Choosing the Right Pump for Your Application & Budget

Harvard Apparatus - Setting the Standards in Pumping Technology

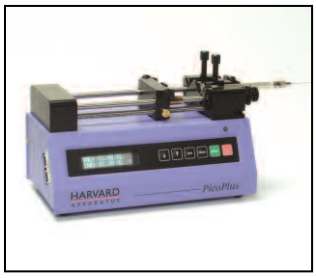
Harvard Apparatus offers a broad selection of syringe, peristaltic and continuous flow pumps to suit almost every application. Syringe pump models have been expanded to include new innovative pumps with the widest range of flow rates and forces of any manufacturer. The following guide and tables were designed to answer most questions regarding syringe and peristaltic pumps. Please review the following pages then contact our technical support department for further assistance, if needed.

Harvard Apparatus has a long history of inventing, innovating and manufacturing syringe pumps. Harvard Apparatus invented the lead screw based syringe pump in the 1950's and introduced the first microprocessor pump, the now legendary Pump 22, in the 1980's. Our syringe pumps are so accurate, even at low flow rates, that they have become the standard for mass spectrometry calibration and anywhere accurate volumes must be delivered. The innovations continue with recent additions to the PHD 22/2000 programmable pump line with enormous pressure and flow capability; the New 11 Plus, the standard for general laboratory experiments; the New Pump 11 Pico Plus for picoliter and small volume injections; an entire new selection of peristaltic pumps; an expanded line of component pumping modules for the OEM and do-it-yourself markets, and much, much more.

We are frequently asked to assist in the selection of the appropriate pump for a variety of research applications. The following list was developed as a guide to help you quickly and easily choose the right pump for your application. Consider the following questions when selecting your pump. If your specifications do not appear to be met by these pumps, please call our technical support department for further assistance.

1. Brief overview of advantages and disadvantages of each type of pump, see below and next page.
2. Syringe Pump Selection Guide, see pages A4 and A5.
3. Syringe Pump Application Guide, see pages A6 and A7.
4. Peristaltic Pump Selection Guide, see page A38.

1. Pump Types: Advantages and Disadvantages



SYRINGE PUMP

(PHD 22/2000 Programmable and Pump 11 Pico Plus Shown)

Syringe pumps provide the most accurate delivery of fluids. They use a syringe for the fluid reservoir. The syringe pump motor moves the pusher block forward which depresses the syringe plunger causing the dispensing of fluid. See pages A8 to A37.

PERISTALTIC PUMP

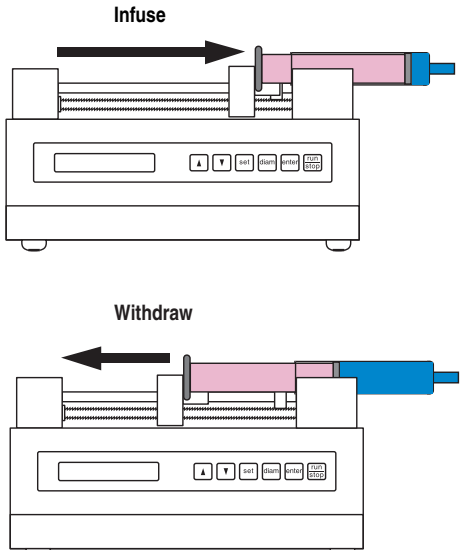
(MPII Mini-Peristaltic and 66/77 Peristaltic Pumps Shown)

Peristaltic pumps dispense fluid using a rotating head mechanism. The rotating head has a number of rollers that depress the tubing driving the fluid forward. These pumps have an external reservoir and therefore can accommodate a much larger volume of fluid. See pages A38 to A42.

Choosing the Right Pump for Your Application & Budget

1. Pump Types: Advantages and Disadvantages (continued)

SYRINGE PUMPS



A motor driven threaded rod (lead screw) slowly turns, moving the plunger of the syringe in, and pushing the fluid out. Reversing the direction of the motor allows for withdrawal of fluids.

ADVANTAGES

- Works at pressures up to 3000 psi
- Highest precision < 0.1%
- Pulse free flow
- Accurately dispense very small to large volumes < ±0.5%
- Easily sterilizable
- Can dispense or withdraw
- Many easily programmable dispensing profiles: gradients
- 1 to 10 channels of operation

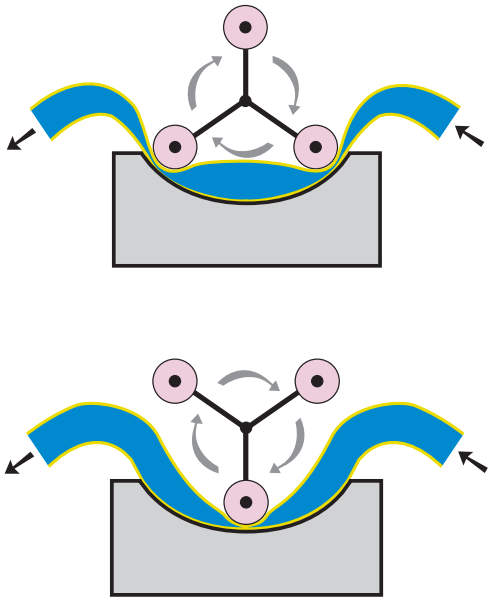
DISADVANTAGES

- Pumps finite volumes
- Slightly more expensive

TYPICAL APPLICATIONS

- Pumping sample/ calibrant into Mass Spectrometer
- Accurate dispensing of drugs in animals
- High pressure flow into reaction chamber

PERISTALTIC PUMPS



In this example three rollers on rotating arms pinch the tube against an arc and push the fluid along. There are usually three or four sets of rollers.

