected to pins 4 and 9, programmable output and the event input, on the user I/O connector. When the pump receives a start signal, it first refills the syringe and stops when the limit switch is sensed. The pump then waits for a start trigger and performs a dispense then refills the syringe and waits again for the next start trigger.

PROGRAM PRINTOUT

PROG1 SEQ 1: EVENT GO TO 7 PROG1 SEQ 2: TTL OUT ON PROG1 SEQ 3: PAUSE 0:00:01 INTERVAL PROG1 SEQ 4: TTL OUT OFF PROG1 SEQ 5: PAUSE 00:00:01 INTERVAL PROG1 SEQ 6: PUMP	75.000 ml/mn PROG1 SEQ 7: DISPENSE 10.000 ml/mn 0.0001 ml 1. REPEAT REFILL PROG1 SEQ 8: PUMP 75.000 ml/mn 10.000 ml INFUSE PROG1 SEQ 9: RESTART

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Remote Control Via. The RS-232 Interface Using HYPERTERMINAL

PHD4400 OEM Module

1. Connect the telephone cable between the High Force Modular Pumping Component RS-232 IN port (J3) and a PC's serial port using the telephone jack to 9-pin D-sub adapter.
2. On the PC (running a Microsoft Windows Operating System), select START – PROGRAMS – ACCESSORIES – HYPERTERMINAL – HYPERTERMINAL to start the Hyperterminal application. If Hyperterminal is not available, install it from the Microsoft Windows Operating System Install disks or CD ROM.
3. Set up the appropriate COMPORT for the following:





Configure:

Baud Rate :	9600
Data Bits:	8
Parity:	None
Stop Bits:	2
Flow Cntrl:	None
Emulation:	Auto Detect

ASCII Setup:

Echo typed characters locally.
Line delay: 0
Character delay: 0
Wrap lines

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You may want to save the setup information under a descriptive filename.

4. At the PC, launch hyperterminal with the above setup specifications (if it is not already running). Type ver at the PC keyboard and verify PHD 1.2 is displayed at the PC terminal.

   Note: The PHD4400 OEM Module is preset to the MODEL 44 PROTOCOL, 9600 Baud, and ADDRESS 00.

5. Type run to start the pump; type stp to stop the pump. After starting the pump, 0> should be displayed, indicating address 0 pump is infusing. After stopping the pump, 0* should be displayed.

   Optional: For users that have purchased and connected the optional display and keypad, the following additional operations are possible.

6. **Changing the RS-232 Communications Protocol:** At the PHD4400 keypad, press and release the SET key and press and release the "1" key. Verify MODEL 44 PROTOCOL is displayed. To toggle to the MODEL 22 PROTOCOL, press and release the "1" key again and then the ENTER key. Otherwise just press the ENTER key to keep the MODEL 44 PROTOCOL. Note: Be sure to use the appropriate command set for the protocol selected.

7. **Changing the Pump Address and Baud Rate:** Press and release the SET key and then the RS-232 key. Verify PUMP CHAIN is displayed (if not, toggle through the modes by pressing the RS-232 key until it is). Press and release the ENTER key. Verify ENTER ADDRESS: 00 is displayed. Use the numeric keypad to enter the desired address and press the ENTER key. Verify BAUD RATE: 9600 is displayed. Toggle through the available Baud Rates by pressing the RS-232 key and then press and release the ENTER key to accept the desired baud rate.

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Daisy-chaining Pumps: To daisy-chain pumps, connect another telephone cable between the RS232 OUT port of the first pump in the PUMP CHAIN (address 00) to the RS232 IN port of the next pump in the chain. The address of the second pump should be set to 01. Commands at the PC terminal must include the pump address to control all pumps other than pump 0 (i.e. 1run, 1ver, 1stp).

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Note: Changing pump addresses is only possible with the optional display and keypad.

The Pump Chain RS-232 interface allows up to 100 pumps and, in certain cases, other RS-232 devices to be controlled from a single RS-232 communication port on a computer.

Assign each pump in the pump chain a unique address from 0 to 99. This address is used to identify which pump is to receive a command and which pump is responding. Configure each pump with its assigned address and the baud rate being used (See Section 10, External Control & Interfaces).

When the control device communicates with the pump, a diamond appears on the far right of the display indicating that it is receiving RS-232 commands. The diamond remains on the display until the pump is turned off or SET RS-232 is entered on the keyboard, indicating a change in the RS-232 configuration.

A pump will not respond to pump chain communication while it is in a setting mode (entered when user presses the SET key on the optional keypad). The pump can still be controlled from the keypad while it is in a pump chain. Control data that is changed via RS-232 will be stored in the pump's nonvolatile memory.

After each command is received and executed, the pump terminates its responses with a prompt. A prompt is a string of ASCII characters sent by a pump.

The High Force Modular Pumping Component is capable of using two sets of pump interface commands. This will allow users of Harvard Apparatus Model 22 and Model 44 pumps to use existing programs to control the High Force Modular pumps. The two sets of commands are contained on the following pages.

For customer reference, the High Force Modular Pumping Component is factory set at the "44" Protocol

Each command sent to the pump chain is a string of ASCII characters, with leading zero's on numbers and all spaces optional. Numbers are a maximum of five digits. The following symbols are used in describing the commands:

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Pump Chain Commands - Model '22' Protocol (Model 44 Protocol on page 35)

After each transmission to the Pump terminating with a CR character (ASCII 13), the pump enters remote mode and responds with the three character sequence:

CR LF prompt

The prompt character indicates the status of the pump as follows:

:	When stopped	(ASCII 58 decimal)
>	When running forward	(ASCII 62 decimal)
<	When running reverse	(ASCII 60 decimal)
*	When stalled	(ASCII 42 decimal)

Note: With a pump chain, if no address precedes the command transmitted, the pump at address 0 will respond to the command.

