instruction manual for the Collins Body Plethysmograph System 09001 09103 09905 09911

manual number 22148

PRODUCT CERTIFICATION

Warren E. Collins, Inc. certifies that this equipment was thoroughly inspected and tested and met its published specifications when it was shipped from the factory.

GUARANTEE*

All apparatus and accessories, with the exception of rubber and plastic materials, are guaranteed for one year from the date of delivery to be free from original defects in workmanship and materials under normal and proper use. All rubber or plastic materials are guaranteed for 90 days from the date of delivery. This guarantee covers the repair or replacement of the equipment at the option of the manufacturer.

Defective parts or components must be returned to the factory for repair or replacement after verbal or written return authorization is granted. No charge will be made under warranty except transportation to and from the factory. All returns should be prepaid. Upon request, a qualified technician will service the equipment at an hourly charge plus transportation and expenses. No other warranties are expressed or implied and the manufacturer is not liable for any special or consequential damages that may result in the use of this equipment.

*Those items manufactured by other than Warren E. Collins, Inc. are subject to that manufacturer's guarantee only.

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LIST OF ILLUSTRATIONS

*Courtesy Beth Israel Hospital, Boston, Massachusetts

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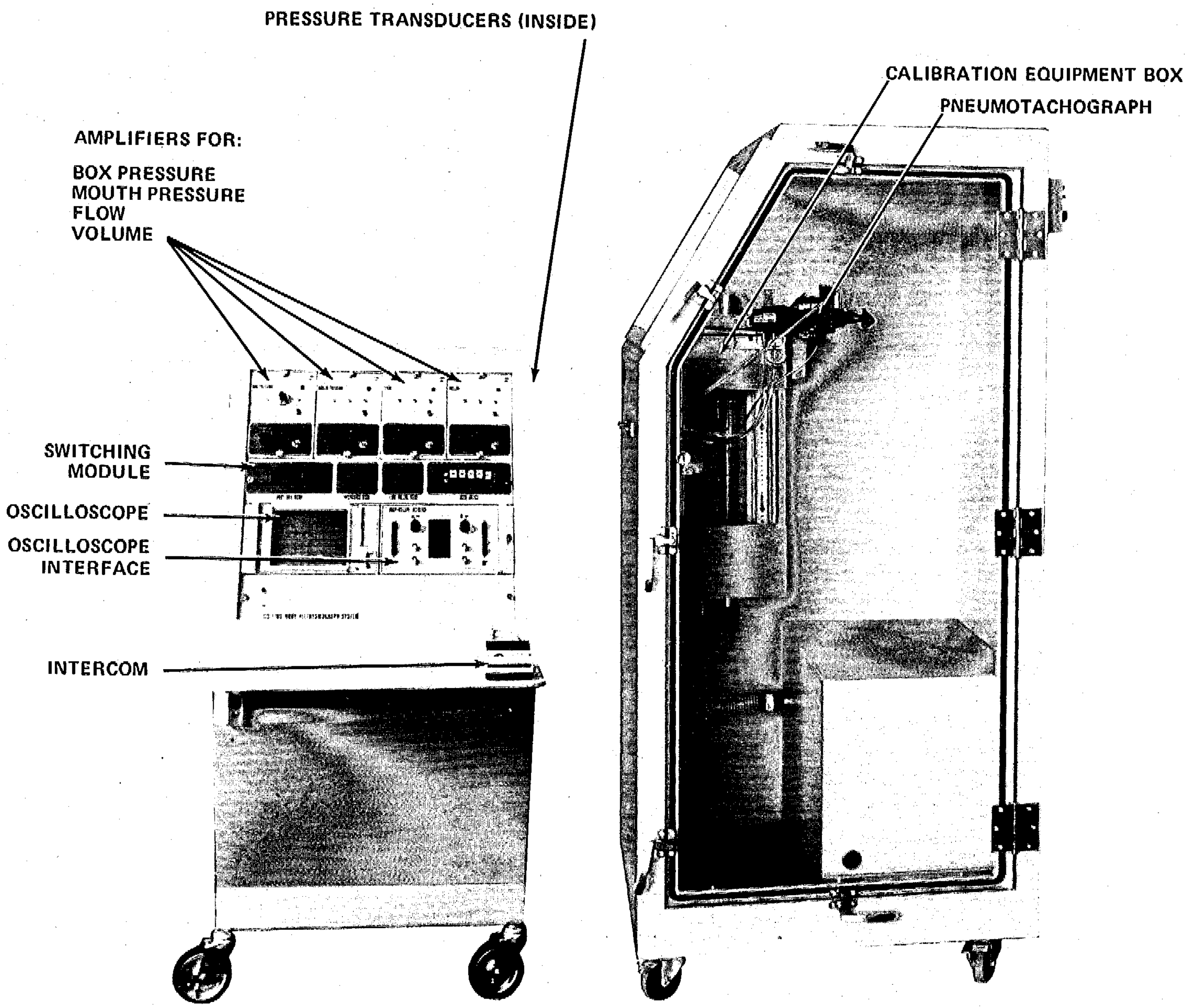


Figure 1 - Body Plethysmograph Components

INSTRUCTION MANUAL FOR THE COLLINS BODY PLETHYSMOGRAPH

I. GENERAL INFORMATION

I.A. DESCRIPTION

A.1. Components

The Collins Body Plethysmograph System consists of several electronic modules, pressure transducers and calibration equipment packaged in two portable enclosures which are referred to as the Electronics Console and the Body Box. Figure 1 shows the basic equipment layout with all the major components identified.

A.2. Accessories

The following accessories are shipped with your unit:

a. Small Rubber Mouthpiece (3)
b. Rubber Tipped Noseclip (1)

A.3. Optional Equipment

The optional equipment for the Body Plethysmograph is shown in Figure 2. The installation and operation of each one is fully covered in the appropriate sections of this manual.

a. Tektronix C-59 Camera

This camera is an extra-cost option which can be used instead of the standard Model C-5 camera when exacting laboratory work calls for a wider range of shutter and lens controls.

b. X-Y (X-Y-T) Recorder

The X-Y recorder is used to record flow-volume loops and, with the optional time base generator (X-Y-T), it can record conventional spirometry.

c. Power Options (not shown)

The system may be ordered for operation on 115 VAC, 50 or 60 Hz or 220 VAC, 50 Hz. Operation from a DC power source can also be arranged. Please consult the factory if these power requirements are indicated.

I.B. MECHANICAL SPECIFICATIONS

B.1. Dimensions

Body Box: 60" High x 30" Wide x 25" Deep
Electronics Console: 40.8" High x 21.75" Wide x 24" Deep
Body Box Volume: 527.2 liters
531.5 liters without calibration equipment box

B.2. Weight

Body Box: 450 lbs. with all accessories
Electronics Console: 180 lbs. with all accessories

I.C. ELECTRICAL SPECIFICATIONS

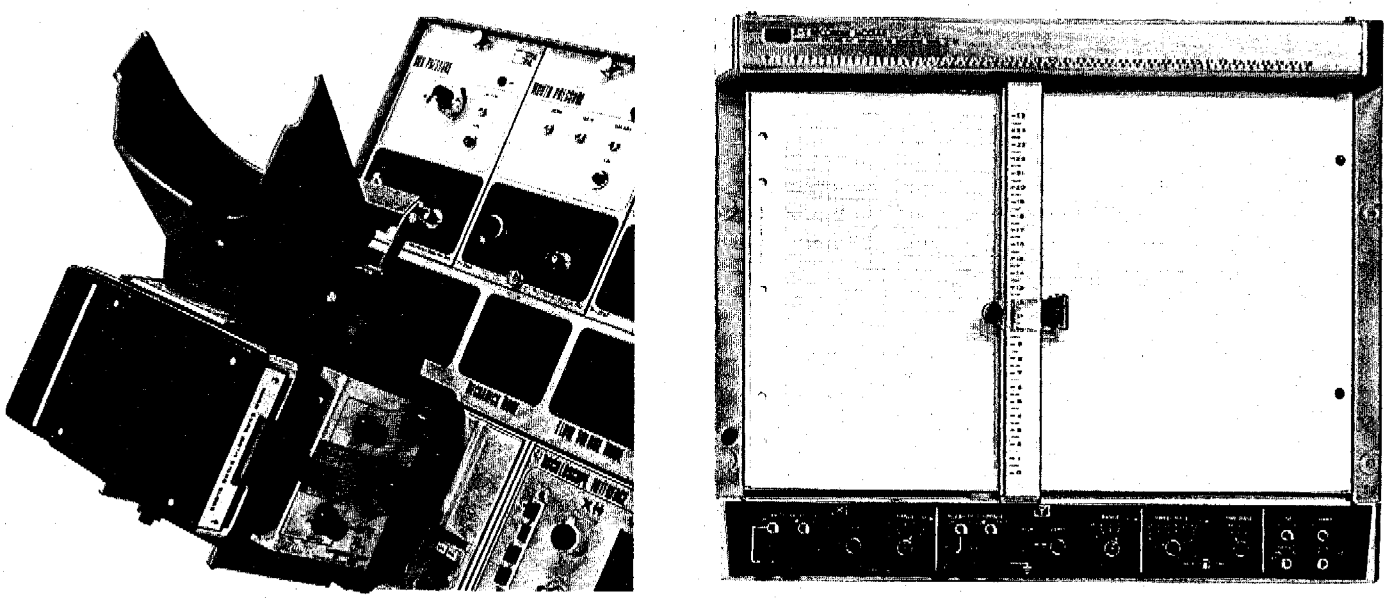
C.1. Operating Ranges

The following are linear within ±½% of the stated ranges.
Box Pressure: ± 2 cm. H_2O
or ± 100 cc. of Box Volume
Mouth Pressure: ± 50 cm. H_2O

The following are linear within ±3% of the stated ranges.
Flow: ± 12 Liters per second
Volume: ± 10 Liters

C.2. Drift

Box Pressure: Unmeasurable due to environmental pressure fluctuation
Mouth Pressure: ± 2mv./hour = 2×10^{-2} cm. Hg/hour



A B

Figure 2 - Optional Equipment for Body Plethysmograph

Flow: 4mv./hour = 8 ml./sec./hour
Volume: 20mv./hour = 20 ml./hour

C.3. Outputs — All outputs are single-ended analog signals, ± 10 volts. All outputs are available on the front panel and may be connected to any high impedance (at least 10 kilohms) recording device.

C.4. Calibration — All calibration is done with self-contained apparatus. Equipment is provided for the calibration of all four amplifiers.

C.5. Transducer Limits — Will withstand 1 atmosphere over pressure without damage.

I.D. ELECTRICAL REQUIREMENTS

Unless otherwise specified on the original order, the Body Plethysmograph operates on 115 VAC, 60 cycle, single phase, 12 amps. Operation from any other power source will seriously damage the instrument. Such damage is not covered by the warranty. The proper power source is noted on a tag near the fuse holder.

II. THEORY

II.A. BACKGROUND AND APPLICATIONS

A.1. In patients with airway disease, flow rate is diminished due to increased resistance to flow and poorly ventilated areas containing what has been called "trapped" gas.

A.2. The body plethysmograph is a closed chamber, measuring slightly over 530 liters, which may be used to determine the actual resistance to air flow in the tracheobronchial tree and the total gas volume in the lung whether in communication with the trachea or not. The body plethysmograph is connected to a console via plastic tubing and electrical wiring; inside the console there are gauges which measure pressure at the mouth proximal to the mouth shutter, inside the chamber and across a calibrated resistance (the pneumotachograph).

A.3. The patient enters the chamber and sits quietly for two to three minutes. During this time, the temperature inside increases due to body heat, and the resultant increase in pressure is vented off. When the temperature and pressure stabilize, testing begins.

A.4. The testing procedures are quite simple from the patient's point of view and usually take four to five minutes depending upon patient cooperation and health. The patient breathes through a mouthpiece attached to a mouth shutter and pneumotachograph which measures flow. The mouth shutter merely closes the inlet to the pneumotachograph at predetermined points during the testing procedure.

A.5. The Collins Body Plethysmograph can be used to measure thoracic gas volume (V_{TG}) [almost the same as functional residual capacity (FRC)], airway resistance (R_{aw}), static and dynamic compliance, maximal voluntary ventilation (MVV), pulmonary resistance and flow-volume loops. If the system is equipped with the optional X-Y-T Recorder, hard copies of spirograms and flow-volume loops are made available.

A.6. Figure 3 is a block diagram which shows the system configuration with the standard and optional equipment.

A.7. A complete description of the testing procedures and calculations can be found in Section VI. and VII.

II.B. STANDARD AND OPTIONAL EQUIPMENT

B.1. Signal Sources
The system uses three pressure transducers, and an associated pneumotachograph, as signal sources. The pneumotachograph, mounted inside the Body Box on an adjustable arm, is linear within ±3% of the reading from 0-12 lps. The three pressure transducers are mounted inside the Electronics Console. The pneumotachograph is coupled to a transducer with a range of ±2 cm. H_2O and ±0.5% linearity. Pressure within the box is measured with an identical unit, while mouth or transpulmonary pressure is measured with a transducer having a range of ±50 cm. H_2O and ±0.5% linearity.

B.2. Amplifiers
The amplifiers for box pressure, mouth pressure and flow are of the carrier-demodulator type while volume is measured with a separate amplifier which integrates flow. Each amplifier is an individual plug-in module with controls for zeroing, gain and calibration. Where necessary, an amplifier is fitted with specialized controls applicable to its particular function.

B.3. Switching Module
The switching module contains the controls needed for selecting the mode of operation. Large push buttons on the right select the group of tests to be enabled, while toggle switches along the rest of the panel choose the exact test within a group to be performed.

B.4. Oscilloscope Interface
After the appropriate signals of interest are selected with the switching module, they are routed to the oscilloscope interface. Controls on this module permit positioning of the trace on the oscilloscope, amplification of either or both channels by fixed amounts (X½, X1 (normal), X2, X5), monitoring of the inputs to the oscilloscope and insertion of external signals for display (when switching module is in **EXT** mode). In addition, the LED display matrix indicates which signals appear on the X and Y axes, eliminating possible confusion.

B.5. Oscilloscope
The monitor oscilloscope (Tektronix Model 603 storage scope) is fitted with a 'snap-on' rotating graticule so that the angles of the displayed curves may easily be read as required for calculations. A convenient tangent table is provided on the panel beneath the oscilloscope.

B.6. Camera
The standard camera is a Tektronix Model C-5 which is

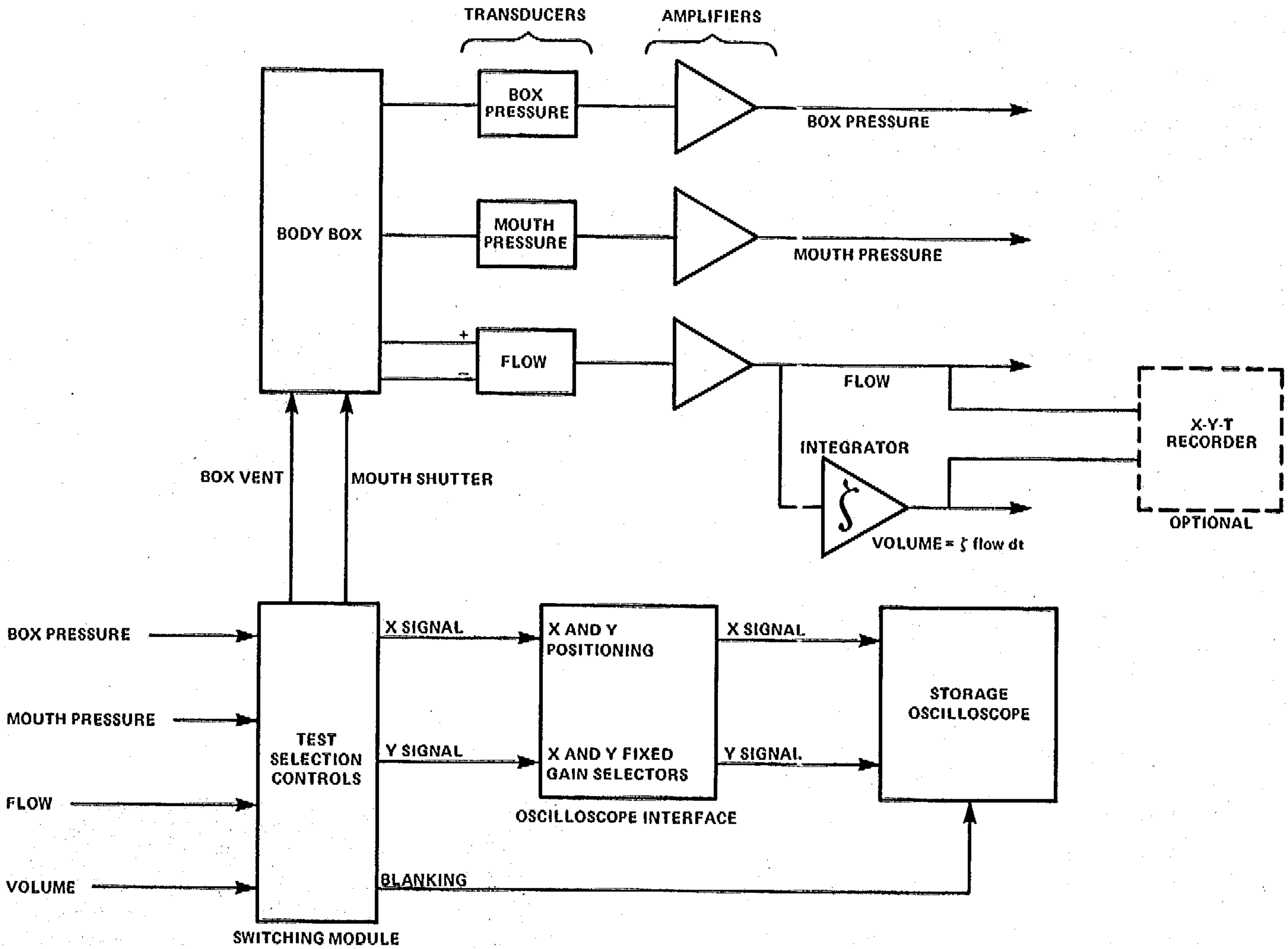


Figure 3 - Block Diagram of Body Plethysmograph

appropriate for general laboratory work. It uses standard Polaroid Type 107 film packs.

B.7. Calibration Equipment
The Body Plethysmograph is equipped with the following calibration equipment.

a. Two rotameters, one for 0-100 lpm, the other for 100-1000 lpm, both for flow calibration.
b. A 30cm water manometer for mouth pressure calibration.
c. A Collins 1 liter syringe for volume calibration.
d. A Collins variable speed, 30 cc. reciprocating pump for box pressure calibration.
e. A variable speed air pump for flow calibration.
f. A hand-held speed control to control the operation of (d) and (e) above.
g. Two sections of hose (A33-13 and A13-34).

B.8. C-59 Camera (Optional)
This Tektronix camera performs the same function as the C-5 camera, but has a much wider selection of shutter and lens controls.

B.9. X-Y Recorder (Optional)
By adding the X-Y recorder to the Body Plethysmograph System, flow-volume loops can be recorded, and if the recorder is fitted with the optional time generator (X-Y-T), conventional spirometry can be recorded.

III. INSTALLATION

III.A. VISUAL CHECK

A.1. This equipment met strict electrical and mechanical quality control standards before leaving the factory. After uncrating, thoroughly inspect the equipment for visual defects such as bent or broken cases, controls, switches, displays or connectors. Contact the factory, local representative and the carrier immediately for instructions on handling damaged equipment.

III.B. GENERAL PRECAUTIONS

B.1. Do not operate the Body Plethysmograph on any voltage other than specified.

B.2. The system must be operated only when the power cord is plugged into a 'U' ground receptacle.

B.3. When using the hand held speed control, always start by turning the knob fully counterclockwise, then rotating it clockwise to the desired calibration setting.

B.4. Erase any stored oscilloscope trace after a particular test is completed, otherwise the life expectancy of the tube is decreased.

B.5. Do not leave the Body Box door in the sealed position when not in use as this can cause the seal to become permanently deformed.

B.6. FORESEEABLE MISUSE - Never leave the box vent activated for more than 2 minutes as this can cause the solenoid to overheat resulting in a blown fuse on the side of the power supply box.

B.7. FORESEEABLE HAZARD - Never leave unattended patients sealed in the Body Box as this may cause panic or hysteria. A doctor or technician must always be present to prevent this condition from occurring.

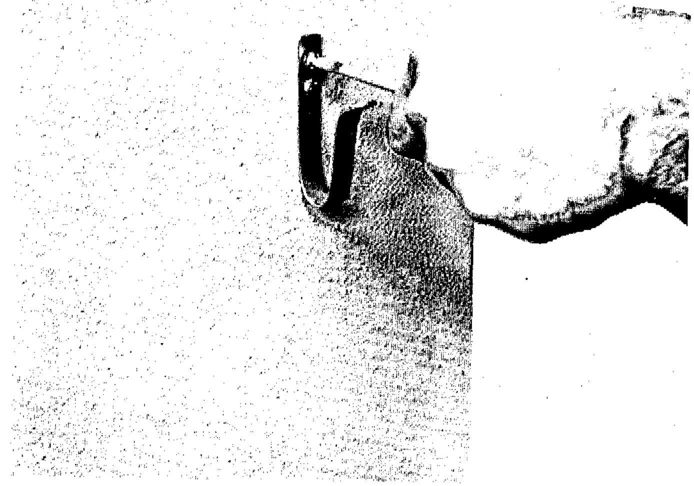


Figure 4 - Installing Power Cord Brace

III.C. SET-UP AND PREPARATION

NOTE: If your system consists of just a Body Box (no Electronics Console), perform steps C.1. - C.4., then proceed to step C.27.

C.1. Make sure all packing material has been removed from inside the Body Box and calibration equipment box.

C.2. Temporarily remove the protective screen from the rear of the Body Box and pull the foam rubber packing from inside. The AC power cord comes out with it. Discard the packing, then replace the screen when the set-up is completed.

C.3. Peel off the protective paper from both sides of the plexi-glass door. Any adhesive left behind can be removed with warm soap and water.

C.4. If necessary, install the power cord braces on the Body Box (2 places) and Electronics Console (1 place) as shown in Figure 4. These braces may already be in place on some units.

NOTE: For the remaining steps of Section III.C., refer to Figures 5, 6, 7 and 8 where necessary.

C.5. Connect the long cable with a 3-pin plug at both ends between the socket labeled **J30 VENT** on the back of the power supply chassis (A of Figure 5a and 5b) and the socket labeled **VENT** on the right side of the Body Box (A of Figure 6).

C.6. Locate the cable with a 9-pin connector on the free end. Plug the connector into the socket on the left side of the Body Box (Figure 7), then tighten the two hold-down screws.

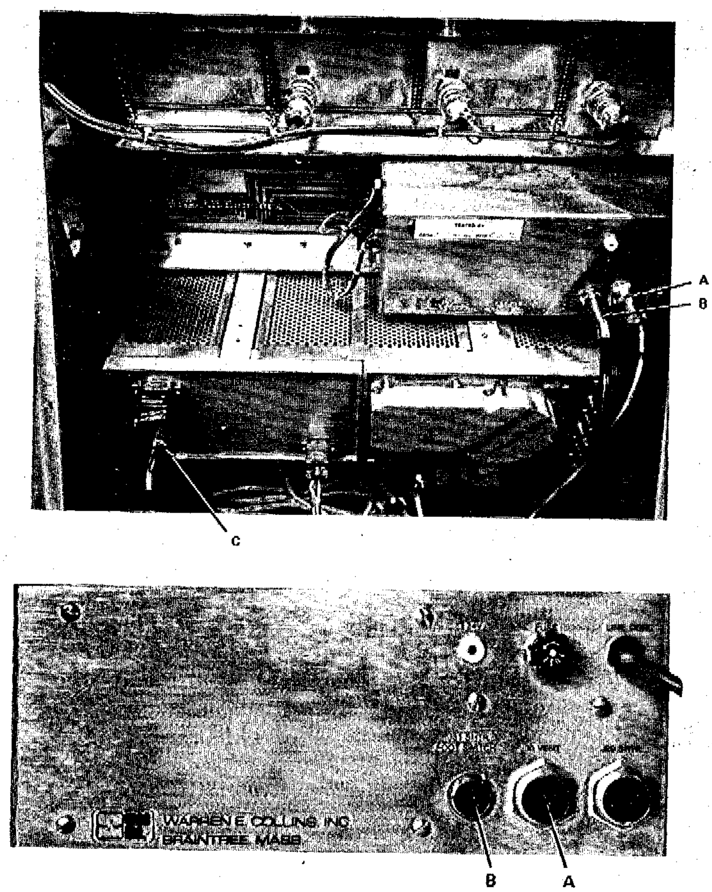


Figure 5 - Cable Connections Inside Electronics Console

C.7. Locate the two remote foot switches. Connect the cable from the one labeled **SHUTTER** to the socket labeled **J31 SHTR FOOT SWITCH** on the back of the power supply chassis (B of Figure 5a and 5b). The cable from the second foot switch marked **ERASE** is connected to the socket on the back of the oscilloscope interface (C of Figure 5b).

C.8. Locate the four loose pieces of plastic tubing. Connect them between the Electronics Console and the Body Box (Figures 7 and 8) as follows:

From (Body Box)	To (Console)
1. BOX +	BOX PRESSURE +
2. MOUTH +	MOUTH PRESSURE +
3. FLOW +	FLOW +
4. FLOW –	FLOW –

NOTE: The small piece of tubing may be connected between the two **AUX** nipples.

C.9. Connect the plug on the end of the speed control cable to the socket labeled **HAND CONTROL** on the right side of the Body Box (B of Figure 6). Place the speed control in the hook provided for it at the top of the Body Box.

C.10. Locate the calibration equipment box. Remove the manometer by grasping the wooden frame and lifting it straight up until it is free from the hooks. Then lower the manometer and bring the top section forward and out of the calibration equipment box.