ADVANTAGES

- Pumps continuous volumes
- Sterilizable
- Less expensive for multiple channel dispensing
- 1 to 16 channels of operation
- Can dispense or withdraw

DISADVANTAGES

- Low pressure operation, 30 psi or less
- Pulsing flow
- Moderate precision 1 to 3%

TYPICAL APPLICATIONS

- Perfusion flow across tissue or cells
- Pump in and out with balanced flow
- Transfer bulk liquids ie. controlled animal feeding

Choosing the Right Pump for Your Application & Budget

2. Syringe Pump Selection Guide

Answer questions, then call Technical Support if you require additional assistance

Features & Specifications	INFUSION ONLY					INFUSE/WITHDRAW										PUSH/PULL
STANDARD PUMP MODEL	Pump 11 Plus 70-2208	Pump 11 Plus 70-2209	Pump 22 55-2222	Physio 22 70-2222•	PHD 22/2000 70-2000	Pump 11 Plus 70-2211	Pump 11 Plus 70-2212	Pico Plus 70-2213	Nanomite 70-2217	Pump 22 55-2226	Pump 33 55-3333	PHD 22/2000 70-2001	MRI PHD 22/2000 70-2130	PHD 22/2000 Hpsi –	PHD 4400 Hpsi –	PHD 22/2000 70-2020 or 71-2020
PROGRAMMABLE PUMP MODEL	–	–	–	–	–	–	–	–	–	–	–	Available	Available	Only Programmable	Only Programmable	Available
Number of Syringes	1	2	2 to 10*	2 to 10*	2 to 10*	1	2	2	1	2 to 10*	2	2 to 10*	2	4	1	4 (2 on each side of pusher block)
Minimum Syringe Size	0.5 µl	0.5 µl	0.5 µl	0.5 µl	0.5 µl	0.5 µl	0.5 µl	0.5 µl	0.5 µl	0.5 µl	0.5 µl	0.5 µl	0.5 µl	20 ml	2.5 ml	0.5 µl
Maximum Syringe Size	50/60 ml	10 ml	140 ml	140 ml	140 ml	50/60 ml	10 ml	10 ml	1 ml	140 ml	140 ml	140 ml	140 ml	200 ml	100 ml	30 ml+
Minimum Flow Rate	0.0014 µl/hr	0.0014 µl/hr	0.002 µl/hr	0.002 µl/hr	0.0001 µl/hr	0.0014 µl/hr	0.0014 µl/hr	3.3 pl/min	3.3 nl/hr	0.002 µl/hr	0.0004 µl/hr	0.0001 µl/hr	0.0001 µl/hr	1.5 µl/hr	0.0076 µl/min	0.0001 µl/hr
Maximum Flow Rate	26.56 ml/min	7.91 ml/min	55.1 ml/min	55.1 ml/min	220.82 ml/min	26.56 ml/min	7.91 ml/min	0.4394 ml/min	1901 µl/min	55.1 ml/min	106.6 ml/min	220.82 ml/min	220.82 ml/min	112 ml/min	182.40 ml/min	70.518 ml/min
Average Linear Force (lbs)	16	16	47	47	50 or 66**	16	16	25	12	47	57	50 or 66**	50	433	200	50 or 66**
RS-232 Computer Control	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TTL Connection	No	No	Yes	Yes	Yes	No	No	Footswitch	Footswitch	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dimensions (H x W x D)	13 x 22.9 x 11.4 cm (5 x 9 x 4.5 in)	13 x 22.9 x 11.4 cm (5 x 9 x 4.5 in)	28 x 22.2 x 14 cm (11 x 8.75 x 5.5 in)	28 x 22.2 x 14 cm (11 x 8.75 x 5.5 in)	15.9 x 22.8 x 27.9 cm (6.3 x 9 x 11 in)	13 x 22.9 x 11.4 cm (5 x 9 x 4.5 in)	13 x 22.9 x 11.4 cm (5 x 9 x 4.5 in)	11.4 x 22.9 x 11.4 cm (4.5 x 9 x 4.5 in)	8.9 x 22.9 x 11.4 cm (3.5 x 9 x 4.5 in)	28 x 22.2 x 14 cm (11 x 8.75 x 5.5 in)	15.2 x 31.1 x 28.6 cm (6 x 12.5 x 11.25 in)	15.9 x 22.8 x 27.9 cm (6.3 x 9 x 11 in)	9.5 x 27.9 x 22.9 cm (3.75 x 11 x 9 in)	9.5 x 27.9 x 22.9 cm (3.75 x 11 x 9 in)	17 x 23 x 29 cm (6.7 x 9 x 11.4 in)	15.9 x 22.8 x 27.9 cm (6.3 x 9 x 11 in)
Pump Head Dimensions (H x W x D)	–	–	–	–	–	–	–	–	1 x 18.5 x 5 cm (2.5 x 7.25 x 2 in)	–	–	–	22.9 x 43.2 x 30.5 cm (9 x 17 x 12 in)	22.9 x 43.2 x 30.5 cm (9 x 17 x 12 in)	–	–
Weight	2.1 kg (4.6 lbs)	2.1 kg (4.6 lbs)	4.5 kg (10 lbs)	4.5 kg (10 lbs)	4.5 kg (10 lbs)	2.1 kg (4.6 lbs)	2.1 kg (4.6 lbs)	2.3 kg (5 lbs)	2.06 kg (4.6 lbs)	4.5 kg (10 lbs)	6.8 kg (15 lbs)	4.5 kg (10 lbs)			6.4 kg (14 lbs)	4.5 kg (10 lbs)
Catalog Page	A8	A8	A12	A13	A16	A8	A8	A9	A10	A12	A14	A16	A15	A20	A21	A16

