USER'S MANUAL

FOR

VICTOREEN

PRECISION ELECTROMETER

MODEL 500

DOCUMENT NUMBER TD V115.0190

RECORD OF REVISIONS

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USER'S MANUAL
FOR
VICTOREEN
PRECISION ELECTROMETER
MODEL 500

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USER'S MANUAL FOR MODEL 500

PRECISION ELECTROMETER

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USER CAUTION

This instrument is intended solely for the detection and measurement of ionizing radiation. It should be used only by persons who have been trained in the proper interpretation of its readings and the appropriate safety procedures to be followed in the presence of radiation.

All instructions and warnings contained in this manual or on the instrument must be read before use and must be strictly followed. Failure to follow these instructions and warnings may result in inaccurate readings and/or user hazard. Indicated battery and other operational tests must be performed prior to each use to assure that the instrument is functioning properly.

READ YOUR INSTRUCTION MANUAL

WARRANTY

This instrument with its accessories, excluding those accessories listed below, is warranted by **VICTOREEN, INC.**, against defects in materials and workmanship for a period of one year from the date of original shipment. During the warranty period **VICTOREEN** will repair, or at its option replace, at no charge an instrument containing such defect, provided that it is returned, transportation prepaid, to the **VICTOREEN** repair facility listed on the back page. Instruments repaired under warranty will be returned transportation prepaid.

In addition, the nuclear radiation calibration (when applicable) for each instrument is warranted to be within its specified accuracy at the time of shipment. If an error in this initial calibration is discovered, the instrument will be recalibrated at no charge, provided it is returned as described above. This does not apply to any calibration deviation that may result from normal use.

There are no warranties, express or implied, including without limitation any implied warranty of merchantibility or fitness, which extend beyond the description on the face hereof. This express warranty excludes coverage of and does not provide relief for incidental or consequential damages of any kind or nature, including, but not limited to loss of use, loss of sales or inconvenience. This exclusive remedy of the purchaser is limited to repair, recalibration, or replacement of the instrument at **VICTOREEN's** option.

This warranty does not apply if the product, as determined by **VICTOREEN**, has been damaged by accident or misuse, or as a result of service or modification by other than an authorized **VICTOREEN** repair facility. This warranty is void if the unit is subjected to temperatures above 55° C unless otherwise indicated.

This warranty specifically excludes the following items which are covered by their original manufacturers' warranties: Photomultiplier tubes, Geiger and proportional tubes, crystal and other solid-state detectors, batteries, and major ancillary items of instrument systems, such as, but not limited to, recorders and pumps.

PROCEDURES AND WARNINGS

The equipment herein described is designed and manufactured in compliance with all applicable safety standards. Nevertheless, certain hazards are inherent in the use of electronic and radiometric equipment. Adequate warnings are included in this manual and on the product itself to cover hazards that may be encountered in normal use and servicing of this equipment. No other procedures are warranted by **VICTOREEN**. It shall be the owner's or user's responsibility to see to it that the procedures herein are meticulously followed, and especially that the warning and cautionary notes are heeded. Failure on the part of the owner or user in any way to follow the prescribed procedures shall absolve **VICTOREEN** and its agents from any resulting liability.

If applicable, failure to conduct periodic performance tests in accordance with ANSI N323-1978, paragraphs 4.6 and 5.4, and to keep records thereof in accordance with paragraph 4.5 of the same standard, could result in erroneous reading of potential danger. ANSI N323-1978 becomes, by this reference, a part of this operating procedure.

INSPECTION AND MATERIAL RETURN INSTRUCTIONS

Instruments should be examined and tested as soon as received by the purchaser. Claims for damage, if any, should be filed at once with the carrier. Instruments returned to the plant for warranty service, repair, calibration, replacement or credit must be accompanied by **VICTOREEN's** Return Material Authorization, Form 9083E-7-79.

Any material returned for repair must be accompanied by a valid customer purchaser order, identifying the work to be done.

Material valued at $200.00 or more and/or weighing more than twenty pounds should be shipped the best way prepaid and fully insured.

We suggest that any instrument weighing over twenty pounds be wrapped in heavy kraft paper and packed in a double corrugated carton or wooden box. Protect the instrument on all sides with at least three inches of excelsior or similar padding. Mark the case plainly with suitable caution warnings to insure careful handling.

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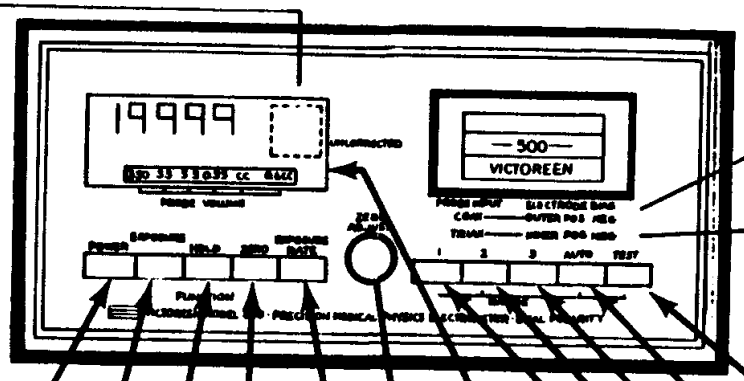


UNITS DISPLAY AREA

nC pA V — Lit for test.

mR/MIN ZERO

A.C. LINE ON - OFF

ADJUST ZERO

Feedback element shorted. Zero lamp lit.

Last reading retained on display. Feedback element shorted.

Instrument measures rate in mR/min or R/min.

Instrument integrates input current. mR or R lit.

In all modes, the decimal point is positioned for direct readout consistant with the units displayed and the probe volume switch position selected. Readings are uncorrected and appropriate probe calibration factor should be used.

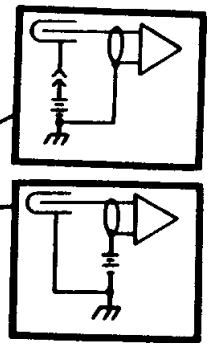
Probe volume lamps selected by switch on back of instrument.

Display readings are divided by 2 in 0.66 cc position.

In electrometer mode these lamps are off and nC unit lamp is lit for exposure.

OR

pA (picoamperes) lamp is lit for exposure rate.



