Jim & Holly

OPERATING MANUAL

DU PONT CONSTANT FLOW AIR SAMPLING PUMP

MODEL P4000

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DU PONT CONSTANT FLOW PUMP MODEL P4000

The Du Pont Constant Flow Pump Model P4000 is a personal air sampling pump that moves a constant volume airflow through an external collection device. An automatic flow control system maintains the rate within ± 5 percent at pressure drops of up to 25 inches water column (w.c.). (See Figure 1.)

With a flow range of 20 to 4000 cc/min, the P4000 can be used in almost any air sampling application:

- Filter sampling.
- Impinger sampling.
- Adsorption tube sampling (charcoal, silica gel, Tenax, etc.).
- Eight-hour detector tube sampling.
- Area or personal sampling.
- Air bag sampling.

The P4000 features an electronic timing circuit that can be set in one of two modes of operation. When the controls are set for an automatic sampling period, the timing circuit automatically shuts off the pump when the time has elapsed. In the normal mode of operation, the pump has to be turned off manually. In both modes an electronic circuit accumulates and displays the total time of operation. The P4000 also features two light-emitting diodes (LED's) that indicate constant flow was maintained and whether the battery has been charged. The pump is housed in a dust-resistant aluminum case with a cover that can be attached for easy or limited access. (See Figure 2.)

INSTRUMENT AND ACCESSORIES

The P4000 Pump system (see Figure 3) contains:

1	Pump.
1	Balston filter with Tygon adapter.
1	110 volt, 60 Hz battery charger (220 volt, 50 Hz where applicable).
1	Length of tubing.
1	Package of 4 internal filters and 1 drive belt.
1	Exhaust port hose barb with washer.
1	Package of 2 socket head screws with retaining washers and 1 hex key.
1	Operating Manual.

The Calibrator Pack (see Figure 4) contains:

5	Pumps.
1	Calibrator case.
5	Balston filters with Tygon adapters.
1	110 volt, 60 Hz multicharger unit (220 volt, 50 Hz where applicable).
1	Bubble tube (500 cc).
1	Bubble solution container.
1	Bubble tube stand.
5	Spare parts kits (5 exhaust port hose barbs, 20 internal filters, and 5 drive belts).
5	Packages of 2 socket head screws with retaining washers and 1 hex key.
1	Operating Manual.

Each Calibrator Case includes:

1	Calibrator panel.
1	Bubble tube (500 cc graduated).
1	Bubble tube stand.
1	Bubble solution container.
1	Set of foam inserts.
1	Plastic tube.

PUMP OPERATING INSTRUCTIONS

1. Before operating for first time, fully charge battery.
2. Remove the cover. (See Figure 2.)
3. Set the timing mechanism. (See Sampling Procedure, page 10.)
4. Turn pump on.
5. Check that battery LED is lit, indicating battery has been charged.

   NOTE: When flow control LED is not lit, flow is being controlled.
6. Connect to flow calibration instrument.
7. Adjust pump flow until proper flow is set. (See Pump Calibration section beginning on page 4.)
8. Attach collection device to the inlet.
9. Replace cover.
10. Attach pump on belt of the person to be monitored. (See Figure 5.)
11. Position collection device near user's breathing zone.

CALIBRATION

PUMP CALIBRATION

The pump flow rate will remain stable for long periods. For the most accurate test results, however, daily calibration is recommended.

The following procedure provides detailed instructions for calibration of the pump using the Du Pont Constant Flow Pump calibrator case. This procedure can be adapted to a bubble tube, manometer, and stopwatch calibration system; however, the use of the Du Pont calibrator case facilitates the test of the automatic control device.

1. Attach the tubing labeled "pump" to the pump inlet hose barb. (See Figure 6.) Open the pressure valve ("Simulated Filter Adjustment") during this step. (See Figure 7.)
2. Set the flow rate for the pump for the desired flow range.

Low Flow Range 20-500 cc/min

- Rotate the flow range selector valve (see Figure 2) three turns counterclockwise from the fully closed position.

- Align the drive belt in the low flow position.
- Rotate the flow rate adjusting valve until the desired flow is reached.