*** Depends upon the Syringe Rack**

Single or Dual Syringe Rack	Maximum syringe size varies depending upon pump model
4 x 140 Syringe Rack	Holds four 60 ml or 140 ml plastic syringes only
6 x 10 Syringe Rack	Holds six 30 to 60 ml syringes or ten 0.5 µl to 20 ml syringes
Microliter Syringe Rack	Holds four 0.5 µl to 10 ml syringes

****Available in standard force= 50 lbs or high force= 66 lbs**
•Low RFI (Radio Frequency Interference) Pump

+ Push/Pull pump can hold syringes up to 140 ml if full stroke is not required. Larger syringes will not fully infuse or withdraw.

Syringe Pump Questions

How many syringes will be used simultaneously?
What size syringe will be used?
What flow rate(s) will be used? See pump reference pages A69-A71
What is the total volume to be delivered?
Does the pump need to withdraw (fill the syringe) as well as infuse (dispense)?
What is the viscosity of the liquid you are pumping? See pump reference pages A68 and A75
What are the pressure requirements of your experiment? See pump reference pages A68 and A75
Does the pump need to continuously infuse over a 24 hour period of time?
Does the pump need to be programmable (store up to 4 programs with 10 sequences each)?
Does the pump need to be controlled with a computer?
Does the pump need to have TTL capabilities (ex. external control of valves, use of footswitch, etc)?

Choosing the Right Pump for Your Application & Budget

3. Syringe Pump Application Guide

Find your application and go to the pages indicated for more information

Syringe Pump Application Guide

															OEM SYRINGE PUMP MODULES (RS232)			
	Pump 11 Plus	Pump 11 Pico Plus	Nanomite	Pump 22	Physio 22	Pump 33	PHD 22/2000	PHD 22/2000 Push/Pull	MRI PHD 22/2000	PHD 22/2000 Hpsi	PHD 4400 Hpsi	Multiple Animal Feeding Station	Biomedical Dispensing System	Micro-liter	Milliliter	Programmable	High Pressure
See Page	A8	A9	A10	A12	A13	A14	A16	A16	A15	A20	A21	A27	A11	A32	A33	A34	A36
Accurate Delivery of Coatings		X					X	X								X	X
Animal Feeding	X			X			X					X					
Biomedical Dispensers	X												X				
Bulk Fluid Transfer						X		X								X	
Cell Cultures						X		X									
Cellular Injection		X	X		X		X							X	X		
Continuous Infusions						X		X						X	X	X	
Doping	X			X			X										
Drug Delivery (same infusion rates)	X			X			X										
Drug Delivery (different infusion rates)	X (RS232)*			X (RS232)*		X				X (RS232)*							
Drug Delivery (time released)							X				X						
Drug Development				X			X										
Electrospinning	X						X										X
Fluid Blending	X (RS232)*			X (RS232)*		X	X (RS232)*				X			X	X		
Fluid Blending (2 independent channels)						X								X	X		
Fluid Sampling	X	X	X	X		X	X							X	X	X	
Gradients	X (RS232)*			X (RS232)*		X	X (RS232)*							X	X	X	
High Pressure Injection		X								X	X						X
Highly Corrosive Fluids										X	X		X			X	X
HPLC	X	X				X		X									
Injecting Into High Pressure Reaction Vessels		X								X	X						X
Injection Pressure Calculations	X			X			X										
Instrument Injections	X			X			X							X	X	X	X
Low Pressure Chromatography	X																
Mass Spectometry	X	X		X			X										
Medical Coating Delivery													X			X	X
Microdialysis	X	X		X			X										
MRI Studies									X								
Multiple Simultaneous Feeding Stations	X (RS232)*			X (RS232)*			X (RS232)*					X			X		
Nano Fluidics		X					X							X			
Nutritional Studies	X			X								X					
OEM Modules														X	X	X	X
Oocyte Applications		X			X												
Patch Clamping					X												
Remote Pumping of Hazardous Material			X				X			X	X			X	X	X	X
Stereotaxic Devices			X														
Titrations	X (RS232)*			X (RS232)*		X								X	X		
Viscous Solutions		X								X	X						X

**Note: Can be done using RS232 Computer Control*

pump selection guide

Choosing the Right Pump for Your Application & Budget

3. Syringe Pump Application Guide (continued)

Choosing the Right Pump for Your Application & Budget

4. Peristaltic Pump Selection Guide

- Broad selection of pumps for every application
- Wide range of flow rates ml/hr to L/min
- Multiple multi-channel models with up to 32 channels
- Peristaltic and non-peristaltic pumps
- Continuous delivery and batch mode dispensing

Harvard Apparatus now offers an extensive selection of peristaltic and other continuous flow pumps to suit the needs of a wide range of research applications. Pumps which offer features such as multi-channel pumping, computer control, analog control, low electrical noise and a wide range of fluid flow rates are now available. Pump styles include traditional roller type peristaltic pumps, our exclusive double linear sinusoidal peristaltic pump, shuttle pumps which utilize check valves, and diaphragm pumps.