COAX MODE

1. Close door over triax connector opening "safety" switch to coax.
2. Set triax-coax switch to coax.

TRIAX MODE

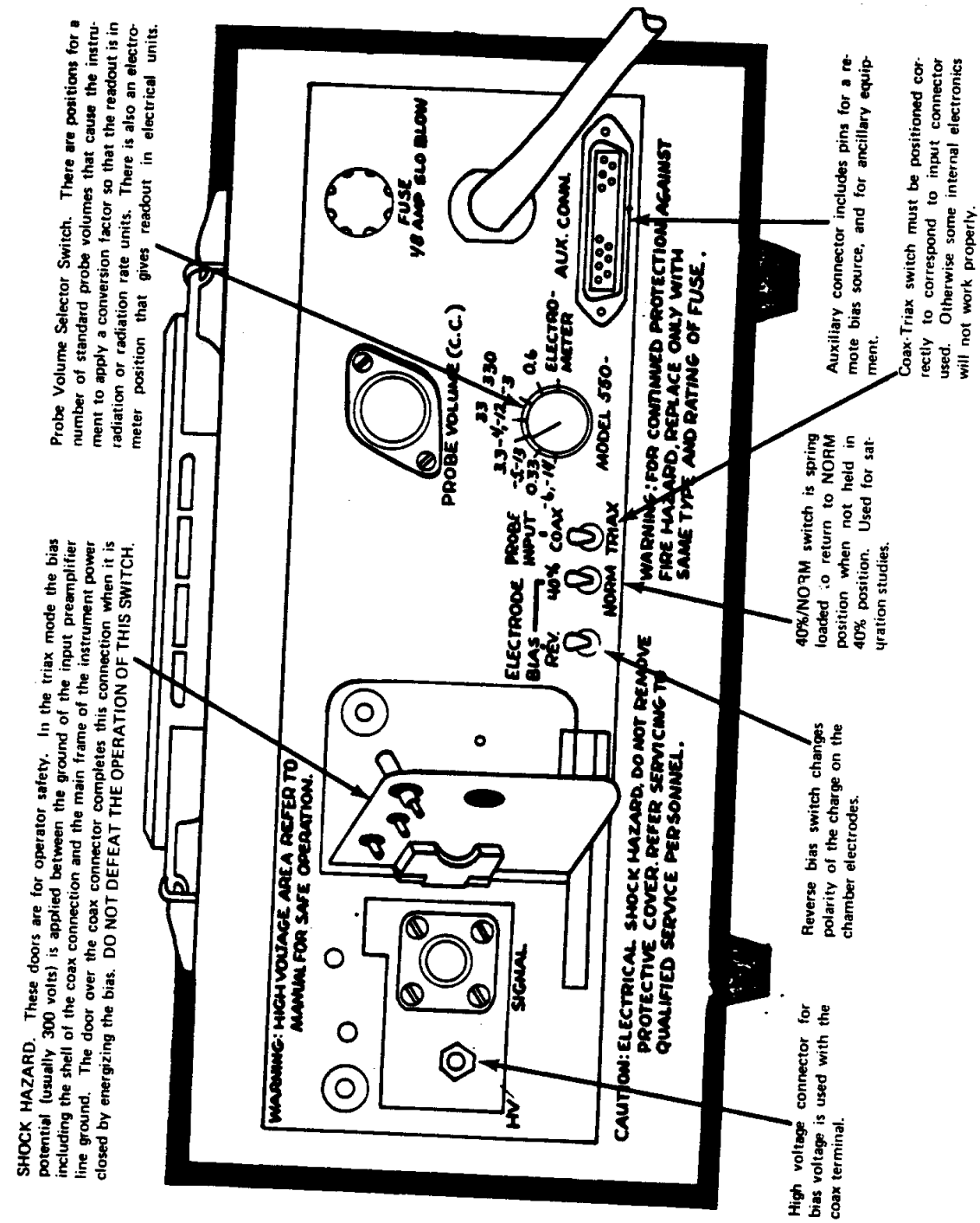
1. Close door over coax connector.
2. Set triax-coax switch to triax.

Switch function to zero. Depress test to measure bias voltage. V lamp in units display area lit. If instrument indicates 0 volts, bias is not present or triax-coax switch on back panel is improperly set or micro switch failure.

AUTOMATIC RANGE

MANUAL SELECTION OF:

3. Least Sensitive Range
2. Mid Range
1. Most Sensitive Range


SHOCK HAZARD. These doors are for operator safety. In the triax mode the bias potential (usually 300 volts) is applied between the ground of the input preamplifier including the shell of the coax connection and the main frame of the instrument power line ground. The door over the coax connector completes this connection when it is closed by energizing the bias. DO NOT DEFEAT THE OPERATION OF THIS SWITCH.
Probe Volume Selector Switch. There are positions for a number of standard probe volumes that cause the instrument to apply a conversion factor so that the readout is in radiation or radiation rate units. There is also an electrometer position that gives readout in electrical units.
WARNING: HIGH VOLTAGE AREA REFER TO MANUAL FOR SAFE OPERATION.
CAUTION: ELECTRICAL SHOCK HAZARD. DO NOT REMOVE PROTECTIVE COVER. REFER SERVICING TO QUALIFIED SERVICE PERSONNEL.
HV
SIGNAL
ELECTRODE BIAS REV.
PROBE INPUT
40% COAX
NORM TRIAX
PROBE VOLUME (c.c.)
33 330
3.3-4.7-3
0.33 -6.-14
0.6
ELECTRO-METER
MODEL 550-
AUX. CONN.
FUSE
1/8 AMP SLO BLOW
WARNING: FOR CONTINUED PROTECTION AGAINST FIRE HAZARD, REPLACE ONLY WITH SAME TYPE AND RATING OF FUSE.
High voltage connector for bias voltage is used with the coax terminal.
Reverse bias switch changes polarity of the charge on the chamber electrodes.
40%/NORM switch is spring loaded to return to NORM position when not held in 40% position. Used for saturation studies.
Auxiliary connector includes pins for a remote bias source, and for ancillary equipment.
Coax-Triax switch must be positioned correctly to correspond to input connector used. Otherwise some internal electronics will not work properly.

ELECTROMETER 500

1 General Description - Electrometer 500 is a MOS-FET electrometer of high precision. It is used to interpret charge or current inputs from ion chambers subjected to ionizing radiation in dosimetry and exposure measurements. This electrometer can be used with most of the commercially available probes whether they have coaxial or triaxial cable terminations. Furthermore it can be so used without danger of shock to personnel in normal use. Chamber bias potential is placed automatically whichever type of termination is used. The instrument also has provision for compliance with modern dosimetry protocols that call for polarity reversal and saturation studies. This includes a switch for reversing chamber bias, and a switch for reducing chamber bias to 40% of normal. Readout is displayed on a 4½-digit panel with automatic range changing.

2 Specifications - Specifications for Electrometer 500 are given in Table I. Table II gives a list of top-of-the-range readings with various probe volumes.

These readings are nominal amounts. It would be unlikely that any particular probe would match these readings exactly even if its nominal volume were the same as one of those listed. The variations will not follow any pattern, but the farther they are from the norm, the harder it will be to correct for them. Correction factors can and should be applied to all probes that vary not more than ten percent from the listed norm. Each correction factor is specific to an individual probe. It is determined by a calibration laboratory equipped to make such determinations. Any probe that varies more than ten percent, but not more than twenty percent from the nominal volume is in a marginal area where its readings, made with the aforementioned correction, may be acceptable in non critical applications.

Probes whose nominal volumes differ from the listed volume by more than twenty percent definitely should be used with the volume selector switch on the back panel in the ELECTROMETER position. A conversion (calibration) factor must be used with such probes to convert the electrical readings (nonocoulombs or picoamperes) to radiation units (roentgens or milliroentgens; roentgens per minute or milliroentgens per minute).