Intermediate Flow Range 500-2000 cc/min

- Rotate the flow range selector valve clockwise until it is closed. Do not overtighten because damage could result.
- Align the drive belt in the low flow position.
- Rotate the flow rate adjusting valve until the desired flow is reached.

High Flow Range 2000-4000 cc/min

- Rotate the flow range selector valve clockwise until it is closed. Do not overtighten.
- Align the drive belt in the high flow position.
- Rotate the flow rate adjusting valve until the desired flow is reached.

After each flow adjustment, allow time for the flow control mechanism to respond. If the pump is operating at maximum speed and not responding to flow control changes, the flow rate adjusting valve is open too far. Once the flow rate has been adjusted, verify the reading with the bubble tube. See Bubble Tube Use on page 8.

3. Check the operation of the pump's automatic flow control feature by setting the pressure drop adjustment knob (see Figure 7) to read up to 25 inches w.c. for flows up to 2000 cc/min. Adjust pressure drop up to 10 inches w.c. at flow rate of 4000 cc/min. To increase the pressure drop, move the pressure drop adjustment knob clockwise. Note that the flow will decrease momentarily as the pressure drop increases. A properly functioning flow controller will automatically reset the flow to the original set point.
4. Repeat the bubble tube test after the pressure drop has been set. See Bubble Tube Use on page 8. You will note that the needle has returned to its original set point position, showing that the constant flow control has operated correctly and compensated for the increased pressure drop.
5. Check whether the pump controller is operating properly. The difference between the initial flow rate and the flow rate with pressure drop should be within 5 percent of the zero pressure drop flow rate.
6. Turn pump off.

CALIBRATION CHECKOUT

1. Place the 500 cc bubble tube, open end down, into the bubble tube stand. Connect the top end of the bubble tube to the shorter piece of tubing, marked "Bubble Tube," on the calibrator panel. (See Figure 8.)

2. Set the pressure drop meter to read zero inches w.c. during the initial calibration with the bubble tube and flow rate meter. Turn the pressure drop adjustment ("Simulated Filter Adjustment") knob counterclockwise until the needle is near zero to adjust the pressure drop meter reading.
3. Readjust the meters to mechanical zero if the calibrator case has been moved or subjected to rough handling. With no flow through the pack, readjust the meters to zero by readjusting the small screw located below the caution label on the meter face. (See Figure 7.)
4. Calibrate the flow rate meter, located at the left side of the calibrator panel, by comparing it to the more accurate flow measuring device, the bubble tube. See Bubble Tube Use on page 8. Turn pump on. Set the pump at a desired flow rate. (See Step 2 above.) Determine the actual flow rate with the bubble tube. Then set the flow meter adjustment knob at the same flow rate. To increase the reading, turn the flow meter adjustment knob clockwise. Turn pump off.
5. Recalibrate the meter once a week or whenever the calibrator case is moved to a new location. Once the flow meter is calibrated against the bubble tube, however, it need not be checked each time it is used with a pump. The

meter is accurate to within ± 10 percent over the entire scale. A bubble tube calibration performed at the flow rate to be used will improve accuracy.

6. Read the flow rate meter for a quick indication of the flow rate in cc/min. For a more accurate determination, use the bubble tube method. See the Bubble Tube Use section.

BUBBLE TUBE USE

1. Verify the exact volume flow rate with the bubble tube. To obtain the volume flow rate, divide the volume of air sampled by the time it takes for a bubble to traverse that volume.

$$\text{Flow rate} = \frac{\text{Volume}}{\text{Time}}$$

2. Turn pump on. (See Figure 9.) Wet down the inside of the bubble tube with any soap solution by allowing several bubbles to pass up the full length of the bubble tube.
3. Use a stopwatch to measure the time it takes for one bubble to rise between any two graduated marks. The volume is the value difference from one mark to another. This volume divided by the elapsed time will equal the flow rate. Turn pump off.