Commands - Response: CR LF prompt

RUN	Infuse (forward direction)
REV	Start (reverse direction) Not accessible on Infusion model
STP	Stop
CLV	Clear volume accumulator to zero
CLT	Clear target volume to zero
MLM number	Set rate, units are milliliters per minute
ULM number	Set rate, units are microliters per minute
MLH number	Set rate, units are milliliters per hour
ULH number	Set rate, units are microliters per hour
MMD number	Set diameter, units are mm. Rate is set to 0
MLT number	Set target infusion volume, units are ml.

Numbers between 0 and 1999 will be accepted by the pump. Leading zeros and trailing decimal point are optional. Any number of digits to the right of the decimal point may be transmitted. The number received will be rounded to four significant digits if the leading digit is 1, or three significant digits if the leading digit is 2 to 9.

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Queries - Response: CR LF Value CR LF Prompt

Queries with Numeric Response:

DIA	Send diameter value, units in mm
RAT	Send rate value in current range units
VOL	Send current accumulated infused volume, units are ml.
TAR	Send target volume, units are ml.
VER	Send model and version number

Value format: nnnn.nnn

The transmitted value is an 8 character string with leading zeros converted to SP characters. (ASCII 32) The fifth character is a decimal point (ASCII 46).

Query - Response: CR LF Range CR LF Prompt

Queries with String Response:

RNG:	Send range message
Range is a character string, one of:	ML/H ML/M UL/H or UL/M

Error Responses:

CR LF ? CR LF prompt	Unrecognized command
CR LF O O R CR LF prompt	Out of range

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Pump Chain Commands - Model '44' Protocol

Symbol	Meaning
[. . .]	optional
{. . .}	select one
|	either/or
f	digits 0 – 9 or a decimal point
d	digits 0 – 9
<cr>	carriage return (ASCII 13)
<lf>	line feed (ASCII 10)
<float>	f f f f f f
<integer>	ddddd
<time>	d:dd:dd
<text>	any string of ASCII characters

Command Formats and Meanings:

Command Format	Meaning
<cr>	Stops all pumps. All pumps on the pump chain interpret this as a stop command.
pump address, <cr>	Request for prompt The pump with the indicated address responds with its prompt
optional pump address, command, <cr>	Send a command to a pump. The pump with the indicated address executes the command then responds with its prompt. The optional pump address, if not specified, will default to pump address 0.

After each command is received and executed, the pump acknowledges the command with a prompt. Preceding the prompt may be some additional text responses. The additional text will be one or more lines of ASCII text, each preceded by a line feed and terminated by a carriage return:

<lf>, <text>, <cr>

A prompt is a string of ASCII characters sent by a pump indicating the pumps address and its present state:

<lf>, 1 or 2 digit address, prompt character

Prompt Characters	Meaning
:	Pump stopped
>	Pump infusing
<	Pump refilling
/	Pause interval (pump stopped)
*	Pumping interrupted (pump stopped)
^	Dispense trigger wait (pump stopped)

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Pump Commands and Responses

RUN Starts pumping according to the present setting of the pump. If pump is already pumping, a 'Not Applicable' response will be given.

STP Stops pump if it was running. If pump was already stopped, a 'Not Applicable' response will be given.

DEL Request for volume delivered, in ml.
Response is of the following format:
space, space, f f f f f f

CLD Request to zero volume delivered. If the pump was interrupted, it will cancel the interrupted condition. If the pump is running, request will not be accepted and a 'Not Applicable' response will be given. Otherwise, no response is given.

RAT [<float> [<units>]]

Request to set or query infusion rate setting.

Set infusion rate:
RAT rate

Set infusion rate and units:
RAT rate units

Rate is of format: f f f f f f
Units are one of:

	Definition
UM	µl/mn
UH	µl/hr
MM	ml/mn
MH	ml/hr

If rate is accepted and valid, rate will become the new infusion rate.
If the rate is invalid, an 'Out Of Range' response will be given.
Command will not be accepted if the pump is running in the Program Mode and a 'Not Applicable' response will be given.

Query infusion rate: RAT

Response is of the following format:
space, space, f f f f f f units

Where units is one of the following:

ml/mn
ul/mn
ml/hr
ul/hr

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RFR [<float> [<units>]]

Request to set or query refill rate setting.

Set refill rate:
RFR rate

Set refill rate and units:
RFR rate units
Rate is of format: f f f f f f
Units are one of:

	Definition
UM	µl/mn
UH	µl/hr
MM	ml/mn
MH	ml/hr

If rate is accepted and valid, rate will become the new refill rate. If the rate is invalid, an 'Out Of Range' response will be given. Command will not be accepted if the pump is running in the Program Mode and a 'Not Applicable' response will be given.

Query refill rate: RFR

Response is of the following format:
space, space, f f f f f f units
Where units is one of the following:
ml/mn
ul/mn
ml/hr
ul/hr

PGR Request for the rate of pumping set during the running of a program.
Response is of the following format:
space, space, f f f f f f units
Where units is one of the following:
ml/mn
ul/mn
ml/hr
ul/hr

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DIA [<float>]

Request to set or query syringe diameter setting.

Set diameter:

DIA diameter
Diameter is of format: f f f f f f
Units are MM.

INFUSE and REFILL rates will be set to zero and AUTO FILL will be set to off.

If diameter is accepted and valid, diameter becomes new diameter.
Diameter will not be accepted if the pump is running and a 'Not Applicable' response will be given.
If the diameter is invalid, an 'Out Of Range' response will be given.

Query diameter: DIA

Response is of the following format:
space, space, f f f f f f
Units are MM.

TGT [<float>]

Request to set or query target volume setting.

Set target volume:

TGT volume
Volume is of format: f f f f f f
Units are ML.
If volume is accepted and valid, volume becomes new target volume.
Volume will not be accepted if the pump is running and a 'Not Applicable' response will be given.
If the volume is invalid, an 'Out Of Range' response will be given.

Query volume:TGT

Response is of the following format:
space, space, f f f f f f
Units are ML.

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MOD [{PMP | VOL | PGM}]

Request to set or query pumping mode
Set: MOD PMP (Puts pump in Pump Mode)
MOD VOL (Puts pump in Volume Mode)
MOD PGM (Puts pump in Program Mode)

Command will not be accepted if the pump is running and a 'Not Applicable' response will be given.