VICTOREEN has two laboratories equipped for determining these factors (correction or calibration). One is a factory calibration laboratory

TABLE I: GENERAL SPECIFICATIONS FOR ELECTROMETER 500

Feature	Specification
Dimensions:	
Instrument	30 cm wide, 15.4 cm high, 27.5 cm deep (11.8 in. by 6 in. by 10.8 in.)
Carrying Case	59 cm wide, 20 cm high, 40 cm deep (23.2 in. by 7.9 in. by 15.75 in.)
Weight:	
Instrument	5.5 kg (12.2 lb)
Carrying Case (With instrument)	10.8 kg (23.7 lb)
Input Line Voltage	115 V or 230 V $\pm$ 13%; 50/60 Hz (determined during manufacture)
Maximum Power	10 W
Power Dependence	Less than 0.02% variation per 10% power change
Operating Temperature Range	10^{0}C to 40^{0}C
Storage Temperature Range	-20^{0}C to $+60^{0}$C
Temperature Stability	Within 0.03% per ^{0}C
Long Term Stability	Within 0.5% of full scale per year
Operating Humidity Range	0 to 80% relative humidity (non condensing)
Display	$4\frac{1}{2}$-digit LED Readout
Precision	Within 0.01% of full scale
Accuracy . current and charge measurements	Within 0.5% of full scale
Linearity Variations	Within 0.03% of full scale
Input Impedance	Greater than 10^{14} Ω
Input Offset Current	Less than 3×10^{-15} A
Amplifier Gain	$> 10^{5}$
Decay Time Constant of Integrating Capacitor	$> 2 \times 10^{6}$ s
Response Time (0 to 90% reading)	2.3 s
Overrange Indication	Flashing display
Front Panel Controls:	
Pushbuttons	POWER (red)
	EXPOSURE
	HOLD
	ZERO
	EXPOSURE RATE
	1
	2
	3
	AUTO
	TEST (red)
Knob	ZERO ADJUST

TABLE 1: GENERAL SPECIFICATIONS FOR ELECTROMETER 500 (CONT'D)

Feature	Specification
Front Panel Displays	4½ Digit Readout Display
	Units Display
	PROBE INPUT
	ELECTRODE BIAS
Rear Panel Controls:	
Toggle Switches	BIAS - REV
	BIAS - 40% - NORM
	INPUT-COAX-TRIAX
Selector Switch	PROBE VOLUME (cc)
Connectors	COAX
	TRIAX
	FUSE - 1/8 AMP SLO BLOW
	AUX CONN

TABLE II: MAXIMUM RANGE READINGS FOR PROBE SIZES LISTED*

Probe Volume cc	Range 1	Range 2	Range 3	Display Units
0.6	9.999	99.99	999.9	R, R/min
0.33	19.999	199.99	1999.9	R, R/min
3.3	1.9999	19.999	199.99	R, R/min
33	199.99	1999.9	19999	mR, mR/min
330	19.999	199.99	1999.9	mR, mR/min
Electrometer (Exposure Mode)	1.9999	19.999	199.99	nC
Electrometer (Rate Mode)	19.999	199.99	1999.9	pA

* The probe multiplier as found on the handles of 550 and 555 series probes are not to be used with the model 500. The selector switch has positions for these probe volumes.

Probes whose nominal volumes differ by more than plus or minus 10 to plus or minus 20 percent from those indicated above should be used on the Model 500 in the Electrometer Mode. The probes must have a calibration factor from the calibration laboratory so equipped and the calibration factor must have units of exposure per nC/ or exposure-rate per pA. The Model 500 readout is then multiplied times the calibration factor to give the desired measurement in exposure or exposure-rate units.

Victoreen has two such laboratories at the factory. One of the laboratories is a factory calibration laboratory for general purpose calibration of all VICTOREEN equipment. The other is a Regional Calibration Laboratory accredited by the American Association of Physics in Medicine primarily to provide calibration for Medical therapy and diagnostic dosimetry systems.

3 Operation - Read the manual through with particular attention to section 4 before attempting to operate the electrometer.

3.1 Set-Up and Electrometer Functional Test

1. Depress the ZERO and AUTO pushbuttons.
2. Plug the power cord into a power outlet.
3. Depress the POWER pushbutton.
4. Does the probe to be used have a coax or triax connection? If coax, open the coax door but leave the cap on the connector; if triax, leave both doors closed.
5. Adjust the rear-panel COAX/TRIAX switch to agree with the connection of the probe to be used.
6. Put the volume selector switch in the ELECTROMETER position.
7. Depress the ZERO pushbutton and adjust the ZERO ADJUST knob until the readout shows 0 $\pm$ 4 units (40 μV).
8. Wait 15 minutes and then readjust the ZERO ADJUST knob as in Step 7. If the zero changed by more than 50 counts, wait five minutes and make another adjustment.
9. Depress the EXPOSURE RATE pushbutton. The readout should be less than $\pm$ 0.015 pA.
10. Depress the EXPOSURE pushbutton. Note the reading. The reading is to be subtracted from the final reading.
11. Allow the electrometer to integrate charge for five minutes. Subtract the beginning reading, and divide the net reading by the exact number of seconds of integration. The net average current should be less than 3×10^{-15}A.

3.2 Electrometer and Probe Functional Test - After the function of the electrometer is tested alone, the electrometer-probe combination should be tested to make a basis for future corrections, if needed.

1. Connect the probe to the rear input connector.
2. Depress the ZERO pushbutton and adjust the ZERO ADJUST knob to make the readout indicate 0 $\pm$ 4 (40 μV).
3. Wait 15 minutes and then readjust the ZERO ADJUST knob as in Step 2. If the zero changed more than 50 counts, wait five minutes and make another adjustment.
4. Depress the EXPOSURE RATE pushbutton. If it is more than, or if it is appreciably more than the reading with the electrometer above, make a note of the reading for future reference.
5. Depress the EXPOSURE pushbutton. Note the reading.
6. Allow the electrometer to integrate charge for five minutes. Subtract the beginning reading, and divide the reading by the exact number of seconds of integration. The net average current should be less than 3×10^{-15} A. If it is more, make a note of the discrepancy to use in future corrections.

3.3 Data Collection - Depress either EXPOSURE or EXPOSURE RATE depending on the mode you want, and proceed with data collection.

3.4 Ion Chamber Bias - It is important that the ion chamber probe which is connected to the electrometer be properly biased. Depressing the TEST pushbutton causes the bias voltage to be displayed on the readout. This voltage is measured at the bias battery terminals. See the complete Bias Voltage Location Test, Paragraph 5.1.4.

3.4.1 Chamber Bias Continuity Test - The recommended test for continuity in connections of a fully guarded chamber is performed with the chamber not in a beam of ionizing radiation.

1. Switch the electrometer to EXPOSURE mode, AUTO range, and ELECTROMETER.
2. Record the reading, and wait one minute.
3. Record the new reading. There should not be a change of more than six in the least significant digit.

N O T E

If the above procedure yields a change of more than six in the least significant digit, it might be worth verifying in the absence of a radiation field with another instrument.

4. Watch the display and reverse the bias using the bias toggle switch on the rear panel. The display should immediately jump to a new reading. The change in reading will be about equal to the net voltage change (around 700 volts) times the capacitance of the fully guarded chamber.*
5. Record the new reading, and wait one minute.
6. Record the present reading. There should not be a change of more than six in the least significant digit from the reading recorded in Step 5.

(Positive results from this test indicate good continuity to inner and outer electrodes, and proper bias of the ion chamber).

3.4.2 Collection Efficiency Test - With a chamber connected and reading non-fluctuating radiation in the rate mode, record the reading observed, and note the amounts of indicated fluctuation. Press the spring-loaded 40% BIAS switch upward. Read and record the reading on the digital readout after the reading stabilizes in the 40% mode. The second reading should be lower than the first and should fall on the collection efficiency curve for the probe in use. Refer to Appendix.