The following table was designed to answer most questions regarding our continuous flow pumps. Please contact our technical support department for further assistance.

Peristaltic and Continuous Flow Pumps

Traditional peristaltic pumps utilize a series of rollers (1 to 8) to push fluid through tubing held within a pump head. Peristaltic flow is typically pulsatile, but can be made smoother with the use of more rollers in the pumping head. Our Mini-Peristaltic Pump (MPII, see page A39) features two speed ranges, reversability and dual channel pumping at a very reasonable price. Many pumps offer external control either through the input of an analog signal proportional to the speed or by RS-232 (serial) communication.

Pump Selection Guide

Pump	MPII 70-2027	Pump 66 55-7766	Pump 77 55-7777	Model 720 72-0002	Model 720 61-0098 61-0239	Model 720 72-0001 72-0008	Shuttle Pump 61-0128 72-0011
Number of Channels	1 to 2	1	1	1 to 2	1 to 2	1 to 2	2
Number of Rollers	4	3	3	3	3	3	1
Tube Size (Inner Diameter)	1.6 mm (1/16 in)	1.6 mm and 3.2 mm (1/16 in and 1/8 in)	3.2 mm and 6.4 mm (1/8 in and 1/4 in)	0.38 mm to 2.4 mm (0.015 in to 0.093 in)	0.38 mm to 2.4 mm (0.015 in to 0.093 in)	0.38 mm to 2.4 mm (0.015 in to 0.093 in)	-
Flow Rate (ml/min/Per Channel):							
Minimum	0.8	0.01	0.01	0.02	0.2	2	1.25
Maximum	12.25	210	750	12	145	1100	25
RS-232 Computer Control	No	Yes	Yes	No	No	No	No
TTL Control	No	Yes	Yes	No	No	No	No
Analog Control	No	No	No	Yes	Yes	Yes	No
Power	115/230 VAC 50/60 Hz	115/230 VAC 50/60 Hz	115/230 VAC 50/60 Hz	120 VAC, 50 Hz 230 VAC, 60 Hz	120 VAC, 50 Hz 230 VAC, 60 Hz	120 VAC, 50 Hz 230 VAC, 60 Hz	120 VAC, 50 H 230 VAC, 60 Hz
Battery Backup	No	No	No	9V Lithium Battery up to 30 hours	9V Lithium Battery up to 30 hours	No	9V Lithium Battery up to 50 hours
Dimensions (H x W x D)	189 x 114 x 105 cm (3.5 x 4.5 x 4 in)	22.9 x 20.6 x 8.9 cm (9 x 8.125 x 3.5 in)	24.1 x 20.6 x 12.7 cm (9.5 x 8.125 x 5 in)	6.4 x 5.7 x 10.2 cm (2.5 x 2.25 x 4 in)	6.4 x 5.7 x 10.2 cm (2.5 x 2.25 x 4 in)	6.4 x 5.7 x 10.2 cm (2.5 x 2.25 x 4 in)	3.3 x 11.4 x 7.2 cm (1.3 x 4.5 x 2.8 in)
Weight	0.96 kg (2.1 lbs)	3.53 kg (7.85 lbs)	5.1 kg (11.25 lbs)	375 g	375 g	375 g	-
Catalog Page	A39	A40	A40	A41	A41	A41	A42

Peristaltic Pump Questions

How many channels (tubes) will be used simultaneously?

What size tubing will be used (inner diameter)?

What flow rate(s) will be used?

What is the total volume to be delivered?

Do you need continuous flow?

Does the pump need to be battery operated?

Do you need to control the pump with a computer?

Do you need analog control?

Does the pump need to have TTL capabilities (external control of valves, use of footswitch etc)?

How to Calculate The Pressure Requirement of Your Experiment

The following chart will help you determine the pressure requirement of your experiment. This is important in selecting the correct pump with the proper psi capability for your application. Choose the selections that are the closest to your experimental conditions or write in your actual values. Once you have filled in the chart call us for technical assistance if needed.

1. **Nature of the sample you are flowing into (Application)**
2. **The flow rate of the material**
3. **The surface area of the syringe and the linear force capability of the pump**
4. **The tubing diameter**
5. **The tubing length**
6. **Viscosity of the material being pumped**
7. **The temperature of the material being pumped**