C.11. Remove the two red shipping plugs at both ends of the manometer as shown in Figure 9, being careful not to spill any of the indicator fluid. If any is spilled, add water mixed with food coloring or water soluble ink until the level is at about 0. Whether or not fluid is added, the exact location of 0 can be adjusted by loosening the two thumb screws as shown in Figure 10, and sliding the scale up or down. **DO NOT ATTEMPT TO MOVE THE GLASS.**

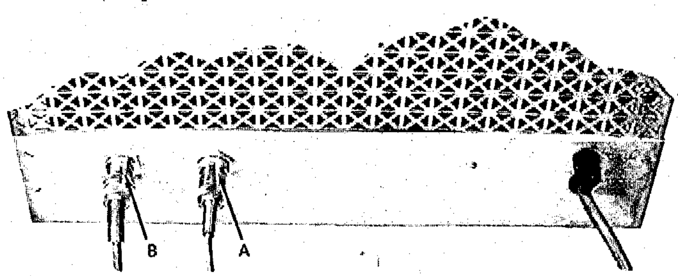


Figure 6 - Cable Connections - Body Box Right Side Panel

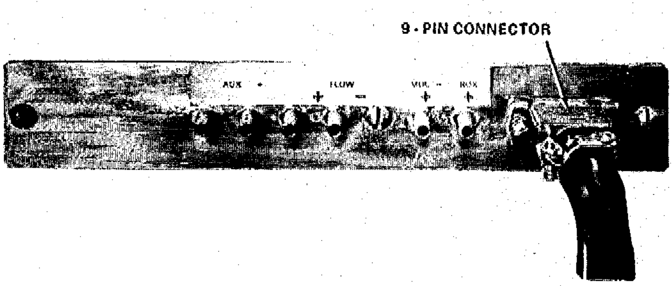


Figure 7 - Body Box - Left Side Connector Panel

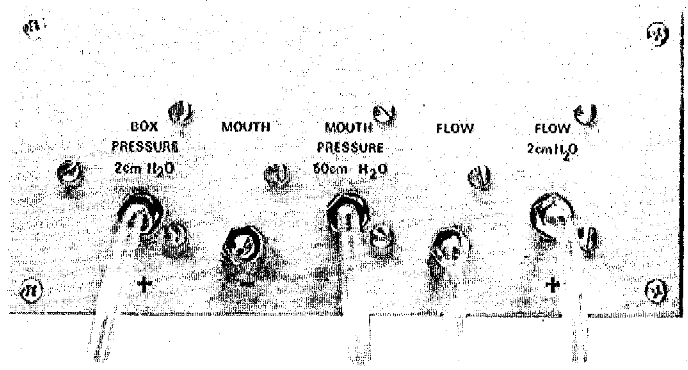


Figure 8 - Electronics Console - Transducer Connector Panel

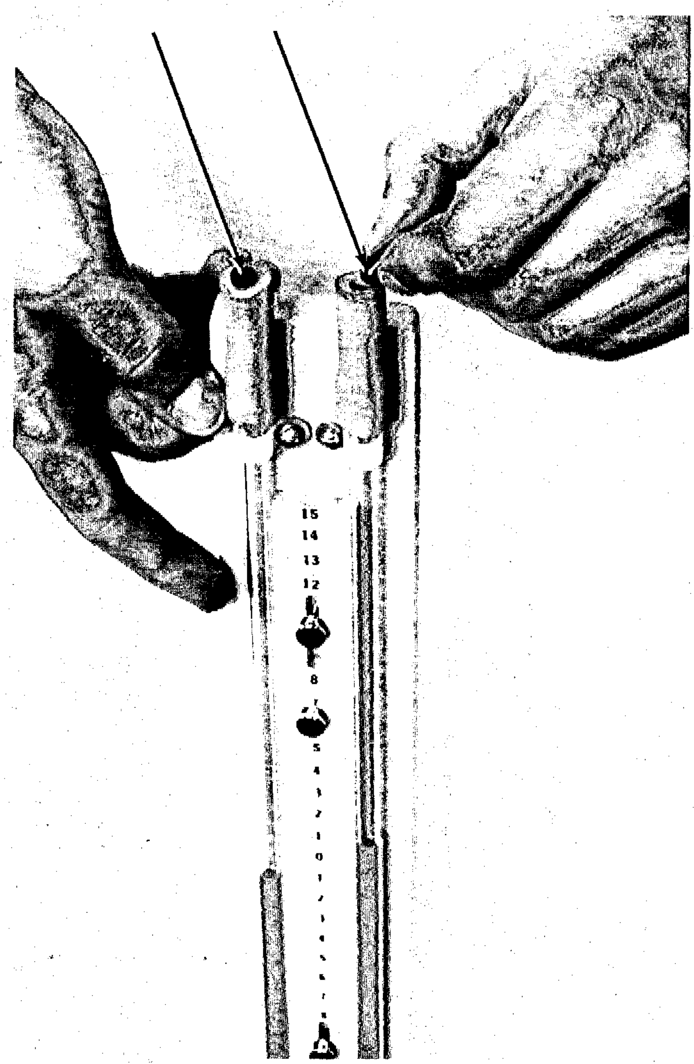


Figure 9 - Removing Shipping Plugs From Manometer

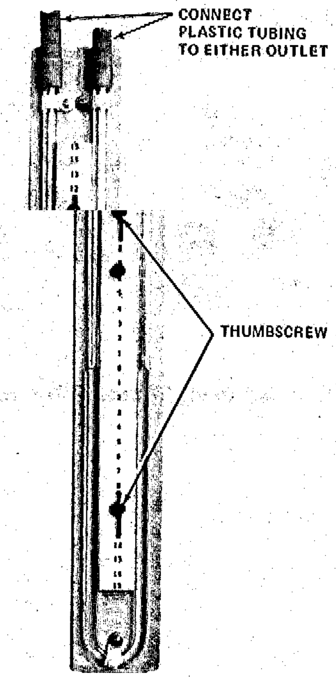


Figure 10 - Manometer

C.12. To reinstall the manometer into the calibration equipment box, insert the bottom end first into the frame. Then connect the single piece of plastic tubing to either outlet of the manometer (refer to Figure 10). Make sure the plastic tubing is inserted far enough into the rubber sleeve to insure leak-free operation. Finally, slip the manometer assembly down over the hook until it locks in place.

C.13. Notice the hook placement on the body box wall and the back of the calibration equipment box as shown in Figures 11 and 12. They are designed to fit together and provide a secure mount for the calibration equipment box.

C.14. Refer to Figure 13. Hold the calibration box against the Body Box wall and, at the same time, against the small shelf in front of the patient. Lower the assembly until it is locked in place on the hooks.

C.15. If the front half of the patient intercom is not installed, do so now. Place it on the rear half of the intercom and gently push on it until it snaps into place.

C.16. Plug the small white cable fitted with a miniature phone plug into the jack on top of the intercom inside the Body Box.

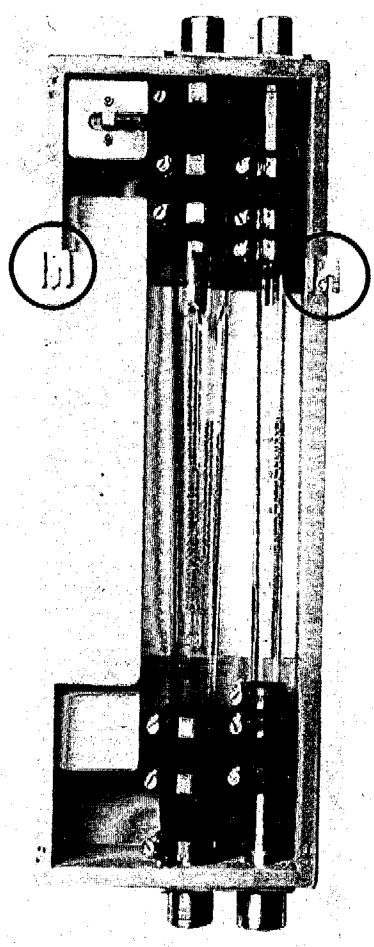


Figure 11
Hooks on Calibration Equipment Box

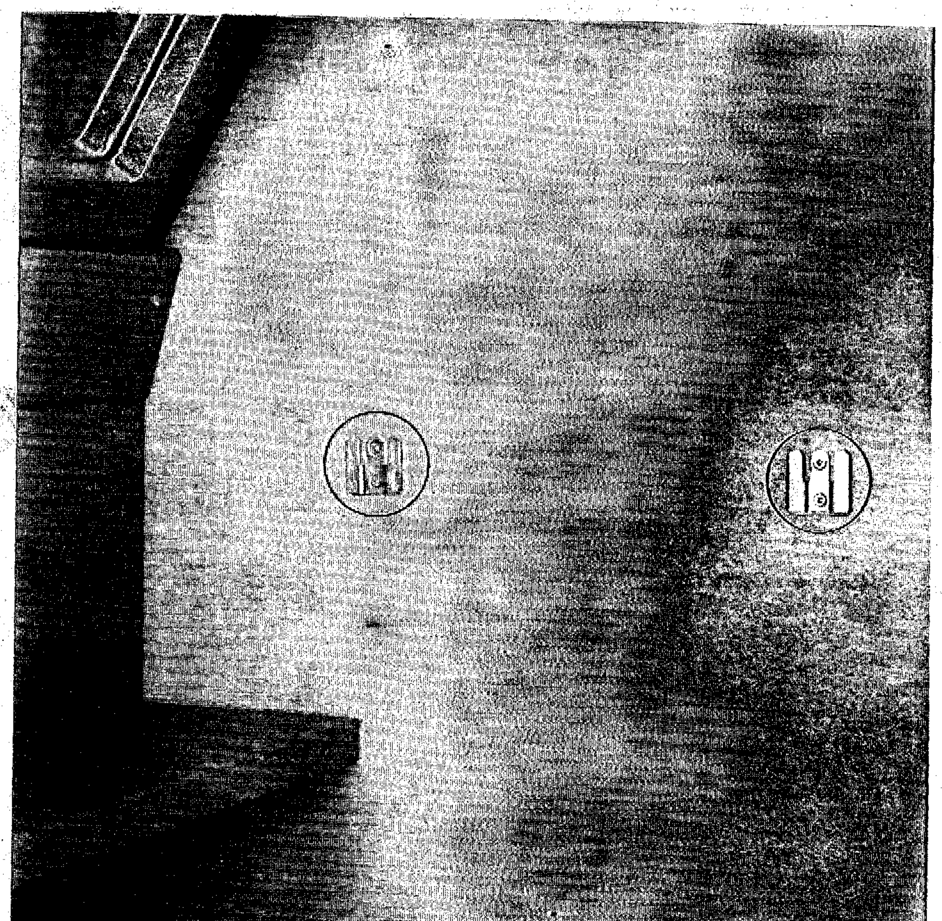


Figure 12 - Hooks on Body Box Wall

NOTE: Refer to Figure 14 for Steps C.17. - C.22.

C.17. Connect the longest piece of plastic tubing (A) running from MOUTH + to the nipple nearest the mouthpiece.

C.18. Connect the next piece of tubing (B) running from FLOW + to the middle nipple on the pneumotachograph.

C.19. Connect the remaining piece of tubing (C) running from FLOW – to the remaining nipple on the pneumotachograph.

C.20. Connect the cable with the blue, 4-pin connector (D) to the socket on the mouth shutter assembly. Insert the connector, then rotate the movable collar to lock it in place.

C.21. Connect the remaining cable with the 5-pin connector (E) to the other socket on the mouth shutter. As before, rotate the collar to lock it in place.

C.22. If the multi-pin connector (F) is not secured, insert it into the connector and tighten the two screws.

C.23. Locate the two large diameter plastic tubes.

C.24. Connect the large diameter end of the longest tube to the top connector attached to the 100-1000 lpm (large) rotameter. Leave the other end disconnected for the time being.

C.25. Connect either end of the short tube to the similar connector at the bottom of the large rotameter. Again, leave the other end disconnected.

C.26. Plug the AC power cords from the Electronics Console and the Body Box into the appropriate power source.

C.27. For the cable connections of the manual Body Box (no Electronics Console), refer to Figure 15. Connect as follows:

A - To mouth shutter foot switch.
B - To hand held speed control.
C - To flow calibration air pump.
D - To box vent solenoid - 4 pin.
E - To box pressure calibration pump - 3 pin.
F - To pneumotachograph mouth shutter - 5 pin.

C.28. After the connections have been made, plug the AC power cord into the appropriate power source. Push the power switch (G) and check for proper operation.

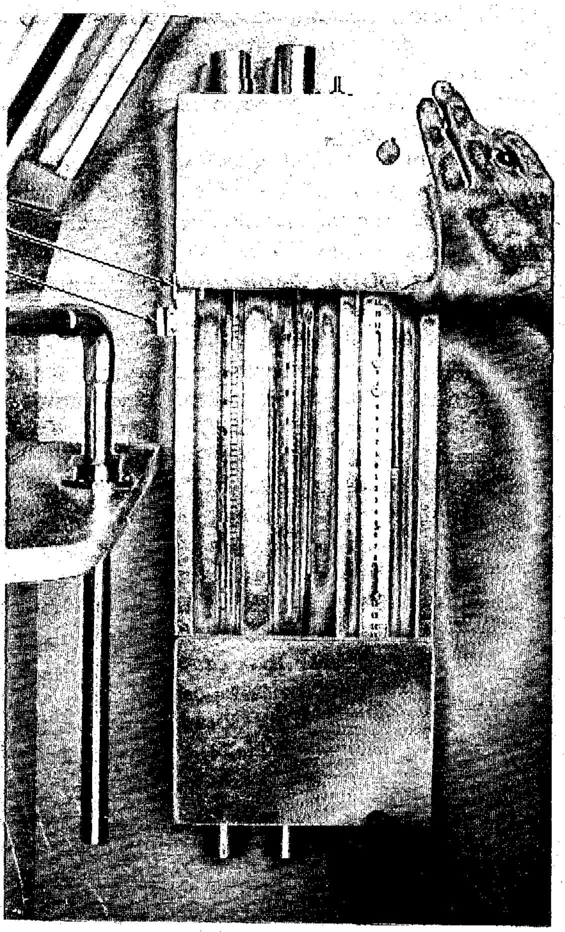


Figure 13 - Installing Calibration Equipment Box

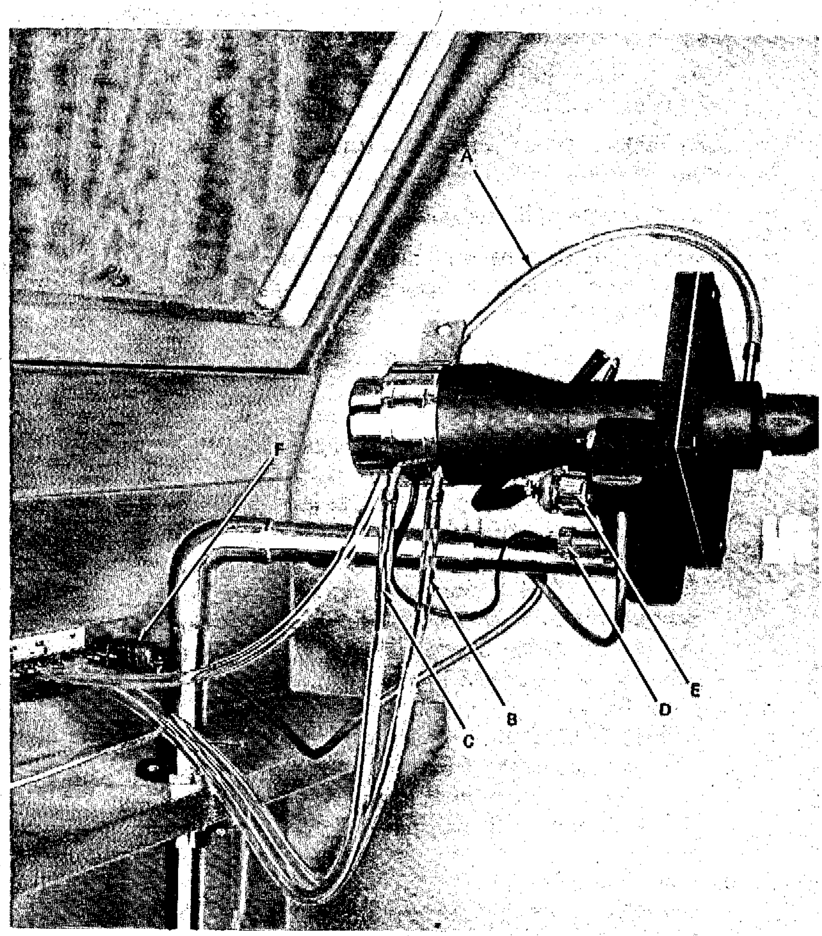


Figure 14 - Cable and Tubing Connections Inside Body Box

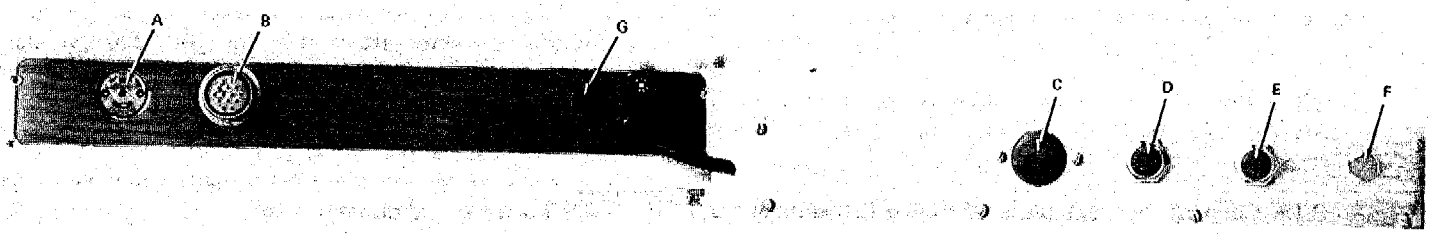


Figure 15 - Cable Connections - Manual Body Box

IV. OPERATION

IV.A. CONTROLS, CONNECTORS AND DISPLAY (Refer to Figure 16)

The function of each control, connector and display is described briefly in the following sections. Where more information is desired, another section of this manual or the manufacturer's manual (where applicable) may be referenced.

A.1. Amplifiers

The four amplifiers are provided with the following front panel controls:

ZERO: Allows setting the amplifier baseline to exactly zero volts.

GAIN: Allows varying the gain from zero to approximately 2 times the normal operating level.

CAL: Pushing this button produces a 3 division calibration signal to check the amplifier gain.

CAL ADJ.: Allows setting the **CAL** signal to exactly 3 major divisions on the oscilloscope.

ON: Red light indicates power is on.

OUT: Allows connecting the amplifier output to an external high impedance recording or display device. The signal range is ± 10 volts.

The following controls are unique to the individual amplifiers:

a. Box Pressure Amplifier
   WEIGHT-LBS: The patient's weight is entered *after* calibration to compensate for the internal free air volume displaced by the patient in the Body Box.

b. Mouth Pressure Amplifier
   LOOP-CLOSE: 'Closes the loop' during the performance of resistance and compliance plots by subtracting a percentage of volume or flow. Subtraction is completely stopped when the control is turned fully counterclockwise to the 'snap' position.

c. Flow Amplifier
   OPERATE/ZERO: With no flow through the pneumotachograph, a baseline on the oscilloscope is automatically established in the **ZERO** position. For normal operation, the switch is left in the **OPERATE** position.

d. Volume Amplifier
   OPERATE/ZERO: Operates similarly to the **OPERATE/ZERO** switch on the Flow Amplifier.
   NORMAL/MBC: In the **NORMAL** mode, flow is integrated both ways, so the volume signal is the integral of all flow, both positive and negative. In the MBC mode, only positive flow is integrated to allow measurement of MBC (MVV - Maximal Voluntary Ventilation) on the oscilloscope or optional X-Y-T recorder. As a convenience, the gain is divided by a factor of ten in this mode.

A.2. Switching Module

a. **MODE SELECT:** These pushbuttons select the mode of operation as follows:
   1. **ON:** Turns on all power to the Electronics Console, except the oscilloscope and pneumotachograph heater.
   2. **BB:** Permits performance of tests using the Body Box such as V_{TG} and R_{aw} (airway resistance).
   3. **MEC:** Permits performance of mechanics studies such as compliance (static and dynamic) and resistance.
   4. **F/V:** Permits flow-volume loops to be displayed on the oscilloscope.
   5. **EXT:** Permits use of oscilloscope to display external signals which are connected to the **EXT IN** connectors on the oscilloscope interface.

b. Toggle Controls, Left to Right
   1. **BODY BOX MODE:** Controls Body Box functions as follows:
      A. **BOX VENT SWITCH:** Allows box pressure to equilibrate with atmospheric pressure in the up (permanent) or down (momentary) position, while lighting light. Center position **(OFF)** isolates box pressure from atmosphere while tests are conducted. DO NOT leave this switch in either the up or down position for more than 2 minutes as this can cause the solenoid coil to overheat and blow a fuse.
      B. **DISPLAY SELECT SWITCH:** Allows choice of **BP/FLOW** (box pressure/flow display), display off, or **BP/MP** (box pressure/mouth pressure display). In the last position, the mouth shutter is automatically closed.
   2. **MECHANICS MODE SWITCH:** Allows choice of **P - $\frac{V}{C}$ / FLOW**, display off, or **P - F•R/VOLUME**.
   3. **FLOW-VOLUME MODE SWITCH:** Allows choice of displaying flow-volume loops or turning the display off.

A.3. Oscilloscope Interface

a. **X-POSITION, Y-POSITION:** These controls allow

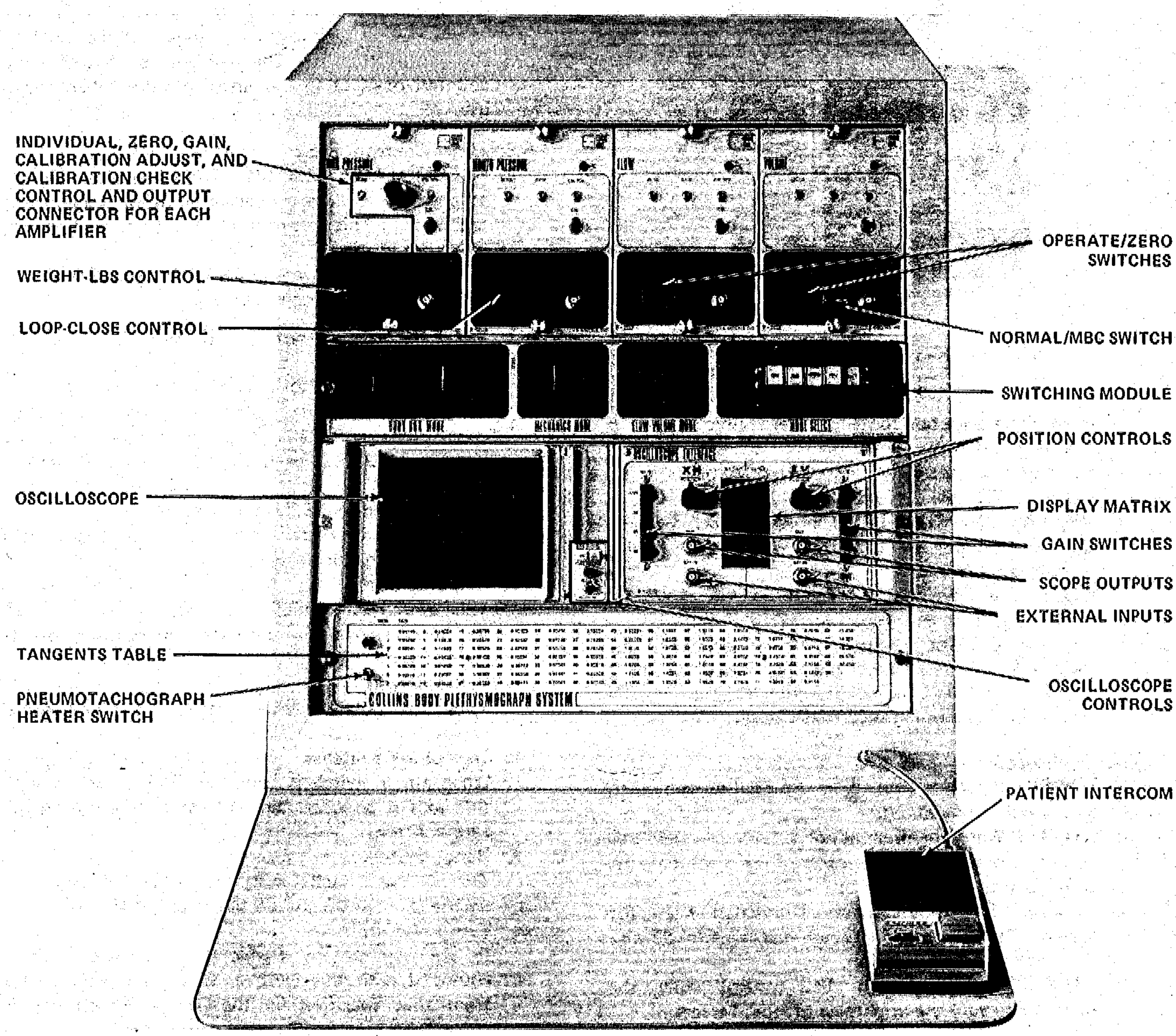


Figure 16 - Electronics Console - Front Panel Controls

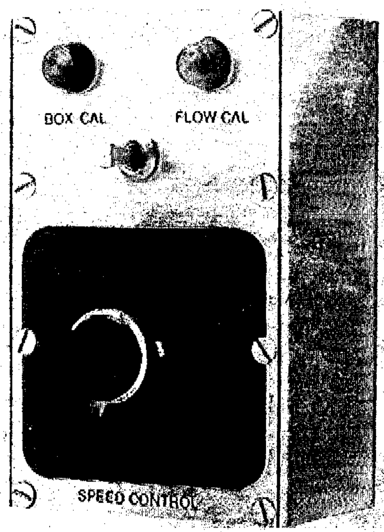


Figure 17 - Hand Held Speed Control

moving the trace horizontally or vertically.

b. **X-GAIN, Y-GAIN:** These controls increase the gain (size) of the display by the indicated factors (½X, 1X (normal), 2X, 5X).

c. **DISPLAY MATRIX:** LED's indicate which signal is displayed on the X and Y axes. When no light is lit, the display is blanked.

d. **OUT:** The signals as displayed on the scope are available at these connectors for external display.

e. **EXT IN:** External signals may be connected here for display on the scope when the Electronics Console is in the **EXTERNAL** mode. The **POSITION** and **GAIN** controls are still functional in this mode.

A.4. Oscilloscope

a. **POWER:** Power is applied to the oscilloscope when this switch is pulled out.

b. **STORE:** When the oscilloscope is turned on, and this button is pushed, traces are stored for measurements or photographs.

c. **ERASE:** Stored traces are eliminated from the screen. The remote foot switch marked **ERASE** also performs the same function.

d. **STORED BRIGHTNESS:** This control allows the operator to vary the brightness of stored traces.

NOTE: The use of the oscilloscope and oscilloscope interface is explained in detail in Sections V. and VI.

A.5. Speed Control (Refer to Figure 17)

a. The three position switch allows for selection of either the calibration pump (**BOX CAL**) or the vacuum pump (**FLOW CAL**) during calibrating procedures. The red or orange light indicates which position is selected. The center position is **OFF**. The variable control changes the speed of the selected pump as required. The control is rotated fully counterclockwise to the 'snap' position when not in use.

A.6. Other Controls, Etc.

a. **PNEUMOTACH HEATER:** Turns heater on (or off) to prevent moisture condensation inside the pneumotachograph. This control should be turned off (down) when not in use.

b. **TANGENTS:** This convenient table supplies all tangent values for test computations.