Query: MOD
If mode is PUMP, response will be:
PUMP
If mode is VOLUME, response will be:
VOLUME
If mode is PROGRAM response will be:
PRGRAM

DIR [{INF | REF | REV}]

Request to set or query pumping direction

Set: DIR INF (sets pumping direction to infusion)
DIR REF (sets pumping direction to refill)
DIR REV (reverses current pumping direction)

Command will not be accepted if the pump is running in volume or program modes and a 'Not Applicable' response will be given.

Query: DIR
If pump direction is infusion, response will be:
INFUSE
If pump direction is refill, response will be:
REFILL

AF [{ON | OFF}]

Request to set or query auto fill setting

Set: AF ON (turns Auto Fill feature on)
Note: The syringe volume is also needed for auto fill to operate. (See SYR command)
AF OFF (turns Auto Fill function off)
Command will not be accepted if the pump is running and a 'Not Applicable' response will be given.

Query: AF
If Auto Fill function is ON, response will be: ON
If Auto Fill function if OFF, response will be: OFF

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SYR [<float>]

Request to set or query syringe volume setting for auto fill.
Used in conjunction with Auto Fill feature. (See AF command).

Set syringe volume: SYR volume
Volume is of format: f f f f f f
Units are ML.
If volume is accepted and valid, volume will become the new syringe Auto Fill volume.
Volume will not be accepted if the pump is running and a 'Not Applicable' response will be given.
If the volume is invalid, an 'Out Of Range' response will be given.

Query syringe volume: SYR
Response is of the following format:
space, space, f f f f f f

IN d

Request to read the TTL logic level of the specified pin on the external 9 pin D-SUB connector. Valid pin numbers for input are:
6, 7, 8 and 9
If the pin specified is valid and if the pin level is high, response will be:
ON
If the pin level is low, response will be:
OFF
If the pin specified is invalid:
An 'Out Of Range' response will be given

OUT d = <ON|OFF>

Request to set the TTL logic level at the specified pin on the external 9 pin D-SUB connector.
Valid pin number for output is: 4
If the pin specified is invalid:
An 'Out Of Range' response will be given

Example:
Set pin 4 high:
OUT 4 = ON
Set pin 4 low:
OUT 4 = OFF

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SEQ [<integer>] [<entry>]

Request to set or query programming sequences. <integer> is sequence number. Default is Sequence 1. Command only applicable while pump is stopped. Valid sequence numbers, 'n', are 1 to 10. 'n' defaults to 1 wherever it is optional. See program examples.

Query entire program: SEQ

Example response:

```
SEQ 1: DISPENSE
75.000 ml/mn
43.155 ml
0:00:01 INTERVAL
   3 REPEAT
INFUSE
SEQ 2: PROFILE
100.00 ml/mn
150.00 ml
REFILL
SEQ 3: RESTART
```

Query program sequence [n]: SEQ n

Example response to the command 'SEQ 2' with the previous example's program:

```
SEQ 2: PROFILE
100.00 ml/mn
150.00 ml
REFILL
```

Query program sequence n's mode: SEQ [n] MOD

Response will be according to the following table:

Response	Description	Response	Description
STP	stop	RST	restart
PRO	profile	GOT	go to
INC	increment	EVN	event
DEC	decrement	PMP	pump
DIS	dispense	OUT	TTL out
PAS	pause		

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Query data item of program sequence n:

Command	Description
SEQ [n] RAT	Query rate Response: f f f f f f units Where units is one of the following: ml/mn ul/mn ml/hr ul/hr
SEQ [n] GOT	Query go to sequence number Response: <n>
SEQ [n] TGT	Query target volume Response: <float>
SEQ [n] INT	Query time interval Response: <time>
SEQ [n] RPT	Query repetition count Response: <float>
SEQ [n] OUT	Query output pin level setting Response: <ON/OFF>
SEQ [n] DIR	Query pumping direction Possible responses: INFUSE REFILL

Set mode of program sequence n:

SEQ [n] MOD mode

Where mode is as follows:

Mode	Description	Mode	Description
STP	stop	RST	restart
PRO	profile	EVN	event
INC	increment	GOT	go to
DEC	decrement	OUT	set output pin
DIS	dispense	PMP	pump
PAS	pause		

Set data item of program sequence n:

Set sequence's rate:

SEQ [<n>] RAT <float> [<units>]

Rate is of format: f f f f f f

Units are one of :	Description
UM	µl/mn
UH	µl/hr
MM	ml/mn
MH	ml/hr

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Set sequence's go to sequence number
SEC [<n>] GOT <n>
Set sequence's target volume:
SEQ [<n>] TGT <float>
Set sequence's time or target:
SEQ [<n>] INT <time>
Set sequence's repetition number:
SEQ [<n>] RPT <integer>
Set sequence's pumping direction:
SEQ [<n>] DIR <INF|REF>
Set sequence's output pin level
SEQ [<n>] OUT <ON|OFF>

VER Request for version of pumps embedded software.

Pump Chain Error Messages

Error messages are in the format:
<lf>, space, space, <message>, <cr>,

Where <message> is one of the following:

?	Syntax error in a received command
NA	Command not applicable at this time
OOR	Control data is out of the operating range of the pump

Note: If assistance is needed in programming pump control via RS-232, call Harvard Apparatus Customer Service Support at 1-800-272-2775.

