Neurophore BH-2

Micro-Iontophoresis

System User's Manual

BH-2 Mainframe Chassis	*65-0200*
IP-2 Iontophoresis Pump Module	*65-0203*
PPM-2 Pneumatic Pump Module	*65-0204*

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Warranty and Repair Information

Manual Description

This manual is designed to provide all operational and program information required to operate and maintain the PHD 4400 series pumps. The functions and features are described in the Technical Specifications section.

Warranty

Harvard Apparatus warranties this instrument for a period of one year 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 materials. 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 consumer purchaser.

IN NO EVENT SHALL HARVARD APPARATUS BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES. Some states do not allow the 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 one–year warranty period, promptly contact ***Harvard Apparatus, 84 October Hill Road, Holliston, Massachusetts 01746*** using our toll free number 1–800–272–2775. Email Address is bioscience@harvardapparatus.com. 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 or replacement. 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 a part number obtained from our Customer Service department. If practical, enclose a sample part or sketch. We offer a complete reconditioning service.

Serial Numbers

All inquiries concerning our product should refer to the serial number of the unit, located on the rear panel.

CAUTION

This apparatus is not registered with the FDA and is not for clinical use on human patients.

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Introduction

Micro-Iontophoresis of ionized drugs from multi-barreled electrodes has evolved into a practical method of testing electrophysiological action of putative neurohormones. The NeuroPhore BH-2 System has been designed to facilitate the most stringent requirements and provides precise stimulation and quantitative control for ejection of drugs, in pharmaceutical studies of drug evoked neurosynaptic discharges. The BH-2 System has been developed with the guidance of active researchers with extensive experience in Ionto-Phoresis techniques. Emphasis has been given in the design of this system to reliability, performance, compliance to accommodate high impedance multi-barreled micro-pipettes and to simplicity of operation. The NeuroPhore BH-2 is modular and the system is comprised of the following assemblies:

* BH-2 Mainframe & BM-2 Balance Module
* IP-2 Pump Module
* PPM-2 Pneumatic Pump Module
* MS-2 Power Supply
* MS-7PB/MS-7MT Seven Barrel Pipettes

Features

* Modular Design
* Will accommodate 7 barrel pipette
* All Solid State
* +105V compliance (no batteries)
* Automatic Current Neutralization
* Digitally controlled eject and pause timing
* Injection and retention currents and electrode resistance readout with digital display
* Unbalance and out of compliance auto-indicators
* External analog input control over injection current

Cautions

- Do not remove any modules while the power in ON.
- When a module is removed ascertain that same is placed in a non-electrostatic or grounded environment since electrostatic charges may damage some of the integrated circuits.
- Allow minimum equipment warm up time of 15 minutes prior to use.
- When measuring electrode resistance it is recommended that the electrode resistance values be measured "one module" at a time. In other words select the positive or negative position on the Current Resistance Selector Switch (2a - page 9) and after the resistance measurement has been completed, return the switch to the center nA position.
- It is recommended that the resistance measurement be made with the auto balance switch (3b - page 18) on the BM-2 balance module, set in the UNBAL current position. It is noteworthy that when the instrument is set up for automatic current balance (switch set in UNBAL CURR position on Auto Bal/Current Selector (3b - page 6) the current used for electrode resistance Measurement 50 nA is automatically balanced and as such prevents any ground going currents at the cell junction. It is therefore required that the current be measured one at a time to prevent any feedback between resistance current channels.
- In order to operate this system it is required that the OUTPUT (13b - page 6) be terminated into an external load. This applies specifically to the balance channel since no internal (dummy load) is provided. In other words, the Micropipette balance barrel when connected provides such a termination.

Specifications

Specifications

MSC-2 POWER SUPPLY

Outputs	+/-125 V @ 0.1 Amps, +/-15 V @ 0.5 Amps, +/- 5 V @ 3 Amps, line operated 115-220 V.A.C. 50-60 Hz

IP-2 MODULE

Current Pump	Compliance +/- 105 V, linear constant current source
Ejection Current	Pulsing controlled by ejection timing module switch; amplitude adjustable by 10-turn ejection control and range switch from 0-50 or 0-500 nA; polarity selected by polarity switch; accuracy=+/- 1 nA
Ejection Indicator	Red LED lamp indicates eject time period; green LED lamp indicates pause time period
Retention Current	Amplitude adjustable by front panel dial from 0-50 nA; polarity is automatically set opposite to ejection current polarity
Analog Input	Lemo miniature receptacle ground referenced 5mV/nA; input impedance 100 k
Analog Output	Lemo miniature receptacle ground referenced 5mV/nA
Sync Output	Lemo miniature receptacle, TTL pulse time incident with eject pulse