A.7. X-Y-T Recorder - Front Panel (Figure 18)

a. Input Terminals

Each axis has an input terminal labeled **HI-LO** and accepts banana plug connectors (supplied). When connections are made, the side of the connector marked **GROUND** or **GND** is inserted into the **LO** side.

b. Polarity Switches (-RT, +RT, -UP, +UP)

These switches provide polarity reversal for the input signal on each axis.

c. Response Switch

This switch is provided on both axes. The **FAST** position is used when recording flow-volume loops or spirograms.

d. Zero Controls

These two potentiometers, one for each axis, adjust the pen's zero position on the chart paper.

e. Zero Check Switches

When either switch is depressed, the input signal to that axis is disconnected and the pen returns to its zero position.

f. Range Switches

The selector switch for each axis has five calibrated positions ranging from .05 V/CM to 1.0 V/CM.

g. Vernier Controls

In addition to the Range Switches, each axis is equipped with this control. It alters the sensitivity from that specified by the Range Switch and is generally left fully clockwise (calibrated).

h. Time Base Switch

This three position switch allows the time base

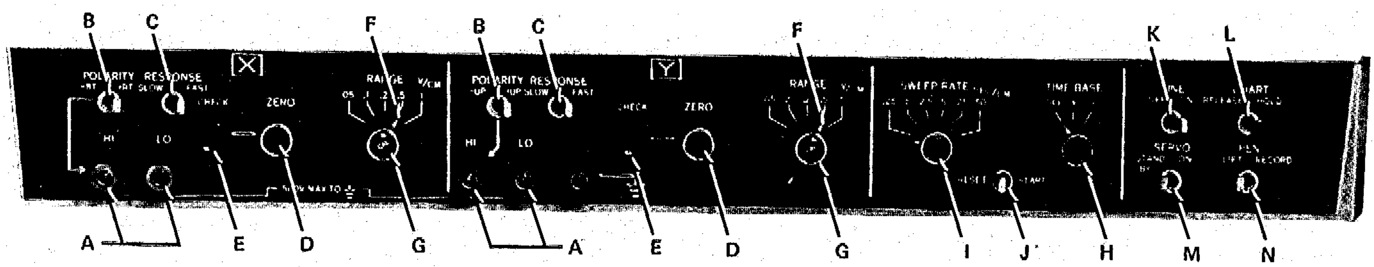


Figure 18 - X-Y-T Recorder - Front Panel Controls

portion of the recorder to be turned **OFF** or to sweep either the X or Y axis.

i. Sweep Rate Switch
This switch allows selection of six sweep rates ranging from .25 SEC/CM to 50 SEC/CM.

j. Reset/Start Switch
This momentary switch has two positions. The **RESET** position stops the sweep cycle, lifts the pen and resets it to the original starting position. In the **START** position, the pen drops and sweeps the chart paper on the X or Y axis at the selected rate.

k. Line Switch
This switch applies power to the recorder.

l. Chart Switch
In the **HOLD** position, the chart paper is automatically held to the plotting surface. The paper is removed by moving the switch to **RELEASE.**

m. Servo Switch
The pen position can be adjusted manually when the switch is set to **STAND BY.** When tests are to be recorded, the switch is left in the **ON** position.

n. Pen Switch
The pen is raised from the chart paper when in the **LIFT** position. The **RECORD** position then drops the pen.

IV.B. INITIAL TURN ON AND CHECKOUT

NOTE (1): Assemble all components and cables as described in Section III.C.

NOTE (2): Where an instruction calls for the use of the mouth shutter or the oscilloscope **ERASE** switch, either the appropriate switches on the Electronics Console or the remote foot switches may be used.

B.1. Turn on the Electronics Console by pushing the **ON** button in the **MODE SELECT** section of the switching module.

B.2. Turn on the oscilloscope by pulling the knob marked **POWER** (Figure 16). About 5 minutes is required for proper warm-up.

NOTE: On the brand new oscilloscopes, the tube must be conditioned so that the storage feature operates properly. After the scope has been turned on for the first time, push the **STORE** button - the screen turns green. After ½ hour, push the **ERASE** button, then push the **STORE** button again to take the scope out of the store mode.

B.3. Turn on the pneumotachograph heater by pushing up the **HEATER** switch (to the left of the tangents table). Allow the heater to warm-up for about 5-10 minutes or until the pneumotachograph is warm when touched.

B.4. Push the **1X GAIN** switch on the X and Y axes of the oscilloscope interface.

B.5. Push the **EXT** button and center the oscilloscope trace (dot) using only the X and Y **POSITION** controls on the oscilloscope interface. The normal position for these controls is with their pointers about straight up. The position controls located behind the oscilloscope's plastic access door are factory set and normally need no adjustment.

B.6. Check the calibration of each amplifier module. To do this, connect each amplifier to the oscilloscope interface by moving the appropriate switches (refer to Table 1) on the switching module, then push its **CAL** button. A deflection of 3 major divisions should be observed. If any amplifier is not properly calibrated, do not simply change the **GAIN** control or **CAL ADJ** control to produce the correct deflection. Recalibrate as described in Section V.

B.7. Check the operation of the box vent control and the mouth shutter. Refer to the troubleshooting section if trouble arises.

B.8. Return all the switches to their original position.

TABLE 1

CALIBRATION CHECKS

TO CHECK	MODE SELECT	MOVE	TO POSITION
Box Pressure Amplifier (1) (2)	BB	Right Hand Switch of Body Box Mode	BP/FLOW (UP)
Mouth Pressure Amplifier (2)	BB	Right Hand Switch of Body Box Mode	BP/MP (DOWN)
Flow Amplifier	BB	Right Hand Switch of Body Box Mode	BP/FLOW (UP)
		and	
		Operate/Zero Switch	OPERATE (UP)
Volume Amplifier	F/V	Flow Volume Mode Switch	VOL/FLOW (UP)
		and	
		Operate/Zero Switch	ZERO (DOWN)

(1) Trace jitters slightly due to environmental pressure fluctuations.

(2) **WEIGHT-LBS** and **LOOP CLOSE** controls fully counterclockwise to check calibration.

V. ADJUSTMENTS AND CALIBRATIONS

NOTE: All the calibration factors referenced in this section are stated with the oscilloscope interface **GAIN** switches in the **1X** position, whether or not the actual calibrations are performed at a different setting.

V.A. PREPARATORY STEPS FOR CALIBRATION

A.1. Perform Steps B.1., B.2., and B.3. as described in Section IV.B. In addition, disconnect either end of the large diameter tube going into the Body Box seat.

V.B. BOX PRESSURE AMPLIFIER

B.1. Open the Body Box door.

B.2. Move the **BOX VENT** switch to **CLOSE** (center position).

B.3. Push the **1X GAIN** switch on the X axis of the oscilloscope interface.

B.4. Push the **EXT** switch on the **MODE SELECT** section of the switching module. Center the trace using the X and Y axis **POSITION** controls.

B.5. Push the **BB** switch on the **MODE SELECT** section of the switching module.

B.6. Move the right-hand switch of the **BODY BOX MODE** section of the switching module to **BP/FLOW.** Using the **ZERO** control on the Box Pressure Amplifier, center the trace to within one division of center.

B.7. Move the **BOX VENT** switch to **OPEN**, then seal the Body Box by closing the door and locking the five handles. Because of the sudden increase in the pressure inside the box, the trace may go off the edge of the screen, then reappear. Move the **BOX VENT** switch to **CLOSE.** A gradual temperature change inside the Body Box may cause the trace to drift somewhat to the right or left. If this occurs, depress the **BOX VENT** switch occasionally to **MOM. OPEN** until the position of the trace stabilizes.

B.8. Set the Box Pressure Amplifier **WEIGHT-LBS** control to zero.

B.9. Move the toggle switch on the hand-held speed control to **BOX CAL.** Adjust the control until the oscilloscope trace moves left to right at a rate of three to four complete cycles per second.

B.10. Place the oscilloscope in the store mode by pushing the **STORE** button, then the **ERASE** button once to clear the green color.

B.11. Move the trace slowly up and down the screen with the Y axis **POSITION** control.

B.12. As the trace is moved up and down, adjust the Box Pressure Amplifier **GAIN** control until the *peak* to *peak* deflection measures three major divisions on the scope (Figure 19). The normal setting of this **GAIN** control is about 70-130. Do not be alarmed if your unit requires a slightly different adjustment.

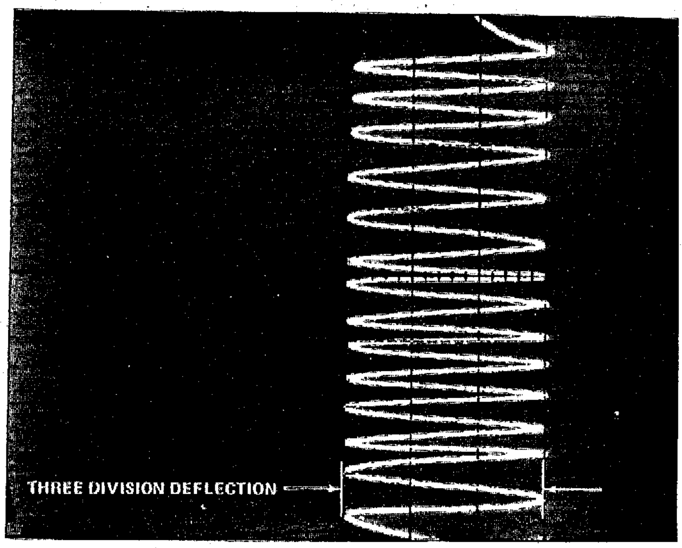


Figure 19 - Calibration of Box Pressure Amplifier

B.13. After the adjustment is completed, proceed as follows:

a. Lock the Box Pressure Amplifier **GAIN** control.
b. Move the toggle switch on the hand-held speed control to the center position.
c. Push the oscilloscope **STORE** button to take the unit out of the store mode.
d. Push the **EXT** switch in the **MODE SELECT** section of the switching module and reposition the trace to the center of the screen using the X and Y axes **POSITION** controls.

B.14. Push the **BB** switch in the **MODE SELECT** section, depress the Box Pressure Amplifier **CAL** button and observe the deflection on the screen. If a three major division deflection is not observed, adjust the **CAL ADJ** control as needed.

B.15. The Box Pressure Amplifier is now calibrated to 10cc/division.

V.C. MOUTH PRESSURE AMPLIFIER

C.1. Open the Body Box door.

C.2. Push the **EXT** switch in the **MODE SELECT** section of the switching module. Center the trace using only the X and Y axes **POSITION** controls on the oscilloscope interface.

C.3. Push the **MEC** switch on the **MODE SELECT** section of the switching module, then move the **MECHANICS MODE** switch to **P** - $\frac{V}{C}$ **/ FLOW.**

C.4. Rotate the **LOOP CLOSE** control fully counterclockwise until a 'click' is heard.

C.5. Push **2X** on the X axis of the oscilloscope interface.

C.6. Locate the length of tubing inside the Body Box running from the nipple labeled **MOUTH +** to the pneumotachograph mouth shutter. Remove the end connected to the mouth shutter and connect it to the nipple labeled

MOUTH PRESSURE LINE on top of the calibration equipment box as shown in Figure 20.

C.7. Notice that a very small variation in the manometer water level occurs. Return the two columns to equal height by turning the **CAL MOUTH PRESSURE** knob. If necessary, center the trace on the oscilloscope screen using the Mouth Pressure Amplifier **ZERO** control.

C.8. Refer to Figure 20. Turn the **CAL MOUTH PRESSURE** knob to displace one water column exactly 5 cm., thus moving the other column 5 cm. in the opposite direction. This displacement produces a total pressure change of 10 cm. H_2O.

C.9. Observe the scope and notice that the trace has moved approximately four major divisions to the right or left of center. If necessary, adjust the Mouth Pressure Amplifier **GAIN** control until the trace moves exactly four major divisions from the center.

NOTE: After this portion of the calibration is complete, it is a good idea to turn the **CAL MOUTH PRESSURE** knob back to its original starting position. This does not have to be done, but insures that there will be adequate rotation left on the shaft the next time the manometer is used.

C.10. Remove the tube from the nipple on the manometer and return it to the pneumotachograph mouth shutter.

C.11. Return the X axis gain setting to **1X**.

C.12. Depress the Mouth Pressure Amplifier **CAL** button and observe the deflection on the screen. If a three major division deflection is not observed, adjust the **CAL ADJ** control as needed.

C.13. The Mouth Pressure Amplifier is now calibrated to 5 cm. H_2O/division.

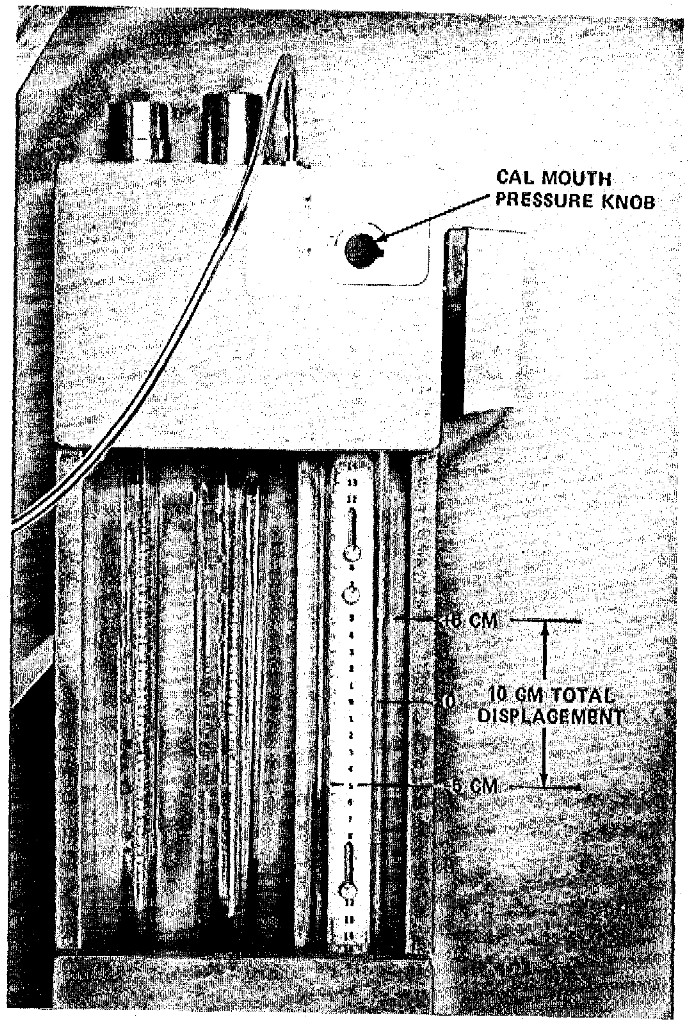


Figure 20 - Calibration of Manometer

V.D. FLOW AMPLIFIER

D.1. Open the Body Box door.

D.2. Push the **1X GAIN** switch on the X and Y axes of the oscilloscope interface.

D.3. Push the **EXT** switch on the **MODE SELECT** section of the switching module. Center the trace using only the X and Y **POSITION** controls on the oscilloscope interface.

D.4. Push the **F/V** switch on the **MODE SELECT** section of the switching module.

D.5. Move the **FLOW-VOLUME MODE** switch of the switching module to **VOL/FLOW**.

D.6. Move the **OPERATE/ZERO** switch on the Flow and Volume Amplifiers to the **ZERO** position.

D.7. Push the **5X GAIN** switch on the X and Y axes of the oscilloscope interface.

D.8. Adjust the Flow Amplifier **ZERO** control until switching between **F/V** and **EXT** on the switching module produces the smallest Y axis deflection. Any X axis deflection indicates that the Volume Amplifier **ZERO** control needs adjustment.

D.9. Push the **1X GAIN** switch on the X and Y axes of the oscilloscope interface.

D.10. Rotate the knob on the hand-held speed control fully counterclockwise to the 'snap' position, then move the toggle switch to the **FLOW CAL** position.

D.11. Connect the short hose from the Body Box seat to the 100-1000 lpm rotameter (large diameter tube). When sickly patients are to be tested, use the 0-90 lpm rotameter.

D.12. Connect the long hose from the top of the selected rotameter to the mouth shutter opening.

D.13. Return the Flow Amplifier **OPERATE/ZERO** switch to **OPERATE**. Position the trace one major division from the bottom of the screen with the Y axis **POSITION** control.

D.14. Move the **BOX VENT** switch to **OPEN**.

.15. Rotate the knob on the hand-held speed control

Figure 21 - Correct Way to Read Rotameter

slowly until the rotameter reads 480 lpm (8 LPS). The correct way to read the rotameter is shown in Figure 21.

D.16. At this flow rate, the trace should move up four major divisions from where it started. If necessary, adjust the trace to this point using the Flow Amplifier **GAIN** control. The trace may jitter around due to high frequency noise in the pump signal.

NOTE: When the small rotameter is used for calibration, adjust the flow to 60 lpm (1 LPS). This flow rate should produce a ½ major division deflection. If the proper deflection is not observed, adjust the Flow Amplifier **GAIN** control as necessary.

D.17. Return the toggle switch on the hand-held speed control to the center position and turn the knob fully counterclockwise until a 'click' is heard.

D.18. Reposition the trace to the center of the screen using the Y axis **POSITION** control.

D.19. Depress the Flow Amplifier **CAL** button and observe the deflection on the screen. If a three major division deflection is not observed, adjust the **CAL ADJ** control as needed.

D.20. Move the **BOX VENT** switch to **CLOSE**.

D.21. The Flow Amplifier is now calibrated to 2 liters/sec./division.

D.22. Disconnect the long and short sections of hose.

V.E. VOLUME AMPLIFIER

E.1. Open the Body Box door.

E.2. Push the **IX GAIN** switch on the X and Y axes of the oscilloscope interface.

E.3. Push the **EXT** switch on the **MODE SELECT** section of the switching module. Center the trace using only the X and Y axes **POSITION** controls.

E.4. Push the **F/V** switch on the **MODE SELECT** section of the switching module.

E.5. Move the **OPERATE/ZERO** switch on the Flow and Volume Amplifiers to the **ZERO** position.

E.6. Move the **NORMAL/MBC** switch to the **NORMAL** position.

E.7. Move the **FLOW-VOLUME MODE** switch of the switching module to **VOL/FLOW.**

E.8. Push the **5X GAIN** switch on the X and Y axes of the oscilloscope interface.

E.9. Adjust the Volume Amplifier **ZERO** control until switching between **F/V** and **EXT** on the switching module produces the smallest X axis deflection. Any Y axis deflection indicates that the Flow Amplifier **ZERO** control needs adjustment.

E.10. Push the **1X GAIN** switch on the X and Y axes of the oscilloscope interface.

E.11. When using the 1 liter syringe for calibration, push the **5X GAIN** switch on the X axis of the oscilloscope interface. When using the 3 liter syringe, push the **1X** switch.

E.12. Move the trace two major divisions to the left of the center using the X axis **POSITION** control.

E.13. Refer to Figure 22. Connect one end of the long hose to the mouth shutter opening and the other end to the syringe. Pull the syringe handle fully back.

E.14. Return the Flow and Volume Amplifier **OPERATE/ZERO** switches to **OPERATE.** Push the plunger in quickly and evenly so that the syringe empties at a rate of about 1 liter/sec.

E.15. Adjust the Volume Amplifier **GAIN** control so that the trace is five major divisions to the right of the starting

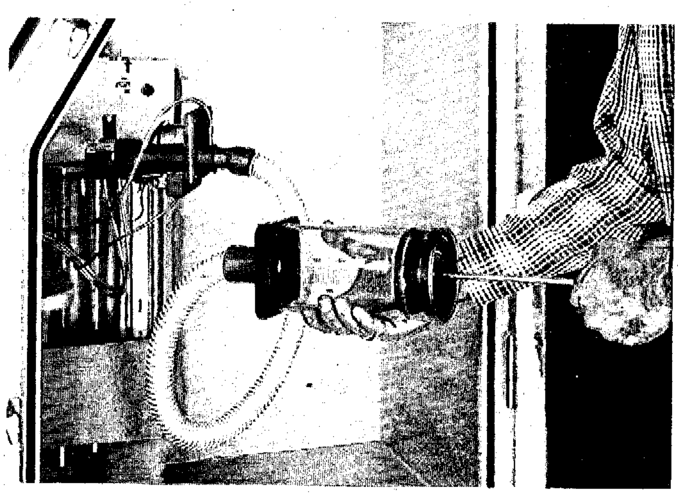


Figure 22 - Connecting Syringe to Pneumotachograph

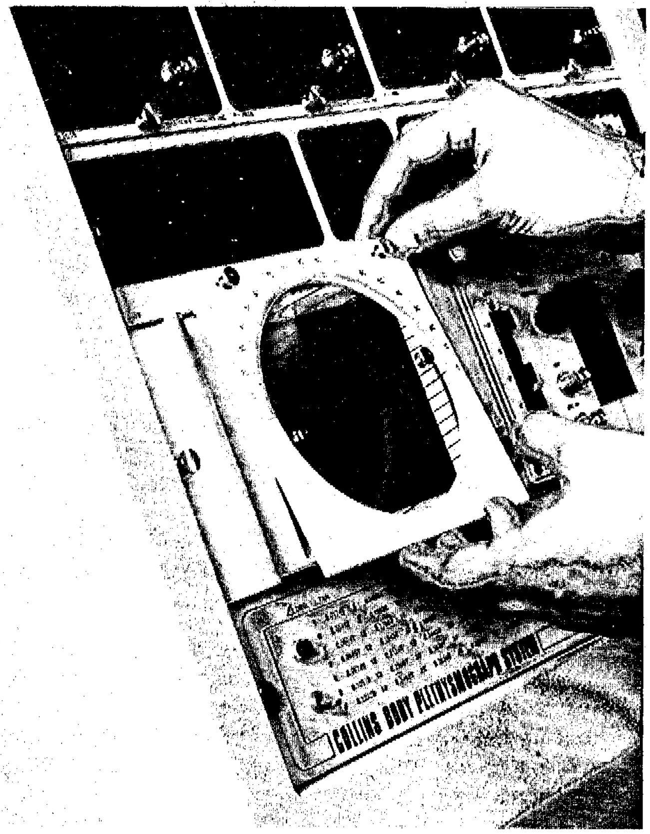


Figure 23 - Placing Graticule on Oscilloscope

point (3 major divisions for the 3 liter syringe).

E.16. Move the Volume Amplifier **OPERATE/ZERO** switch to **ZERO** then back to **OPERATE**.

E.17. Push the **1X GAIN** switch on the X axis of the oscilloscope interface, then reposition the trace to the center of the screen using the X and Y axes **POSITION** controls.

E.18. Depress the Volume Amplifier **CAL** button and observe the deflection on the screen. If a three major division deflection is not observed, adjust the **CAL ADJ** control as needed.

E.19. The volume amplifier is now calibrated to 1 liter/division.

VI. PERFORMING TESTS

VI.A. GENERAL

A.1. Once a day, after the Body Plethysmograph System is turned on, and prior to any testing, the calibration of the amplifiers to be used must be checked and corrected if necessary. The checkout procedure is described in Section IV.B., while the calibration procedures are described in Section V.

A.2. Once the system is operating properly, it is not necessary to recheck any of the amplifiers unless trouble arises or any of the adjustments are inadvertently changed. A daily calibration check is sufficient.

A.3. The special rotating graticule supplied is designed for easy installation and removal and mounts on the front of the oscilloscope screen. To install the graticule, hang it by the top brackets (Figure 23), then push on the bottom edge until it snaps into place (Figure 24). To remove the graticule, simply pull it by the bottom edge until the brackets release.

A.4. Recording angles with the graticule is a simple task. Refer to Figure 25. When a satisfactory trace has been stored, rotate the center section of the graticule until one of the fine hairlines is parallel to the desired angle of the trace. Then, follow the center hairline over to the scale and read the tangent of the angle (in degrees).

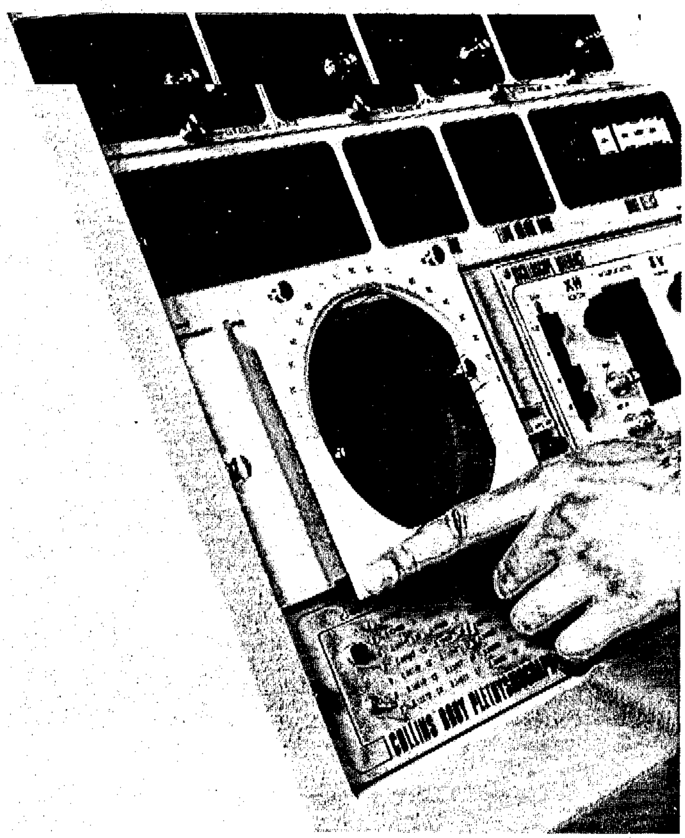


Figure 24 - Securing Graticule on Oscilloscope

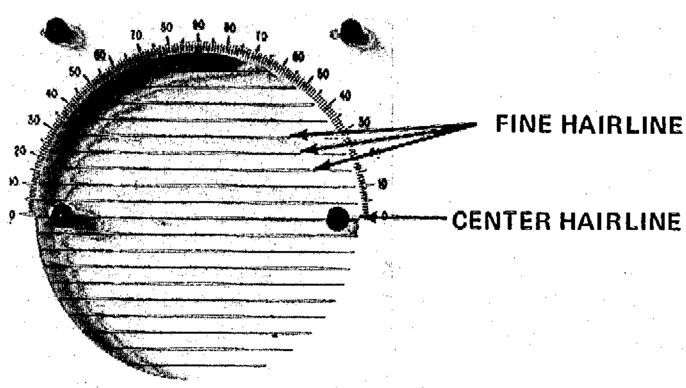


Figure 25 - Reading Angles With Graticule

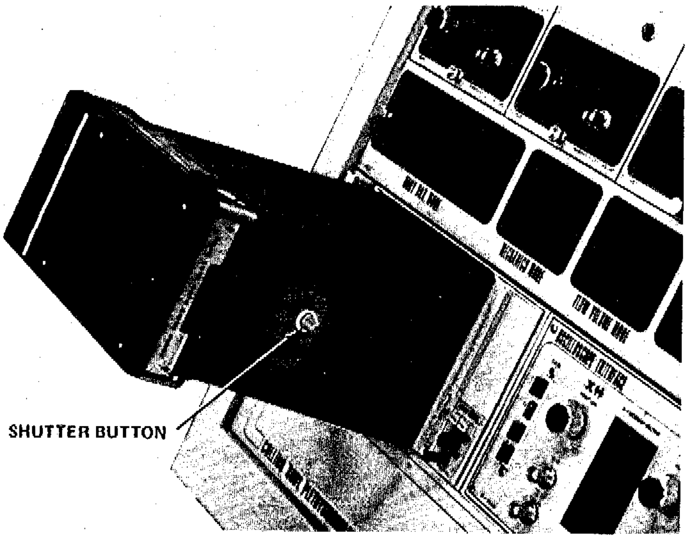


Figure 26 - Using Camera to Photograph Traces

A.5. When a trace is to be photographed, the graticule is removed and the C-5 camera (or optional C-59 camera) is hung on the front of the oscilloscope screen (Figure 26) much in the same fashion as the graticule. The shutter is then correctly set as outlined under the plastic viewing door. With a film pack in the camera, the SHUTTER button is pressed, the film is pulled out and at least 10 seconds is allowed for proper development. A more detailed explanation of the C-5 and C-59 cameras is offered in the manufacturer's manual.