If time is measured in SECONDS:

$$\text{Flow Rate} = \frac{\text{Bubble Tube Volume (cc)}}{\text{Elapsed Time (sec)}} \times \frac{60 \text{ sec}}{1 \text{ min}} = \frac{\text{cc}}{\text{min}}$$

Stopwatch	Graduation Mark
Start	0 cc
Stop	500 cc

Volume = 500 cc
Time = 48 sec

$$\text{Flow Rate} = \frac{500 \text{ cc}}{48 \text{ sec}} \times \frac{60 \text{ sec}}{1 \text{ min}} = 625 \text{ cc/min}$$

If time is measured in MINUTES:

$$\text{Flow Rate} = \frac{\text{Bubble Tube Volume (cc)}}{\text{Elapsed Time (min)}}$$

Stopwatch	Graduation Mark
Start	0 cc
Stop	500 cc

Volume = 500 cc
Time = 0.8 min

$$\text{Flow Rate} = \frac{500 \text{ cc}}{0.8 \text{ min}} = 625 \text{ cc/min}$$

SAMPLING PROCEDURE

1. Remove pump cover. (See Figure 2.)
2. Set the timing mechanism. The programmable timing circuit permits the pump to operate in three modes:
   A. To measure the elapsed time of sampling from the start of the pump to shutdown.
   B. To measure the elapsed time when the pump is turned on and off several times.
   C. To sample for a predetermined time and then automatically shut off.

   The timing circuit is programmed by the 8 two-position switches shown in Figure 2. Switches 1 through 6 program the time of sampling from one quarter to eight hours. Switches 7 and 8 are control switches.

   A. To measure the elapsed time of sampling from the start of the pump to shutdown:
      - Set switch 7 to manual position (MAN).
      - Set switch 8 to normal position (NORM).
      - Set the six timer switches to "on." (Depress bottom half of switch with a pencil tip.)

      The pump will now run until it is manually turned off or until the battery is drained. The elapsed time can be determined by depressing the test button and noting which LED timer indicator lights are energized. The

total sampling time is determined by adding the hours and/or minutes indicated by the energized LED's.

Caution: When the pump is operating in this mode, the elapsed time should be read before the "on-off" switch is moved to "off." Turning the switch off resets the timing mechanism.

B. To measure the elapsed time when the pump is turned on and off several times:

- Set switch 7 to manual position (MAN).
- Set switch 8 to interrupt position (INT).
- Set switches 1 through 6 to "on." The pump will run until it is manually turned off.
- Depress the test button to determine the total sampling time.

C. To sample for a predetermined time period with automatic shutoff:

- Set switch 7 to automatic position (AUTO).
- Set switch 8 to interrupt position (INT).
- Select the sample time period and program switches 1 to 6 accordingly. This is done by depressing the appropriate switches on the bottom side. (See Figure 2.)
- The pump will automatically shut off at the end of the programmed sampling period.

3. Turn on the "on-off" switch.
4. Wait a few seconds until the flow has stabilized.
5. Check the LED's. The battery check LED will light to indicate the battery has been charged. Charging time of 14 to 16 hours is required to ensure a fully charged battery.
6. Attach collection device to the inlet hose barb.
7. Attach pump to user's belt for personal sampling. Position collection device near user's breathing zone. Use pump for area monitoring by positioning the collection device appropriately.
8. Record:
    - Date.
    - Pump serial number.
    - Flow rate.
    - Unusual conditions (weather, interrupted operation).
    - Employee's name.
    - Survey supervisor.
9. Retrieve the pump at the end of the sampling time. Observe the flow control LED before turning off pump. If the LED is lit, flow has been restricted during the sampling period and the test is invalid.
10. Turn the unit off and record:
    - Elapsed sampling time represented on the LED timer indicator lights.

- Flow rate, after rechecking it.
- Any unusual conditions that occurred during the sampling period.

11. Prepare the collection device for analysis.
12. Set up the pump to recharge the battery in the case for 14 to 16 hours, or
13. Replace used batteries with fully charged batteries for continuous operation, and charge used batteries outside the case. See Battery Charge and Recharging section beginning on page 15.

CAUTIONS

- Don't short battery.
- Check filter for liquids.
- Don't overcharge.
- Don't introduce solvents or liquids to "rinse out."