CURRENT AND RESISTANCE

Metering System	Digital meter display 3 digits and sign

RESISTANCE/CURRENT SWITCH

Current Mode	Switch in center "nA" position; digital display reads total current in nA passed through the microelectrode pipette (sum of retention and ejection current)
Resistance Mode	Switch in either (pos.) or (neg.) megaohms position; digital display reads actual electrode barrel resistance in megaohms derived by passing positive or negative constant current (50nA) through electrode pipette
No Compliance Indicator	Digital display flashes whenever electrode barrel resistance exceeds working range of current pump (i.e., when electrode resistance times current exceeds compliance of +/-105V)
Voltage Readout Switch	Depressing switch causes digital display to read voltage across pipette

BM-2 BALANCE MODULE

Neutralization (Bal.) Pump Range	Max. +/- 2500 nA automatically controlled
Current Pump	Compliance +/- 105 V linear constant current source, manually adjust. 0-500 nA by pump control; polarity selected + /OFF/ - switch
Dig. Meter Display	3 digits and sign

Specifications (Continued)

UNBALANCE CURRENT/CURRENT PUMP SWITCH

Unbalance Current Mode	Digital display reads unbalance (ground going) current in nA; in this mode, automatic current neutralization provided
Current Pump Mode	Auto. balance feature is switched off; display reads amount of current in nanoamperes passed through balance barrel as adjusted by Pump control
Single Cycle/Recycle	In single cycle mode start switch or external trigger initiates each cycle; in recycle mode, once start switch or external trigger is actuated, repetitive cycles commence automatically
Time Unit Switch	Two basic time units selectable, 10 ms. or 1 sec.; in 10 ms. position, eject and pause time switches of IP-2 modules can be set to cover time range from 0-990 ms. with 10 ms. resolution; in I sec. position, time scale expanded from 0-99 sec. with one sec. resolution
Inputs	Cycle start, stop, trigger/gate # 1 through # 5; banana jacks terminals, floating input, optically coupled; input voltage +/- 5 to +/- 15 V TTL compatible
Analog Input	Lemo miniature receptacle, ground referenced 5mV/nA; input impedance 100
Analog Output	Lemo miniature receptacle, 5mV/nA ground referenced
Sync Output	Lemo miniature receptacle, TTL pulse
Output Connector	Seven pin miniature connector, mates with ultra flexible cable leading to microelectrode holder

PPM-2 MODULE

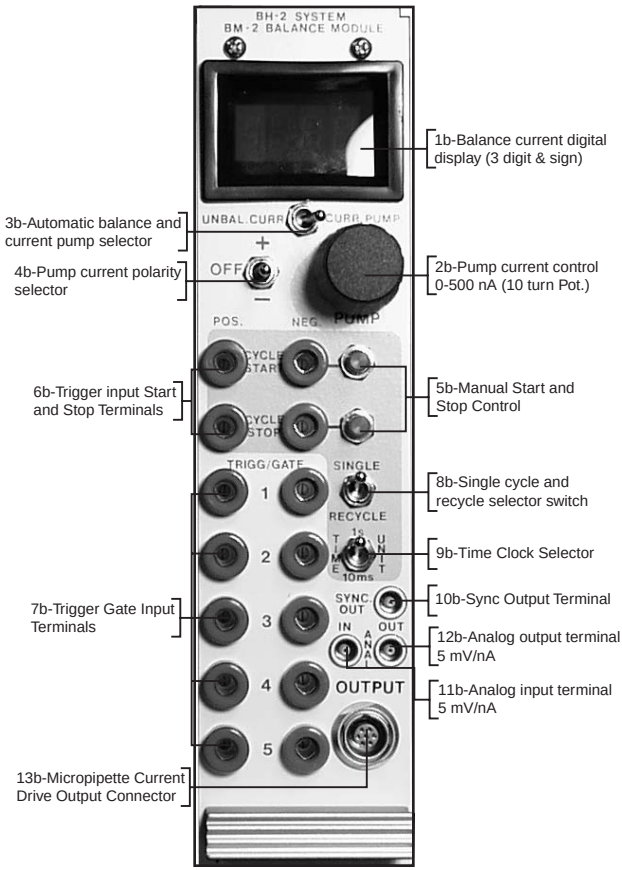
Source Gas	Air or nitrogen recommended (no explosive or combustible gases)
Max. Input Pressure	125 psig (7.8 kg/cm^2)
Input Filter	5 micron element
Output Pressure	0-99.9 psig (0-7 kg/cm^2)
Output Pressure Display	Three decimal digits
Min. Pressure Pulse Width	30 msecs.
Max. Pressure Pulse Width	99 secs. (990 secs. optional)
Gas Input and Output Couplings	Quick connect type
Analog Output	Lemo miniature connector voltage proportional to output pressure; 0 to -999 mV full scale in psig setting 0 to 700 mV full scale in kg/cm^2 setting
Sync. Output	Lemo miniature connector TTL pulse, time incident with output pressure pulse
Eject Time Indic.	Red LED
Pause Time Indic.	Green LED
System Dimen.	19' W x 83/4" H x 14" D (47 x 21 x 35 cm)
Weight	System: 18 lbs. (8.2 kg); Power Supply: 24lbs. (11 kg)

BH-2 Mainframe and Balance Module

The BH-2 mainframe is designed to be 19" rack mounted and is prewired to accept one balance and a combination of five IP-2 pump modules and/or pneumatic pressure modules (any combination of five plus balance module). The balance module in addition to providing current neutralization (automatic feedback and control of inverse sum of all pump currents) has independent capability of current pump settings with a working range of 0-500 nanoamperes. The module includes a digital display, time clock, provisions for electrical and manual Cycle, Start/Stop and Single Cycle Recycle switch, Trigger and Gate input terminals to initiate externally controlled Eject pumping action of respective modules. Analog input for balance or drive with override capability. Analog output for monitoring of unbalanced currents.