3.4.3 External Bias - An external bias supply can be connected to the electrometer through pins 11 (-) and 12 (+) of the auxiliary connector. The slide switch inside the instrument should be set with the button toward the rear of the instrument.

The external bias supply must be extremely stable and free of noise. Suppose, for example, the chamber in use had a capacitance of 10 pF. If the bias supply changes 1 mV in 1s, an input signal current of 10^{-14} A will be generated. On Range 1 in the rate mode this much change will cause a ten-digit change in the readout. Very few electronic power supplies have better stability than this. Electrometer 500 uses a bias battery because fresh batteries are free from line noise and fluctuation. However, the battery should be changed at least once a year because old batteries tend to get noisy.

4 Functional Description

4.1 Rear Panel Components - The rear panel of Electrometer 500 contains the following components: Connectors for coaxial and tri-

* See Appendix I for sample calculations.

axial cable connections in a mutually exclusive arrangement behind mechanically and electrically interlocked doors that make only one connector available at a time to prevent inadvertent contact with the unused connector, a selector switch for matching the electrometer ranging systems with the volume of the chamber in use, two bias toggle switches; one to reverse bias polarity, and the other to reduce bias to 40% of its nominal level, one toggle switch to actuate a display showing whether the coaxial, or triaxial probe connection is in use, an auxiliary connector with connecting pins for external bias input, and for external instruments to monitor the electrometer output, and a fuse mounting socket.

4.1.1 Connectors for Coaxial and Triaxial Probe Cables - Two input connectors have been provided so that a wide variety of probes can be used with Electrometer 500. The connectors are behind two interlocking doors so arranged that only one door at a time can be open. The COAX door operates limit switches that alter circuit connections to suit the circuitry of the connector chosen. With the COAX door closed and the limit switches depressed, the circuit is correct for TRIAXIAL operation. With the COAX door open and the limit switches released, the circuit is correct for COAXIAL operation. The two switches are connected in tandem so that if either switch fails in any mode, the net effect will be to remove the charge from the floating ground at the connector, and ground it to the chassis regardless of which door is open. The likelihood of both switches failing at once is remote.

W A R N I N G !

Do not attempt to bypass the action of the limit switches in any way. To do so would be likely to cause personal injury from shock from the 350-volt potential existing between the floating ground and the chassis ground.

4.1.2 Selector Switch for Chamber Volumes - There are six positions of the selector switch corresponding to five chamber volumes and an electrometer position that reads directly in current or charge. The applicable volumes are printed at the other locations along with 550 dash numbers of VICTOREEN probes that have those volumes. To use other probes with different volumes, use the electrometer setting to get a reading in nanocoulombs or picoamperes. Convert this reading to radiation units using the conversion factor supplied with the probe by the manufacturer.

4.1.3 Bias Toggle Switches - The toggle switch marked REV reverses the direction of the bias on the ion chamber. The electrode and the sign of the bias are indicated by an LED display under ELECTRODE BIAS. The sign also shows on the digital readout when the TEST pushbutton is depressed.

The 40%/NORM toggle switch is spring loaded to remain down, which is the position for normal operation. When desired for saturation tests, the switch can be held up manually in the 40% position. When it is released, it will return automatically to the NORM position. An easy verification of this switch's function is to depress TEST, note the voltage displayed; operate the 40%/NORM switch and note the new voltage indicated. The second reading should be 40% of the first reading.

4.1.4 COAX-TRIAX Switch - When a probe is connected to the electrometer, this switch should be put in the position corresponding to the type of connector used. This will set the front panel lamp functions properly, but will have no effect on the bias. If the switch is not set properly, the bias voltage will show zero during TEST, although the bias voltage will actually be applied to the probe. See the Bias Voltage Location Test, paragraph 5.1.4.

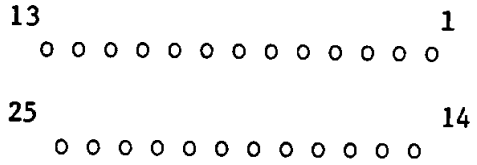
4.1.5 Auxiliary Connector - The auxiliary connector provides connections for external reading of electrometer output, and for connection of an external bias supply, among other connections. Table III gives a list of the pins in the Auxiliary Connector and their functions.

TABLE III: PIN CONNECTIONS OF THE AUXILIARY CONNECTOR

Pin	Function	Pin	Function	Pin	Function
1	Chassis Ground	10	Jumper to 6	19	Spare
2	Relay - NO	11	External bias (-)	20	Spare
3	Relay - NC	12	External bias (+)	21	Spare
4	Relay - C	13	Electrometer Output	22	Spare
5	NU	14	Spare	23	Spare
6	Plot Output - Hi	15	Spare	24	Spare
7	Plot Output - Lo	16	Spare	25	Spare
8	NU	17	Spare		
9	Floating Ground (electrometer low)	18	Spare		

NO = normally open; NC = normally closed; NU = not used; not available as a spare.

Functions for pins 1 thru 7 available only with dose trip option.



Auxiliary Connector as viewed from rear of Electrometer 500

4.1.6 Fuse - The Electrometer 500 circuits are protected with a 1/8 - amp, slo blow fuse. Do not use any other type as a replacement.

4.1.7 Line Power - 115 - or 230-volt 50/60 Hz line power enters the electrometer through a power cord passing into the electrometer through the right-hand side of the rear panel. The electrometer is designed to tolerate a ± 13% variation from nominal line voltage.

4.2 Front Panel Components - The following components are located on the front panel of Electrometer 500: The digital readout, the units indicators, the probe volume indicator, the probe input and electrode bias indicators, the zero adjust knob, the red POWER pushbutton, the red TEST pushbutton, and the following white pushbuttons - EXPOSURE, HOLD, ZERO, EXPOSURE RATE, Range Pushbuttons; 1,2,3, and AUTO RANGING.

4.2.1 Digital Readout - A 4½ - digit display gives the numerical level of the readout. The leftmost digit, the half digit, can show only 0 or 1. All other digits can show any value from 0 to 9. Thus the display can show any level from 0 to 19999.

The decimal point is placed automatically by instrument circuit logic. Negative levels are indicated by a - sign to the left of the digital display.

4.2.2 Units Display - The units display area shows what units are to be applied to the digital display. There are display symbols for:

nanocoulombs		n C
picoamperes		p A
milliroentgens		m R
roentgens		R
per minute		/ min
volts	(lighted for TEST)	V
zero	(lighted for HOLD, ZERO, and ZERO ADJUST)	zero

4.2.3 Probe Volume Display - The probe volumes for which the back panel selector switch has a setting are printed across the bottom of the display panel along with the cc indication for cubic centimeters. The volume indication that corresponds to the current setting of the selector switch is backlighted. If the selector switch is in the electrometer position, these lamps will be out.

4.2.4 Probe Input and Electrode Bias Indicators - Above the range pushbuttons on the front panel are two strips of panel lights. There are six indications in all: COAX with POS and NEG indications, and TRIAX with POS and NEG indications. Any time the instrument is on, two of these indications will be lighted. Selection of the COAX or TRIAX strip is by means of the COAX/TRIAX selection, but must be set by hand. If the PROBE INPUT indication does not agree with the connector in use, no readout will appear on the digital display. In this case, when the TEST pushbutton is depressed, the display will indicate 0 volts.