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Appendix A: Syringe Diameters in mm

Stainless Steel

Size	Diameter
8 cc	9.525 mm
20	19.130
50	28.600
100	34.900
200	44.755

Becton Dickinson Plastic 'Plasti-pak'

Size	Diameter
1 cc	4.78 mm
3	8.66
5	12.06
10	14.50
20	19.13
30	21.70
50/60	26.70

Air–Tite 'All Plastic'

Size	Diameter
2.5 cc	9.60 mm
5	12.45
10	15.90
20	20.05
30	22.50
50	29.00

Unimetrics Series 4000 & 5000

Size	Diameter
10 µl	0.460 mm
25	0.729
50	1.031
100	1.460
250	2.300
500	3.260
1000	4.610

Terumo

Size	Diameter
3 cc	8.95 mm
5	13.00
10	15.80
20	20.15
30	23.10
60	29.10

Sherwood–Monoject Plastic

Size	Diameter
1 cc	4.65 mm
3	8.94
6	12.70
12	15.90
20	20.40
35	23.80
60	26.60
140	38.40

Popper & Sons, Inc. 'Perfektum' Glass

Size	Diameter
0.25 cc	3.45 mm
0.5	3.45
1	4.50
2	8.92
3	8.99
5	11.70
10	14.70
20	19.58
30	22.70
50	29.00
100	35.70

Renfac

Size	Diameter
2 cc	9.12 mm
5	12.34
10	14.55
20	19.86
30	23.20
50	27.60

SGE Scientific Glass Engineering

Size	Diameter
25 µl	0.73 mm
50	1.03
100	1.46
250	2.30
500	3.26
1.0 ml	4.61 mm
2.5	7.28
5	10.30
10	14.57

Hamilton–Microliter Series Gastight

Size	Diameter
0.5 µl	0.103 mm
1	0.1457
2	0.206
5	0.3257
10	0.460
25	0.729
50	1.031
100	1.46
250	2.3
500	3.26
1.0 ml	4.61 mm
2.5	7.28
5	10.3
10	14.57
25	23.0
50	32.6

Becton Dickinson Glass-All Types

Size	Diameter
0.5 µl	4.64 mm
1	4.64
2.5	8.66
5	11.86
10	14.34
20	19.13
30	22.70
50	28.60
100	34.90

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Appendix B: Stainless Steel Syringes



Harvard High Pressure Stainless Steel Syringes

Harvard now offers a completely new line of Stainless Steel Syringes intended for high pressure applications with good resistance to most aggressive liquids. Wetted parts are #316 stainless steel or Viton. Syringes are available in 20, 50, 100 and 200 ml sizes with removable replaceable tips. Genuine SWAGELOK® syringe to tube fittings are available in 1/16, 1/8 and 1/4 inch sizes. A luer lock end fitting is also available. All tips are interchangeable with all syringes (20 to 200 ml) in the series. Both syringe barrel end plungers are #316 stainless steel. A Viton O-ring seal between top and end of the barrel insures against leakage. Syringes are guaranteed to be leak free for pressures up to 700 psi.

All syringes are supplied with inside diameter dimensions for use with Harvard microprocessor controlled pumps and rate charts for use with older 'classic' pumps. Replacement Viton O-Rings are available, as are the more chemically resistant Chemraz® O-Rings.

Harvard High Pressure 8 ml Stainless Steel Syringe

This syringe has been designed to utilize the high forces available in our syringe pumps to produce pressures up to 1500 psi. The syringe is constructed entirely of #316 stainless steel with two Chemraz® O-Ring seals, two Teflon O-Ring seals and 1.6 mm (1/16 in) SWAGELOK® end. When this syringe is used in the 70-2200 or 70-2201 Harvard PHD 4400, pressures in excess of 1500 psi are consistently achieved for chromatography and process control applications.

Specifications:

Volume	8 ml
Dimensions:	
Length of Barrel	16.5 cm (6-1/2 in)
Plunger Excursion	11.4 cm (4-1/2 in)
OD	1.6 cm (5/8 in)
ID	0.95 cm (3/8 in)
Max Test Pressure	4000 p.s.i
Working Pressure	1500 p.s.i

Cat. No.	Product
55-3369	Harvard High Pressure 8 ml Stainless Steel Syringe Replacement Parts
5013-089	Chemraz® O-Ring 20 ml
5013-090	Chemraz® O-Ring 50 ml
5013-091	Chemraz® O-Ring 100 ml
5013-092	Chemraz® O-Ring 200 ml
5013-087	Chemraz® Tip Seal O-Ring, all sizes
72-2472	Replacement Viton O-Ring 20 ml, 10
72-2473	Replacement Viton O-Ring 50 ml, 10
72-2474	Replacement Viton O-Ring 100 ml, 10
72-2475	Replacement Viton O-Ring 200 ml, 10
72-2476	Replacement Viton Tip Seal O-Ring, 10

Harvard High Pressure Stainless Steel Syringes

Syringe Size	With SWAGELOK® Diameter 1/16 inch	1/8 inch	With Luer Lock 1/4 inch	
20 ml	**55-4199**	**55-4205**	**55-4209**	**55-4214**
50 ml	**55-4200**	**55-4206**	**55-4210**	**55-4215**
100 ml	**55-4201**	**55-4207**	**55-4211**	**55-4216**
200 ml	**55-4202**	**55-4208**	**55-4213**	**55-4217**
Replacement Tips, Furnished with Sealing O-Ring				
	55-4220	**55-4221**	**55-4222**	**55-4223**

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Appendix C: Min/Max Flow Rates

Minimum flow rates are taken from the smallest inside diameters and maximum flow rates are taken from the largest inside diameters of the syringes supplied by the eleven most widely used syringe manufacturers.