MS-2 Power Supply

The A.C. power supply is self contained in a rack-mount cabinet and provides all voltages required to operate the NeuroPhore System. The power supply interconnects to the mainframe via flexible cable. The supply works off either 115 or 220 V.A.C., 50 or 60 Hz source (a selectable jumper is provided).



The system housing (mainframe) can accommodate up to five IP-2 pump modules and as such will accommodate a seven barrel pipette to handle five drug, one balance and one recording barrel. Each IP-2 pump module includes control for precise settings of current magnitude and polarity (retention 0 to 50 nanoamperes, ejection 0 to 500 nanoamperes). The actual current and polarity is continuously displayed digitally and can be externally monitored at the analog output terminal.

Note: The system can also accommodate up to 5, any combination of pneumatic and iontophoretic modules and thus provide full control of simultaneous pneumatic and iontophoretic ejection of drugs.

Ejection Timing and Mode Switch

The mode switch provides five push button controls which include operations such as Cycle, Trigger, Gate, Continuous and Termination.

Cycle Mode

In the cycle mode, by virtue of selecting single or recycle operation on the BH-2 module, an incoming trigger or cycle start push button will initiate the ejection pumping action. In this mode each succeeding pump module is automatically triggered after the pause time of the preceding event has been completed. Both EJECT and PAUSE times can be preset to cover a range from 10 to 990 milliseconds with a 10 millisecond resolution and 1 to 99 seconds with a 1 second resolution.

Trigger Mode

When the TRIG. switch is energized the eject time interval will be started by virtue of the respective incoming trigger pulse applied to the input panel of the BH-2 balance module. Eject timing interval can be preset covering a range form 10 to 990 milliseconds with a 10 millisecond resolution and 1 to 99 seconds with a 1 second resolution.

Gate Mode

When the Gate switch is energized the eject current will be started by virtue of a gate input signal provided to the respective TRIG/GATE terminals on the BH-2 balance module. The Eject-Pause time settings are automatically disengaged in this mode, since the Eject time is slaved to the duration of the gate input.

Continuous Mode

When the CONT. switch is energized the ejection pump current is continuously maintained.

Termination Mode

When the TERM. switch is energized the output is automatically diverted from the micropipette preparation into an internal "dummy load" (100 megohms). This function is particularly useful for testing of possible instability in the preparation pipette.

Analog Input

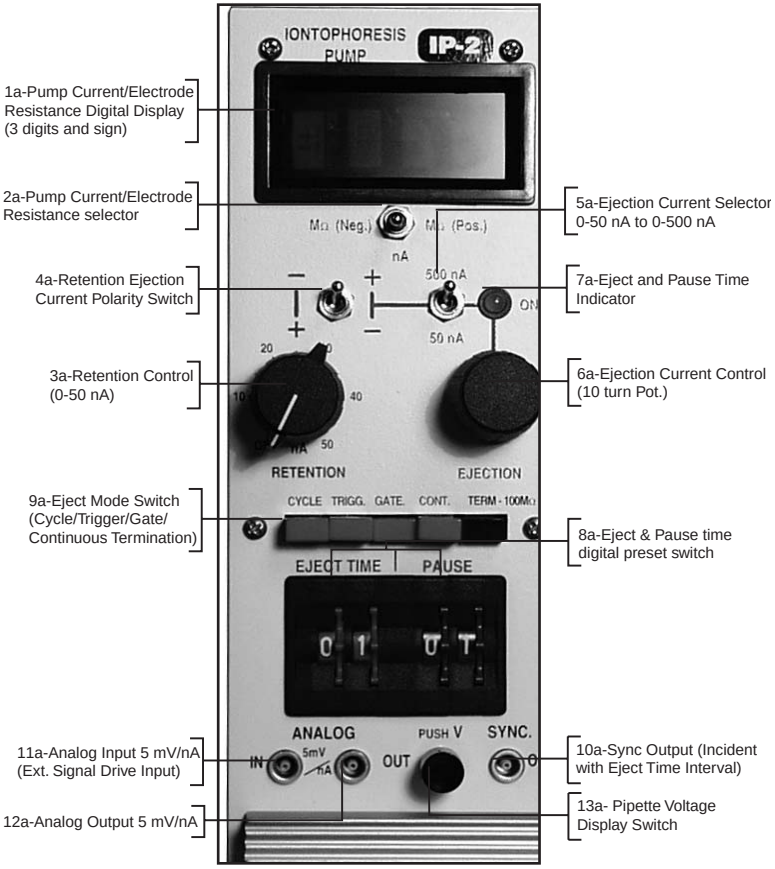
The analog input terminal is available to facilitate externally controlled current pumping action. An external voltage applied to the input will generate a pumping current at a ratio of 5 millivolt/nanoampere. This current will be summated with any preset pump current governed by both the Retention and Eject controls. The combined magnitude and sign of the summated pumping current is displayed on the digital display of each corresponding pump module. This input can be connected to a computer D/A converter when external programming is desired.