	NORMAL PRESSURE 0 to 30 psi (0 to 2 bar)	HIGH FORCE 31 to 150 psi (2.1 to 10.2 bar)	XTREME HIGH PRESSURE 151 to 2000 psi (10.3 to 137 bar)
1. APPLICATION			
LOW Flow into open containers i.e. titrations, food trays filling			
LOW Inject into Tissue i.e. Drug infusion into muscle, brain			
HIGH Flow into closed container, i.e. Reaction Chamber 350 to 400 psi			
HIGH High viscosity solutions at high flow rates in a short period of time, i.e. Corn syrup			
2 FLOW RATE - Pumping Speed (The faster the flow rate, the higher the pressure)			
0.003 µl/hr to 140 ml/min			
141 ml/min to 220 ml/min			
3. SYRINGE SIZE (Syringe volume/plunger area + linear force of pump)			
10 µl to 1 ml ie. 500 µl/min x 20 Lbs = 500			
4. TUBING SIZE (Inner diameter, Smaller ID = higher pressure)			
Small - capillary (the longer more pressure)			
Large - Hose			
5. TUBING LENGTH - DISTANCE (Depends on ID Smaller ID = higher pressure)			
Short, < 1M			
Long, > 1M			
6. VISCOSITY OF MATERIAL TO BE PUMPED (Higher viscosity = higher pressure)			
Air 18˚C = 0.0182 cP			
Water 20˚C = 1.002 cP			
Olive Oil 20˚C = 84 cP			
Pancake Syrup 20˚C = 2500 cP			
Honey 20˚C = 10000 cP			
Peanut Butter 20˚C = 250000 cP			
7. TEMPERATURE OF SOLUTIONS BEING PUMPED (Higher temperature = lower viscosity = lower pressure)			
0 to 15˚C			
15 to 80˚C			

Syringe Pump Pressure and Flow Rate

How to Calculate the Pressure of Various Syringe Sizes

The pressure that a syringe pump can generate is a function of both the force of the pump (measured at the pusher block in pounds) as well as the physical characteristics of the syringe and setup used. The following table compares various syringe pumps and the pressures in PSI (pounds per square inch). Each data point was calculated by dividing the average pump force by the surface area (in square inches) of syringes with diameters from 0.1 to 50 mm. Diameters and surface areas for a variety of syringes can be found in the table on page A72. This table is intended to be a guide of total pressures generated. Actual values may be higher or lower than the listed pressures due to the influence of other factors such as tubing diameter and length. When using more than one syringe sharing the same pusher block, the pressure is calculated by dividing the force (lbs) by the total surface area (square inches) of all syringes on the pump. For example, nominal pressure obtained using two 25 ml Hamilton Gastight® syringes on a PHD 22/2000 standard pressure syringe pump would be: 50 lbs / (0.644 in2 X 2) = 38.81 PSI (2.68 bars).

Pump Average PressureA (PSI)B

Syringe Size	Syringe Dia (mm)	Pump 11 Plus	Pump 11 Pico Plus	Pump 22	Pump 33	PHD 22/2000	PHD 22/2000 Hpsi	PHD 4400 Hpsi
0.5 µl	0.1	>1000	>1000	>1000	>1000	>1000	–	>1000
10 µl	0.5	>1000	>1000	>1000	>1000	>1000	–	>1000
50 µl	1	>1000	>1000	>1000	>1000	>1000	–	>1000
1 ml	5	526	821	>1000	>1000	>1000	–	>1000
5 ml	10	131	205	386	468	394	–	1438
10 ml	15	58	91	172	208	175	–	639
50 ml	25	21	33	62	75	63	569	230
Force (lbs)		16	25C	47	57	48	433	200
see page		A8	A9	A12	A14	A16	A20	A21

A. Calculated pressure based on pump force at average speed

- *Higher pressures may be achieved at minimum speed and lower pressures at maximum speed.*
- *Pump speed and force are inversely proportional.*
- *Most syringes are pressure rated and may not be able to tolerate pressure generated by the syringe pump. Consult Harvard Apparatus or your syringe manufacturer for syringe details and specifications.*

B. To convert pressure from PSI to bars use the following equation: bar pressure = PSI x 0.0690.

C. Actual force is higher. Use of pump with greater back pressure may result in premature wear of syringe pump halfnut.

Minimum/Maximum Flow Rates By Pump and Syringe Size

Flow rates were calculated based on the pusher block travel rate for each pump (rate at which the syringe pump moves the syringe plunger) and the diameter of the syringe.

Pump 11 Pico Plus Flow Rates

Syringe Size	Nominal Diameter, mm*	Minimum	Maximum
0.5 µl	0.10	1.3 pl/min	20.00 nl/min
1 µl	0.15	3.0 pl/min	46.00 nl/min
10 µl	0.46	27.0 pl/min	400.00 nl/min
100 µl	1.46	270.0 pl/min	0.004 ml/min
1000 µl	4.61	2,690.0 pl/min	0.043 ml/min
10 ml	14.57	27.0 nl/min	0.439 ml/min

** Note: These figures have been rounded and therefore may not exactly match the Syringe Diameter Chart on page A72.*

PHD 22/2000 Hpsi Flow Rates* (High Volume and Pressure)

Syringe Size	Diameter, mm	Minimum, µl/hr	Maximum, ml/min
20 ml	19.13	1.5	20
50 ml	28.60	3.4	46
100 ml	34.90	5.0	68
200 ml	44.75	8.2	112

**The Rates listed are for single stainless steel syringe*

Syringe Pump Pressure and Flow Rate

Minimum/Maximum Flow Rates By Pump and Syringe Size (continued)