In line with the connector mode chosen, either the POS or the NEG lamp (but not both) will be on. This indicates the bias sign of the outer electrode (shell) for a coax chamber, or the inner electrode (collector) for a triax chamber. The back panel BIAS REV switch alters the reading of these lights.

4.2.5 Zero Adjust - The ZERO ADJUST knob operates a potentiometer that can be used to modify the input offset voltage to the electrometer. The ZERO pushbutton must be depressed while this adjustment is made. For proper operation, this offset should be within four units (40 μV) of zero as shown by the display.

4.2.6 Red Pushbuttons - There are two red pushbuttons, one at either end of the row of pushbuttons.

4.2.6.1 POWER Pushbutton - The POWER Pushbutton is an alternating on/off switch that provides or interrupts line power.

4.2.6.2 TEST Pushbutton - The TEST pushbutton is a momentary contact pushbutton that causes the display to show the voltage across the bias supply battery. (The V units display is lighted while this pushbutton is depressed).

4.2.7 White Pushbuttons - There are two banks of white pushbuttons between the two red pushbuttons: one on either side of the ZERO ADJUST knob. The HOLD pushbutton is a momentary-contact pushbutton. All of the others are self-latching pushbuttons. Within each bank depressing one self-latching pushbutton will cancel any other self-latching pushbutton in that bank.

4.2.7.1 EXPOSURE Pushbutton - When this pushbutton is depressed, the electrometer is operating in the exposure mode integrating exposure as it is received, and displaying a running total of radiation received since the beginning of the count.

4.2.7.2 HOLD Pushbutton - When this momentary pushbutton is depressed, the last shown display is latched, and the electrometer feedback is shorted. When the pushbutton is released, the electrometer remains in the HOLD mode until the ZERO pushbutton is depressed and released, after which it will return to its previous mode of operation.

4.2.7.3 ZERO Pushbutton - Shorts the electrometer feedback. The word ZERO on the display indicates that either this or the HOLD pushbutton is depressed.

4.2.7.4 EXPOSURE RATE Pushbutton - When this pushbutton is depressed, the feedback is switched to measure ion chamber current of either sign. Internal conversion produces a readout in appropriate units.

4.2.7.5 Range Pushbutton 1 - When this pushbutton is depressed, the electrometer reads only on the most sensitive range (second column of Table II). If the radiation is above that range, the electrometer will indicate it by a flashing readout display.

4.2.7.6 Range Pushbutton 2 - When this pushbutton is depressed, the electrometer reads only on Range 2 (3rd column of Table II). Overrange input is signaled by flashing display.

4.2.7.7 Range Pushbutton 3 - When this pushbutton is depressed, the electrometer reads only on Range 3 (4th column of Table II). This is the maximum range of the electrometer; however, overrange inputs are indicated, as before by flashing display.

4.2.7.8 AUTO Pushbutton - When the AUTO pushbutton is depressed, the electrometer can read on all three ranges and switch from one to the other as the need arises. As in the manual ranges, overrange is indicated by a flashing display.

4.3 Circuit Description - Figure 1 is a simplified schematic of the basic circuit of the electrometer in the COAX mode. Such circuit details as the bias reversing switch are omitted for clarity. The bias voltage is applied to the outer chamber electrode by a separate bias cable. The outer sheath of the coaxial cable is grounded to the power line ground. The output of the operational amplifier has three feedback paths only one of which is chosen at a time: The short circuit is used for zeroing the meter; the resistance path is used for reading current (rate); and the capacitor path is used for charge (integrating). The output can be read by the internal digital voltmeter and shown on the 4½ digit front panel display. It can also be read as an analog signal at pins 13 and 9 of the auxiliary connector.

Figure 2 is a similar simplified schematic showing the TRIAX mode of circuit connection. Most of the elements in this circuit serve the same function as in Figure 1, but the method of connection has the advantage of supplying the bias voltage over the second cable sheath, thus eliminating the need for a separate cable. The disadvantage is that the triaxial connector has two outer rings very close together with a 350-volt potential between them. The inner cable sheath is a floating ground which is also connected to pin 9 of the auxiliary connector, the ground for the output to an external readout device.