Analog Output

The analog output terminal provides a buffered voltage which is proportional in magnitude and polarity to the actual current passed from the current pump into the pipette. The conversation ratio is 5 mV/nA. This output can be polygraphically recorded to monitor progress of the experiment.

Sync Output Terminal

The sync output provides a TTL pulse that coincides with the eject time. This output is provided to trigger external devices such as computer, event counter, etc.



IP-2 Pump Module Controls

The pneumatic pump module has been designed specifically for pressure injection of drugs in pharmacological studies of drug evoked synaptic discharges. Emphasis has been given in the design as to pressure control and regulation (0 to 30 psi) or (0 to 2.2 kg/cm2) as well as precise timing capability.

The Pneumatic Pressure Module PPM-2 is compatible with the BH-2 (NeuroPhore) microiontophoresis main frame. By virtue of interchanging the iontophoresis pump module (IP-2) with a pneumatic pressure pump (PPM-2) the overall system capability can be expanded for simultaneous pressure and iontophoretic injection of drugs from a multibarrel pipette.

The PPM-2 is comprised of a precise pressure regulator, digital display, transducer and a timing mode switch. It connects to an external pressure source (such as a compressed bottle of N_2) can be set to provide continuous or periodic pressure pulses ranging (0 to 30 psi) with 0 to 0.5V) proportional to the output pressure as well as a sync pulse coincident with the pressure start cycle.

Ejection Timing and Mode Switch

The mode switch provides five push button controls which include operations such as Cycle, Trigger, Gate, continuous and termination.

Cycle Mode

In the cycle mode after selecting single or recycle operation, the start push button will initiate the ejection pumping action. In this mode each succeeding pump module is automatically triggered after the pause time of the preceding event has been completed. Both eject and pulse times can be present to cover a range from 1 to 99 seconds with a 1 second resolution.

Trigger Mode

When the Trig. switch is energized the eject time interval will be started by virtue of an externally applied trigger pulse fed to the respective inputs on the control panel. Eject timing interval can be preset covering a range of 1 to 99 seconds with a 1 second resolution.

Gate Mode

When the Gate switch is energized pumping action will be started by virtue of a gate input signal applied to the respective trigger/gate terminals on the control panel. The eject and pause time settings are not operative in this mode, since the eject time function is slaved to the duration of the gate input.

Continuous Mode

When the Cont. switch is energized the eject pump pressure is continuously maintained.

Termination Mode

When the Term. switch is energized the output pressure is automatically diverted from the preparation into an internal "Dummy Load". This function is particularly useful for setting up the desired pressure range and timing while preventing ejection of any drug from the pipette.

Prior to turning power "ON" set (push in) the TERM-100 M Switch (9A, p. 8) on each of the pump modules, thus terminating each pump into the internal 100 M Load.

a) Turn all Retention controls (3A, p. 8) and Eject controls (6A, p. 8) to zero (fully counter clockwise).

b) Connect the reparation to current drive output cable connector (13B, p. 6).

Balance Module Front Panel Connector		**J11 - Balance Module P.C. Board**	
Ground	Black	Pin 7	A
IP-1 Pump Module	Brown	1	G
IP-2 Pump Module	Red	2	F
IP-3 Pump Module	Orange	3	E
IP-4 Pump Module	Yellow	4	D
IP-5 Pump Module	Green	5	C
Balance Module	Blue	6	B

c) Turn power switch ON.

d) Mount the filled pipette into the micromanipulator assembly.

e) Connect the electrical and/or pneumatic connections to the pipette.

f) Advance the pipette into the outer layer of tissue (mainly to establish contact between pipette tip and tissue fluid).

g) Release the TERM switch (by releasing the TERM switch the pipette is electrically/pneumatically coupled to the apparatus).

Electrode Resistance Measurement

Electrode resistance measurement is achieved by setting the switch (Pump current and electrode resistance selector (2A, p. 8) into positive or negative MΩ setting. Ascertain that TERM-100 MΩ (internal dummy load resistor) mode switch (9A, p. 8) is released.

Measure the electrode resistance by immersing the tip of the micropipette at the initial stage of entry into the tissue (or a droplet of saline) to establish the resistance value of each barrel with ground reference. Ascertain appropriate resistance polarity (electrode resistance selector, 2A, p. 8) that coincides with ejection current polarity for each drug contained in the barrel.