NOTE: In each section which describes a specific test procedure, a complete set of instructions is included. Obviously, if a consecutive series of tests is conducted on the same patient, certain steps are repeated.

VI.B. THORACIC GAS VOLUME (V_{TG}) TEST

NOTE: The result of this test is usually called functional residual capacity by the body box method (FRC_{BB}). It is not the same as the functional residual capacity measured by the helium or nitrogen methods because those gas washout methods include only that volume which is ventilated from the mouth. FRC_{BB} includes about 200 ml of gas in the intestines (normal subjects) as well as any gas in non-communicating areas in the lungs. These areas may have a volume of several liters in subjects with obstructive lung disease. The difference between FRC_{BB} and FRC by other methods is usually ignored when "normal" values are considered. You should note that the volume being measured is the total gas volume of the subject at the point the shutter is closed. If the shutter is not closed at exactly end expiration, the measured value will not be FRC_{BB}.

B.1. Push the **EXT** switch on the **MODE SELECT** section of the switching module.

B.2. Push the **1X GAIN** switches on the X and Y axes of the oscilloscope interface. Center the trace using the X and Y **POSITION** controls.

B.3. If this test is the first to be conducted, or the calibration of the Mouth Pressure, Box Pressure and Flow Amplifier has not been checked, please read Section VI.A., paragraphs A.1. and A.2. Otherwise, proceed to Step B.4.

B.4. Enter the patient's weight in pounds by adjusting the Box Pressure Amplifier **WEIGHT-LBS** control.

B.5. Instruct the patient on the proper procedure as described below.

B.6. Seal the patient inside the box, have him attach a noseclip, then place his mouth on the rubber mouthpiece.

B.7. Push the **1X GAIN** switch on the X and Y axes of the oscilloscope interface.

B.8. Push the **BB** switch on the **MODE SELECT** section of the switching module, then move the right hand switch of the **BODY BOX MODE** section to **BP/FLOW.**

B.9. Place the oscilloscope in the store mode by pushing the **STORE** button, then the **ERASE** button once to clear the green color.

B.10. While the patient breathes normally through the mouthpiece, the trace appears as in Figure 27. Notice that the trace drifts to the right. Occasionally vent the Body Box by moving the **BOX VENT** switch to **MOM. OPEN** for a few seconds. The trace should stabilize in the center of the screen within 2-5 minutes.

NOTE (1): If the trace does not stabilize within the allotted time, by using the **BOX VENT** switch, remove the short piece of tubing between the two **AUX** nipples on the outside of the transducer connector panel (refer to Figure 7). Then, plug one of the nipples and attach a two-foot section of tubing to the other nipple. This method provides high impedance but does not interfere with high frequency response.

NOTE (2): V_{TG} can also be calculated if the tube from the

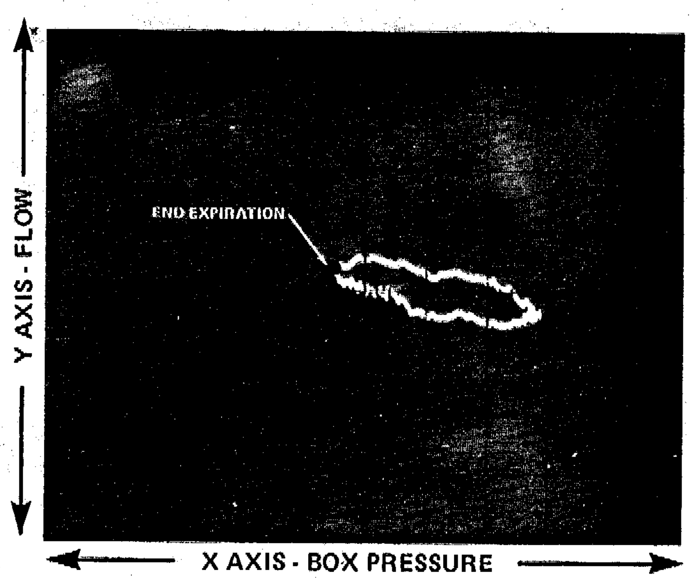


Figure 27 - Trace - Normal Tidal Volume

MOUTH + nipple on the Electronics Console Transducer Panel is connected to the MOUTH - nipple on the Body Box which is the normal connection when airway resistance is measured (section VI.C.). In this case, however, the trace will appear as in Figure 32, not Figure 29. This is useful to avoid changing tubing connections when V_{TG} and R_{aw} is measured on the same subject.

B.11. Use the oscilloscope **ERASE** switch as often as needed to clear unwanted stored traces.

B.12. At precisely end expiration (point marked on Figure 27), move the switch from **BP/FLOW** to **BP/MP**, thus closing the mouth shutter. Before the mouth shutter is closed, the patient must be informed, via the patient intercom, that this is going to happen. When the mouth shutter closes, the patient must attempt to pant, keeping his glottis open and cheeks as rigid as possible. The patient may keep his cheeks rigid by pressing his palms against them (Figure 28).

B.13. Hold the switch in the **BP/MP** position while the patient attempts to pant *once* against the closed shutter, then allow it to return to the center position. The second stored trace is shown in Figure 29.

B.14. Refer to Figure 30. Using the graticule, record the V_{TG} angle (or tan V_{TG}) for calculations. Photograph the trace if desired.

B.15. Repeat the V_{TG} test at least four times, or until repeatable results are obtained.

B.16. After the testing is completed, push the oscilloscope **STORE** button to take the unit out of the store mode.

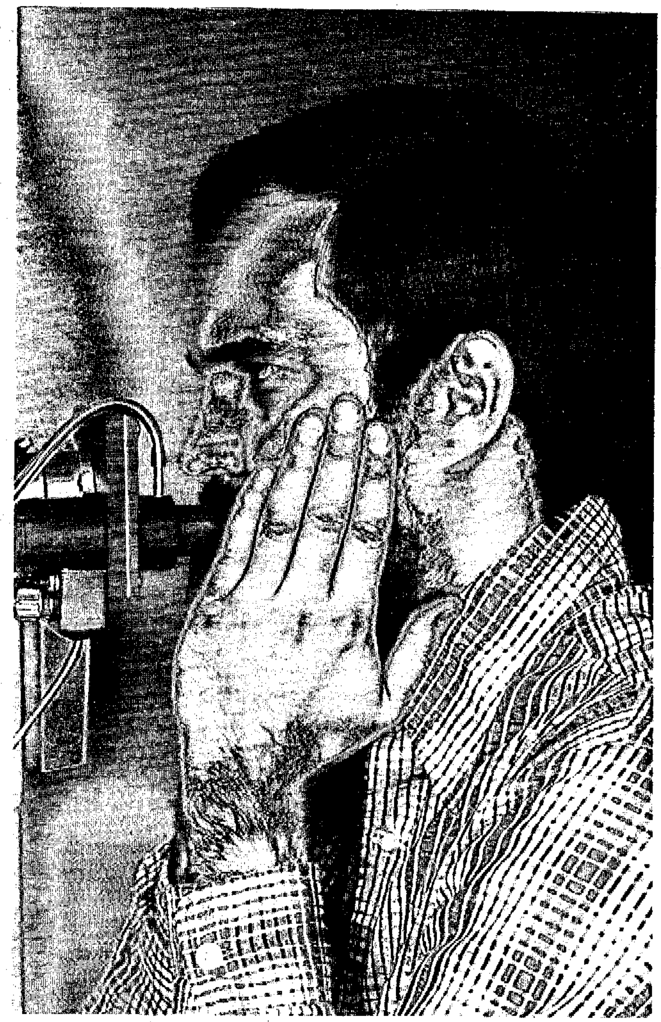


Figure 28 - Method of Keeping Cheeks Rigid

VI.C. AIRWAY RESISTANCE (R_{aw}) TEST

C.1. Push the **EXT** switch on the **MODE SELECT** section of the switching module.

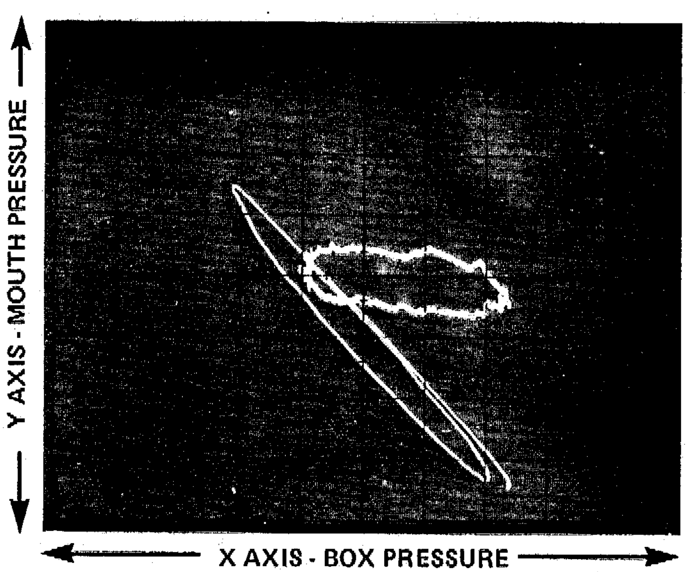


Figure 29 - Trace - V_{TG} Curve

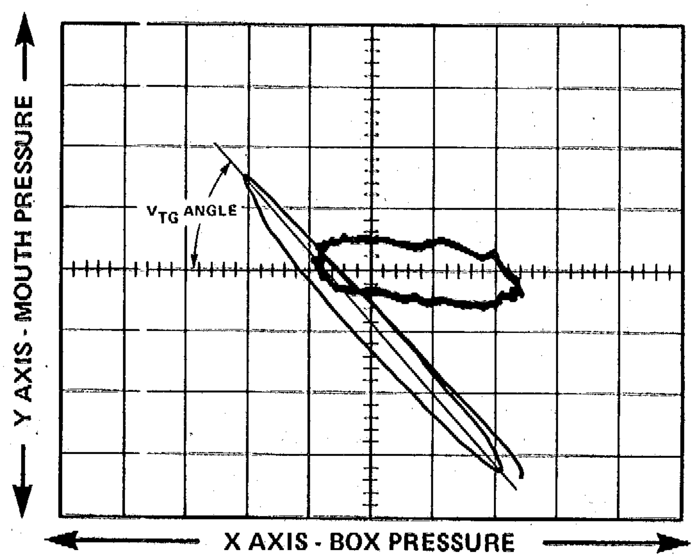


Figure 30 - Measurement of V_{TG} Angle

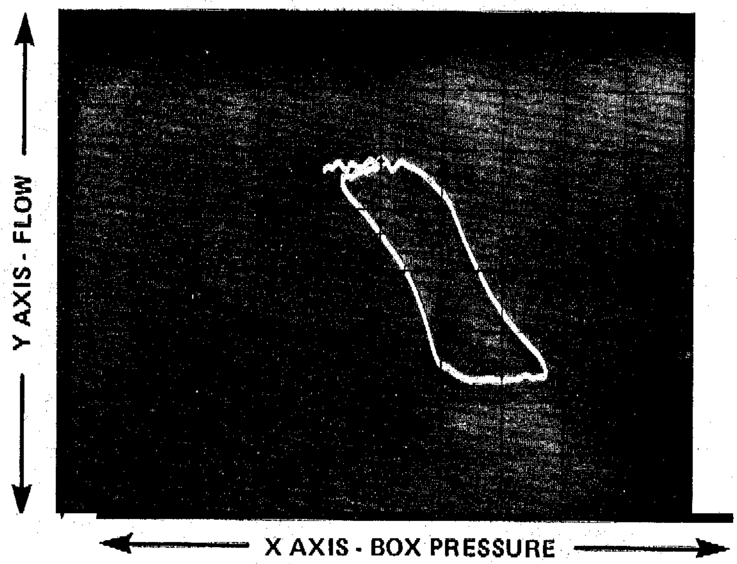


Figure 31 - Trace - R_{aw} Flow Curve

C.2. Push the **1X GAIN** switches on the X and Y axes of the oscilloscope interface.

C.3. If these tests are the first to be conducted, or the calibration of the Mouth Pressure, Box Pressure and Flow Amplifier has not been checked, please read Section VI.A., paragraphs A.1. and A.2.

C.4. Remove the piece of plastic tubing connected to the **MOUTH +** nipple on the Electronics Console Transducer Panel (Figure 8) and connect it to the nipple labeled **MOUTH-**. This does not have to be done, but it provides traces with opposite slopes which are much easier to read.

C.5. Enter the patient's weight in pounds by adjusting the Box Pressure Amplifier **WEIGHT-LBS** control.

C.6. Instruct the patient on the proper procedure as described below.

C.7. Seal the patient inside the Body Box, have him attach a noseclip, then place his mouth on the rubber mouthpiece.

C.8. Push the **BB** switch on the **MODE SELECT** section of the switching module, then move the right hand switch of the **BODY BOX MODE** section to **BP/FLOW**.

C.9. Place the oscilloscope in the store mode by pushing the **STORE** button, then the **ERASE** button once to clear the green color.

C.10. While the patient breathes normally through the mouthpiece, the trace appears as in Figure 27. Notice that the trace drifts to the right. Occasionally vent the Body Box by moving the **BOX VENT** switch to **MOM. OPEN**. The trace should stabilize in the center of the screen within 2-5 minutes.

NOTE: If the trace does not stabilize within the allotted time using the **BOX VENT** switch, remove the short piece or tubing between the two **AUX** nipples on the outside of the transducer connector panel (refer to Figure 7). Then, plug one of the nipples and attach a two-foot section of tubing to the other nipple. This method provides high impedance but does not interfere with high frequency response.

C.11. Use the oscilloscope **ERASE** switch as often as needed to clear unwanted stored traces.

C.12. Have the patient pant so that the peak flow equals about 1-2 liters/second. If the patient pants too deeply, the trace will be too wide, and if he pants too rapidly, the trace will be too high. During this complete test, the patient must keep his cheeks rigid (refer to Figure 28).

C.13. Obtain multiple overlapping traces as shown in Figure 31, using the oscilloscope **ERASE** switch as often as needed to clear unwanted stored traces.

C.14. When a proper trace is stored, move the switch from **BP/FLOW** to **BP/MP**, thus closing the mouth shutter. Before the shutter is closed, the patient must be informed, via the patient intercom, that this is going to happen. When the shutter closes, the patient must attempt to pant, keeping his glottis open and cheeks as rigid as possible.

C.15. Hold the switch in the **BP/MP** position while the patient attempts to pant once against the closed shutter, then allow it to return to the center position. The second stored trace is shown in Figure 32.

C.16. Refer to Figure 33. Using the graticule, record the R_{aw} angles for calculations. Whether expiratory or inspiratory airway resistance is to be measured, Collins recommends that the +2 L/SEC or -2 L/SEC (respectively) flow point (one major division at standard calibration) and FRC point be established for the R_{aw} flow angle. Photograph the trace if desired.

C.17. Repeat this test at least four times, or until repeatable results are obtained.

NOTE: The point at which the mouth shutter is closed varies the value obtained in the V_{TG} calculation. Therefore, the operator should consistently close the mouth shutter at some pre-determined point, either end expiration, end inspiration, or somewhere in between.

C.18. Push the oscilloscope **STORE** button to take the unit out of the store mode.

VI.D. MECHANICS STUDIES (STATIC AND DYNAMIC COMPLIANCE AND PULMONARY RESISTANCE)

D.1. Push the **EXT** switch on the **MODE SELECT** section of the switching module.

D.2. Push both **1X GAIN** switches on the X and Y axes of the oscilloscope interface. Center the trace using the X and **Y POSITION** controls.

D.3. If these tests are the first to be conducted, or the calibration of the Mouth Pressure, Flow and Volume Amplifiers has not been checked, please read Section VI.A., paragraphs A.1. and A.2.

D.4. Rotate the Mouth Pressure Amplifier **LOOP CLOSE**

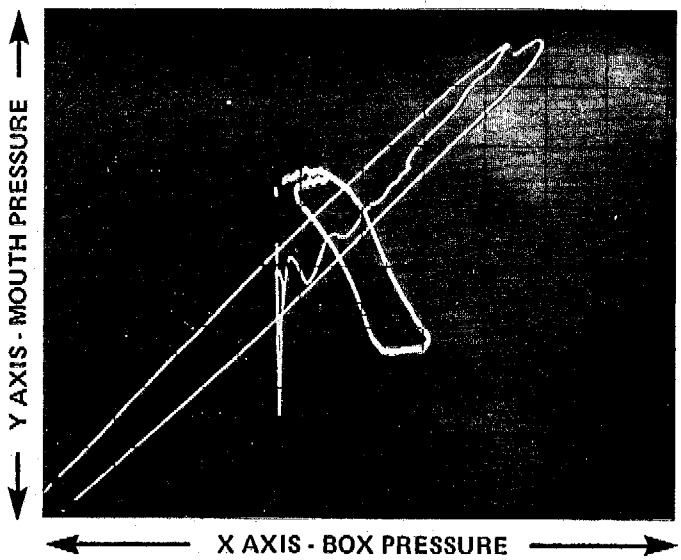


Figure 32 - Trace - R_{aw} Mouth Pressure Curve

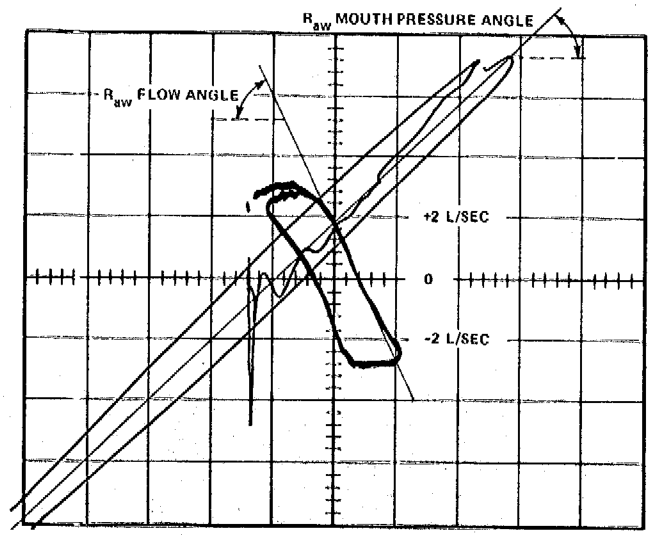


Figure 33 - Measurement of R_{aw} Angles

control fully counterclockwise to the 'snap' position.

D.5. Instruct the patient on the proper procedure as described below, then install the esophageal balloon.

D.6. Have the patient sit inside the Body Box with the door open, attach a noseclip, then place his mouth on the rubber mouthpiece.

D.7. For the Static Compliance test, proceed as follows:

a. Push the **MEC** switch on the **MODE SELECT** section of the switching module.
b. Place the **MECHANICS MODE** switch in the **(P-F•R)/VOL** position.
c. Temporarily push the mouth shutter footswitch and reset the Flow and Volume Amplifiers by moving the **OPERATE/ZERO** switches to **ZERO** then back to **OPERATE**. If the trace is not centered on the screen, use the oscilloscope interface **POSITION** controls. Release the footswitch.

   NOTE: The Flow and Volume Amplifiers may be reset at any time, just as long as there is no flow through the pneumotachograph. If the patient is allowed to remove himself from the mouthpiece between tests, these amplifiers may be reset at this time, prior to the next test. On the other hand, if the patient stays on the mouthpiece for the duration of a test series, then the only convenient way to stop the flow through the pneumotachograph is to use the mouth shutter footswitch as described above. Since it only takes a couple of seconds to complete the reset procedure, most patients do not find it uncomfortable.

d. With the **MECHANICS MODE** switch in the **(P-F•R)/VOL** position and the **LOOP CLOSE** control fully counterclockwise, P/VOL is now displayed on the oscilloscope. Have the patient relax with the mouthpiece in his mouth.
e. Return the **MECHANICS MODE** switch to **OFF** (the trace disappears) and have the patient inspire to TLC.
f. Place the oscilloscope in the store mode by pushing the **STORE** button, then the **ERASE** button once to clear the green color.
g. After the patient has inspired to TLC, close the mouth shutter using the footswitch and quickly move the **MECHANICS MODE** switch from **OFF** to **(P-F•R)/VOL** and back again, thus plotting a point on the screen. If extraneous points ("scatter") are observed, adjust the intensity control behind the oscilloscope's plastic access door until a satisfactory trace is obtained.
h. Open the shutter by releasing the footswitch and have the patient expire slightly (½-1 liter). Repeat steps g. and h. until the patient reaches RV. The resulting points define the static compliance curve as shown in Figure 34.
i. Refer to Figure 35. Using the graticule, record the compliance angle for calculations. Photograph the trace if desired.

   NOTE: If the patient is unable to perform the static compliance test in this manner, place the **MECHANICS MODE** switch in the **(P-F•R)/VOL** position. After the patient inspires to TLC, have him expire as slowly as possible to RV. The resulting curve very nearly defines static compliance.

j. Repeat either of these static compliance maneuvers at least four times, or until repeatable results are obtained.
k. Push the oscilloscope **STORE** button to take the unit out of the store mode.

D.8. For the Dynamic Compliance test, proceed as follows:

a. If the Static Compliance test was just performed, proceed to Step D.8.b. If not, perform Steps

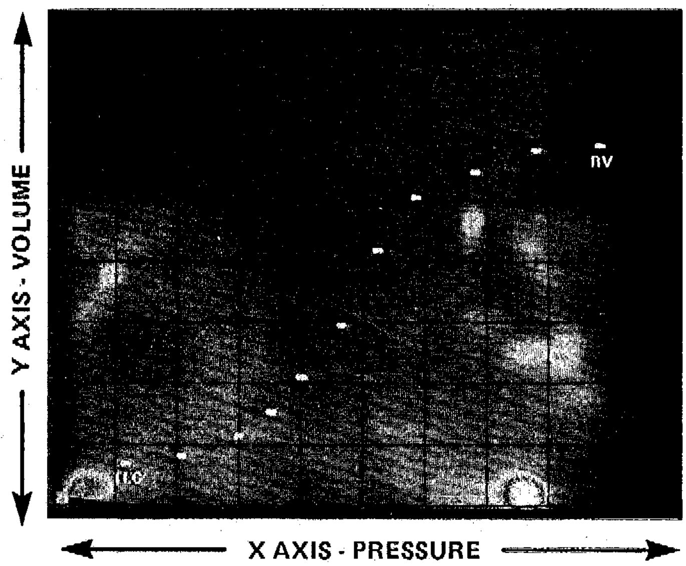


Figure 34 - Trace - Static Compliance Curve

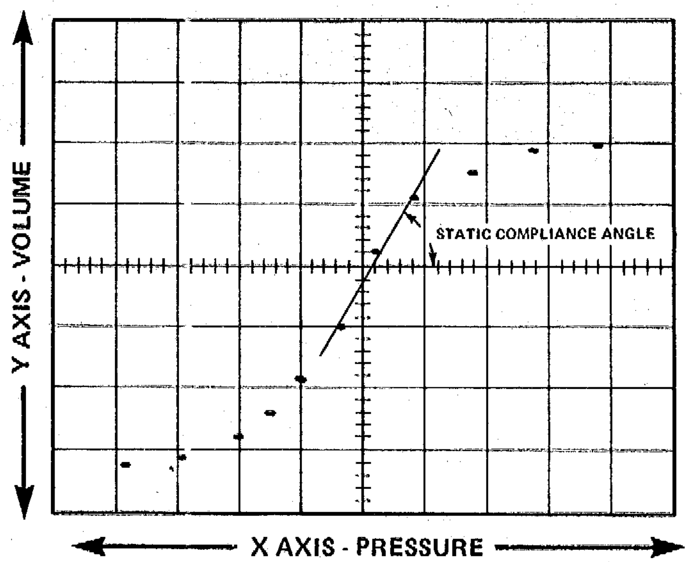


Figure 35 - Measurement of Static Compliance Angle

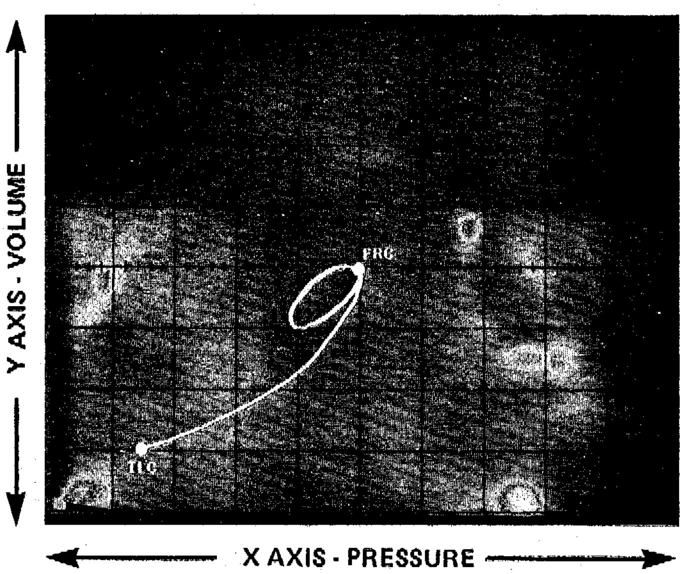


Figure 36 - Trace - Beginning of Dynamic Compliance Curve

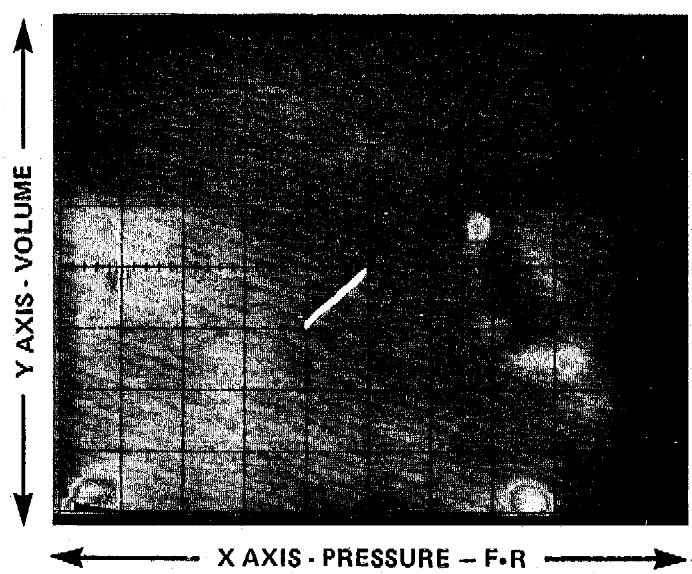


Figure 37 - Trace - End of Dynamic Compliance Curve

D.1.-D.7. as described under Section VI.D.

b. Push the **MEC** switch on the **MODE SELECT** section of the switching module.

c. Place the **MECHANICS MODE** switch in the **(P-F•R)/VOL** position.

d. Temporarily push the mouth shutter footswitch and reset the Flow and Volume Amplifiers by moving the **OPERATE/ZERO** switches to **ZERO** then back to **OPERATE**. If the trace is not centered on the screen, use the oscilloscope interface **POSITION** controls. Release the footswitch.