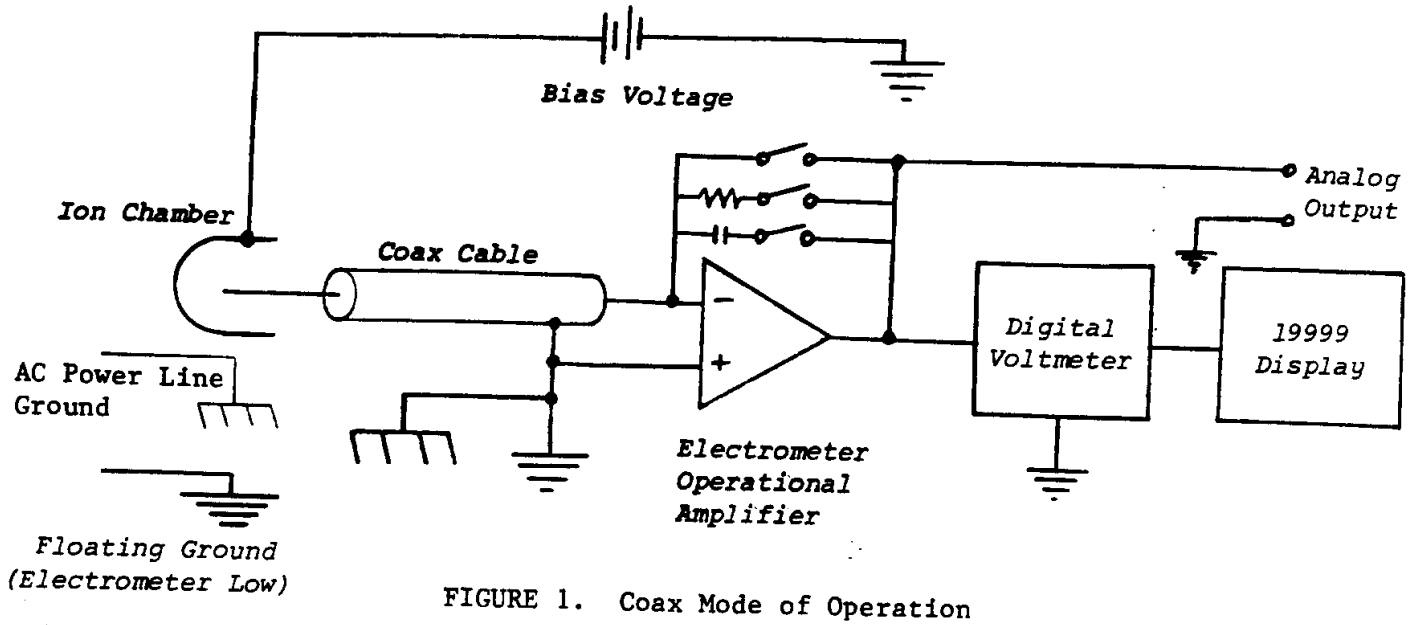


FIGURE 1. Coax Mode of Operation

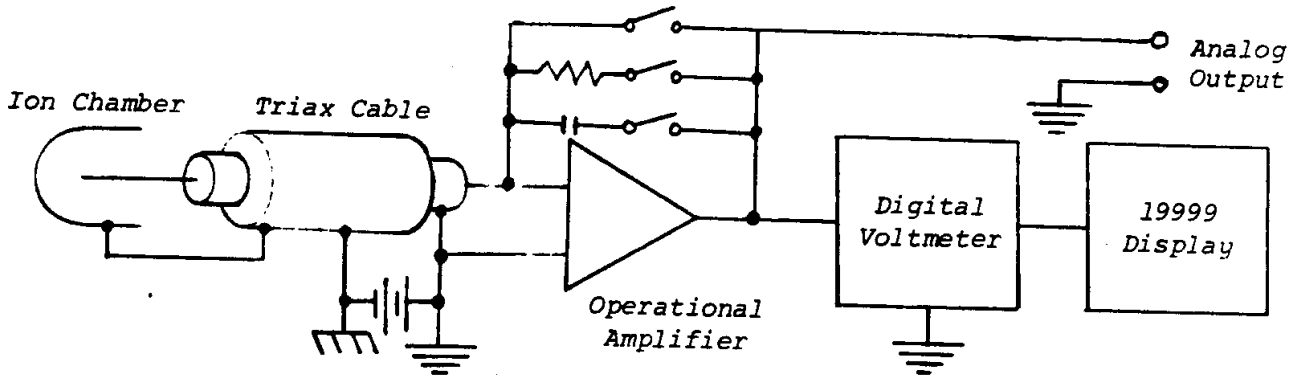


FIGURE 2. Triax Mode of Operation

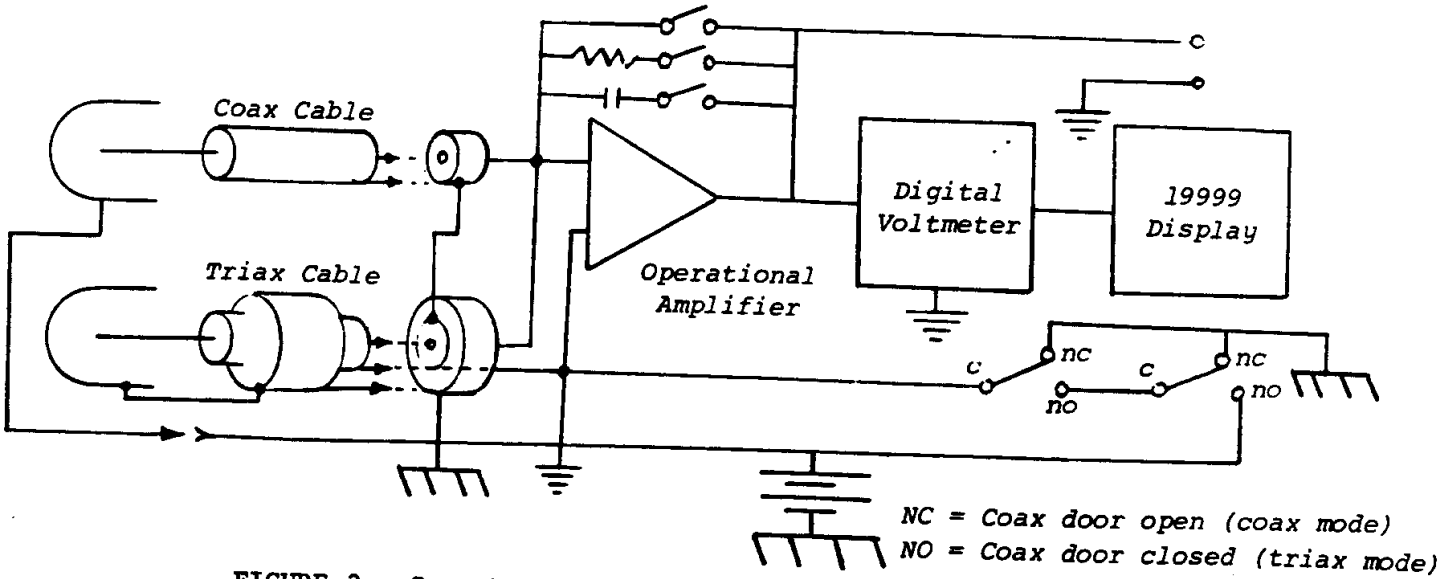


FIGURE 3. Coax-Triax Connections in Electrometer 500

Two input connectors are provided to serve both kinds of chamber connection in the 500. The shock hazard is minimized by interlocking doors over the two connectors arranged in such a way that only one connector can be uncovered at a time. Two limit switches, operated by the doors, are connected as shown in Figure 3. They change the internal connections from the coax mode of operation shown in Figure 1, to the triax mode shown in Figure 2. The possibility that both switches should malfunction at once is slight. However, it is a wise precaution to depress the TEST pushbutton and be sure that the connections are made in the proper mode. When a mode of cable connection is selected, the COAX/TRIAX switch on the rear panel should be set in a corresponding position, or the battery voltage indication will show ZERO during test.

When the TEST pushbutton is depressed, if everything is set properly, the bias voltage at the battery terminals will be shown on the digital display. This should be on the order of 350 V. A display of ZERO volts generally indicates an error in switch setting, but it may also indicate the malfunction of one of the two limit switches.

W A R N I N G !

Be very careful not to touch any ground terminals until the cause of the AERO indication is determined.

The digital voltmeter is an auto-ranging voltmeter with full-scale sensitivities of 0.20000, 2.0000, and 20.000 volts respectively for ranger 1, 2, and 3. The digital circuit and the display are always related to chassis (power line) ground. When the electrometer is operating in the triax mode, the floating-ground circuit and the digital (chassis grounded) circuit are coupled with opto-couplers.

4.4 Dose Trip Option 500-2 - The dose trip option is an optional supplement to Electrometer 500 provided at the plant. Electrometers already in use must be returned to the plant to have the option installed. It occupies a position in the upper righthand corner of the front panel.

4.4.1 Components - The dose option comprises the following components.

- Five TRIP-SET thumbwheels
- DECIMAL POINT-set thumbwheel
- ON-OFF-RESET switch
- COUNTING indicator LED
- TRIPPED indicator LED
- Five decimal point LED's
- Dose trip relay

4.4.2 TRIP-SET Thumbwheels - The TRIP-SET thumbwheels are used to set the display level at which the option will trip. The first (leftmost) thumbwheel can be set only for 0 or 1. The remaining four TRIP SET thumbwheels can be set for any digit from 0 to 9. The trip option will operate with the electrometer in either the EXPOSURE or RATE mode.

4.4.3 DECIMAL POINT - SET Thumbwheel - The DECIMAL POINT-SET thumbwheel establishes the location of the decimal point. The location of the decimal point must be consistent with the setting of the LED display otherwise both indicator lights will blink and the option will not function. When the decimal point is correctly set, the way to clear the circuit is to turn the ON-OFF-RESET switch to RESET. Decimal points are indicated by amber LED's between the TRIP-SET thumbwheels.

4.4.4 ON-OFF-RESET Switch - To operate the trip option the switch must be in the ON position. When the switch is in the OFF position, the electrometer operates as if the trip relay were not present. The RESET position will return the circuit to a counting mode after a trip provided that the total on the thumbwheels exceeds what is displayed in the main electrometer display a manual range pushbutton is depressed, and that the decimal point is correctly set. To reset the circuit the switch is moved momentarily to RESET.