Resistance value for each barrel should be measured one at a time. The selection of the appropriate polarity of the resist°ance selector switch (positive or negative) to correspond to the cathodic or anodic ion composition of the drug is vital. Inasmuch as during the resistance measurement the resistance metered circuit will generate a continuous 50 nanoamperes of current, it is advisable that the polarity of this current be such to eject the drug ions, thus avoiding the possibility of tissue or other particles from the surrounding fluid to clog the barrel. It is also suggested that the front handle bar handles on each module be used for marking information such as type of drug, barrel resistance, retention and ejection values, etc. since such information can be very useful during control of the experiment.

After the resistance value of each pipette has been determined it is recommended that the resistance toggle switch be returned to center or inactive position. The above procedure should be repeated for each active barrel.

Setting of Retention Current

a) Press either Cycle, Trigger of Gate button on the Eject Mode switch (9A, p. 8).

b) Set the retention polarity switch (4A, p. 8) to coincide with the retention required of each drug and set the retention current control (3A, p. 8) for the desired current magnitude. The retention current and polarity can be read on the digital display.

Setting of Ejection Current

a) Set the EJECT Mode switch (9A, p. 8) to CONT. mode and adjust the control (6A, p. 8) to the desired current magnitude.

b) Set the EJECT Mode switch (9A, p. 8) to CYCLE or any other mode if external timing is required.

c) Select the appropriate Eject and Pause time intervals on each of the thumb wheel switches (8A, p. 8).

d) Select the appropriate Time Unit by setting switch on the BM-2 Balance Module (9B, p. 8). (1 sec. or 10 ms.).

e) Select Single or Recycle Mode Switch (8B, p. 6) for desired timing.

f) Press Cycle Stop switch (5B, p. 6) to release latch and then depress Cycle Start Switch to initiate cycle run.

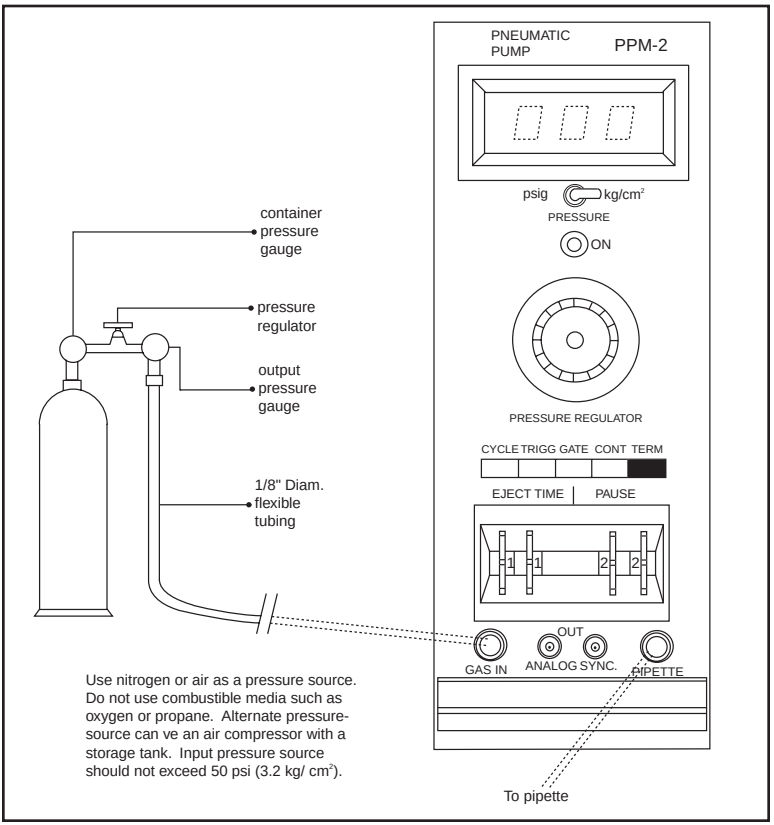
Setup of Automatic Balance

Set Automatic Balance and Current Pump selector switch (3B, p. 6) to the unbalance current position. The 3 digit display will indicate a reading close to zero + 0.001 or 2 nanoamperes. For fine control adjustment it is recommended that the pump current and polarity selector to be switched to either positive or negative position (opposite to the polarity indicated on the digital display).

Adjust the pump current control (2B, p. 6) to as close to zero as possible. NOTE: The slight variations may be noted such as a jump of one digit. This variation is attributed to the inherent noise of A/D converter.

Setup of Pneumatic Pressure Module

1. Connect the gas input pressure as shown below.
2. Push the TERM switch in (with the TERM switch in the "IN" position the module is internally terminated and the pressure is diverted from the pipette into a dummy load).
3. Set the Mode Selector Switch to CONT. operation. Select the pressure units switch to either psig or Kg/cm2 position.
4. Adjust the pressure regulator to the desired pressure level and note the 3 digit pressure display.
5. Set the Eject and Pause time settings for the desired timing.
6. Select the desired mode setting to either cycle or other mode of operation.
7. Release TERM switch (by pushing and releasing the TERM switch pushbutton).The pressure is now directed into the pipette.
8. To monitor analog output connect the polygraph recorder to the Analog Output terminal thus the analog of pressure (0 to 1000 mV full scale in the 100 psi. position) or (700 mV full scale in the Kg/cm2 position) will be recorded.