NOTE: The Flow and Volume Amplifiers may be reset at any time, just as long as there is no flow through the pneumotachograph. If the patient is allowed to remove himself from the mouthpiece between tests, these amplifiers may be reset at this time, prior to the next test. On the other hand, if the patient stays on the mouthpiece for the duration of a test series, the only convenient way to stop the flow through the pneumotachograph is to use the mouth shutter footswitch as described above. Since it only takes a couple of seconds to complete the reset procedure, most patients do not find it uncomfortable.

e. Place the oscilloscope in the store mode by pushing the **STORE** button, then the **ERASE** button to clear the green color.

f. Use the oscilloscope **ERASE** switch as often as needed to clear unwanted stored traces.

g. With the **MECHANICS MODE** switch in the **(P-F•R)/VOL** position, have the patient inspire to TLC, then expire to FRC before beginning the maneuver, as shown in Figure 36.

h. Once the patient reaches FRC, have him breathe with a small fixed tidal volume at a fixed frequency. The end of each tidal breath should be FRC (point marked on Figure 36).

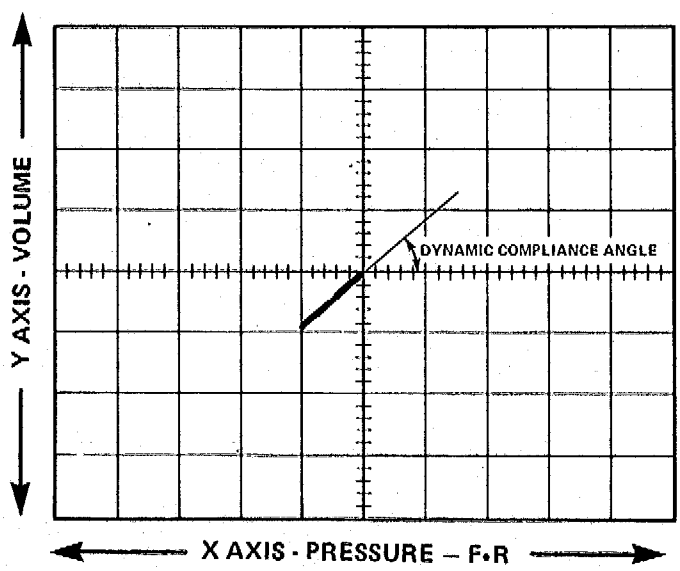


Figure 38 - Measurement of Dynamic Compliance Angle

i. The patient can monitor his tidal volume by connecting a small voltage meter (±10 volts) to the Y axis **EXT OUT BNC** connector on the oscilloscope interface. In addition, the breathing rate can be monitored with a metronome.

j. As the patient breathes, the display now appears as a small loop which can also be seen in Figure 36.

k. Adjust the **LOOP CLOSE** control until the small loop becomes a straight line as shown in Figure 37. The loop closes because the equation:

$$P = \frac{V}{C} + F \cdot R$$

is transformed into:

$$V = C(P - F \cdot R)$$

Plotting P-F•R against V on the oscilloscope screen results in a single curve with slope C.

NOTE: If the loop can not be closed using the **LOOP CLOSE** control, the points of zero flow (the ends of the loop) can be connected by an imaginary straight line.

l. Depending on the method used, it is advisable to have the patient reinspire to TLC at the end of the maneuver to check for drift in the volume signal. If significant drift has occurred, discard those results and start the test again. Any drift can be corrected by slightly adjusting the Flow Amplifier **ZERO** control.

m. Refer to Figure 38. When a satisfactory test is completed, record the dynamic compliance angle for calculations using the graticule. Photograph the trace if desired. Since dynamic compliance is a function of frequency and lung volume, it is usual to note these as well as the peak flow rate.

n. The dynamic compliance test should be performed at least ten times or until repeatable results are obtained.

o. Push the oscilloscope **STORE** button to take the unit out of the store mode.

D.9. For the Pulmonary Resistance test, proceed as follows:

a. If the Static and/or Dynamic Compliance test was just performed, proceed to Step D.9.b. If not, perform Steps D.1.-D.7. as described under Section VI.D.

b. Push the **MEC** switch on the **MODE SELECT** section of the switching module.

c. Place the **MECHANICS MODE** switch in the **(P - $\frac{V}{C}$)/FLOW** position.

d. Temporarily push the mouth shutter footswitch and reset the Flow and Volume Amplifiers by moving the **OPERATE/ZERO** switches to **ZERO**, then back to **OPERATE**. If the trace is not centered on the screen, use the oscilloscope interface **POSITION** controls. Release the footswitch.

NOTE: The Flow and Volume Amplifiers may be reset at any time, just as long as there is no flow through the pneumotachograph. If the patient is allowed to remove himself from the mouthpiece between tests, these amplifiers may be reset at this time, prior to the next test. On the other hand, if the

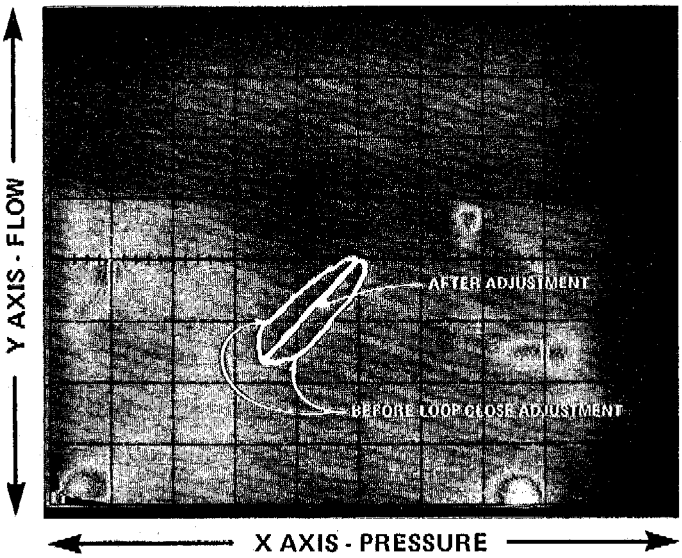


Figure 39 - Trace - Pulmonary Resistance Curve

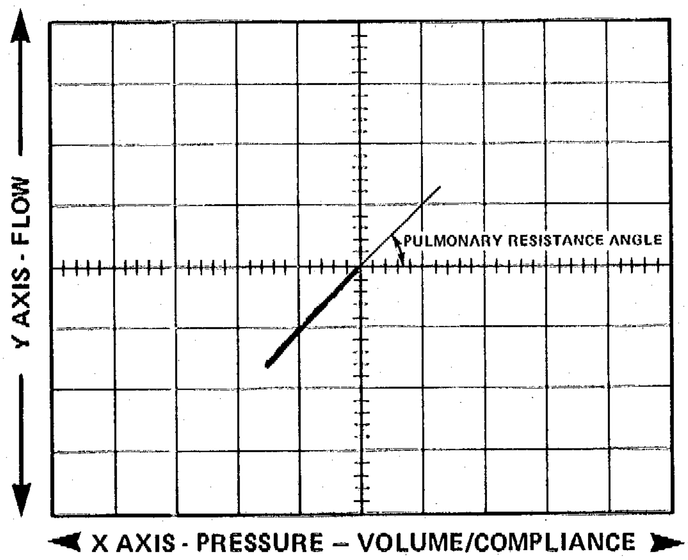


Figure 40 - Measurement of Pulmonary Resistance Angle

patient stays on the mouthpiece for the duration of a test series, the only convenient way to stop flow through the pneumotachograph is to use the mouth shutter footswitch as described above. Since it only takes a couple of seconds to complete the reset procedure, most patients do not find it uncomfortable.

e. With the **MECHANICS MODE** switch in the $(P - \frac{V}{C})/$ **FLOW** position, have the patient breathe normally through the mouthpiece.
f. Place the oscilloscope in the store mode by pushing the **STORE** button, then the **ERASE** button to clear the green color.
g. Use the oscilloscope **ERASE** switch as often as needed to clear unwanted stored traces.
h. As the patient breathes, close the loop by rotating the **LOOP CLOSE** control as shown in Figure 39. The loop closes because the equation:

$$P = \frac{V}{C} + RF$$

is transformed into:

$$F = \frac{1}{R}(P - \frac{V}{C})$$

Thus, the plot is a function of the type y=mx, where m=slope. The slope of the plot is $\frac{1}{R}$, which is read directly as a tangent.
i. Refer to Figure 40. Using the graticule, record the pulmonary resistance angle for calculations. Photograph the trace if desired. As with dynamic compliance, it is usual to note lung volume and peak flow rate.
j. Push the oscilloscope **STORE** button to take the unit out of the store mode.

VI.E. FLOW-VOLUME LOOPS

E.1. Push the **EXT** switch on the **MODE SELECT** section of the switching module.

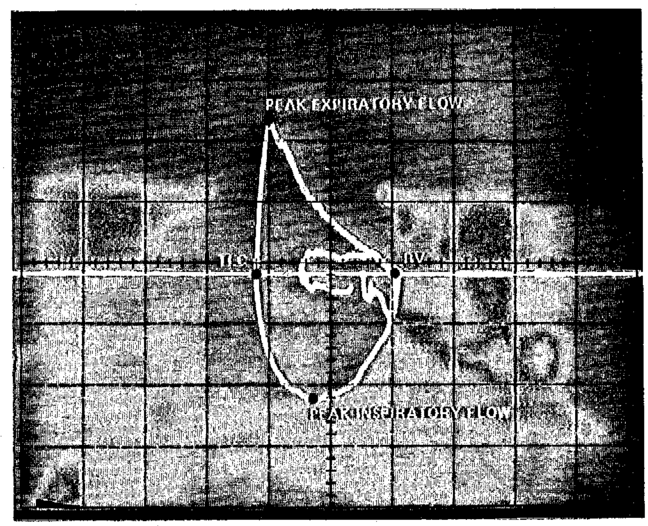


Figure 41 - Trace - Flow-Volume Loop

E.2. Push the **1X GAIN** switches on the X and Y axes of the oscilloscope interface. For most patients, this gain setting is adequate. Patients with diminished flow rates may necessitate a different setting (2X or 5X) to maintain an adequate deflection. The trace may be positioned as shown in Figure 41, although some experimentation may be necessary to prevent the trace from going off the screen at peak inspiratory and expiratory flow.

E.3. If this test is the first to be conducted, or the calibration of the Flow and Volume Amplifiers has not been checked, please read Section VI.A. Otherwise, proceed to Step E.4.

E.4. Instruct the patient on the proper procedure as described below.

E.5. After the patient is seated inside the Body Box with the door open, have him attach a noseclip, then place his mouth on the mouthpiece.

E.6. Push the F/V switch on the **MODE SELECT** section of the switching module, then move the **FLOW-VOLUME MODE** switch to **VOL/FLOW**.

E.7. Temporarily push the mouth shutter footswitch and reset the Volume and Flow Amplifiers by moving the **OPERATE/ZERO** switches to **ZERO** and then back to **OPERATE**. If the trace is not properly positioned on the screen, use the oscilloscope interface **POSITION** controls. Release the footswitch.

NOTE: The Flow and Volume Amplifier may be reset at any time, just as long as there is no flow through the pneumotachograph. If the patient is allowed to remove himself from the mouthpiece between tests, these amplifiers may be reset at this time, prior to the next test. On the other hand, if the patient stays on the mouthpiece for the duration of a test series, the only convenient way to stop the flow through the pneumotachograph is to use the mouth shutter footswitch as described above. Since it only takes a couple of seconds to complete the reset procedure, most patients do not find it uncomfortable.

E.8. After several tidal breaths, place the oscilloscope in the store mode by pushing the **STORE** button, then the **ERASE** button once to clear the green color. The tidal volume may be recorded at this time, if desired.

E.9. Use the oscilloscope **ERASE** switch as often as needed to clear unwanted stored traces.

E.10. Have the patient expire slowly to RV, then have him inspire quickly to TLC. The patient then expires as hard and quickly as possible all the way back to RV. This completes the loop as shown in Figure 41 and the patient may be removed from the mouthpiece. During the test, the operator must encourage the patient to obtain a maximum effort.

E.11. After the flow-volume loop is completed, inscribe a zero flow reference line through the loop by turning the X axis **POSITION** control. The zero flow line simplifies measurements. Photograph the trace, if desired.

E.12. The necessary information to interpret flow-volume loops is contained in Section VII.

E.13. Push the oscilloscope **STORE** button to take the unit out of the store mode.

VI.F. MAXIMAL VOLUNTARY VENTILATION (MVV) TEST

F.1. The procedure for this test is similar to that for flow-volume loops. Therefore, perform Steps E.1. - E.9. as described under Section VI.E. with the following changes:

a. After the Flow and Volume Amplifiers are reset, leave the Volume Amplifier **OPERATE/ZERO** switch in the **ZERO** position until the start of the test.
b. Move the Volume Amplifier **NORMAL/MBC** switch to the **MBC** position.
c. Position the trace 3 or 4 major divisions to the left of center which provides an initial measurement point.

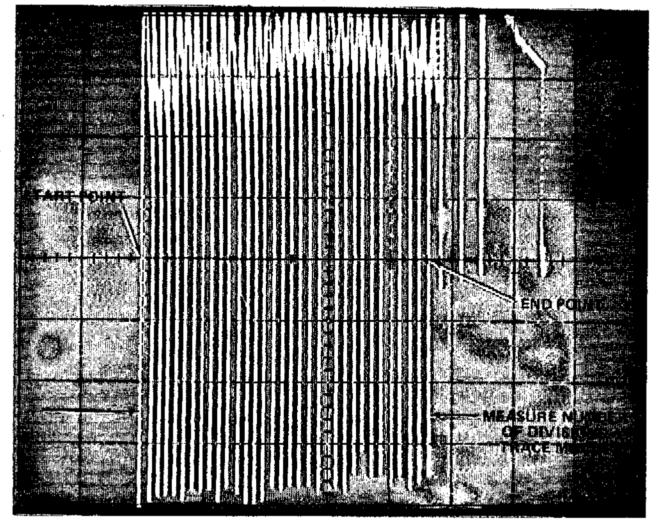


Figure 42 - Trace - Maximal Voluntary Ventilation

F.2. When the switch is set to **MBC**, the gain of the Volume Amplifier is divided by a factor of 10 and only positive volume changes are displayed on the oscilloscope screen.

F.3. After the patient is settled, have him breathe as deeply and rapidly as possible. At some predetermined point (either end expiration or end inspiration), move the Volume Amplifier **OPERATE/ZERO** switch to **OPERATE**. At the same instant, begin to time either 10 or 15 seconds with a stop-watch.

F.4. During this interval, the operator must encourage the patient to obtain a maximum effort. Immediately, at the end of the time period, push the Flow Amplifier **CAL** button. Doing this abruptly alters the position of the trace providing a second measurement reference point. The test is now complete and the patient may be removed from the mouthpiece. The complete trace is shown in Figure 42.

F.5. For calculations, measure the number of divisions the trace moved during the test. Photograph the trace, if desired.

F.6. The MVV test should be repeated until repeatable results are obtained.

F.7. Push the oscilloscope **STORE** button to take the unit out of the store mode.

VI.G. FLOW-VOLUME LOOPS AND SPIROGRAMS (RECORDED ON OPTIONAL X-Y/X-Y-T RECORDER)

For Flow-Volume Loops . . .

G.1. Connect a cable from the Volume Amplifier **OUT BNC** connector to the recorder's X axis **HI-LO** connectors. Connect another cable from the Flow Amplifier **OUT BNC** connector to the Y axis **HI-LO** connectors. The side of the banana plug marked **GROUND** or **GND** must go to the **LO** side of the **HI-LO** connectors.

G.2. Set the recorder controls as follows:
LINE switch to **ON**
PEN switch to **LIFT**
TIME BASE switch to **OFF**
SERVO switch to **STANDBY**
RESPONSE switches to **FAST**

G.3. Move the **CHART** switch to **RELEASE**. Place a piece of clean chart paper on the plotting surface, then move the switch to **HOLD**. Move the **SERVO** switch to **ON**.

G.4. When a flow-volume loop is recorded, the X and Y axis **POLARITY** switches can be set to either + or - depending upon the operator's preference. The sample flow-volume loop, shown in Figure 43, was recorded with both **POLARITY** switches set to +.

G.5. Set the X and Y axis **RANGE** selectors to .5V/CM or as desired for each patient. When a sick or elderly patient is tested, it may be necessary to change this setting to maintain an adequate pen deflection (8-10 cm).

G.6. Instruct the patient on the proper procedure as described below.

G.7. After the patient is seated inside the Body Box with the door open, have him attach a noseclip, then place his mouth on the mouthpiece.

G.8. Temporarily push the mouth shutter footswitch and reset the Volume and Flow Amplifiers by moving the **OPERATE/ZERO** switches to **ZERO** then back to **OPERATE**. If necessary, adjust the pen's starting position by turning the X and/or Y axis **ZERO** controls.

NOTE: The Flow and Volume Amplifiers may be reset at any time, just as long as there is no flow through the pneumotachograph. If the patient is allowed to remove himself from the mouthpiece between tests, these amplifiers may be reset at this time, prior to the next test. On the other hand, if the patient stays on the mouthpiece for the duration of a test series, the only convenient way to stop the flow through the pneumotachograph is to use the mouth shutter footswitch as described above. Since it only takes a couple of seconds to complete the reset procedure, most patients do not find it uncomfortable.

G.9. As the patient breathes normally, the pen moves around slightly reflecting his tidal volumes.

G.10. If the tidal volumes are to be recorded, move the **PEN** switch to **RECORD**. Otherwise, wait until just before the patient begins the maneuver.

G.11. Have the patient expire slowly to RV, then have him inspire quickly to TLC. The patient then expires as hard and quickly as possible all the way back to RV. This completes the loop as shown in Figure 43 and the patient should now be removed from the mouthpiece. During the test, the operator should encourage the patient to obtain a maximum effort.

G.12. After the flow-volume loop is completed, inscribe a zero-flow reference line through the loop by turning the X axis **ZERO** control. After this is completed, move the **PEN** switch to the **LIFT** position.

G.13. Additional loops may be recorded on the same piece of chart paper by repositioning the pen as described in Step G.8.

G.14. Figure 43 also shows where to establish points for the calculations.

For Spirograms . . .

G.15. Connect a cable from the Volume Amplifier **OUT BNC** connector to the recorder's Y axis **HI-LO** connectors. No connection is made to the X axis.

G.16. Set all controls as above (Steps G.2. - G.8., including the amplifier reset procedure) except move the **TIME BASE** switch to X and set the **SWEEP RATE** selector to .5 **SEC./CM.** or as desired. Changing this setting merely expands or compresses the spirogram.

G.17. The Y axis **POLARITY** switch can be set to either + or - depending upon the operator's preference. The sample spirogram (Figure 44) was recorded with this switch in the - position. Notice that end expiration is at the bottom of the tracing.

G.18. When the patient is to perform a maneuver, move the **RESET/START** switch to **START**. The pen lowers automatically and sweeps the X axis at the selected rate. The pen automatically lifts and returns to the starting position when it reaches the far right hand side of the plotting surface. If the operator desires, the pen may be reset at any time by moving the **RESET/START** switch to **RESET**.

G.19. The sample spirogram (Figure 44) shows where to establish some of the basic points required for calculations.

VI.H. MAXIMAL VOLUNTARY VENTILATION TEST (RECORDED ON OPTIONAL X-Y-T RECORDER)

H.1. The MVV testing procedure utilizing the X-Y-T recorder is identical to that when the oscilloscope is used. However, the recorder tracing is easier to interpret and yields slightly more accurate results.

H.2. Perform Steps G.15. and G.16. as described under Section VI.G., except move the Y axis **RANGE** selector to **.25V/CM** (or as desired), move the Volume Amplifier **NORMAL/MBC** switch to the **MBC** position and set the Y axis **POLARITY** switch to +.

H.3. When the patient is to perform the MVV test, move the **RESET/START** switch to **START**. The pen lowers automatically and sweeps the X axis at the selected rate. The pen automatically lifts and returns to the starting position when it reaches the far right hand side of the plotting surface. If the operator desires, the pen may be reset at any time by moving the **RESET/START** switch to **RESET**. As before, the patient must be encouraged to obtain a maximum effort.

H.4. At the end of the test, the operator may easily select any specific time interval from the trace where he sees the patient was making a maximum effort. A sample MVV test recorded with the X-Y-T recorder is shown in Figure 45.

H.5. The MVV test should be repeated until consistent results are obtained.

VII. CALCULATIONS

NOTE (1): This section contains all the calculations which are necessary to obtain results for the tests explained in Section VI. In some cases, additional theory or development is included as an instructional aid. Please note that simplified calculation forms are found at the end of this manual. They may be removed to make additional copies.

NOTE (2): The standard calibration factor for each of the four amplifiers, as described in Section V, is as follows:

Box Pressure Amplifier (box cal): 10cc/division

Mouth Pressure Amplifier (mouth cal): 5cm H_2O/division

Flow Amplifier (flow cal): 2 liters/sec./division

Volume Amplifier (vol cal): 1 liter/division

VII.A. V_{TG}

A.1. In the V_{TG} test, the patient is asked to breathe quietly through the mouthpiece and the rate of flow is plotted against the simultaneous changes in box pressure on the oscilloscope (Figure 27). After the trace stabilizes, the mouth shutter is closed at end expiration and the subject attempts to pant against the closed system. The mouth pressure is then plotted against the simultaneous changes in the box pressure (Figure 29). Using Boyle's Law, the value of V_{TG} can be found as follows:

Boyle's Law is stated:

$$P_1 V_1 = P_2 V_2$$

or:

$$V_1 = P_2 \times \frac{V_2}{P_1}$$

where,

V_1 = thoracic gas volume at the time the shutter is closed

V_2 = box volume

P_1 = mouth pressure

P_2 = barometric pressure

Additionally, we may say:

$$V_1 = P_2 \times \frac{dV_2}{dP_1} = P_2 \times \frac{d\text{ (box volume)}}{d\text{ (mouth pressure)}}$$

Remember that d (box volume) is proportional to -d (box pressure) for small changes in either factor.

$$V_1 = -P_2 \frac{d\text{ (box pressure)}}{d\text{ (mouth pressure)}}$$

The slope of the V_{TG} curve (Figure 29 and 30) is:

$$\frac{d\text{ (mouth pressure)}}{d\text{ (box pressure)}}$$

$$\therefore V_1 = V_{TG} = \frac{-P_2}{\text{slope}}$$

Since the slope of the curve as displayed is negative, we may write:

$$V_{TG} = \frac{P_2}{|\text{slope}|}$$

To this basic formula we must add calibration, attenuation and correction factors. Therefore, the final formula for determining V_{TG} is:

$$V_{TG}\text{ (ml)} = \frac{P_c\text{ (corrected }P_2\text{)} \times \text{box cal}}{V_{TG}\text{ tan} \times \frac{X\text{ att}}{Y\text{ att}} \times \text{mouth cal}}$$