BATTERY CHARGE AND RECHARGING

The rechargeable nickel cadmium (Ni-Cd) battery pack can be charged in place within the pump or removed from the pump case and charged separately. Du Pont has a battery charger for this purpose.

REMOVING BATTERY

1. Remove pump back cover. (See Figure 10.)
2. Pull batteries up from bottom to disengage Velcro.
3. Pull batteries away from terminal connectors and from battery compartment. (See Figure 11.)

INSTALLING FRESH BATTERY

1. Press battery terminals to engage them with battery connectors.
2. Lower battery into compartment to engage Velcro.

   Note: If only one battery pack is to be used, be sure to connect the battery to the longer of the two battery connectors.

RECHARGING BATTERY IN PLACE

1. Turn the unit to "off."
2. Plug the battery charger into a 110 volt AC wall outlet. The light on the charger will be off. Insert the charging

plug into the battery charger jack. If the charger light comes on dimly, the batteries are being charged. (See Figure 12.) If the light comes on very brightly the charging plug is shorted. Check for proper insertion of the plug in the charging jack.

Note: If the charger light does not glow, the charger may still be operating even though the bulb has failed. To test for this condition, place the unit on "charge" for the prescribed 14 to 16 hours and then determine whether the battery check light energizes. If it does, only the bulb has failed. If not, the battery charger should be replaced.

3. Allow 14 to 16 hours to fully recharge the Ni-Cd battery; then remove the battery from the charger and return the pump to use.
4. Unplug the battery charger.

USING MULTICHARGER

The pump multicharger will charge five pumps at one time. (See Figure 13.) It has a charge switch with "fast" and "trickle" positions. The batteries are charged for 14 hours at the "fast" setting. Once the batteries have been charged, the switch should be changed to the "trickle" position to maintain the charge indefinitely.

Plug the multicharger into a 110 volt AC wall outlet. Insert the five charging plugs into the pumps' battery charging jacks. Each of the charging circuits is connected to an LED. The LED's intensity will indicate that:

1. The battery charging cord is shorted when the light intensity is high.
2. The battery is accepting a charge when the light intensity is low.
3. The battery is not accepting a charge when the light is off.

RECHARGING BATTERY EXTERNALLY

Use a battery charging adapter (part No. P431). (See Figure 14.) This device has a battery charger jack and battery connector snaps. Connect the battery charger plug to the adapter. Then connect the adapter to the battery terminals. Refer to the comments on use of the indicator and the other charging instructions above.

THEORY OF OPERATION

The Du Pont pump uses simple feedback control to monitor flow through the pump mechanism and to adjust pump speed to maintain constant flow. This control system ensures constant flow regardless of load variations or other factors that would normally change the flow rate.

THE PUMP

The diaphragm pump is moved by a DC motor with an eccentric crankshaft.

The flow control needle valve creates in the flow passage a pressure drop that varies with the airflow rate and the valve opening.

The differential pressure switch connected across the needle valve is operated by the pressure drop. Thus, it operates as a flow switch, opening on low flow rates and closing on high flow rates. The flow point at which the change occurs depends on the needle valve setting and pressure switch. The pressure switch used in these pumps operates at 3 inches w.c. pressure drop.

THE CONTROL ASSEMBLY

The control assembly has four main sections: integrator, amplifier, flow control light, and battery check circuit. (See Figure 15.)

The integrator is a special circuit with an output voltage that varies with time. The integrator continually increases or decreases depending on the condition of the pressure switch connected to it. When the pressure switch opens, the output of the integrator gradually increases. When the pressure switch closes, the output of the integrator gradually decreases.

The amplifier is a circuit that increases the voltage from the integrator and provides enough current to drive the pump motor. The voltage output of the amplifier increases and decreases exactly with the integrator voltage.

The DC motor, which is connected to the amplifier output, increases its speed as voltage increases. In normal operation at a constant flow, the pump moves air through the needle valve, which causes a pressure drop at the pressure switch operating point.

An on-off sensor signal is converted to a constant analog control signal to give smooth, precise control of motor speed and pump flow.