Use nitrogen or air as a pressure source. Do not use combustible media such as oxygen or propane. Alternate pressure source can be an air compressor with a storage tank. Input pressure source should not exceed 50 psi (3.2 kg/cm2).

Advantages of Micro-Pressure Ejection

a) Pressure ejection can be used to administer drugs which are difficult to deliver with conventional microiontophoretic techniques.

b) Does not share the leakage and warm-up problems associated with microiontophoretic techniques.

c) Micropressure ejection may be more amiable to dose dependent relationships.

d) Offer linear and reproducible delivery characteristics. (See illustrations.)

Pressure Ejection into Saline

Figure 1

The effect of increasing ejection time on the release of 3H-sucrose. 3H-Sucrose was pressure ejected from a multibarreled pipette at 5 (open circles), 10 (closed squares), 20 (open triangles) or 30 (closed circles) psi of nitrogen. The ordinate represents total counts per minute tritium collected minus the blank.

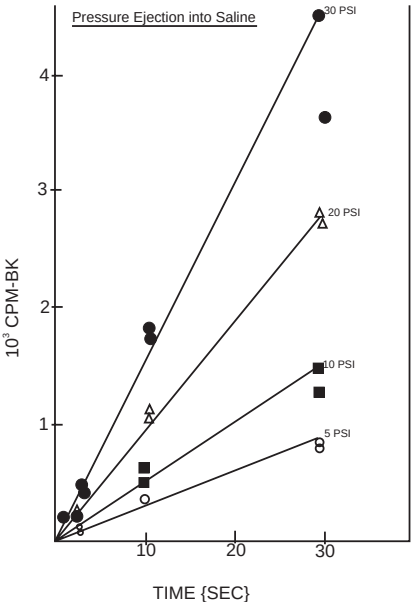


Figure 2
The effect of increasing ejection pressure on the release of 3H-sucrose. 3H-sucrose was pressure ejected from a multibarreled pipette in 1-(open circles), 2-(closed squares), 10-(open triangles) or 30-(closed circles) second pulses. The ordinate represents total counts per minute tritium collected minus the blank.

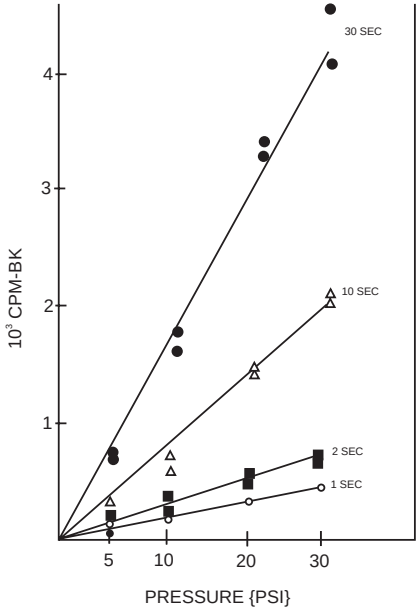


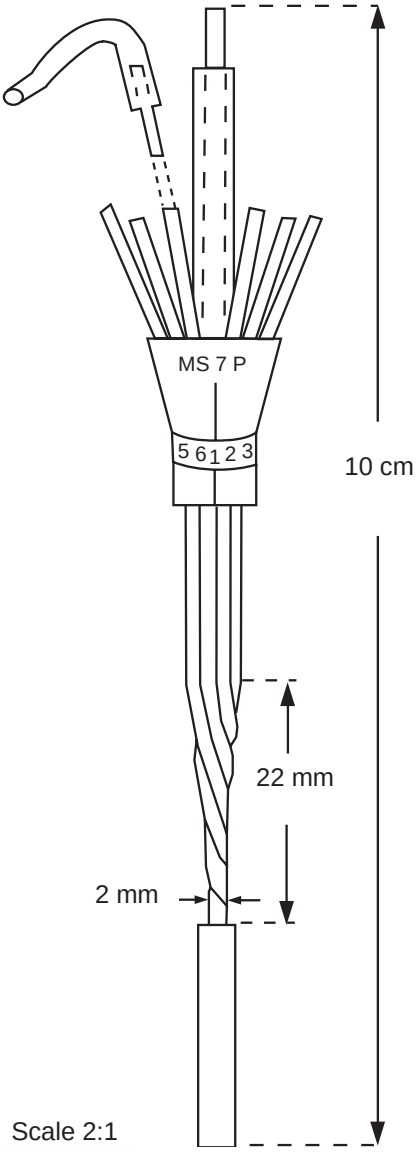
Figure 3
Dose dependent inhibition of cortical neuronal discharge induced by micropressure ejection of 2dA in the absence of regularly repeated pulses of drug. (A, B, and C) Ratemeter records from a single cerebral cortical neuron showing the magnitude of inhibitions elicited by applying various pressures to the 2dA-filled barrel. Duration of ejection is shown by the underlying bar. Percent inhibition is indicated above each 2dA response. (D) Dose-dependent inhibitions produced in one cell. The 2dA is applied with large variations in interejection time over a 60-minute period.