4.4.5 Counting Indicator LED - When this LED alone is blinking, the thumbwheels have been correctly set, and the instrument is counting. The trip relay is enabled.

4.4.6 Tripped Indicator LED - When this LED alone is blinking, the thumbwheels have been correctly set, and the instrument count has exceeded the thumbwheel input. The trip relay has been tripped.

N O T E

Both LED's blinking simultaneously usually indicates an erroneous setting of the DECIMAL POINT thumbwheel. It may also mean the electrometer is in the AUTO mode of ranging. The dose trip option can only be used with one of the three manual ranging levels.

4.4.7 Dose Trip Relay - When the trip option is counting, the trip relay is energized. The relay is deactivated when the option is tripped, the decimal thumbwheel is incorrectly set, or the LED readout is overloaded.

4.4.8 Operation of Dose Trip Option

1. Turn on Electrometer 500.
2. Turn on the dose trip option. (both LED's will blink)
3. On the electrometer front panel select the proper manual range.
4. Using the DECIMAL POINT thumbwheel, move the decimal point on the option display to match the position of the decimal point on the main electrometer display.
5. Use the TRIP-SET thumbwheels to dial in the desired trip point. The most significant digit can be 1 or 0 only.
6. Move the ON-OFF-RESET switch momentarily to RESET. (If the settings have been correctly made, only the counting LED should be blinking now. When the trip position is reached in the display, the COUNTING LED will stop blinking, and the TRIPPED LED will start blinking. Meanwhile the trip relay will switch from energized to deenergized.

5 Maintenance - Electrometer 500 should be kept in a dry, dust-free environment. Dirt, grease, even the tars from cigarette smoke can generate leakage paths that are difficult to locate and clean. If kept clean, the electrometer circuits should function properly for many years. The following function tests can be used to verify proper functioning of the various components.

5.1 Front Panel Control Functions

W A R N I N G !

Be sure the input connectors are covered during the following tests.

1. Depress the ON-OFF switch. The alternate-action mechanical latch should operate smoothly. When the switch is in the ON position, the display lights.
2. With the instrument on, depress the ZERO switch. The display should read on or near zero.
3. Depress the RANGE 1 pushbutton, and holding the ZERO switch depressed, turn the ZERO ADJUST knob to its two extremes. The range should be approximately 500 digits without regard for the decimal point. Set the ZERO ADJUST knob at its middle setting (five turns from either end). The instrument should read 0000 $\pm$ 150.
4. Depress the EXPOSURE RATE pushbutton. Vary the readout using the ZERO ADJUST knob, and while the display is changing, depress HOLD. The instrument will perform a ½-second conversion (or complete the conversion in process), and then it will hold the reading. The ZERO light will light.
5. Depress the ZERO pushbutton momentarily to reset the electrometer.
6. Try the same procedure with the EXPOSURE pushbutton depressed.
7. Use the ZERO ADJUST knob to create as high a reading as possible on RANGE 1. Depress RANGE 2, then RANGE 3. The decimal point should move one place to the left with each range change.
8. Zero the instrument. Depress EXPOSURE RATE. The switching transient will cause a jump in the readout. It should return to zero $\pm$ 50 in five seconds. Depress EXPOSURE. There will be another jump in the readout caused by the switching transient. The change should not be more than $\pm$ 100. After the new reading is displayed, it should not change by more than $\pm$ 5 in 30 seconds.

5.2 Rear Panel Switching Functions

1. Verify front panel displays for various settings of the PROBE VOLUME SWITCH according to Table IV.

TABLE IV: DISPLAY FUNCTIONS FOR VARIOUS SETTINGS OF THE PROBE VOLUME SWITCH

PROBE VOLUME SWITCH	FUNCTION BUTTON [1]	UNITS	RANGE 1	RANGE 2	RANGE 3	VOLUME LAMP	CC LAMP
ELECTROMETER	EXPOSURE	nC	1.XXXX	1X.XXX	1XX.XX	None	Off
ELECTROMETER	EXP. RATE	pA	1X.XXX	1XX.XX	1XXX.X	None	Off
ELECTROMETER	ZERO	Zero	1X.XXX	1XX.XX	1XXX.X	None	Off
0.6	EXPOSURE	R	X.XXX	XX.XX	XXX.X	.6cc	Off
0.6	EXP. RATE	R/min	X.XXX	XX.XX	XXX.X	.6cc	Off
0.6	ZERO	Note 2	X.XXX	XX.XX	XXX.X	.6cc	Off
330	EXPOSURE	mR	1X.XXX	1XX.XX	1XXX.X	330	On
330	EXP. RATE	mR/min	1X.XXX	1XX.XX	1XXX.X	330	On
330	ZERO	Note 2	1X.XXX	1XX.XX	1XXX.X	330	On
33	EXPOSURE	mR	1XX.XX	1XXX.X	1XXXX	33	On
33	EXP. RATE	mR/min	1XX.XX	1XXX.X	1XXXX	33	On
33	ZERO	Note 2	1XX.XX	1XXX.X	1XXXX	33	On
3.3	EXPOSURE	R	1.XXXX	1X.XXX	1XX.XX	3.3	On
3.3	EXP. RATE	R/min	1.XXXX	1X.XXX	1XX.XX	3.3	On
3.3	ZERO	Note 2	1.XXXX	1X.XXX	1XX.XX	3.3	On
.33	EXPOSURE	R	1X.XXX	1XX.XX	1XXX.X	.33	On
.33	EXP. RATE	R/min	1X.XXX	1XX.XX	1XXX.X	.33	On
.33	ZERO	Note 2	1X.XXX	1XX.XX	1XXX.X	.33	On

1. When TEST is depressed, all lamps go off except ZERO and V.
2. When the instrument is switched from EXPOSURE to ZERO, the R or mR units remain displayed. When the instrument is switched from EXPOSURE RATE to ZERO, the R/min or mR/min units remain displayed.

2. Verify that the display of the TRIAX/COAX lamps on the front panel match the settings of the PROBE INPUT toggle switch.
3. Position the PROBE INPUT switch to agree with the door setting. Note whether the POS or NEG lamp is lighted. Depress the test switch. The DVM sign should agree with the lamp condition switch. Switch the ELECTRODE BIAS REV switch and verify the above agreement again.
4. Depress the TEST pushbutton on the front panel and read the bias voltage. Hold the ELECTRODE BIAS switch in the 40% position, and repeat the TEST reading of bias voltage. The second reading should be 40% of the first reading.
5. Test the operation of the connector cover doors. It should be impossible to open both doors at the same time.
6. Open the COAX door. Connect a digital voltmeter to chassis ground, and to the frame of the preamplifier box. Do not touch the latter connection and chassis ground simultaneously. The DVM should read zero volts and one ohm or less. Set the DVM to the 1000 V dc range. Use a small screwdriver to actuate the other microswitch. The DVM should still read zero. Actuate both switches together. The DVM should read on the order of 350 V.
7. Connect an external battery or power supply of less than 500 V through a milliammeter to pins 11 (-) and 12 (+) of the auxiliary connector. Set the internal slide switch to the position for external battery connection. Battery current should be less than 1 μA for either position of the doors, or for either setting of the polarity switch.