The integrator also drives another circuit called the flow control light. If the pressure switch stays in the open position for approximately 15 to 45 seconds, the output of the integrator will continue to go up beyond the normal operating point. The low flow detector will trigger on this condition and light an LED, showing that the pump could not maintain flow control. The low flow detector circuit will "latch" or stay in this condition even though flow is later reestablished. Thus, the operator has a visual indication that a problem occurred with flow control or that flow was impeded in some way, such as by a pinched collector tube. The flow control circuit will reset when the pump is started for the next test.

The fourth part of the control assembly is the battery check circuit. This circuit is activated when the battery voltage is above 5.16 volts to show that the battery has been charged.

MAINTENANCE

MATERIALS OF CONSTRUCTION

The pump is constructed of the following materials:

- Parts of black anodized aluminum.
- Valves of Viton® fluoroelastomer.
- Stainless steel needle and bypass valve.
- Neoprene and Buna-N elastomers.
- Aluminum case.

These materials are generally unaffected by atmospheres encountered in industrial hygiene monitoring. However, concentrated solvents or liquids should never be used to "rinse out" the pump.

STORAGE

When the pump is not in use, store it in a safe, cool, dry place. Do not store it for an extended period without removing the batteries.

DRIVE BELT

The drive belt is designed to meet the operating specifications of the pump. If the belt wears out, it should be replaced only by the proper belt specified by Du Pont. The amount of belt

tension against the pulleys is important and must not be too great or reduced battery life will result.

BATTERY

The rechargeable batteries supplied with the pump will provide maximum life if the recharging instructions are followed closely. Continuous recharging for more than 16 hours at the maximum rate will shorten the life of the Ni-Cd battery. The battery can, however, tolerate occasional weekend charging (Friday evening to Monday morning). Continuous charging at the trickle rate is acceptable.

Self-discharge is a common occurrence with any Ni-Cd battery. It may take months for a battery to completely discharge on the shelf; after several days, however, a battery may discharge enough that the "Battery Full Charge" LED does not light. Recharging for approximately one hour will fully recharge the battery.

For safety reasons, the battery contains an internal current limiting resistor. Do not short the battery terminals because this resistor may overheat or burn out.

Some older batteries may not seem to hold a full charge because of a memory developed in the battery. Try a complete discharge

by continuous pump operation and then complete recharge of the battery. If this procedure does not help, the battery should be replaced.

The battery will normally last 200 to 500 cycles of charge and discharge before replacement is required.

FILTER REPLACEMENT

To protect internal parts, the pump uses two filters, a small polyurethane filter behind the inlet hose barb (part No. P419) and a larger external filter (part No. 101). These filters will usually last about a year; however, under dusty conditions, more frequent replacement may be necessary. Replace the filters immediately when:

- Liquid is noticed in the filter.
- The pump cannot maintain flow for eight hours at its designed flow rate.
- The pressure drop across the filter exceeds 8 inches w.c.

To replace or install filters:

- Internal
  - Remove the inlet hose barb.
  - Remove and discard the inlet filter inside the pump housing by inserting needle nose pliers into the inlet hose barb opening.

- Insert a fresh filter into the inlet port.
- Replace the inlet hose barb in the inlet port.
- Tighten the hose barb.

- External
  - Use appropriate lengths of supplied tubing to attach the filter to the pump as shown in Figure 16.
  - Orient the filter so the air flows in the direction indicated by the arrow on the filter housing.

CONTROL FUNCTION

It is normal for a pump to take several seconds to start. If the automatic controller appears not to function properly, review the following:

1. To determine whether the controller is compensating for change in flow, alter the flow by placing your finger across the inlet. If the pump begins to run faster, the controller is functioning. However, if the pump does not speed up or does slow down, use the calibrator case to verify that the unit is operating within its designed flow and pressure drop range. Follow calibration instructions.

2. If the flow control light comes on 15 to 45 seconds after the pump is started, the flow adjustment is open too far or the pump lacks capacity. Close the flow adjustment and try again.
3. If any unusual flow changes occur, remove the needle valve and check for possible dirt on the needle. Wipe clean and replace. Be sure to check the inlet filter for dirt or liquids.
4. If the pump is operating at maximum speed and not responding to flow control changes, the flow control adjustment screw is open too far. See the Calibration section on page 4.
5. Return the pump to Du Pont for service if the above checks fail to correct the malfunction.