Nominal Minimum/Maximum Flow Rates for Various Syringes (Actual Limits will vary depending on manufacturer)

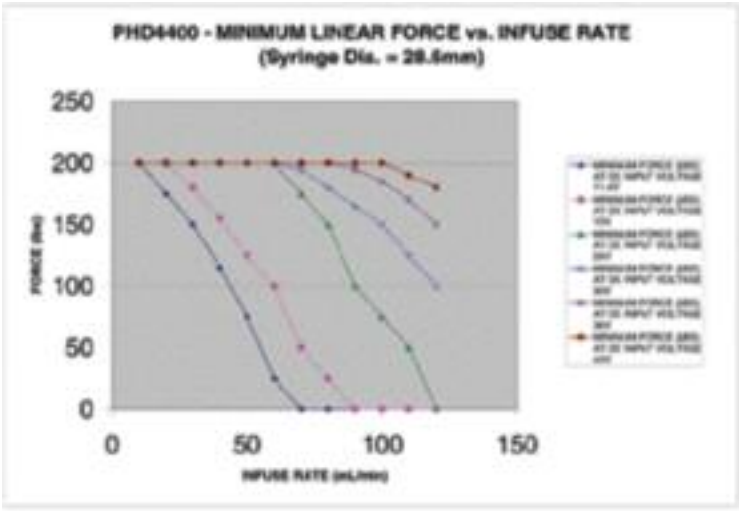
Syringe Size	µl/hr Min.	µl/hr Max.	µl/min Min.	µl/min Max.	ml/hr Min.	ml/hr Max.	ml/min Min.	ml/min Max.
0.5 µl	0.0001	95.330						
1 µl	0.0002	190.70						
2 µl	0.0004	381.30						
5 µl	0.0010	953.17						
10 µl	0.0019					1.9013		
25 µl	0.0046					4.7752		
50 µl	0.0092					9.5511		
100 µl	0.0183					19.153		
250 µl	0.0454					47.532		
500 µl	0.0911					95.492		
1000 µl			0.0031			190.95		
1 ml			0.0033			205.30		
2 ml			0.0119			747.35		
2.5 ml			0.0076			476.21		
3 ml			0.010					11.231
5 ml			0.0208					21.781
10 ml			0.0301					31.486
20 ml			0.0523					54.804
30 ml			0.0673					70.518
50 ml			0.1019					106.76
100 ml			0.1740					182.40
140 ml			0.2106					220.82

Appendix D: Custom Applications

The Harvard High Force Modular Pumping Components lend themselves to a multitude of OEM industrial applications. For all types of custom pumping or pilot plant applications, the pump's programming capabilities can be enhanced. Please contact the Harvard Development Group if we can be of help.

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Appendix F: PHD 4400 to PC Connection

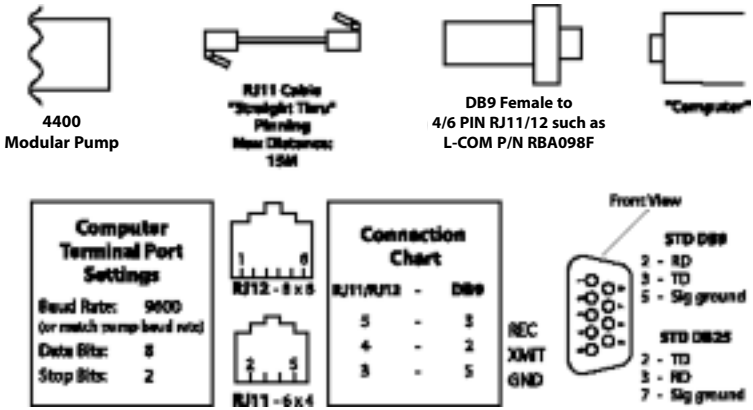


Figure 10. PHD 44 to PC Connection

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Appendix G: RS-232 Specifications

Pump Chain

Pump Port 1 – Computer control side
Pump Port 2 – Connection for remainder of pump chain
Baud Rate – 1200, 2400, 9600 or 19,200
Word Size – 8
Parity – none
Stop Bits – 2
Factory set at 9600 baud

Scale

Connect scale to Pump Port 1

Supported scales:

Mettler
Baud Rate – 2400
Word Size – 7
Parity – even
Stop Bits – 1
Pause – 0

Sartorius
Baud Rate – 2400
Word Size – 7
Parity – even
Stop Bits – 1
Code Settings:
311 – Weigh only (models with PLUS performance package)
211 – External print command with out stability
225 – 2400 baud
234 – Even Parity
432 – Beeper off

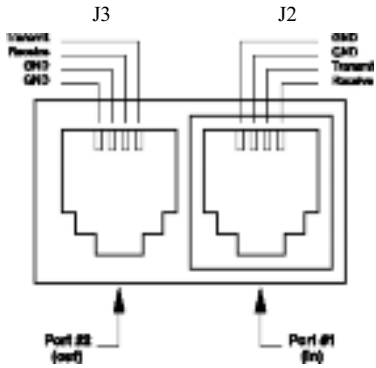


Figure 11. RS-232 Connection

Ohaus
Baud Rate – 2400
Word Size – 8
Parity – even
Stop Bits – 1
Auto print feature – off
Stable data only – off
Serial data frame selection – Fr.7

Printer

Serial printer with print buffer:
Baud Rate – 2400
Word Size – 8
Parity – none
Stop Bits – 2

Appendix H: Symphony - *(Included with OEM kit)*

Symphony, the Windows® Pump Manager software, allows you to control your High Force Modular Pumping Component from your remote computer. With Symphony, you can orchestrate all pump functions from a virtual control panel via the serial communications link built into every High Force Modular Pumping Component.

See Appendix M for complete manual

Catalog Number	Product
70-3000	Symphony - Windows Pump Manager

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Appendix I: User I/O Connector Specs

User I/O (input/output) connections are via a 9 pin D-sub type connector. All inputs are internally pulled up to a logic high.

Pin Assignments

1. Vss (Ground reference, logic low)
   Falling edge starts/stops pump
2. Valve control output:
   Low – Infusing
   High – Refilling
3. Running Output Indicator
   Low - Pumped stopped
   High - Pump running
4. Programmable output
5. Logic High Reference (5V, 6 mA)
6. Foot switch input
7. Timer Input
   Rising edge starts pump
   Falling edge stops pump
8. Directional control input
   Rising edge sets pump to infuse
   Falling edge sets pump to refill

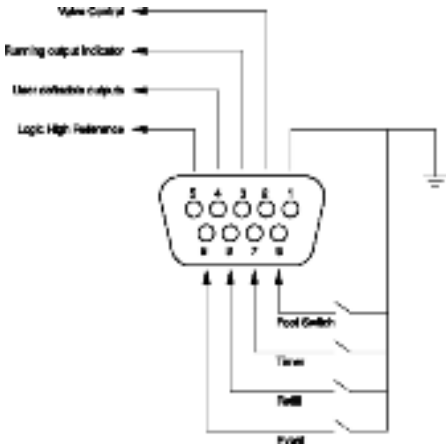


Figure 12. User I/O Connector Specifications

9. Event input
   Falling edge triggers program event

Logic Low: 0 V – 0.8 V
Max. 6 mA current sink

Logic High: 2 V – 5 V
Max. 6mA current source

Appendix J: Accessories & Spare Parts

Auto Fill Accessory

To operate the Auto Fill feature, either the low pressure or high pressure valve assembly is required. Each assembly contains the solenoid valve, connector cable, power cable, and tubing and fittings to connect to the syringe. Operates at 115/230 VAC, 50/60 Hz via a selector switch.