Figure 4
Ratemeter records from two neurons demonstrating typical controls for the physiological effects of micropressure ejected drugs. 2dA caused marked inhibitions of Purkinje cell firing rate when applied at 20 psi for 2 seconds.

Figure 5
Reproducibility of the micropressure ejection technique. (A) An average of 1057 $\pm$ 24 counts per minute of tritium was collected from five separate pressure ejections of ^{3}H- sucrose from one pipette, each applied at 20 psi for five seconds. Vertical line represents one standard error of the mean. (B and C) Ratemeter records from two cerebellar Purkinje cells which illustrate the reproducible physiological responses to repeated micropressure ejections of drugs at two-second pulses of 1 psi (underlying bars). NE (B) or GABA (C), when repeatedly applied, produced uniform inhibitions of neuronal activity which did not vary for periods of time of up to 1.5 hours.

Figure 6
Typical results illustrating spontaneous Purkinje cell discharges (recorded with MSC multibarrel pipette).

Seven Barrel Micropipette: Model MS-7PB

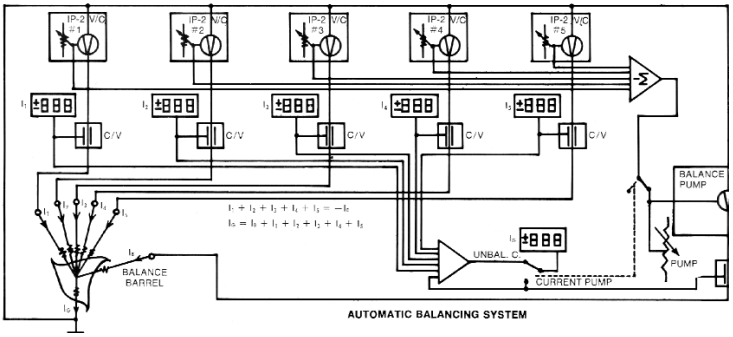


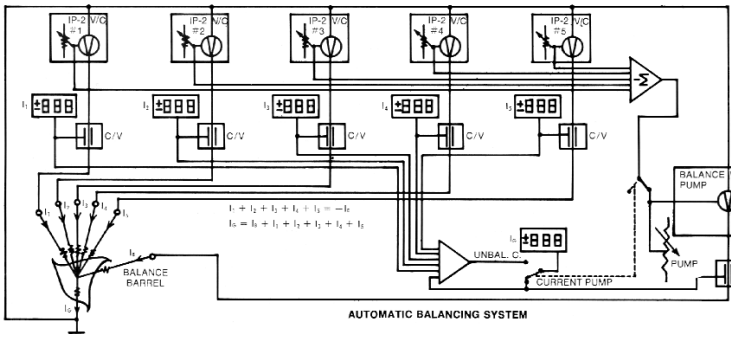
The MS-7PB pipette has been designed for iontophoretic use as well as pneumatic ejection of drugs and compliments the BH-2 NeuroPhore System. The standard blank consists of seven barrels, pyrex Omegadot tubing, 1.5 mm O.D. and 1.2 mm I.D, prepulled to 2 mm formation as shown.

The design of the pipette readily lends itself for electrical connection by inserting Ag wire or tube attachment for pneumatic use. The overall length of the blank assembly is 10 centimeters and fits the Narishige or an equivalent electrode puller.

The pipette can be supplied in either configuration, prepulled blanks as shown or in a pulled micron tip format. The micron tip is not bumped and therefore can be finalized prior to use.

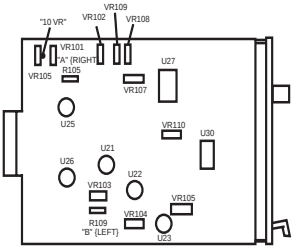
The orifice ratio of each barrel is 0.80 and thus is optimized for minimal tip resistance when pulled to micron size. Omegadot tubing permits easy filling. Fanned-out outer barrel assembly provides separation thus avoiding leakage due to spills between barrels. The 22 millimeter long twisted segment of the blank assembly assures singular tip formation during pulling action and provides flexibility in selection of a desired tip configuration.





BH-2 Balance Module

The BH-2 System is designed to provide an "Automatic Balancing" feature in order to null out any voltage that may appear due to retention and/or ejection at the cell junction.



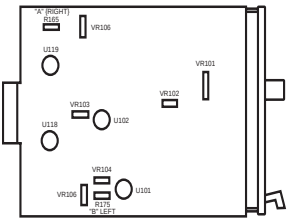
BH-2 Balance Module

Needless to say when a system is dispatched the automatic balancing controls is precisely adjusted at the factory and as such will track pump current (500 nA) retention and/or ejection accurately and balance well within + 1 nA at full scale. However, in the field, situations may arise whereby an IP-2 pump module is added and realignment of the balancing may become necessary. To accommodate this eventuality the realignment procedure as outlined here and should be followed.