SPECIFICATIONS

Operating Range:	20-4000 cc/min.
Pressure Range:	0-25 inches w.c. up to 2000 cc/min. 0-10 inches w.c. at 4000 cc/min.
Flow Control:	Automatically maintained at ± 5 percent of set point over operating range.
Flow Control Indicator:	If flow is interrupted for 15-45 seconds, the LED will light, indicating lack of control.
Battery:	One or two rechargeable Ni-Cd battery packs, depending on operating conditions of time, flow, and pressure drop.
Battery Check Indicator:	An LED indicates the batteries have sufficient charge to operate the pump for a minimum of eight hours.

Pump Controls:	"On-off" switch, timer switches, test push button switch, flow rate adjusting screw, flow range valve.
Timer:	Time of pump operation can be read out for up to 16 hours' operation in 1 minute increments. Accuracy is $\pm$ 1 percent, $\pm$ 1 minute.
Automatic Shutoff Time:	Pump can be programmed for up to 15-3/4 hours in 15 minute increments. Pump automatically shuts down at end of programmed time. Accuracy is $\pm$ 1 percent, $\pm$ 1 minute.
Pump Case:	Three-piece aluminum case with foam insulation for dust protection.
Dimensions:	2-5/8 in. x 4 in. x 6 in. (6.9 cm x 10.4 cm x 15.5 cm).
Weight:	With one Ni-Cd battery pack, 34 ounces (1 kg). With two Ni-Cd battery packs, 42 ounces (1.2 kg).

Operating Temperature Range:	20°F to 120°F (-7°C to 49°C).
Accessories:	Battery charger; inlet filter; inlet tube 1/4 in. ID x 36 in.; package internal filters and spare drive belt; exhaust port hose barb for bag filling; access key; socket head screw to convert from easy to difficult access; operating manual; external filter instructions; and repair card.
Approvals:	Mine Safety and Health Administration Intrinsic Safety Approval issued under Schedule 2G.

SERVICE

Technical assistance or advice is available by calling (800) 344-4900. In Pennsylvania, call (215) 444-4035.

For repairs, return the unit with the following information:

Company name
Return shipping address
Contact name and telephone number
Serial number of pump
Description of problem

Forward this information with your purchase order and instrument via UPS or insured mail to:

E. I. du Pont de Nemours & Co. (Inc.)
Applied Technology Center
N. Walnut Road, P. O. Box 10
Kennett Square, PA 19348
Attention: Repair Service