Cat. No.	Accessories
72-2748	Daisy-Chain Cable, 1.8 m (6 ft)
55-7760	Daisy-Chain Cable, 0.6 m (2 ft)
70-2022	Daisy-Chain Connector, 9 PIN
55-4145	Daisy-Chain Connector, 25 PIN
55-4144	Foot Switch
55-7002	'Auto Fill' Valve Box–Regular Pressure – to 20 psi
55-1145	'Auto Fill' Valve Box–High Pressure – 200 psi
5108-032	Adjustable Stop
2400-252	Operating Keypad
2400-235	LCD Display

Cat. No.	Spare Parts
0606-086	Magnalube - Lead Screw Lubricant
4430-034	Syringe Clamp
5100-060	Thumb Screw, Syringe Clamp
5100-059	T Knob, Withdraw & Anti-Siphon Bracket
5406-002	High Force Modular Pumping Component Operators Manual
4430-066	6ft Motor/Encoder Extension Cable
4430-063	6ft DC Power Extension Cable

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Maintenance

The High Force Modular Pumping Component series pumps require no special maintenance, other than keeping them clean by avoiding accidental spills of pumped material.

The two guide rods and the lead screw should be sparingly lubricated periodically. The guide rods and the lead screw should be lubricated with Magnalube-G R grease (Catalog #0606-086) provided with the pump.

Solvents of any type should never be used to clean the pump. A mild detergent solution may be used to clean the keypad.

Troubleshooting

Infusion Accuracy

To ensure infusion accuracy always use new syringe(s) and measure syringe bore diameter and enter actual dimensions in millimeters (mm). Additionally make sure that the guide rods and lead screw are properly lubricated.

RS-232 Difficulties

Verify that the baud rates and data framing parameters on all devices are the same. With the pump chain, a "Communication timeout" error on a computer is usually caused by the computer errantly handshaking on the RTS, CTS and DSR lines. Verify pins 4, 5 and 6, on the 25 pin connector, are jumped on the computer side of the cable.

PHD 4400 Display Messages -

(Only if you have a optional display & keypad)

Pump Stalled

This indicates that the pusher block travel has been impeded. This may be caused by the syringe plunger hitting bottom, a kink in the tubing, syringe plunger binding or any situation requiring more force to the head of the syringe than the pump is capable of delivering. To restart the pump, remove the cause of stalling and press RUN. The pump will continue the interrupted procedure where it stopped. Also note, a large increase in the pumping rate could also stall the motor.

Out of Range

A value was entered or encountered in a pump program that was beyond the pump's limits. Also, verify that the Infuse Rate is not 0. Note that rates must be less than 42949. Express larger rates using different units.

EEPROM Data Lost

The values stored in the nonvolatile memory have been lost. This should never occur under normal operation.

Replace NOVRAM

The nonvolatile memory has failed. This should never occur under normal operation.

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There are two 'Auto Fill' Valve models available:

Catalog No.	Product
55-7002	Supplied with 1/8 inch I.D., 1/4 inch O.D. silastic tubing and connector to syringe
55-1145	Supplies with 1/4 inch O.D. 304 stainless steel tubing with Swagelok fittings

Setting Up the Valve

Set up consist of three phases: Voltage selection (110 or 220 V), Pump to valve electrical connection and Valve tubing to syringe hook up.

1. Voltage Selection

Valves are shipped from the factory with an American line cord with three wire molded power connector and the pump set for 115 - 125 VAC.

For 220 - 240 VAC operation the molded power connector must be cut off and replaced with an appropriate type. The line cord is color coded in International standard colors:

Brown - High **Blue - Neutral** **Green - Ground**

Observe the polarities when installing the new connector. To adjust the valve for 220 - 240 volt operation an international voltage selector switch must be set. Remove the top panel by removing eight screws, four on each end of the valve. Identify the voltage selector switch located directly below. Using a screw driver turn the switch from 110 to 220. The pump is now set up for 220 volt operation.

2. Pump to Valve Electrical Connection

The cable fitted with a male 9 pin D-sub connector must be connected to the female D-sub connector on the rear of the High Force Modular Pumping kit. Power can now be switched on with the illuminated power On/Off switch on the front valve housing.

3. Pump to Valve Tubing Connection

Swagelok fitting should be finger tight plus 1 1/4 turn. Tubing is 304 stainless steel 1/4 inch O.D. wall thickness 0.035 inch.

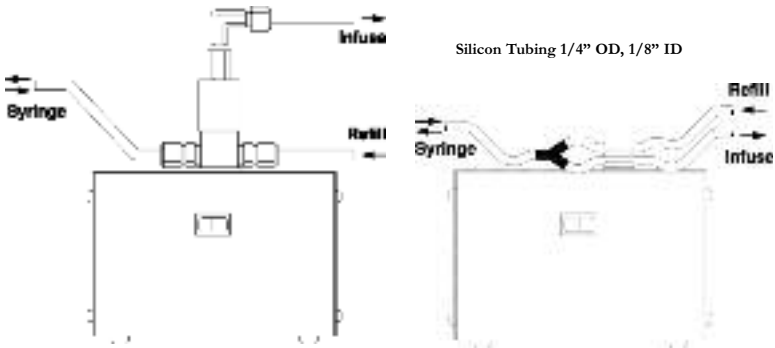


Figure 13. Pump to Valve Tubing Connection

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"Symphony", the Windows Pump Manager, version 1.2.