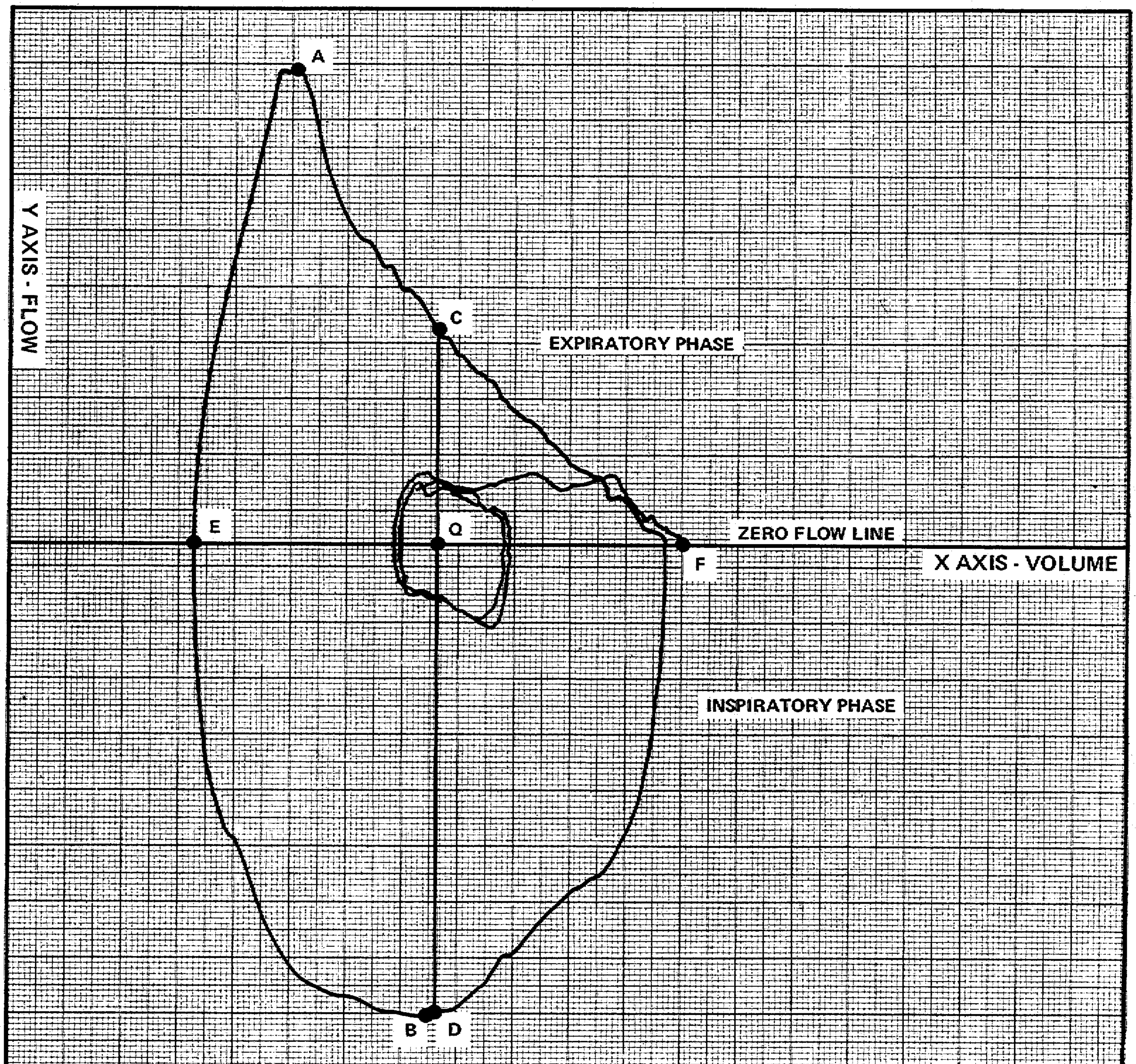

A
Y AXIS - FLOW
C
EXPIRATORY PHASE
E
Q
ZERO FLOW LINE
F
X AXIS - VOLUME
INSPIRATORY PHASE
B
D

Figure 43 - Trace - Flow-Volume Loop Recorded on X-Y-T Recorder

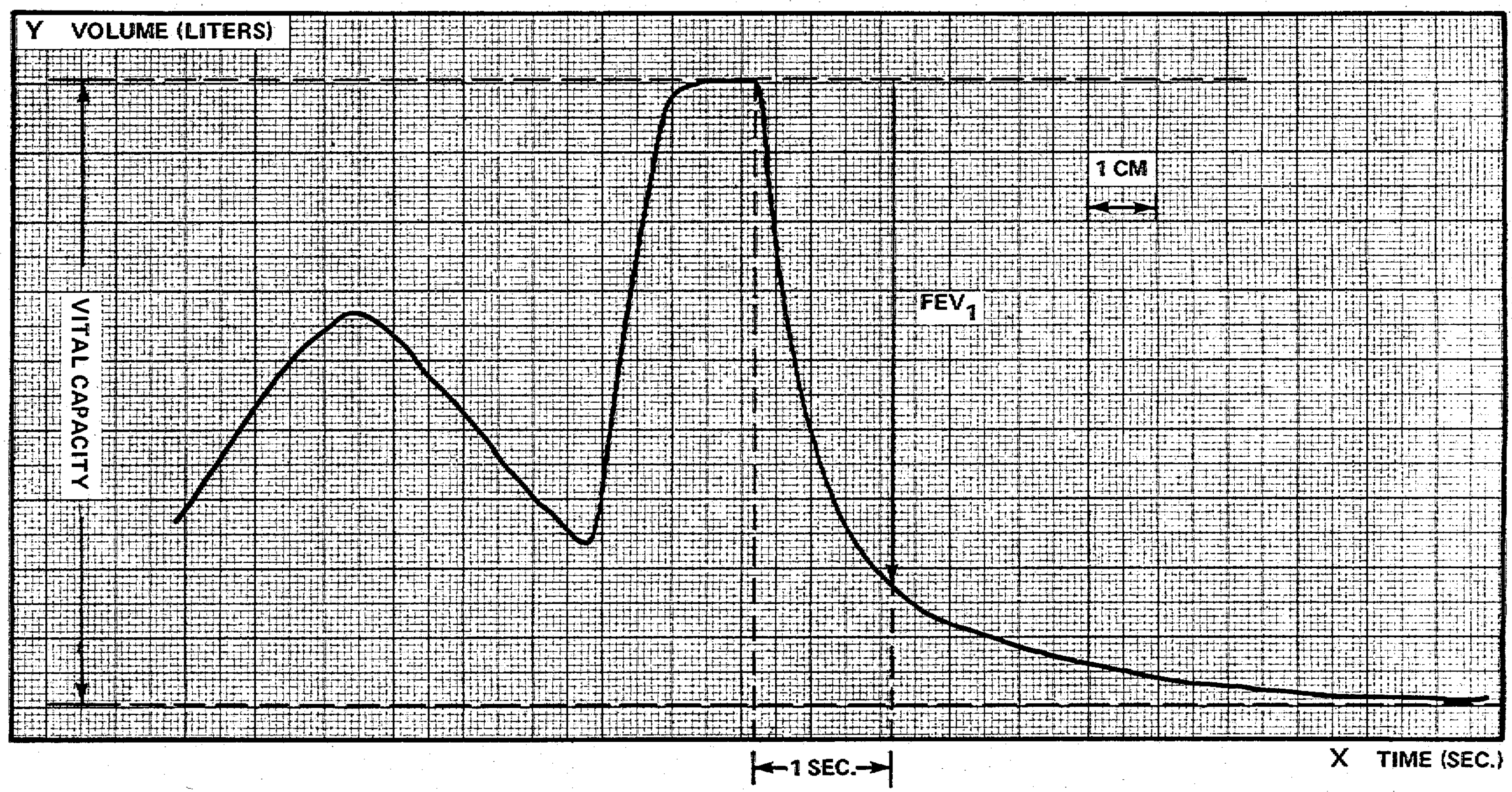


Figure 44 - Trace - Spirogram Recorded on X-Y-T Recorder

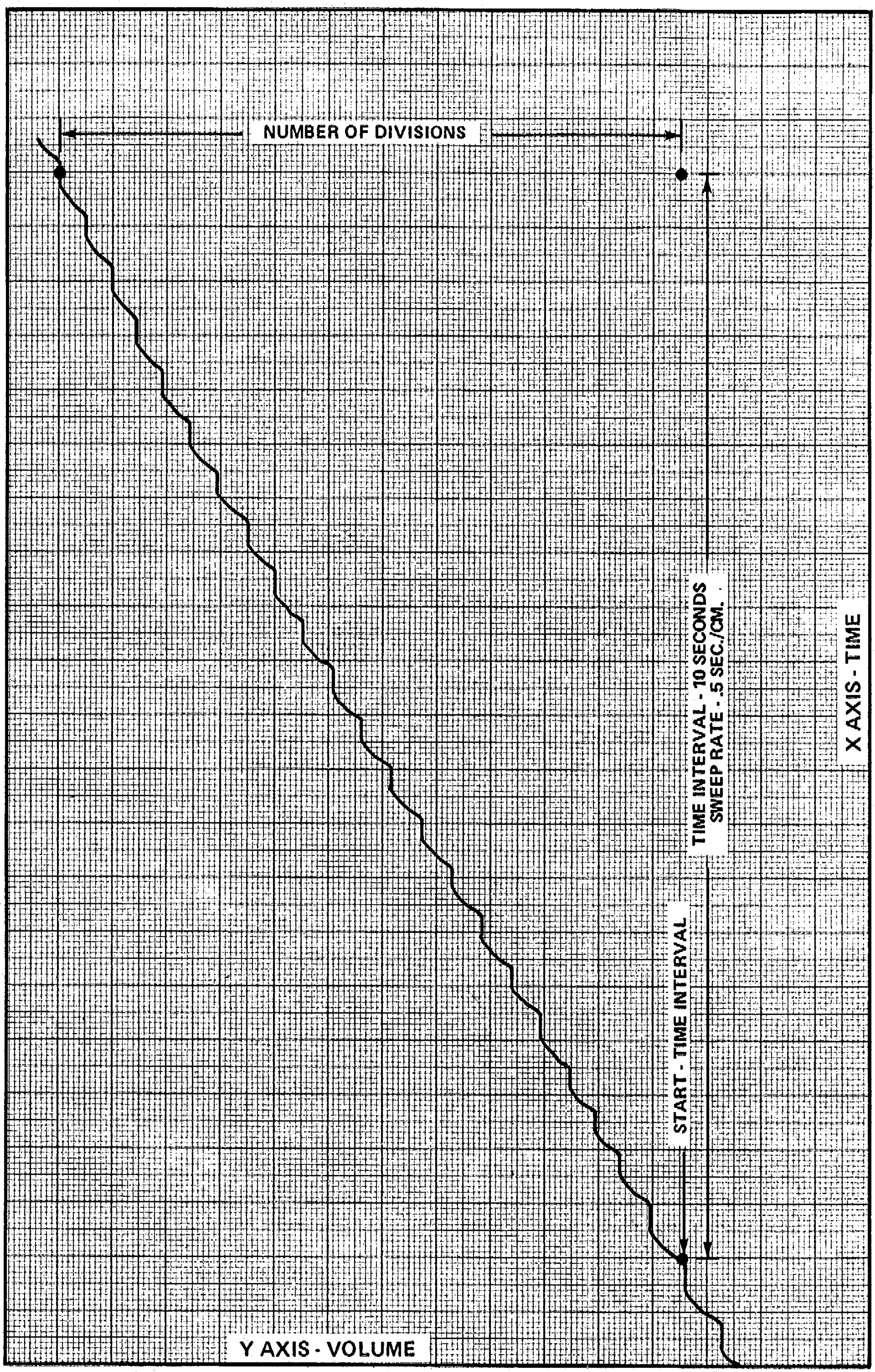


Figure 45 - Trace - MVV Test Recorded on X-Y-T Recorder

VII.B. R_{aw}

B.1. The subject is asked to pant through the mouthpiece and the rate of flow is plotted against the simultaneous changes in box pressure on the oscilloscope. The trace obtained (Figure 31) provides a value for R_{aw} x flow. Then the mouth shutter is closed and the patient pants against the closed system. The mouth pressure is now plotted against the simultaneous changes in the box pressure (Figure 32 and 33). The tangent of this curve produces a value for R_{aw} x mouth pressure (also thoracic gas volume).

B.2. By definition,

$$R_{aw} = \frac{dP \text{ alveolar}}{d \text{ flow}}$$

The problem is to find dP alveolar without introducing a catheter into the alveolus or esophagus. As in the previous section (VII.A.), we use Boyle's Law. Applying this to the lungs when the mouth shutter is closed, gives

$$dP_1 = \frac{P_2}{V_1} \times dV_2$$

where,

dP_1 = change in alveolar pressure

P_2 = average pressure in the lung = P_c

V_1 = average alveolar volume (thoracic gas volume)

dV_2 = change in lung volume

By the previous section:

$$V_1 = \frac{P_c \times \text{box cal}}{V_{TG} \tan \times \frac{X \text{ att}}{Y \text{ att}} \times \text{mouth cal}}$$

therefore:

$$dP_1 = V_{TG} \tan \times \frac{X \text{ att}}{Y \text{ att}} \times \frac{\text{mouth cal}}{\text{box cal}} \times dV_2$$

With the mouth shutter closed, dV_2, the change in lung volume, is reflected in a change in box pressure, dP_{box}, and the relation between the changes is given by the Box Pressure Amplifier calibration factor, box cal. Hence:

$$dP_1 = V_{TG} \tan \times \frac{X \text{ att}}{Y \text{ att}} \times \frac{\text{mouth cal}}{\text{box cal}} \times \text{box cal} \times dP_{box}$$

B.3. With the mouth shutter opened, flow is plotted against box pressure on the oscilloscope which allows one to readily find the relationship between dP_{box} and d flow:

$$\frac{d \text{ flow}}{dP_{box}} = \text{flow tan} \times \frac{X \text{ att}}{Y \text{ att}}$$

or, rearranging terms:

$$dP_{box} = \frac{d \text{ flow}}{\text{flow tan}} \times \frac{X \text{ att}}{Y \text{ att}}$$

where flow tan is the measured tangent of the flow-box pressure curve. Combining this with the results of B.2., gives:

$$dP_1 = \frac{V_{TG} \tan \times \text{mouth cal} \times d \text{ flow}}{\text{flow tan}}$$

Rearranging terms gives:

$$\frac{dP_1}{d \text{ flow}} = R_{aw} = \frac{V_{TG} \tan}{\text{flow tan}} \times \text{mouth cal}$$

When all the calibration factors are taken into account, this gives:

$$R_{aw}\ (\text{cm } H_2O/\text{L./sec.}) = \frac{V_{TG} \text{ tan x mouth cal}}{\text{flow tan x flow cal}}$$

B.4. V_{TG} can also be calculated from the curve obtained when the mouth shutter is closed. The formula is the same as that found in Section VII.A.:

$$V_{TG}\ (\text{ml}) = \frac{P_c \text{ x box cal}}{V_{TG} \text{ tan x } \frac{\text{X att}}{\text{Y att}} \text{ x mouth cal}}$$

where V_{TG} is the volume of the lung when the shutter was closed.

B.5. Since airway resistance is generally dependent on lung volume, most people calculate the "specific conductance" of the airways (SG_{aw}), a number which should be independent of lung volume.

$$SG_{aw} = \frac{1}{R_{aw} \times V_{TG}}$$

VII.C. STATIC COMPLIANCE

C.1. By exhaling slowly, and periodically relaxing against the closed mouth shutter, a curve of volume (Y axis) versus alveolar pressure (X axis) is plotted (Figure 34). The static compliance of the lung is the slope of this curve in the vicinity of the patient's FRC (Figure 35), or dV/dP.

C.2. When the calibration factors are taken into account, the final formula is:

$$\text{Compliance (liters/cm } H_20) = \text{compliance tan x } \frac{\text{X att}}{\text{Y att}} \text{ x } \frac{\text{vol cal}}{\text{mouth cal}}$$

VII.D. DYNAMIC COMPLIANCE

D.1. By subtracting F•R from the pressure difference between the mouth and esophagus, the resulting pressure is proportional to alveolar pressure. Dynamic compliance is simply the ratio of changes in lung volume to changes in alveolar pressure, or:

$$C_{dyn} = \frac{dV}{dP_{\text{alveolar}}}$$

D.2. When the calibration factors are taken into account, the final formula is the same as for static compliance:

$$\text{Compliance (liters/cm } H_20) = \text{compliance tan x } \frac{\text{X att}}{\text{Y att}} \text{ x } \frac{\text{vol cal}}{\text{mouth cal}}$$

VII.E. PULMONARY RESISTANCE AND CONDUCTANCE

E.1. In the pulmonary resistance test, V/C is subtracted from the difference between mouth pressure and esophageal pressure, eliminating the effect of alveolar pressure (Figure 39 and 40). By measuring the ratio of flow to this corrected pressure, the total pulmonary resistance is found.

E.2. Considering calibration and attenuation factors, the final formula is:

$$R_{pul}\ (\text{cm } H_2O/\text{L./sec.}) = \frac{1}{\text{Resistance tan x } \frac{\text{Y att}}{\text{X att}} \text{ x } \frac{\text{flow cal}}{\text{mouth cal}}}$$

E.3. To find conductance, the relationship is simply 1/R.

VII.F. FLOW-VOLUME LOOPS

F.1. The flow-volume loop (Figure 41 and 43) consists of two main portions - the inspiratory phase and the expiratory phase which are separated by a zero flow line. Flow rates and volumes are determined from these two phases.

F.2. Peak Expiratory Flow

a. Peak expiratory flow is the point of maximum flow during expiration. This is measured by establishing point A on the flow-volume loop which is the maximum positive point. Peak flow is measured from the zero flow line to point A. Record this dimension in divisions (for oscilloscope) or centimeters (for recorder). Peak flow is calculated from the formula:

For oscilloscope traces:

$$\text{peak flow (L./sec.) BTPS} = \frac{\text{no. of div.}}{\text{Y att}} \times \text{flow cal} \times \text{BTPS factor}$$

For recorder traces:

$$\text{peak flow (L./sec.) BTPS} = \text{no. of div. (cm)} \times \text{Y sens.} \times \text{flow cal} \times \text{BTPS factor}$$

F.3. Peak Inspiratory Flow (PIF)

a. Peak inspiratory flow is the point of maximum flow during inspiration. This is measured by establishing point B on the flow-volume loop which is the maximum negative point. Peak inspiratory flow is measured from the zero flow line to point B. Record this dimension in divisions (for oscilloscope) or centimeters (for recorder). Peak flow is calculated from the formula:

For oscilloscope traces:

$$\text{PIF (L./sec.) BTPS} = \frac{\text{no. of div.}}{\text{Y att}} \times \text{flow cal} \times \text{BTPS factor}$$

For recorder traces:

$$\text{PIF (L./sec.) BTPS} = \text{no. of div. (cm.)} \times \text{Y sens.} \times \text{flow cal} \times \text{BTPS factor}$$

F.4. Forced Expiratory Flow (FEF 25, 50, 75%)

a. In order to determine FEF, establish point Q between points E and F. For $FEF_{25\%}$, point Q is ¼ of the way between E and F, for $FEF_{50\%}$, point Q is ½ of the way between E and F, and for $FEF_{75\%}$, point Q is ¾ of the way between E and F. Construct a perpendicular line through point Q which intersects both the inspiratory and expiratory curves, establishing points C and D. FEF is measured from point Q to point C. Record this dimension in divisions (for oscilloscope) or centimeters (for recorder). FEF is determined from the formula:

For oscilloscope traces:

$$\text{FEF (L./sec.) BTPS} = \frac{\text{no. of div.}}{\text{Y att}} \times \text{flow cal} \times \text{BTPS factor}$$

For recorder traces:

$$\text{FEF (L./sec.) BTPS} = \text{no. of div. (cm.)} \times \text{Y sens.} \times \text{flow cal} \times \text{BTPS factor}$$

F.5. Forced Inspiratory Flow (FIF)

a. FIF is determined by measuring the distance previously established from point Q to point D. FIF is determined from the formula:

For oscilloscope traces:

$$\text{FIF (L./sec.) BTPS} = \frac{\text{no. of div.}}{\text{Y att}} \times \text{flow cal} \times \text{BTPS factor}$$

For recorder traces:

$$\text{FIF (L./sec.) BTPS} = \text{no. of div. (cm.)} \times \text{Y sens.} \times \text{flow cal} \times \text{BTPS factor}$$

F.6. Forced Vital Capacity (FVC)

The forced vital capacity is the volume of gas expired after full inspiration; expiration being as rapid and complete as possible. This is measured by determining the distance in centimeters or divisions between points E and F. The forced vital capacity is determined by the formula:

For oscilloscope traces:

$$\text{FVC (L.) BTPS} = \frac{\text{no. of div.}}{\text{Y att}} \times \text{vol cal} \times \text{BTPS factor}$$

For recorder traces:

$$\text{FVC (L.) BTPS} = \text{no. of div. (cm.)} \times \text{Y sens.} \times \text{vol cal} \times \text{BTPS factor}$$

VII.G. MVV

G.1. The formulas for determining MVV are as follows:

For MVV recorded on the oscilloscope (refer to Figure 42):

$$\text{MVV (L./min.) BTPS} = \left[\left(\frac{\text{no. of div.}}{\text{X att}} \times 10 \times \text{vol cal}\right)\right] \times \frac{60}{\text{timed interval}} \times \text{BTPS factor}$$

For MVV recorded on the X-Y-T recorder (refer to Figure 45):

$$\text{MVV (L./min.) BTPS} = \left[\left(\text{no. of div. (cm.)} \times \text{Y sens.} \times \frac{60}{\text{time interval}} \times \text{vol cal}\right)\right] \times \text{BTPS factor} \times 10$$

VII.H. SPIROGRAMS

H.1. The sample spirogram (refer to Figure 44) was recorded on the X-Y-T recorder. The X axis is time and the Y axis is volume. The same volume calibrations used for flow-volume loop analysis apply to spirogram analysis.

VIII. REPLACEABLE PARTS LIST

CATALOG NO.	ITEM
22241	Rubber mouthpiece, small
22939	Rubber tipped noseclip
22441	Sponge rubber refill for noseclip
A33-13	Replacement hose, short (for Body Box Seat)
A13-34	Replacement hose, long (for top of calibration equipment)
A22-10	Replacement hose (for vacuum pump)
22047	X-Y or X-Y-T recorder paper
22528	Disposable pen for recorder (black - package of three)
22530	Disposable pen for recorder (red - package of three)
	Clear plastic tubing (state length when ordering)
	BNC/Banana cable (two required if recorder is used)

IX. SCHEMATIC DIAGRAMS AND PRINTED CIRCUIT BOARDS

PAGE NUMBER

IX.A. SCHEMATIC DIAGRAMS

IX.B. PRINTED CIRCUIT BOARDS

A

PARTS LIST				REVISIONS
ITEM NO.	DRWG. NO.	REQ'D.	DESCRIPTION	

THIS SCHEMATIC CONTAINS PROPRIETARY
INFORMATION WHICH WILL BE RELEASED
ON SPECIAL REQUEST ONLY

DO NOT SCALE DRAWING

WARREN E. COLLINS, INC.
220 WOOD RD., BRAINTREE, MASS. 02184

WEC STANDARD SHOP PRACTICE APPLIES

USED ON

TOLERANCES UNLESS OTHERWISE SPECIFIED		TITLE	MATERIAL
FRACT. ±	DRN. BY	SCHEMATIC DIAGRAM	
DECIMAL ±	CH K'D BY	VALIDYNE TRANSDUCER ELECTRONICS	DWG. NO.
ANGULAR ±	JOB NO.		A
	SCALE		

Figure 46 - Validyne Transducer Schematic

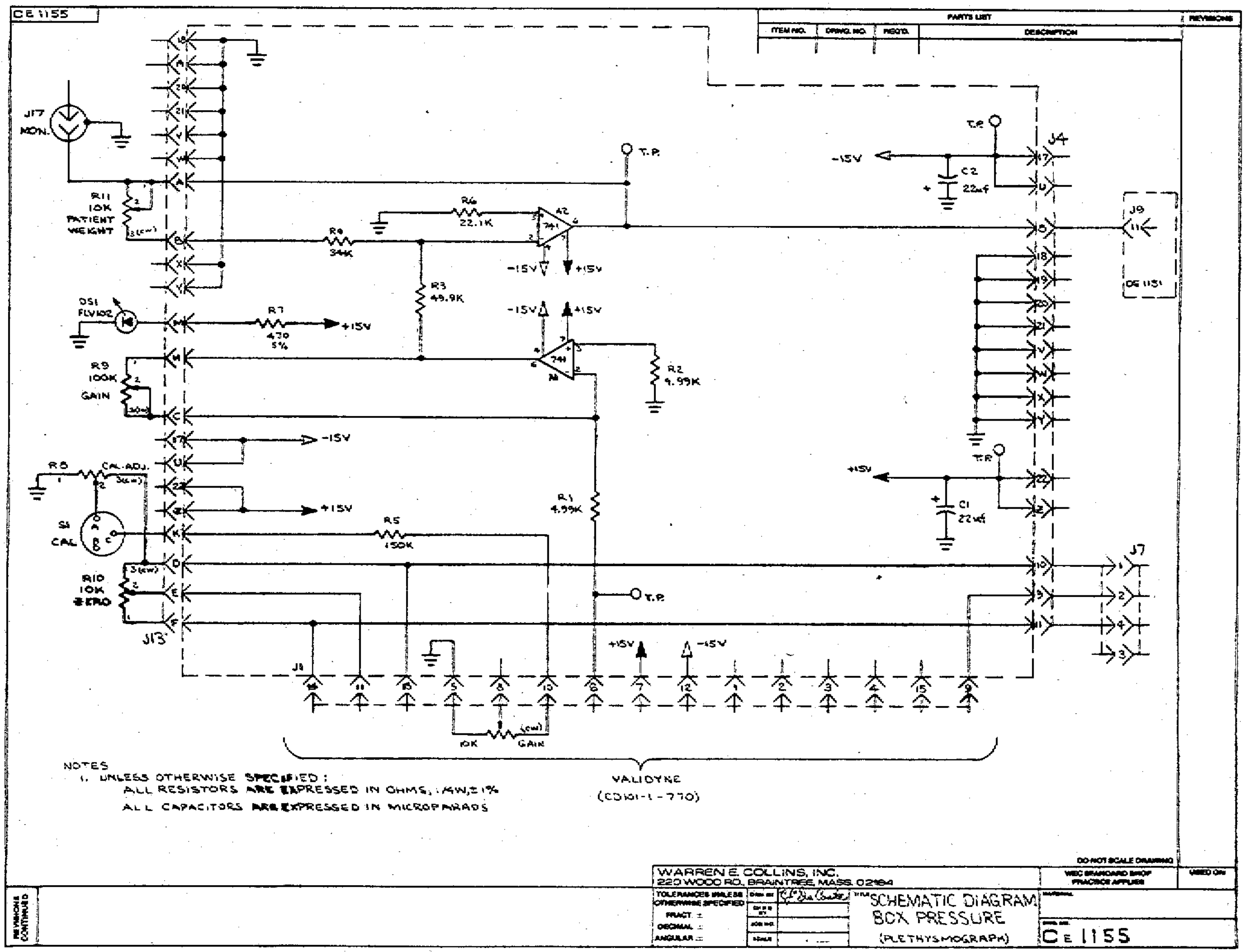
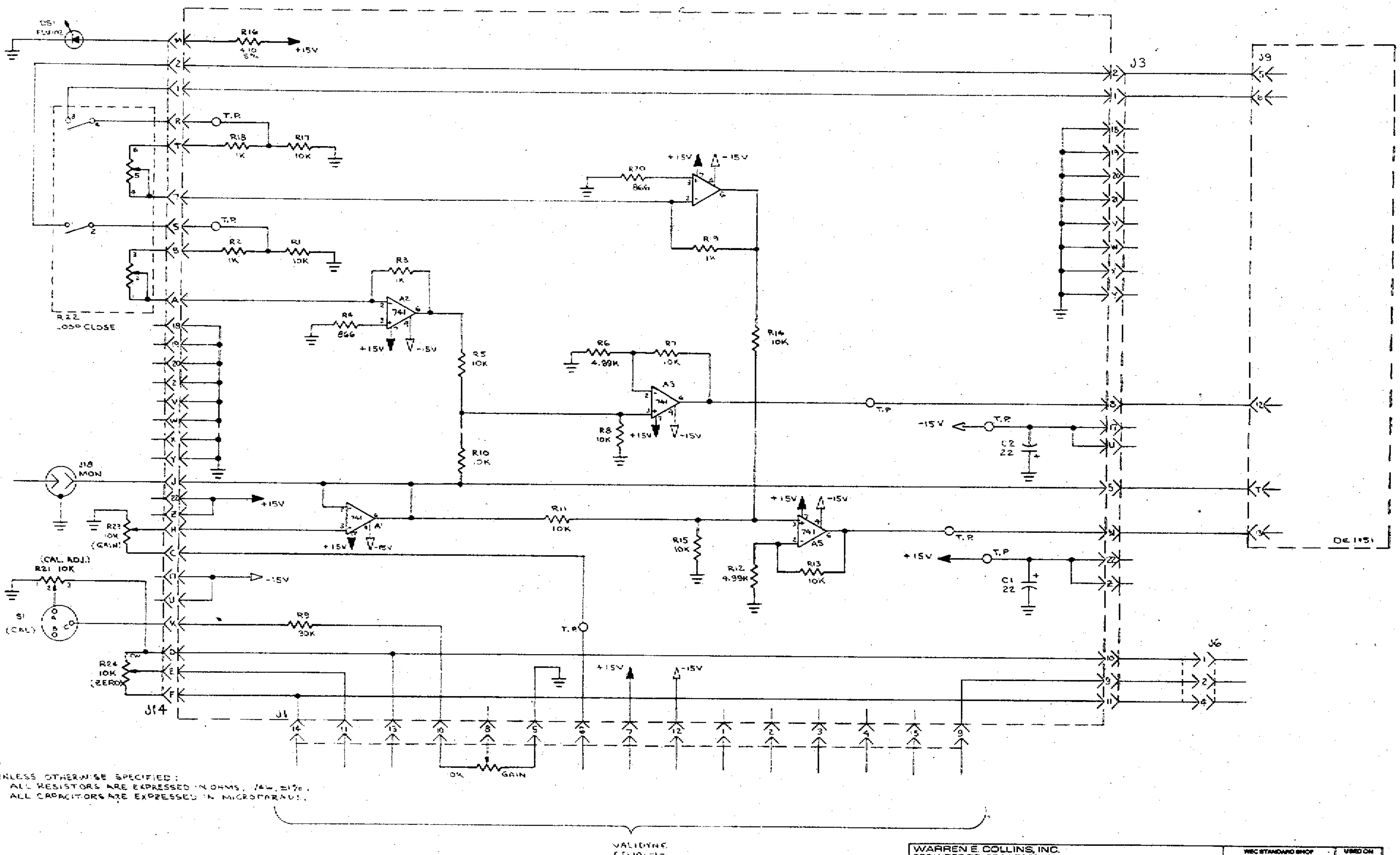


Figure 47 - Box Pressure Amplifier Schematic



NOTES
1. UNLESS OTHERWISE SPECIFIED:
ALL RESISTORS ARE EXPRESSED IN OHMS, 1/4W, ±1%.
ALL CAPACITORS ARE EXPRESSED IN MICROFARADS.