Pump 11 Plus Flow Rates

Syringe Size	Diameter, mm*	µl/hr Min to Max	µl/min Min to Max	ml/hr Min to Max	ml/min Min to Max
0.5 µl	0.10	0.0014 to 22.35	0.0001 to 0.3725	0.0001 to 0.0223	0.0001 to 0.0003
1 µl	0.15	0.0031 to 50.29	0.0001 to 0.8383	0.0001 to 0.0502	0.0001 to 0.0008
2 µl	0.21	0.0061 to 98.58	0.0002 to 1.6430	0.0001 to 0.0985	0.0001 to .0016
5 µl	0.33	0.0149 to 243.4	0.0003 to 4.057	0.0001 to 0.2434	0.0001 to 0.0040
10 µl	0.46	0.0289 to 473.0	0.0005 to 7.883	0.0001 to 0.4730	0.0001 to 0.0078
25 µl	0.73	0.0728 to 1191	0.0013 to 19.85	0.0001 to 1.191	0.0001 to 0.0198
50 µl	1.03	0.1448 to 2371	0.0025 to 39.52	0.0002 to 2.371	0.0001 to 0.0395
100 µl	1.46	0.2909 to 4765	0.0049 to 79.41	0.0003 to 4.765	0.0001 to 0.0794
250 µl	2.30	0.7218 to 9999	0.0121 to 197.0	0.0008 to 11.82	0.0001 to 0.1970
1000 µl	4.61	1.451 to 9999	0.0242 to 395.7	0.0015 to 23.75	0.0001 to 0.3959
1 ml	5.00	2.900 to 9999	0.0484 to 791.8	0.0029 to 47.50	0.0001 to 0.7918
2.5 ml	7.28 to 9.6	7.232 to 9999	0.1206 to 1974	0.0073 to 118.4	0.0002 to 1.974
3 ml	8.66 to 9.0	10.24 to 9999	0.1706 to 2794	0.0103 to 167.6	0.0002 to 2.794
5 ml	10.3 to 13.0	14.50 to 9999	0.2413 to 3952	0.0145 to 237.1	0.0003 to 3.952
10 ml	14.57 to 15.9	28.97 to 9999	0.4828 to 7909	0.0290 to 474.5	0.0005 to 7.909
20 ml	19.13 to 20.05	54.86 to 9999	0.9142 to 9999	0.0549 to 898.6	0.0010 to 14.97
30 ml	21.7 to 23.2	72.81 to 9999	1.214 to 9999	0.0729 to 1192	0.00013 to 19.88
50 ml	26.7 to 32.6	97.27 to 9999	1.622 to 9999	0.0973 to 1576	0.0017 to 26.56

** Note: These figures have been rounded and therefore may not exactly match the Syringe Diameter Chart on page A72.*

Pump 22 Flow Rates

Syringe Size	Diameter, mm*	µl/hr Min to Max	µl/min Min to Max	ml/hr Min to Max	ml/min Min to Max
0.5 µl	0.10	0.002 to 23.8	–	–	–
1 µl	0.15	0.003 to 47.8	–	–	–
2 µl	0.21	0.006 to 95.2	–	–	–
5 µl	0.33	0.015 to 238.0	–	–	–
10 µl	0.46	0.029 to 474.0	–	–	–
25 µl	0.73	0.073 to 1193.0	–	–	–
50 µl	1.03	–	0.002 to 39.7	–	–
100 µl	1.46	–	0.005 to 79.7	–	–
250 µl	2.30	–	0.012 to 197.8	–	–
500 µl	3.26	–	0.024 to 397.0	–	–
1000 µl	4.61	–	0.048 to 795.0	–	–
1 ml	5.00	–	0.049 to 805.0	–	–
2 ml	9.00	–	–	0.011 to 186.6	–
2.5 ml	7.28 to 9.6	–	–	0.10 to 168.2	–
3 ml	8.66 to 9.0	–	–	0.011 to 181.4	–
5 ml	10.3 to 13.0	–	–	0.019 to 317.0	–
10 ml	14.57 to 15.9	–	–	0.028 to 461.0	–
20 ml	19.13 to 20.05	–	–	0.050 to 821.0	–
30 ml	21.7 to 23.2	–	–	0.074 to 1208.8	–
50 ml	26.7 to 32.6	–	–	–	0.002 to 28.4
100 ml	34.9 to 35.7	–	–	–	0.003 to 47.6
140 ml	38.40	–	–	–	0.004 to 55.1

** Note: These figures have been rounded and therefore may not exactly match the Syringe Diameter Chart on page A72.*

Syringe Pump Pressure and Flow Rate

Minimum/Maximum Flow Rates By Pump and Syringe Size (continued)

Pump 33 Flow Rates

Syringe Size	Diameter, mm*	µl/hr Min	µl/min Max	ml/hr Max	ml/min Max
0.5 µl	0.103	0.0004	0.79	–	–
1 µl	0.1457	0.0008	1.58	–	–
2 µl	0.206	0.0015	3.1	–	–
5 µl	0.3257	0.0037	7.93	–	–
10 µl	0.46	0.0073	950.05	–	–
25 µl	0.73	0.0183	2386.10	–	–
50 µl	1.03	0.0365	4772.50	–	–
100 µl	1.46	0.0731	9570.50	–	–
250 µl	2.30	0.1813	–	23.751	–
500 µl	3.26	–	–	–	–
1000 µl	4.61	0.7281	–	95.418	–
1 ml	5.00	0.7828	–	102.580	–
2 ml	9.00	2.8493	–	373.430	–
2.5 ml	7.28 to 9.6	1.8156	–	237.950	–
3 ml	8.66 to 9.0	2.5691	–	336.710	–
5 ml	10.3 to 13.0	4.9824	–	653.010	–
10 ml	14.57 to 15.9	7.2024	–	–	15.733
20 ml	19.13 to 20.05	12.536	–	–	27.384
30 ml	21.7 to 23.2	16.131	–	–	35.236
50 ml	26.7 to 32.6	24.4201	–	–	53.346
100 ml	34.9 to 35.7	–	0.087	–	91.20
140 ml	38.40	–	0.1053	–	110.41