Symphony Installation
To install Symphony, follow one of these procedures:

- **Windows 95 and 98 Users:** Insert Symphony disk number 1 in your floppy drive; choose Run from the Start menu, type a:\setup, and press the Enter key.

- **Windows 3.1 Users:** Insert Symphony disk number 1 in your floppy drive; from the Windows Program Manager choose Run from the File menu, type a:\setup, and press the Enter key.

The Setup program will issue a number of prompts. Unless you have a reason to override the defaults it is strongly recommended that you press the OK or the Yes buttons to accept the installation default settings. You must close all active applications programs before the setup program will run. Standard Setup is recommended for new Symphony users.

CONTENTS:

1.0 System requirements
2.0 Connecting a serial cable from your pump to your PC
How to run Symphony with multiple pumps
3.0 Configuring Symphony to communicate with your PC
4.0 Running Symphony for the first time
5.0 The Symphony screens
5.1. Interactive pump control screen
5.2. Pump graph
5.3. Pump program screen
5.4. Log sheet
5.5. I/O control
6.0 Troubleshooting

1.0 System requirements

Minimum equipment requirements:
- Intel compatible 486/ 33 computer with 8MB RAM
- Hard disk drive with 2MB available space.
- Windows 3.1, Windows 95 or Windows 98
- 3.5" floppy disk drive
- Mouse
- VGA or higher display and driver capable of 800x 600 resolution
- one unused serial communication port

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2.0 Connecting a serial cable from your pump to your PC.

Symphony is designed to work with genuine Harvard Apparatus pumps. The model 44, PHD 2000, and PHD4400 pumps will work with Symphony. Symphony will not work with the model Pump 22 or other older Harvard pumps.

Connect pump to your PC serial communications port with a four wire RJ11 data cable with "straight through" pinning. Do not use a four wire telephone cable. It uses "crossed pinning" and will not work. Depending on your computer, you may have either a DB9, DB25 or other connector on your PC serial port. Refer to your PC hardware manual if you're unsure of the serial communications port type and signal connections. Prepare an adapter to the RJ11 cable with the following connections:

RJ11 pin	signal	(Example) PC DB-9 pin
2	REC	3
3	XMIT	2
4	GND	5

Additional pumps may be connected directly to the first pump in a Daisy chain fashion to the first pump. Refer to your pump manual to set pump addresses, protocol and baud rate. Note: the Harvard Model PHD2000 and PHD4400 pumps must be set in the Pump 44 communications protocol. Refer to your pump user manual to verify this.

How to run Symphony with multiple pumps

Three modes are available. They are:

Mode 1

Use this mode if you want all pumps to perform the same tasks simultaneously.

Connect one comm port on your PC to all syringe pumps in daisy-chain fashion. Set all pumps to the same address, ex- 00.

Remember that the baud rate must be the same for Symphony and all pumps in the chain.

In this mode, all pumps will respond to the same commands from Symphony although a small delay will occur between the first and later pumps. This delay results from the time required to pass serial commands from one pump to the next along the chain. Use the faster baud rates to minimize this delay.

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Mode 2

Use this mode if you have a small number of pumps and you want them to do different tasks.

Connect a single comm port on your PC to all syringe pumps chained together and set all pumps to different addresses, ex- 00, 01, etc..

In this mode, to address a specific pump, you must make it "active" by setting its' unique address via the pump interactive screen. Remember that the baud rate must be the same for Symphony and all pumps in the chain. When running in this mode, the log sheet will only record the activities of the "active" pump. The log sheet header records only the pump address of the "active" pump when Symphony started.

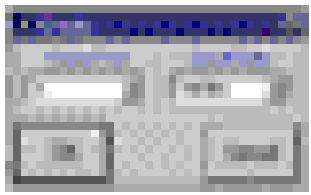
Mode 3

Use this mode if you're controlling a small number of pumps and want them to do different tasks. Your PC must have a separate comm port for each pump.

Connect each separate comm port directly to each syringe pump. Launch a separate instance of Symphony for each pump. (NOTE: pumps must not be chained together)

You need a comm port for each pump to run in this mode. Most PC's have only one or two available comm ports. Running multiple pumps in this mode may fill up your PC screen. To save space, close down all unused screens.

3.0 Configuring Symphony to communicate with your PC



When starting Symphony, all Symphony windows will open automatically. To simplify your start-up, close all Symphony windows except the interactive pump control screen window. From the interactive pump control window, select **view, configuration** pull down menu. This pop-up window allows you to select the comm port you wish to use and the baud rate. Select either comm 1,2,3, or 4 and 1,200, 2,400, 9,600, or 19,200 baud. Note: Select a comm port that is not in use by other PC devices (mouse, modem, etc.) The baud rate that you select here should match the baud rate set in the pump.

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Check for proper communications this way; Symphony will read the PHD 2000 and PHD 4400 firmware revision from the help, view pop-up screen. If the revision field is blank, that means your pump to PC communications link is not working. For help solving communications problems, refer to the communications trouble shooting section.

On the interactive pump control screen, there is an active status indicator to report communication status. It blinks in the color green if communications are normal and it blinks in the color red if you have a communication error. Symphony will not operate correctly if you have a communications error. The most common sources of communication errors are caused by incorrect cabling and communication parameters.

4.0 Running Symphony for the first time

Once you're communicating successfully with the pump (green blinking Comm Active indicator), familiarize yourself with Symphony by practicing with the interactive pump control screen to change pump values. You change pump parameters using common Windows controls such as; direct numeric entry, pull-down menus, on-off buttons and "spin" controls.