WARREN E. COLLINS, INC. 220 WOOD RD., BRAINTREE, MASS. 02184		WEC STANDARD SHOP PRACTICE APPLIES
TOLERANCES UNLESS OTHERWISE SPECIFIED FRACT. ± DECIMAL ± ANGULAR ±	TITLE SCHEMATIC DIAGRAM MOUTH PRESSURE (PLETHYSMOGRAPH)	DE 1154

Figure 48 - Mouth Pressure Amplifier Schematic

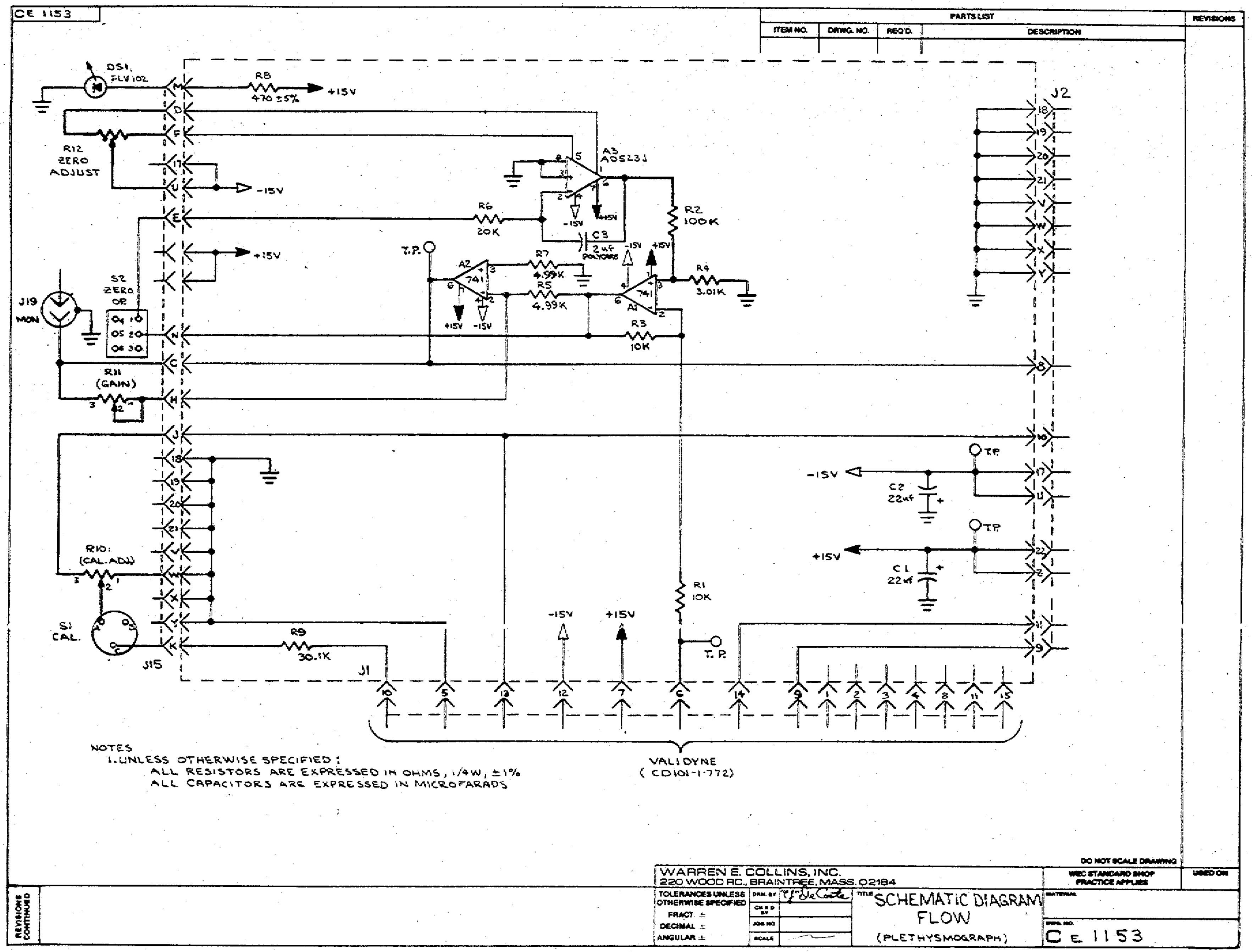


Figure 49 - Flow Amplifier Schematic

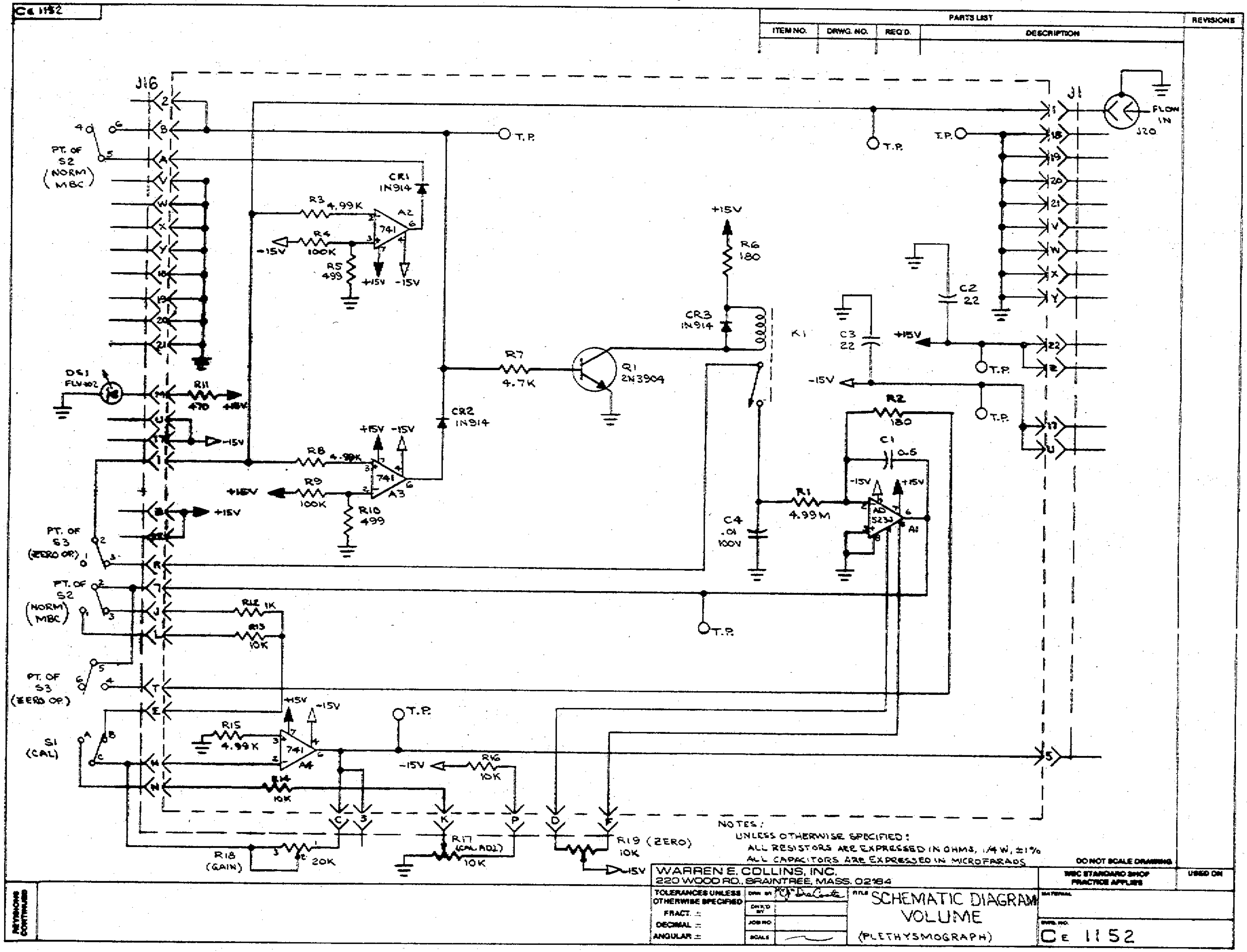
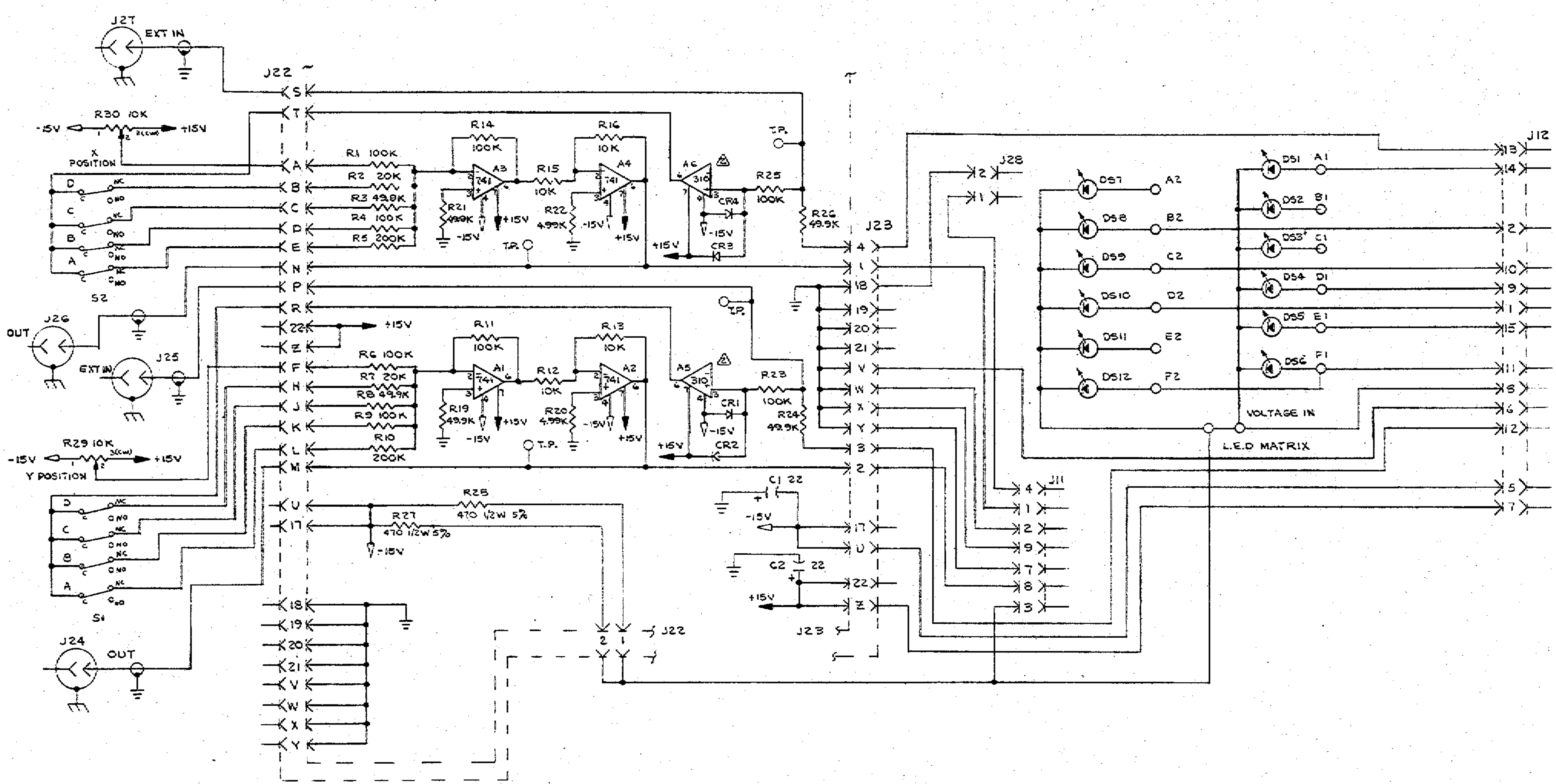


Figure 50 - Volume Amplifier Schematic



NOTES.
1. UNLESS OTHERWISE SPECIFIED:
ALL RESISTORS ARE EXPRESSED IN OHMS, 1/4 W, ± 1%
ALL DIODES ARE IN914
ALL CAPACITORS ARE EXPRESSED IN MICROFARADS

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SCHEMATIC DIAGRAM
OSCILLOSCOPE INTERFACE
PLETHYSMOGRAPH
D E 1177 Rev 2

Figure 51 - Oscilloscope Interface Schematic

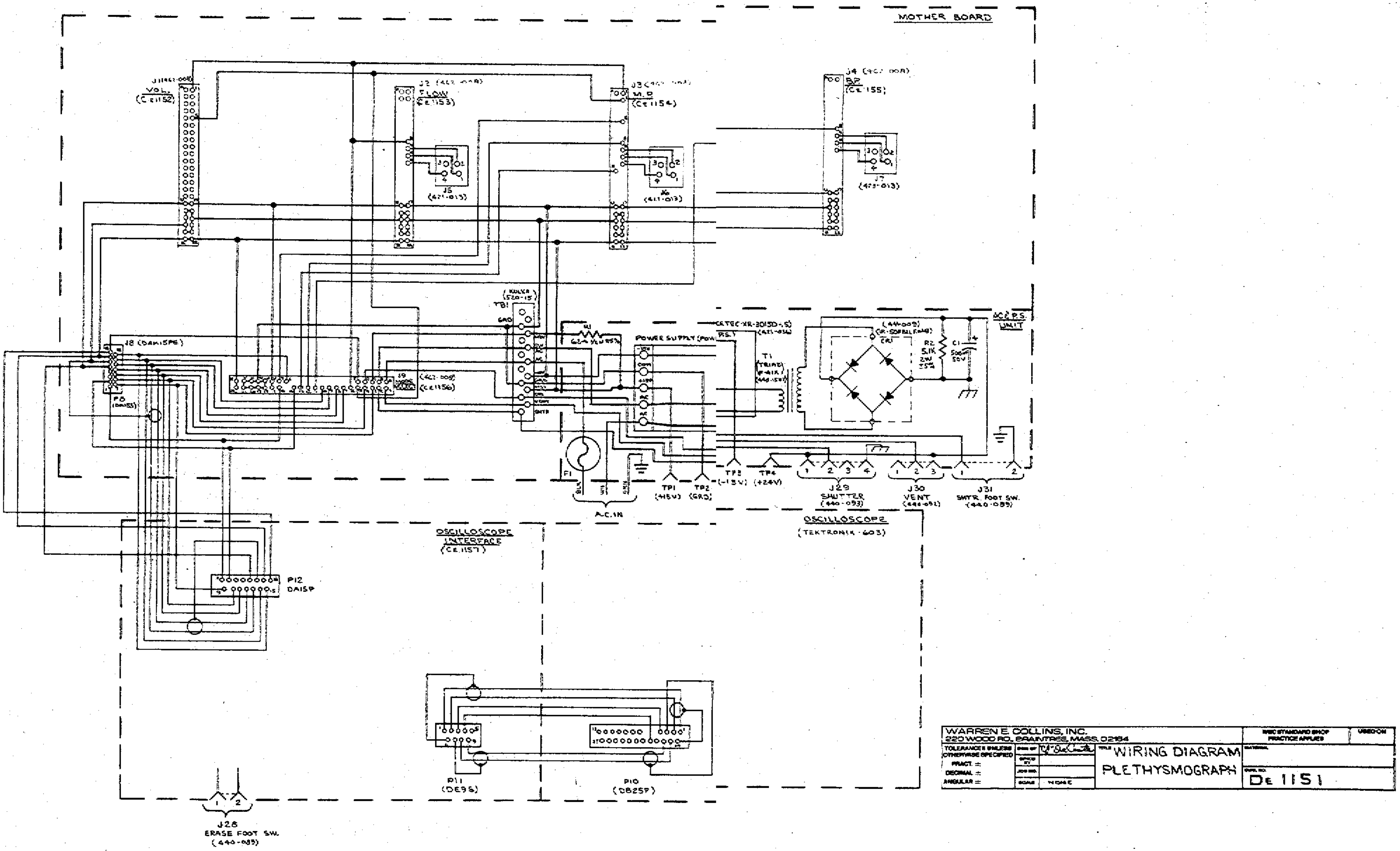
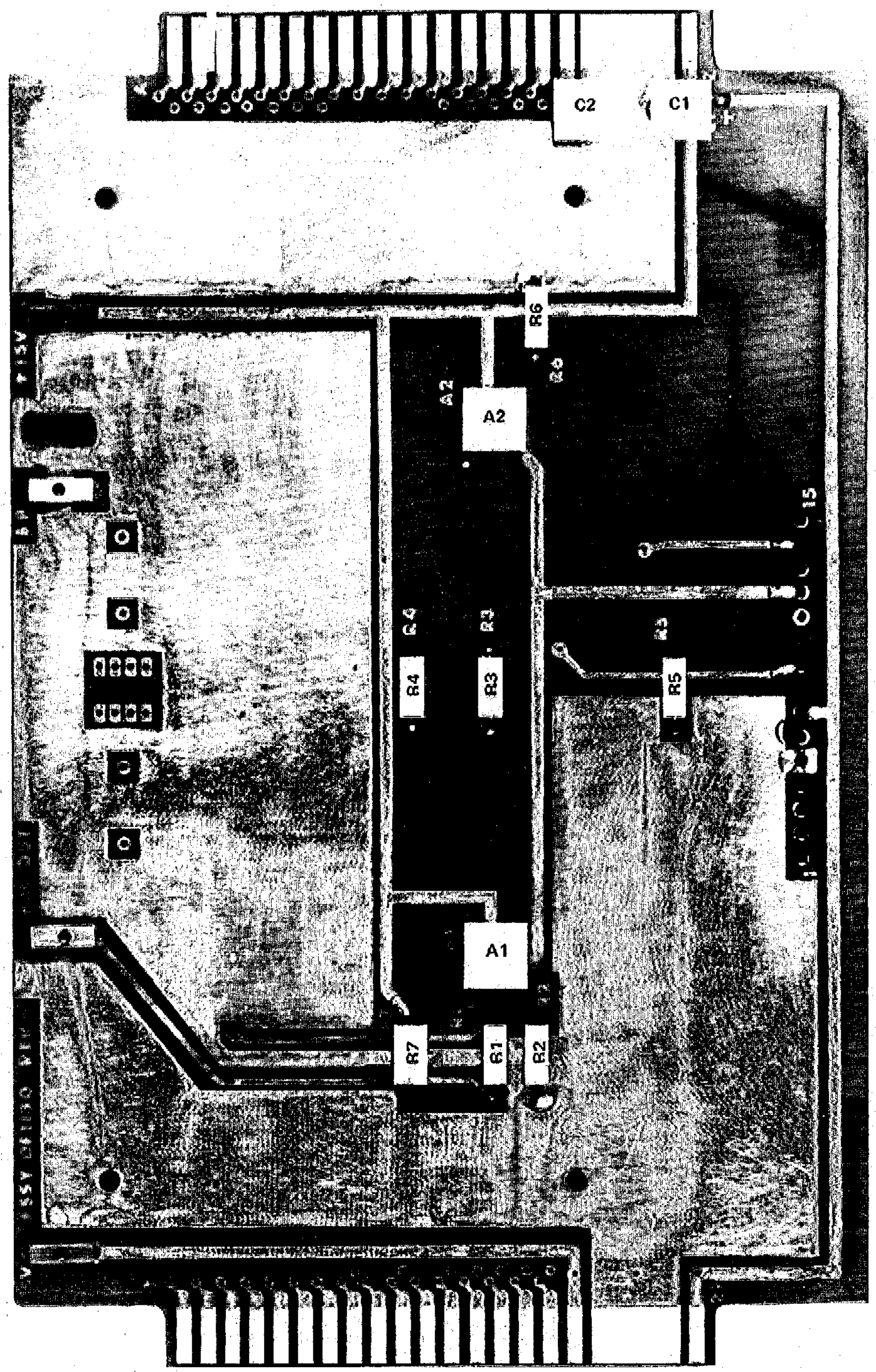


Figure 52 - Body Plethysmograph Wiring Diagram



PARTS LISTING FOR BOX PRESSURE AMPLIFIER CIRCUIT BOARD

R1	4.99K	1/4W	1%
R2	4.99K	1/4W	1%
R3	49.9K	1/4W	1%
R4	34K	1/4W	1%

R5	150K	1/4W	1%
R6	22.1K	1/4W	1%
R7	470	1/2	5%
C1	22 uf		

C2	22 uf
A1	741 OP AMP
A2	741 OP AMP

Figure 53 - Box Pressure Amplifier Circuit Board

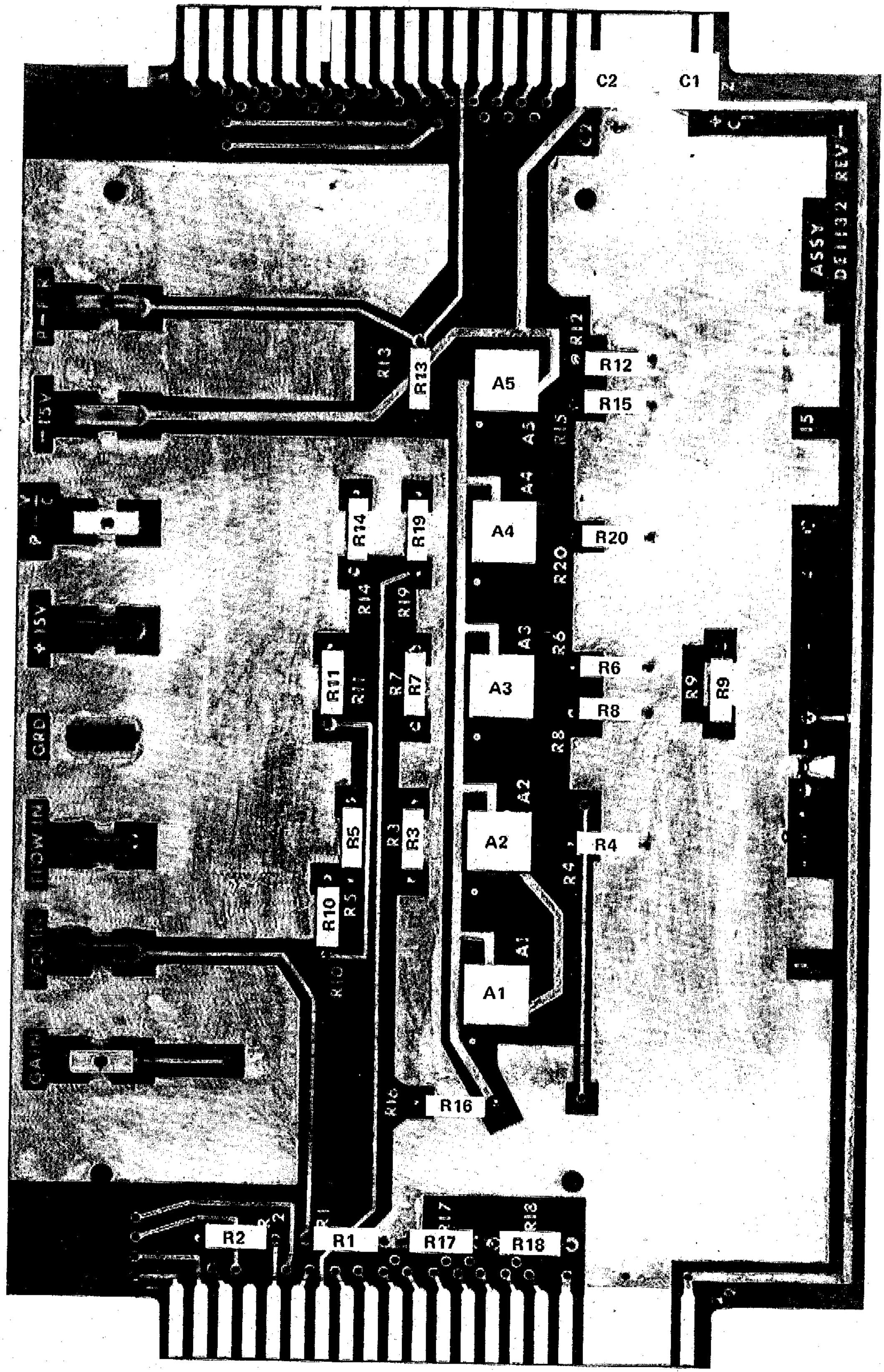
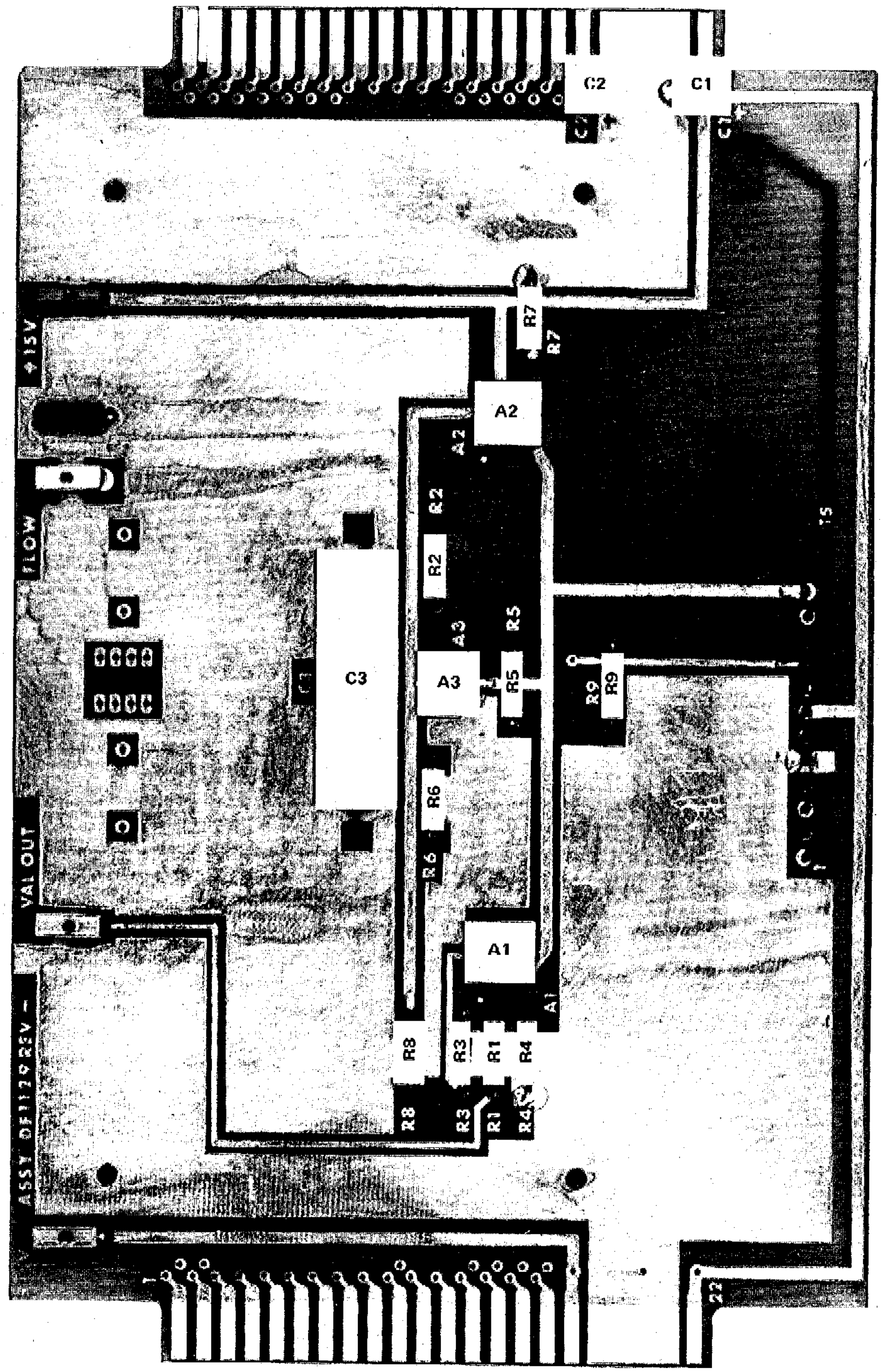