** Note: These figures have been rounded and therefore may not exactly match the Syringe Diameter Chart on page A72.*

PHD 22/2000 and PHD 4400 Hpsi Flow Rates

Syringe Size	Diameter, mm*	µl/hr Min	µl/min Max	ml/hr Max	ml/min Max
0.5 µl	0.10	0.0001 to 95.330	–	–	–
1 µl	0.15	0.0002 to 190.70	–	–	–
2 µl	0.21	0.0004 to 381.30	–	–	–
5 µl	0.33	0.0010 to 953.17	–	–	–
10 µl	0.46	0.0019	–	1.901	–
25 µl	0.73	0.0046	–	4.775	–
50 µl	1.03	0.0092	–	9.551	–
100 µl	1.46	0.0183	–	19.153	–
250 µl	2.30	0.0454	–	47.532	–
500 µl	3.26	0.0911	–	95.492	–
1000 µl	4.61	–	0.0031	190.950	–
1 ml	5.00	–	0.0033	205.30	–
2 ml	9.00	–	0.0119	747.35	–
2.5 ml	7.28 to 9.6	–	0.0076	476.21	–
3 ml	8.66 to 9.0	–	0.0100	–	11.231
5 ml	10.3 to 13.0	–	0.0208	–	21.781
10 ml	14.57 to 15.9	–	0.0301	–	31.486
20 ml	19.13 to 20.05	–	0.0523	–	54.804
30 ml	21.7 to 23.2	–	0.0673	–	70.518
50 ml	26.7 to 32.6	–	0.1019	–	106.76
100 ml	34.9 to 35.7	–	0.1740	–	182.40
140 ml	38.40	–	0.2106	–	220.82

** Note: These figures have been rounded and therefore may not exactly match the Syringe Diameter Chart on page A72.*

Common Syringe Data

Diameter and Plunger Surface Area

The following list is a guide to common syringes and their associated diameters and surface area. Syringe diameter data, in mm, is listed below for each syringe. All Harvard Apparatus microprocessor syringe pumps require the user to input syringe diameter information. The pump uses this diameter data to set flow rates. The PHD 22/2000 series of syringe pumps also has this information built into the pump memory in a handy Syringe Look Up Table. Surface area information was used to calculate PSI (pounds per square inch) data for the pressure table on page A75. Average pressures for any syringe pump and syringe combination can be calculated by dividing the average (nominal) syringe pump force by the syringe diameter (in square inches) to obtain PSI. Example, nominal pressure obtained using a 25 ml Hamilton Gastight® Syringe on a PHD 22/2000 standard pressure syringe pump would be: 50 lbs / 0.644 in2 = 77.6 PSI (5.35 bars).

Common Syringes and Their Diameters

Volume	Dia. (mm)	Surface Area (in^2)
BD Plastic		
1 ml	4.78	0.027815
3 ml	8.66	0.091297
5 ml	12.06	0.177059
10 ml	14.5	0.255952
20 ml	19.13	0.445505
30 ml	21.7	0.573247
50/60 ml	26.7	0.867851
BD Glass		
0.5 ml	4.64	0.026209
1 ml	4.64	0.026209
2.5 ml	8.66	0.091297
5 ml	11.86	0.171235
10 ml	14.34	0.250335
20 ml	19.13	0.445505
30 ml	22.7	0.627298
50 ml	28.6	0.995760
100 ml	34.9	1.482768
SGE Glass		
25 µl	0.73	0.000649
50 µl	1.03	0.001292
100 µl	1.46	0.002595
250 µl	2.3	0.006440
500 µl	3.26	0.012938
1 ml	4.61	0.025872
2.5 ml	7.28	0.064519
5 ml	10.3	0.129151
10 ml	14.57	0.258429
Harvard Apparatus Stainless Steel		
2.5 ml	4.791	0.027937
8 ml	9.525	0.110447
20 ml	19.13	0.445505
50 ml	28.6	0.995760
100 ml	34.9	1.482768
200 ml	44.75	2.438382

Volume	Dia. (mm)	Surface Area (in^2)
Ranfac Glass		
2 ml	9.12	0.101254
5 ml	12.34	0.185376
10 ml	14.55	0.257720
20 ml	19.86	0.480154
30 ml	23.2	0.655237
50 ml	27.6	0.927343
Terumo Plastic		
3 ml	8.95	0.097514
5 ml	13	0.205735
10 ml	15.8	0.303904
20 ml	20.15	0.494279
30 ml	23.1	0.649601
60 ml	29.1	1.030881
Air-Tite All Plastic		
2.5 ml	9.6	0.112193
5 ml	12.45	0.188695
10 ml	15.9	0.307763
20 ml	20.05	0.489386
30 ml	22.5	0.616293
50 ml	29	1.023808
Popper & Sons Perfectum Glass		
0.5 ml	3.45	0.014490
1 ml	4.5	0.024652
2 ml	8.92	0.096862
3 ml	8.99	0.098388
5 ml	11.7	0.166646
10 ml	14.7	0.263061
20 ml	19.58	0.466711
30 ml	22.7	0.627298
50 ml	29	1.023808
100 ml	35.7	1.551525