Figure 1

Du Pont Constant Flow
Air Sampling Pump Model P4000

Figure 2

P4000 with Control Cover Removed

Figure 3

Du Pont Constant Flow
Sampler System Components

Figure 4

Du Pont P4000
Calibrator Pack Components

Figure 5

P4000 Attached for Use

Figure 6

Du Pont P4000 Connected
to Calibrator Panel

Figure 7

Calibrator Panel

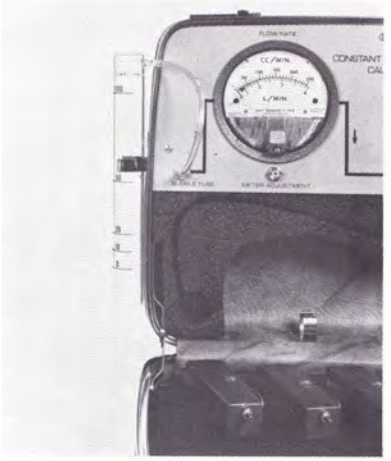

Figure 8

Bubble Tube Connected
to Calibrator Panel

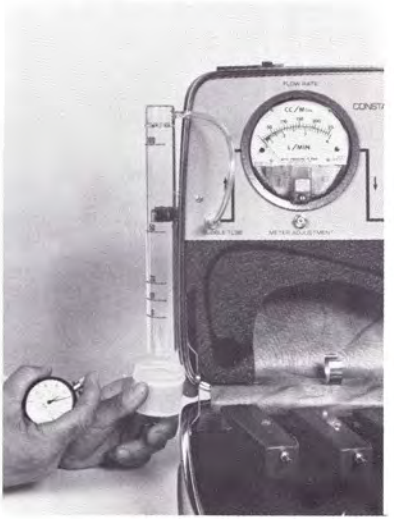

Figure 9

Using the Bubble Tube

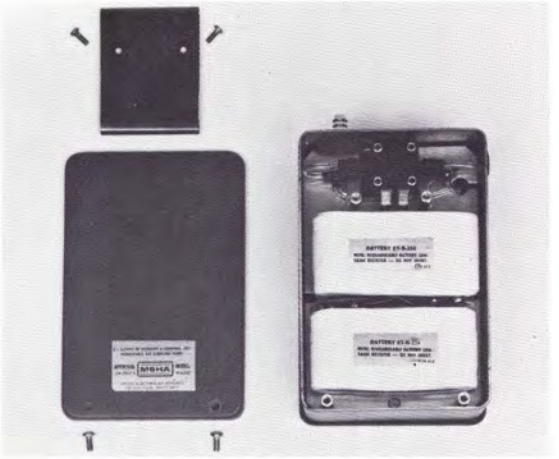

Figure 10

Battery Cover Removed

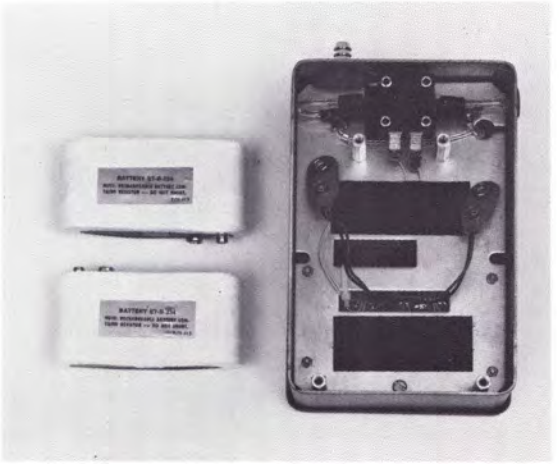

Figure 11

Battery Removed from Case

Figure 12

Battery Charging in Place

Figure 13

Using the Multicharger

Figure 14

External Battery
Charging Using Adapter

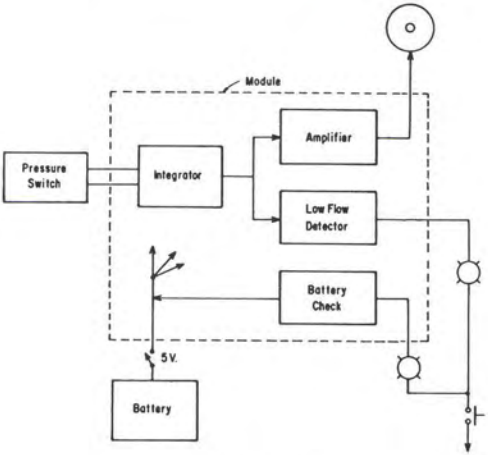

Figure 15

Control Assembly Block Diagram

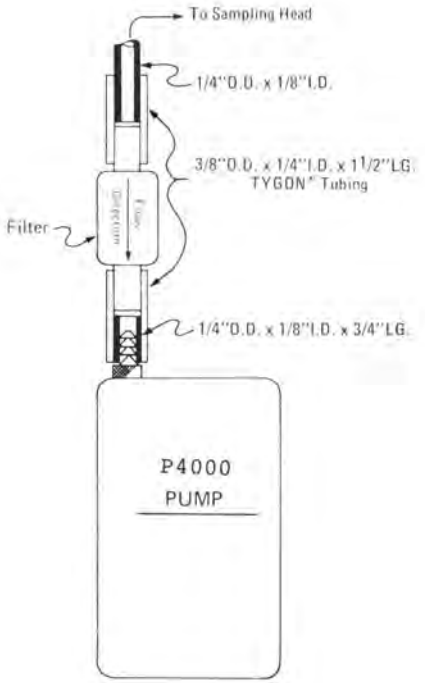

Figure 16

External Filter Replacement