Figure 54 - Mouth Pressure Amplifier Circuit Board

PARTS LISTING FOR MOUTH PRESSURE AMPLIFIER CIRCUIT BOARD

R1	10K	1/4W	1%
R2	1K	1/4W	1%
R3	1K	1/4W	1%
R4	866	1/4W	1%
R5	10K	1/4W	1%
R6	4.99K	1/4W	1%
R7	10K	1/4W	1%
R8	10K	1/4W	1%
R9	30K	1/4W	1%
R10	10K	1/4W	1%
R11	10K	1/4W	1%
R12	4.99K	1/4W	1%
R13	10K	1/4W	1%
R14	10K	1/4W	1%

R15	10K	1/4W	1%
R16	470	1/4W	5%
R17	10K	1/4W	1%
R18	1K	1/4W	1%
R19	1K	1/4W	1%
R20	866	1/4W	1%
A1	741 OP AMP		
A2	741 OP AMP		
A3	741 OP AMP		
A4	741 OP AMP		
A5	741 OP AMP		
C1	22 uf		
C2	22 uf		



PARTS LISTING FOR FLOW AMPLIFIER CIRCUIT BOARD

R1	10K	1/4W	1%
R2	100K	1/4W	1%
R3	10K	1/4W	1%
R4	3.01K	1/4W	1%
R5	4.99K	1/4W	1%

R6	20K	1/4W	1%
R7	4.99K	1/4W	1%
R8	470	1/2W	5%
R9	30.1K	1/4W	1%
C1	22 uf		

C2	22 uf	
C3	2 uf 200 VDC	10%
A1	741 OP AMP	
A2	741 OP AMP	
A3	7514M INTEGRATED CKT	

Figure 55 - Flow Amplifier Circuit Board

PARTS LISTING FOR VOLUME AMPLIFIER CIRCUIT BOARD

R1	4.99M	1/4W	1%
R2	180		5%
R3	4.99K	1/4W	1%
R4	100K	1/4W	1%
R5	499	1/4W	1%
R6	180		5%
R7	4.7K	1/2W	5%
R8	4.99K	1/4W	1%
R9	100K	1/4W	1%
R10	499	1/4W	1%
R11	470	1/2W	5%
R12	1K	1/4W	1%
R13	10K	1/4W	1%
R14	10K	1/4W	1%

R15	4.99K	1/4W	1%
C1	.5 uf 100VDC		5%
C2	22 uf		
C3	22 uf		
CR1	1N914		
CR2	1N914		
CR3	1N914		
K1	POTTER AND BRUMFIELD JRM-1006		
A1	AD523J INTEGRATED CKT ⁄		
A2	741 OP AMP		
A3	741 OP AMP		
A4	741 OP AMP		
Q1	2N3904 TRANSISTOR		

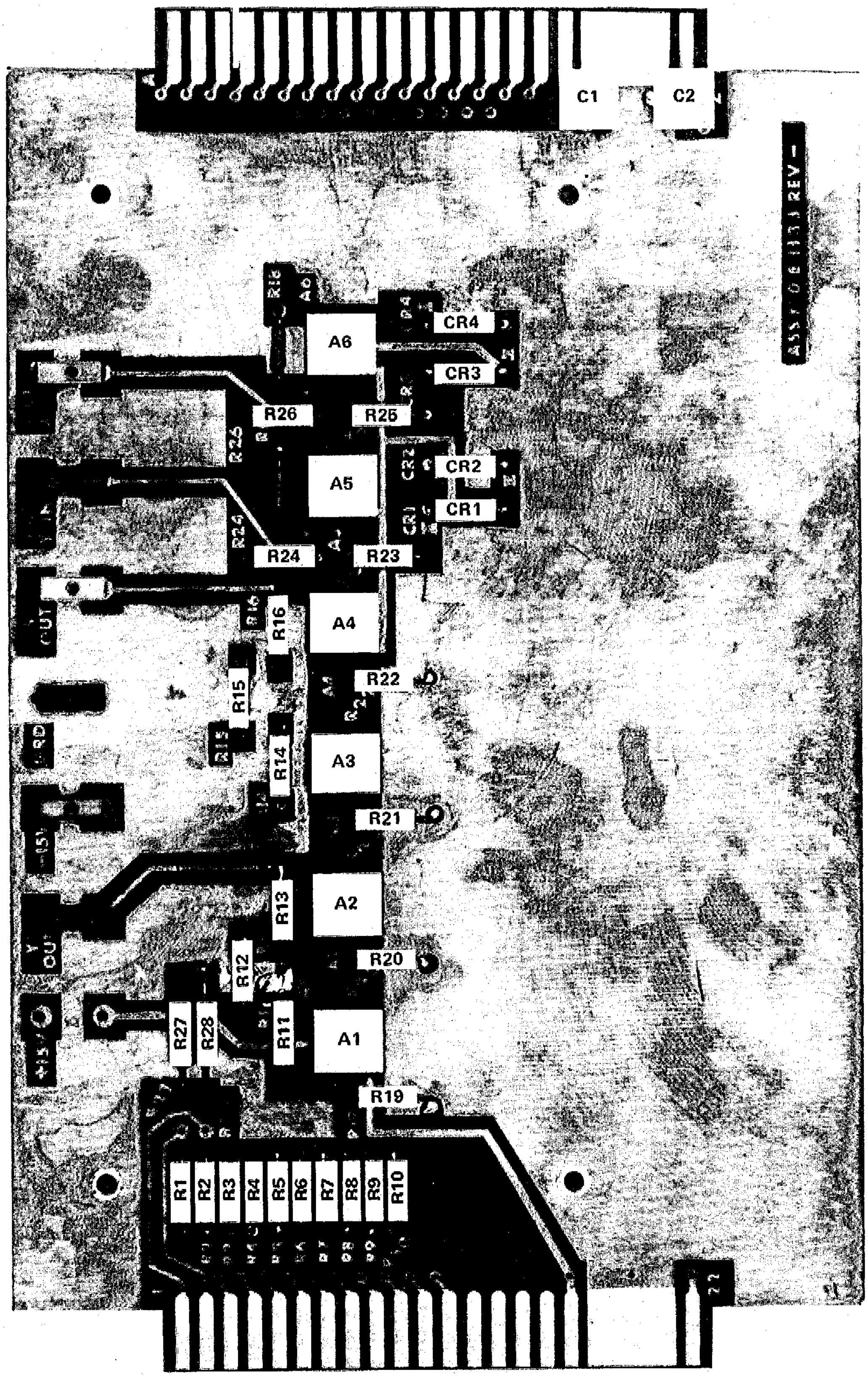
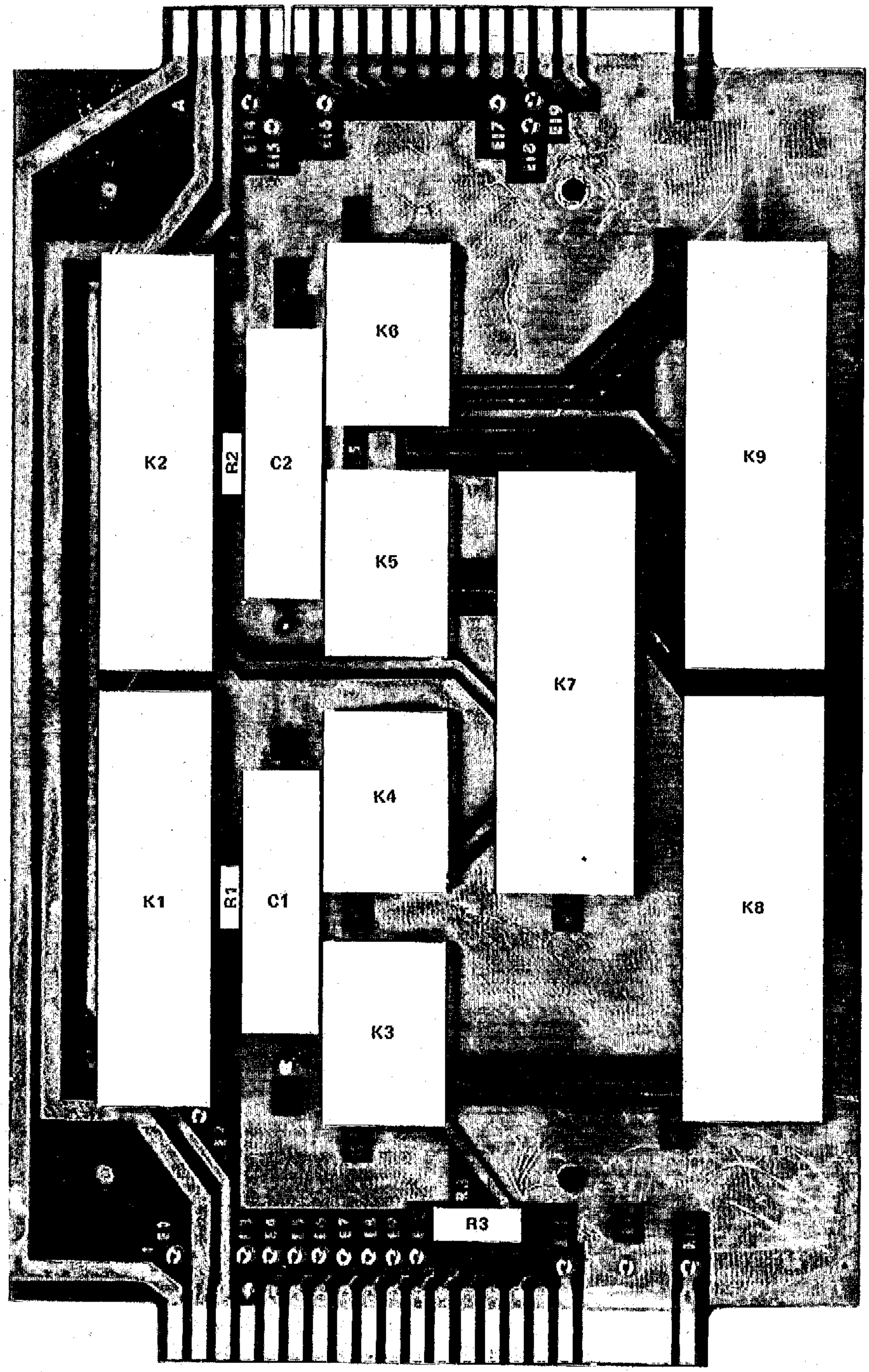


Figure 57 - Oscilloscope Interface Circuit Board



PARTS LISTING FOR SWITCHING MODULE CIRCUIT BOARD

R1	47	1/4W	5%
R2	47	1/4W	5%
R3	470	1/2W	5%
C1	2 uf 200 VDC		
C2	2 uf 200 VDC		
K1	MAGNECRAFT W102MPCX-7		
K2	MAGNECRAFT W102MPCX-7		

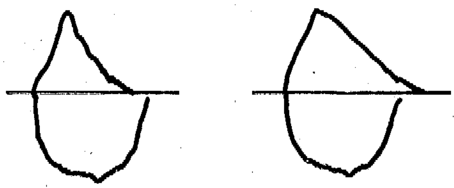
K3	POTTER AND BRUMFIELD JRM - 1009
K4	POTTER AND BRUMFIELD JRM - 1009
K5	POTTER AND BRUMFIELD JRM - 1009
K6	POTTER AND BRUMFIELD JRM - 1009
K7	POTTER AND BRUMFIELD JRM - 1046
K8	POTTER AND BRUMFIELD JRM - 1046
K9	POTTER AND BRUMFIELD JRM - 1046

Figure 58 - Switching Module Circuit Board

X. TROUBLESHOOTING AND MAINTENANCE

X.A. TROUBLESHOOTING

SYMPTOM	CHECK
BOX PRESSURE AMPLIFIER	
1. Noisy signal (greater than one major division)	1. Excessive gain on amplifier or oscilloscope interface. 2. Floor vibration, slamming doors, noisy machines on top of Body Box or Electronics Console, or similar causes. NOTE: Some noise and jitter in the Box Pressure Amplifier signal is normal, due to constant, minute variations in the box pressure.
2. No signal	1. Tubing connections between Body Box and Electronics Console. 2. Gain setting. 3. Position of **GAIN** switches on oscilloscope interface. One of the four switches must be depressed to generate a display.
3. Signal does not center when box vent is opened	1. Operation of vent - solenoid opening should make audible "clunk." 2. Fuse. 3. Small hose at bottom of rotameter - should be disconnected at one end. 4. Trace centered in **EXT** mode - refer to oscilloscope interface section of this chart.
MOUTH PRESSURE AMPLIFIER	
1. Signal does not act properly	1. **LOOP CLOSE** control. At start of testing or calibration, control should be fully counterclockwise to 'snap' position. Recalibrate as described in Section V.C.
2. No signal	1. Proceed as described in Box Pressure Amplifier section.
FLOW AMPLIFIER	
1. Noisy signal (less than one major division)	1. Some high frequency noise from the carrier amp is normal. 2. Calibration signal produced by flow pump is noisy due to design of pump.
2. Non linear throughout range	1. Proper zeroing - only move **OPERATE/ZERO** switch to **ZERO** with no flow through pneumotachograph. 2. Proper reading from rotameter. Refer to Figure 21.
3. **CAL** button produces signal which decays to zero.	1. **ZERO/OPERATE** switch in **OPERATE** position.
4. **CAL** signal or other signal not visible in F/V mode	1. Return Volume Amplifier **OPERATE/ZERO** switch to **ZERO**.
5. No signal	1. Proceed as described in Box Pressure Amplifier section.

VOLUME AMPLIFIER	
1. Drift: flow-volume loops  A B	1. Calibration 2. If the loop appears in Figure A, volume drift is to the right. Figure B shows drift to the left. To correct, move both **OPERATE/ZERO** switches to **ZERO**. Then turn the **ZERO** screwdriver adjust on the *Flow Amplifier* either right or left (½ turn) until loops nearly close. Return switches to **OPERATE**.
2. Constant drift	1. Calibration - refer to Section V.E. 2. Move Flow Amplifier **OPERATE/ZERO** switch to **ZERO** then back. 3. Turn **ZERO** screwdriver adjust as described above.
SWITCHING MODULE	
1. Vent inoperative, but panel lamp illuminates	1. Fuse at back of 24 volt power supply chassis (inside Electronics Console).
2. Mouth shutter inoperative	1. **BB** mode switch depressed. 2. Footswitch. 3. Cable. 4. 24 volt power supply fuse.
3. Toggle switches do not display proper signals	1. LED's in matrix. 2. Proper push button selected.
4. Push buttons in **MODE SELECT** section not illuminated	1. Push button fully depressed. 2. Bulb. 3. Power supply.
OSCILLOSCOPE AND INTERFACE	
1. No display	1. Oscilloscope **POWER** switch. 2. **INTENSITY** and **BRIGHTNESS** controls. 3. **POSITION** controls. 4. Proper selection of switching module switches (refer to previous section).
2. No storage capability	1. **STORE** button. 2. **STORED BRIGHTNESS** control.
3. No erase capability	1. Footswitch.
4. Poor or no film exposure	1. Film packet. 2. Flash on. 3. Camera battery.

X.B. MAINTENANCE

B.1. Except for periodic sterilization of the tubing and pneumotachograph and lubrication of the reciprocating pump, the Body Plethysmograph System is free of routine maintenance.

XI. APPENDIX

V_{TG} AND R_{aw} CALCULATION SHEET

I. PATIENT DATA

Name: ______________________________ Sex: __________

Identification No.: ______________________________ Height: __________ in.

Date: ______________________________ Weight: __________ lb.

Age: __________

II. PARAMETERS

Temperature: _____ °C

Barometric Pressure (B.P.): ________ mm.Hg

Corrected Pressure: P_c = (B.P. -47) x 1.36 = __________ cm H_2O

III. CALIBRATION DATA – STANDARD VALUES

Box Pressure Amplifier (box cal) = 10 cc
Mouth Pressure Amplifier (mouth cal) = 5 cm H_2O
Flow Amplifier (flow cal) = 2 liters/sec.
Volume Amplifier (vol cal) = 1 liter

} per major division (1X att)

IV. RECORDED DATA

V_{TG} tangent = (   ), (   ), (   ), (   ) Average: __________

X attenuator factor (X att): X________

Y attenuator factor (Y att): X________

R_{aw} x Flow tangent (flow tan) = (   ), (   ), (   ), (   ) Average: __________

R_{aw} x Mouth Pressure tangent (V_{TG} tan) = (   ), (   ), (   ), (   ) Average: __________

V. CALCULATIONS

$$V_{TG}\ (\text{ml}) = \frac{P_c\ (\text{corrected } P_2) \times \text{box cal}}{V_{TG}\ \tan \times \frac{X\ \text{att}}{Y\ \text{att}} \times \text{mouth cal}}$$

$$= \frac{(\qquad) \times (\qquad)}{(\qquad) \times (\qquad) \times (\qquad)} = \underline{\hspace{4cm}}\ \text{ml}$$

$$R_{aw}\ (\text{cm } H_2O/\text{L./sec.}) = \frac{V_{TG}\ \tan \times \text{mouth cal}}{\text{flow tan} \times \text{flow cal}}$$

$$= \frac{(\qquad) \times (\qquad)}{(\qquad) \times (\qquad)} = \underline{\hspace{4cm}}\ \text{cm } H_2O/\text{L./sec.}$$

MECHANICS CALCULATION SHEET

I. PATIENT DATA

Name: ____________________ Sex: __________

Identification No.: ____________________ Height: __________ in.

Date: ____________________ Weight: __________ lb.

Age: __________

II. CALIBRATION DATA – STANDARD VALUES

Box Pressure Amplifier (box cal) = 10 cc

Mouth Pressure Amplifier (mouth cal) = 5 cm H_2O

Flow Amplifier (flow cal) = 2 liters/sec.

Volume Amplifier (vol cal) = 1 liter

} per major division (1X att)

III. RECORDED DATA

Static Compliance tangent = (   ), (   ), (   ), (   ) Average: __________

X attenuator factor (X att): X__________

Y attenuator factor (Y att): X__________

Dynamic Compliance tangent = (   ), (   ), (   ), (   ) Average: __________

X attenuator factor (X att): X__________

Y attenuator factor (Y att): X__________

Pulmonary Resistance tangent = (   ), (   ), (   ), (   ) Average: __________

X attenuator factor (X att): X__________

Y attenuator factor (Y att): X__________

IV. CALCULATIONS

Compliance (static or dynamic) = C

$$C \text{ (liters/cm } H_2O) = \text{compliance tan} \times \frac{\text{X att} \times \text{vol cal}}{\text{Y att} \times \text{mouth cal}}$$

$$= (\quad\quad) \times \frac{(\quad\quad) \times (\quad\quad)}{(\quad\quad) \times (\quad\quad)} = \underline{\quad\quad\quad\quad} \text{ liters/cm } H_2O$$

Pulmonary Resistance = R_{pul}

$$R_{pul} \text{ (cm } H_2O\text{/L./sec.)} = \frac{1}{\text{Resistance tan} \times \dfrac{\text{Y att} \times \text{flow cal}}{\text{X att} \times \text{mouth cal}}}$$

$$= \frac{1}{(\quad\quad) \times \dfrac{(\quad\quad) \times (\quad\quad)}{(\quad\quad) \times (\quad\quad)}} = \underline{\quad\quad\quad\quad} \text{ cm } H_2O\text{/L./sec.}$$

TABLE 2

BTPS CORRECTION FACTORS

FACTORS TO CONVERT GAS VOLUMES FROM ROOM TEMPERATURE, SATURATED, TO 37°C, SATURATED

FACTOR TO CONVERT VOL. TO 37°C SAT.	WHEN GAS TEMPERATURE (°C) IS	WITH WATER VAPOR PRESSURE (Mm Hg)* OF
1.102	20	17.5
1.096	21	18.7
1.091	22	19.8
1.086	23	21.1
1.080	24	22.4
1.075	25	23.8
1.068	26	25.2
1.063	27	26.7
1.057	28	28.3
1.051	29	30.0
1.045	30	31.8
1.039	31	33.7
1.032	32	35.7
1.026	33	37.7
1.020	34	39.9
1.014	35	42.2
1.007	36	44.6
1.000	37	47.0

Comroe, J. H., Jr.: *Methods in Medical Research:* Vol. 2. 361 pp. Chicago: Yearbook Publishers, 1950. Pp. 74-244.

*H_2O vapor pressures from *Handbook of Chemistry and Physics* (28th ed.; Cleveland: Chemical Rubber Publishing Co., 1944), p. 1802.

Note:—These factors have been calculated for barometric pressure of 760 mm Hg. Since factors at 22°C, for example, are 1.0904, 1.0910 and 1.0915, respectively, at barometric pressures 770, 760 and 750 mm Hg, it is unnecessary to correct for small deviations from standard barometric pressure.

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TABLE 3

TANGENTS

ANGLE (°)	TANGENT	ANGLE (°)	TANGENT	ANGLE (°)	TANGENT	ANGLE (°)	TANGENT
1	0.01746	26	0.48773	51	1.2349	76	4.0108
2	0.03492	27	0.50952	52	1.2799	77	4.3315
3	0.05241	28	0.53171	53	1.3270	78	4.7046
4	0.06993	29	0.55431	54	1.3764	79	5.1445
5	0.08749	30	0.57735	55	1.4281	80	5.6713
6	0.10510	31	0.60086	56	1.4826	81	6.3137
7	0.12278	32	0.62487	57	1.5399	82	7.1154
8	0.14054	33	0.64941	58	1.6003	83	8.1443
9	0.15838	34	0.67451	59	1.6643	84	9.5144
10	0.17633	35	0.70021	60	1.7320	85	11.430
11	0.19438	36	0.72654	61	1.8040	86	14.301
12	0.21256	37	0.75355	62	1.8807	87	19.081
13	0.23087	38	0.78128	63	1.9626	88	28.636
14	0.24933	39	0.80978	64	2.0503	89	57.290
15	0.26795	40	0.83910	65	2.1445	90	∞
16	0.28674	41	0.86929	66	2.2460		
17	0.30573	42	0.90040	67	2.3558		
18	0.32492	43	0.93251	68	2.4751		
19	0.34433	44	0.96569	69	2.6051		
20	0.36397	45	1.0000	70	2.7475		
21	0.38386	46	1.0355	71	2.9042		
22	0.40403	47	1.0724	72	3.0777		
23	0.42447	48	1.1106	73	3.2708		
24	0.44523	49	1.1504	74	3.4874		
25	0.46631	50	1.1917	75	3.7320		

XI.C. REFERENCES

Dubois, A. B., Botelho, S. Y., Bedell, G. N., Marshall, R. and Comroe, J. H., Jr., *A Rapid Plethysmograph Method for Measuring Gas Volume,* J. Clin. Inv., 35: 322, 1956.

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XI.D. USE OF OPTIONAL EQUIPMENT

D.1. CALIBRATION OF #2 FLEISCH PNEUMOTACHOGRAPH

a. Insure that the #2 Fleisch pneumotachograph is installed at the mouth shutter assembly and that the Body Box door is open.

b. Select the **#2** pneumotachograph circuit on the Flow Amplifier.

c. Push the **1X GAIN** switch on the X and Y axes of the oscilloscope interface.

d. Push the **EXT** switch on the **MODE SELECT** section of the switching module. Center the trace using only the X and Y **POSITION** controls on the oscilloscope interface.

e. Push the **F/V** switch on the **MODE SELECT** section of the switching module.

f. Move the **FLOW-VOLUME MODE** switch of the switching module to **VOL/FLOW**.

g. Move the **OPERATE/ZERO** switch on the Flow and Volume Amplifiers to the **ZERO** position.

h. Push the **5X GAIN** switch on the X and Y axes of the oscilloscope interface.

i. Adjust the Flow Amplifier **ZERO** control until switching between **F/V** and **EXT** on the switching module produces the smallest Y axis deflection. Any X axis deflection indicates that the Volume Amplifier **ZERO** control needs adjustment.

j. Push the **2X GAIN** switch on the X and Y axes of the oscilloscope interface.

k. Rotate the knob on the hand-held speed control fully counterclockwise to the 'snap' position, then move the toggle switch to the **FLOW CAL** position.

l. Connect the short hose from the body box seat to the bottom of the 0 - 90 LPM rotameter (small diameter tube).

m. Connect the long hose from the top of the 0 - 90 LPM rotameter to the mouth shutter opening.

n. Return the Flow Amplifier **OPERATE/ZERO** switch to **OPERATE**. Position the trace one major division from the bottom of the screen with the Y axis **POSITION** control.

o. Move the **BOX VENT** switch to **OPEN**.

p. Rotate the knob on the hand-held speed control slowly until the rotameter reads 60 LPM (1 LPS). The correct way to read the rotameter is shown in Figure 21.

q. At this flow rate, the trace should move up two major divisions from where it started. If necessary, adjust the trace to this point using the Flow Amplifier **GAIN #2** control. The trace may jitter around due to the high frequency noise in the pump signal.

r. Return the toggle switch on the hand-held speed control to the center position and turn the knob fully counterclockwise until a 'click' is heard.

s. Reposition the trace to the center of the screen using the Y axis **POSITION** control.

t. Push the **1X GAIN** switch on the X and Y axes of the oscilloscope interface.

u. Depress the Flow Amplifier **CAL** button and observe the deflection on the screen. If a three major division deflection is not observed, adjust the **CAL ADJ #2** control as needed.

v. Move the **BOX VENT** switch to **CLOSE**.

w. The #2 Fleisch pneumotachograph circuit is now calibrated to 1 liter/sec./division.

x. Disconnect the long and short sections of hose.

D.2. USE OF PLETHYSMOGRAPH OCCLUDERS

a. Some systems include a set of three acrylic plastic occluder boxes which are used to reduce the deadspace within the plethysmograph chamber when testing children.

b. There are no set rules for which boxes are used under given circumstances but patient comfort must be of some consideration. Generally, the boxes are placed on the seat behind the patient or on the floor at the patient's feet.

c. When the occluder boxes are used (singly or any combination), the chart below indicates the additional weight compensation required on the Box Pressure Amplifier **WEIGHT-LBS** control (refer to pp. 14-15). For instance, if a 70 pound child is tested with the large occluder box, the **WEIGHT-LBS** control must be set to 170 LBS.

	DISPLACEMENT (LITERS)	WEIGHT COMPENSATION (LBS)
LARGE	45.45	100
MEDIUM	35.0	77
SMALL	10.0	22

(where 1 liter = 1 kg)