Volume	Dia. (mm)	Surface Area (in^2)
Hamilton Gastight Glass		
0.5 µl	0.103	0.000013
1 µl	0.1457	0.000026
2 µl	0.206	0.000052
5 µl	0.3257	0.000129
10 µl	0.46	0.000258
25 µl	0.729	0.000647
50 µl	1.031	0.001294
100 µl	1.46	0.002595
250 µl	2.3	0.006440
500 µl	3.26	0.012938
1000 µl	4.61	0.025872
2.5 ml	7.28	0.064519
5 ml	10.3	0.129151
10 ml	14.57	0.258429
25 ml	23	0.643989
50 ml	32.6	1.293772
Unimetrics - 4000 and 5000 Glass		
10 µl	0.46	0.000258
25 µl	0.729	0.000647
50 µl	1.031	0.001294
100 µl	1.46	0.002595
250 µl	2.3	0.006440
500 µl	3.26	0.012938
1000 µl	4.61	0.025872
Kendall Monoject Plastic		
1 ml	4.65	0.026323
3 ml	8.94	0.097297
6 ml	12.7	0.196350
12 ml	15.9	0.307763
20 ml	20.4	0.506621
35 ml	23.8	0.689567
60 ml	26.6	0.861362
140 ml	38.4	1.795084

How to Select the Correct Syringe for Your Application

Syringe Type/Size	Swage Lock	Luer Lock	RN	Threaded 1/4• 28	Luer Slip Fit	Pressure Maximum p.s.i.	Compatibility with Substance in Syringe	Accuracy 1%	Accuracy 5%	Materials
Stainless Steel Syringes, see pages A46 to A47										
2.5 ml	•					7,500	Maximum	•		316 / St. Steel
8 ml	•					1,500	Maximum	•		316 / Perfluoroelastomer
20 ml	•	•				750	Maximum	•		316 / Viton or Perfluoroelastomer
50 ml	•	•				750	Maximum	•		316 / Viton or Perfluoroelastomer
100 ml	•	•				750	Maximum	•		316 / Viton or Perfluoroelastomer
200 ml	•	•				750	Maximum	•		316 / Viton or Perfluoroelastomer
Glass GasTight Syringes, see pages A48 to A51										
1 to 100 µl		•	•	•	•	1,000	Maximum	•		Glass and Teflon
250 to 500 µl		•	•	•	•	500	Maximum	•		Glass and Teflon
1 to 10 ml		•	•	•		200	Maximum	•		Glass and Teflon
25 to 100 ml		•	•	•		100	Maximum	•		Glass and Teflon
Glass Multifit Syringes, see page A52										
2 to 50 ml		•				100	Maximum	•		Glass Only
Plastic Syringes, see pages A53 to A54										
1 ml		•			•	125	Minimum		•	Polypropylene and Natural Rubber
5 ml		•			•	125	Minimum		•	Polypropylene and Natural Rubber
10 ml		•			•	125	Minimum		•	Polypropylene and Natural Rubber
20 ml		•			•	125	Minimum		•	Polypropylene and Natural Rubber
30 ml		•			•	125	Minimum		•	Polypropylene and Natural Rubber
50/60 ml		•			•	125	Minimum		•	Polypropylene and Natural Rubber
140 ml		•			•	125	Minimum		•	Polypropylene and Natural Rubber

Pressure Unit Conversion Chart

Pressure Cross Reference Chart

Pressure Unit Cross Reference Chart

	atm	psi (lb/in^2)	cm H_2O (mmWS)	mm Hg (Torr)	kPa (kN/m^2)	inch H_2O	inch Hg	mbar
1 atm =	1	14.696	1030.104	760.000	101.325	2616.464	29.944	986.663
1 psi =	0.068	1	70.094	51.715	6.895	178.039	2.038	68.966
1 cm H_2O =	0.0010	0.0143	1	0.7377	0.0984	2.5400	0.0291	0.9578
1 mm Hg =	0.0013	0.0193	1.355	1	0.133	3.443	0.039	1.298
1 kPa =	0.145	2.131	10.200	7.525	1	4.021	0.296	143.066
1 inch H_2O =	0.433	6.363	445.984	329.042	43.869	1	12.964	427.176
1 inch Hg =	22.390	329.042	23063.927	17016.325	2268.657	58582.373	1	22091.293
1 mbar =	2.985	43.869	3074.937	2268.657	302.463	7810.341	89.385	1

Force Conversion Table

Conversion Table for Force Units

mN	mg-force	mp
0.1	10	10.20
0.2	20	20.39
0.3	30	30.59
0.4	40	40.79
0.5	50	50.99
0.6	60	61.18
0.7	70	71.38
0.8	80	81.58
0.9	90	91.77
1	100	101.97
2	200	203.94
3	300	305.92
4	400	407.89
5	500	509.86
6	600	611.83
7	700	713.8
8	800	815.78
9	900	917.75

1N = 1 Newton = 1 kg m/s^2
1p = 1 Pond