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5.0 The Symphony screens

5.1 Interactive pump control screen

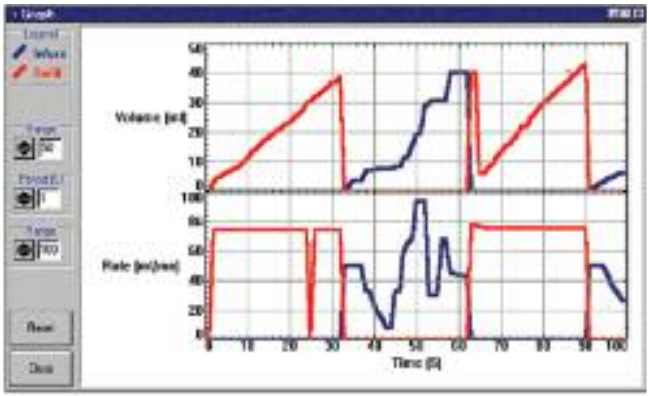


This window allows you to set on-the-fly, all pump parameters (syringe type and diameter, flow rates) and modes (pump, volume, program and auto-fill). Values can be directly entered into fields or scrolled using up and down spin controls. The volume delivered bar indicates percent volume delivered.

From this window, you gain access to all other Symphony windows via the pull down menus or the icon buttons. Custom configurations are saved and opened in the Symphony *.vpc file format.

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5.2 Pump Graph



The pump graph is like a continuously running strip chart recorder. This window allows you to monitor infuse and refill rates of your pump along with dispensed volume. Chart colors have meaning. Infuse is shown in blue and refill in red. The vertical axis scale (range) and horizontal axis, chart speed (period), are selectable. Graphs may be viewed only in the graph window and cannot be saved. The reset button clears the screen.

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5.3 Pump program screen



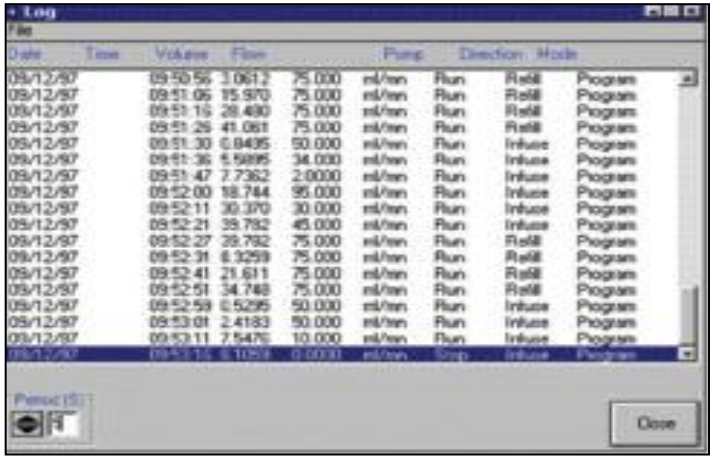
If you have any Harvard model 44, PHD4400, or a PHD 2000 programmable version pump, you may use the Program window to create, review, edit, save, recall and download programs. A pump program once created can be downloaded to any pump in the communications chain. Once there, the pump will run the program.

NOTE: Symphony is not a real-time controller. All pump control is performed by the pump micro-controller. In other words, a program must be first created or loaded in the pump memory in order to run.

Refer to your pump manual for a list and explanation of program instructions. Programs can be saved in *vpp file format. Five sample programs, example1.vpp, example2.vpp, etc., are included with Symphony.

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5.4 Log Sheet



The Symphony log sheet tracks the activities of your pump(s) in a log sheet that can later be reviewed by a Windows text editor or word processor program. The log update period is selectable by the user. Files are stored in *.vpl file format.

5.5 I/O display

Symphony I/O display shows the status of the input and output lines on the I/O port (DB-9). Refer to the pump manual for proper use of the I/O lines.



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6.0 Troubleshooting

6.1 Pump doesn't communicate with PC

Check the following items if you're unable to communicate with your pump.

- Check the pump to PC cabling,
- Check your comm port selection matches Symphony set-up
- Verify the pump baud rate is the same as Symphony baud rate
- Verify the pump address is correct
- Verify that your pump is set for Harvard pump 44 communications protocol.

6.2 Setup program won't run when installing Symphony

Make sure all other applications are turned off. Symphony setup will not run correctly if other applications are running while attempting installation.

6.3 Symphony screens don't all fit on my monitor screen.

Symphony screens are not scaleable. This means that you may move them and close them like other Windows screen but you cannot change their screen size. To gain screen space, try increasing the resolution of your screen from the Windows control panel.

6.4 The pump infuse and refill rates go to zero when I change syringe sizes.

Each time you change the syringe size, you must enter a new infuse rate.

NOTE: Sometimes, when moving around between Pump and Program modes, the infuse and refill rates get set to zero. When this occurs, you must enter new rate via the Interactive Pump Control Screen. A change to correct this is planned for the next release.

6.5 My pump program created in Symphony will not run correctly.

Although you can view and create programs for pumps with Symphony, you can only run pump programs if your pump has program capability and you have downloaded the program to the pump.

NOTE: Pump programs are not run within Symphony. A program must be loaded into pump memory in order to run. There are three different versions of PHD 2000 pumps; Infuse only, Infuse/ Withdraw and Programmable. The program control function will only work with the Programmable version PHD 2000 pump.

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Declaration of Conformity

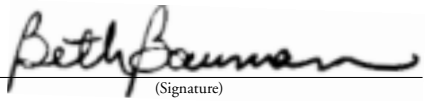
Application of Council Directive(s):	*73/23/EEC*
Standard(s) to which conformity is declared:	*EN61010-1 (1993)+ A2 (1995)*
Manufacturer's Name:	*Harvard Apparatus, Inc.*
Manufacturer's Address:	*84 October Hill Road* *Holliston, Massachusetts 01746* *U.S.A.*
Type of Equipment:	*Syringe Pump*
Model No.:	*70-2202 (High Force Pump Module)*

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directive(s) and Standard(s).

Place:	*United States of America*
Date:	*September 06, 2002*

CE

HARVARD APPARATUS



(Signature)

Beth Bauman

(Full Name)

VP Engineering / Operations

(Position)

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