IP-2 Module Alignment and Control Settings

Test Conditions

1. Only one IP-2 module powered at one time.
2. Retention: Fully CCW (counterclockwise).
3. Ejection: Fully CCW.
4. Current/Resistance switch in "nA" position.
5. "Gate" push button in.
6. "Term" push button in.



IP-2 Module

IP-2 Module Adjustment

a) Set R133 (lower pin) to 0V (zero voltage) (pin 6, U102) by adjusting VR103.

b) Ground point "B" (R172 left pin), set point "A" (R165 right pin) to 0V (zero voltage) by adjusting VR106.

c) Ground point "A" (R165 right pin), set point "B" (R172 left pin) to 0V zero voltage by adjusting VR105.

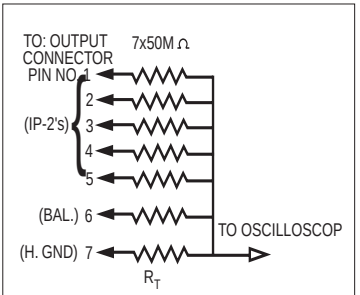
d) Repeat b. and c. two or three times for better adjustment.

e) Adjust VR104 to obtain + 000 reading on digital display.

Balance Module Alignment & Control Setting

Test Conditions

1) Balance module alone (No IP-2's)
2) Output connector terminated by 10 Mohms resistor.
3) Unbal. current/current pump switch in "unbal" position.
4) Polarity switch in center "OFF" position.
5) "Time Unit" switch in 10 ms position.



External Load for Testing and Adjustment

Adjusting Procedure

a) Set R104 (lower pin) for 0V (zero voltage) by adjusting VR 103.

b) Ground point "B" (R109 left pin), set point "A" (R105 right pin), to 0V (zero voltage) by adjusting VR 101.

c) Ground point "A" (R105 right pin), set point "B" (R109 left pin), to 0V (zero voltage) by adjusting VR 102.

d) Repeat b. and c. two or three times for better adjustment.

e) Set 0V (on display) by turning VR 104.

f) Obtain + 000 reading by adjusting VR 105.

g) Set VR 107 to obtain 2.000V+ 1mv at pin 2, U-27.

h) Using voltmeter, set terminal (location: CR114 hole @ 7 o'clock) to 4.500V + 0.1V by adjusting VR 106.

i) Set VR 110 (unlabeled) to obtain 1 ms pulse train at pin 1, U-30.

Final Adjustment and Control Setting

Test Conditions

1. All IP-2 modules in "CONT" mode.
2. "Retention" and "Ejection" fully CCW.
3. "TERM" push button out.
4. All IP-2's and BAL module output connected to common point through 50 Mohm resistor. This point tied to ground through an RT = 50 Mohm resistor.
5. Oscilloscope connected across RT. (Making effective RT/Scope approximately equal to 1 Mohm).
6. Oscilloscope setting: Horizontal 5 ms/division, line sync. Vertical: 5mV/division.

Adjusting Procedure (BM-2 Balance Module)

a. Adjust VR 103 to obtain 0V (zero voltage) on CRO.

b. Adjust VR 104 and/or VR 105 to obtain + 000 Bal display.

c. Set unbalance curr/current pump switch to current pump position. Set VR 108 to obtain 0V on CRO.

d. Set VR109 to get + 001 reading on balance display. Return unbalance current/current pump switch to unbalance current position.

Adjusting Procedure (IP-2 Module)

a. Select one IP-2 module and turn Ejection control fully clockwise. Correct DC offset as measured by CRO by adjusting VR 101 until OV reading is reached. Reverse ejection polarity and correct DC offset on CRO with VR 101 when necessary. Return ejection control to zero (CCW).

b. Repeat step "e" for all IP-2 modules.

c. Press "Gate" button on all IP-2's.

d. Turn ejection controls fully clockwise on all IP-2's.

e. Set range switches to 500 nA on all IP-2's.

f. Depress "CONT" button on one IP-2 and adjust VR102 to obtain + 001 reading on balance display. Depress "GATE" button.

g. Repeat step "f" on all IP-2's.

Ref: Pipette Voltage Display

All IP-2 Modules manufactured after December 1981 are fitted with an additional push button switch. This switch is marked "Push V" and it is mounted above the module handles between the ANALOG and the SYNC OUT connectors.

Depressing this switch will cause the digital display to read the voltage across the pipette equal to the current flow through the pipette times the pipette impedance. (i.e. by Ohms Law: V = R *I)

The voltage readout will function whenever the "Push V" button is depressed, regardless of the position of other controls. Therefore the pipette voltage can be measured during the drug ejection, retention or impedance checks.

Specifications

Resolution	1/10 Volt
Maximum Range	+ 99.9 Volt