N O T E

When the front panel TEST pushbutton is depressed, the panel meter will indicate a voltage on the order of the external voltage applied if the COAX/TRIAX switch and the door microswitches are in agreement. If zero volts is indicated, and the COAX/TRIAX switch and the door position are in agreement, then a microswitch failure has occurred, or the slide switch is improperly set, or the external supply is not operative.

5.3 Function Test

5.3.1 Drift - Instrument sensitivity is ten microvolts per digit on range 1. For the following tests the instrument must be in relatively stable environment.

1. After turn-on and five minutes' stabilization, the drift should be less than 100 microvolts in eight hours. This is the same as a count change of $\pm$ 10 in the least significant digit.

2. Long-term drift should be less than 1000 microvolts per day, and 4000 microvolts per week with the instrument running continuously.

3. Maximum allowable offset from zero in a random turn-on, turn-off test shall be 500 microvolts.

5.3.2 Leakage

1. Put the chamber selector switch on the rear panel in the ELECTROMETER position. Stabilize the instrument in the temperature environment. Depress RANGE 1 and the EXPOSURE RATE pushbuttons. After the initial transient, the reading should be within $\pm$ 15 counts of zero 90% of the time over a five-minute period. Repeat this same test with a zero offset of 1000 counts (disregarding the decimal point) applied. The reading should still be within $\pm$ 15 counts of the steady-state reading 90% of the time over 5-minute period.

2. Stabilize and zero the Instrument. Depress RANGE 1 and EXPOSURE. Note the offset caused by switching transients. After ten minutes, the reading should not have changed more than $\pm$ 3 x 10^{-15}A.

3. Open the COAX connector door and adjust the input switch. Switch from ZERO to EXPOSURE. Carefully short the input terminal to the connector shell. The DVM will show a rapid upscale integration. Remove the short and cap the connector when the reading reaches about 10000 on range. 2. Wait a few seconds for the reading to stabilize. Be careful not to induce a charge by moving charged objects such as clothing near the input. Time the leakage rate for 600 seconds. The change in that time should be less than six counts.

Presuming that the electrometer passed the test of step 2, this amount of change indicates a decay time constant of the feedback capacitor of 1×10^6 sec.

4. Depress the RANGE 3 pushbutton. Short the input as before. Allow the reading to reach 10000, then quickly remove the short. Wait one minute, then depress ZERO and AUTO. Wait ten seconds; then depress EXPOSURE. The display reading should not be higher than 300. This is a test for the soakage of the feedback capacitor.

5. Depress EXPOSURE RATE. Connect a variable dc current input to the input connector, and observe up-ranging on AUTO range at 10000 counts. Try several different current levels.

6. Test for overrange on each manual range. When the input on any range exceeds 10000, the display should flash.

7. Test for automatic down ranging by reducing the current input. Range 3 and Range 2 should downrange at a reading of 1800.

8. Compare the reading with the probe volume switch in the 0.6 cc position and that with the switch in the 0.33 cc position. The 0.6 reading is to be divided by 2.

5.4 Bias Voltage Location Test - The COAX-TRIAX switch works independently of the door microswitches. Therefore, it can be used to verify correct location of the bias in connection with microswitch operation. Use the following procedure to test proper operation of the microswitches and consequent proper location of bias voltage.

W A R N I N G

If either the COAX or the TRIAX test shows incorrect placement of the voltage, do not touch any part of the instrument behind the connector doors until the cause of the incorrect placement has been found and corrected. Failure to heed this warning may result in painful electric shock.

1. Close both doors and put the switch in the TRIAX position. Depress the TEST pushbutton. The digital readout should show the bias voltage. If it shows zero,

there is a fault in the bias path, possibly one of the microswitches. If a fault is found, then the COAX-TRIAX switch to the COAX position, but do not change the position of the doors. Depress the TEST pushbutton. If a voltage appears on the readout, the failure is in a microswitch. If the readout continues to show zero, either the internal slide switch is in the wrong position, or there is an open battery circuit.

2. Open the COAX door. Verify that the COAX-TRIAX switch is in the COAX position. Depress the TEST pushbutton. If a voltage appears on the readout, the bias is in the proper position. If the readout shows zero, turn the COAX-TRIAX switch to the TRIAX position. If a voltage shows, then a microswitch failure has occurred and the shell of the input connector is at high voltage. If the readout continues to show zero, either the internal slide switch is in the wrong position, or there is an open battery circuit.

6 Calibration - Put the instrument in the COAX mode of operation. Connect a 5½-digit DVM to pin 14 (+) and pin 9 (-) of the auxiliary connector. Connect a variable dc current source to the COAX input. Depress the ZERO pushbutton. Zero the instrument on RANGE 1.

6.1 RANGE 2 Calibration - Depress the EXPOSURE RATE, and the RANGE 2 pushbuttons. Apply enough current to drive the front panel display to mid scale (approximately 9500). The reading on the panel display and on the DVM should agree within two counts at the least significant digit (disregarding the position of the decimal point). Increase the input to drive the display nearly to full scale. The two meters should agree within three digits.

6.2 RANGE 3 Calibration - Depress the RANGE 3 pushbutton. Increase the input to drive the panel display to mid scale. The meters should agree within three digits. Continue to raise the input until the display is nearly at full scale. The meters should agree within five digits.

6.3 RANGE 1 Calibration - Reduce the current input to near zero. Depress the RANGE 1 pushbutton. Increase the current input until the display is near half scale. The two meters should agree within four digits. Drive the display to near full scale. The two meters should agree within six digits.

N O T E

If the calibration tests are not satisfactory, return the instrument to VICTOREEN, or to a qualified repair center for calibration. Use the return form in the back of the manual.

APPENDIX I

SAMPLE CALCULATIONS

SAMPLE CALCULATIONS

1 Capacitance of a Chamber - Two of the most common configurations for ion chambers are parallel plate and thimble. The parallel plate configuration has the two chamber electrodes in the form of flat plates, usually round, facing each other across the chamber volume. In the thimble configuration one electrode is rod-shaped and is surrounded by the other electrode in the form of a cylinder.

Textbook formulas for the capacitance of these configurations in free space are as follows:

Parallel Plate:

$$(C = \varepsilon_o \ (A/d))$$

Where

C = Capacitance in farads
A = Area of plate in square meters
d = Separation of plates in meters
$\varepsilon_o = 8.85 \times 10^{-12} \ C^2/N \cdot m^2$

Coaxial Cylinder (Thimble)

$$(C = l \ [\frac{2\pi\varepsilon_o}{r_b/r_a}] \ )$$

Where

C = Capacitance in farads
l = Length of cylinder in meters
r_b = Radius of outer cylinder
r_a = Radius of inner cylinder
$\varepsilon_o = 8.85 \times 10^{-12} \ C/N \cdot m^2$

SAMPLE #1
Given a VICTOREEN Model 550-13 Parallel Plate Probe. The net measured charge with a bias voltage of 700 V is 2.6×10^{-9} C.

The effective diameter of the plate is 35 mm, so the effective area is 0.00096211 m^2. Plate separation is 3.4 mm. Therefore, according to the formula given above,

$$C = 8.85 \ \frac{0.96211}{3.4} \times 10^{-12}$$

$$\approx 2.50 \text{ pF}$$

The measured capacitance is actually

$$\frac{2.6 \times 10^{-9}}{700}$$

$$= 3.72 \text{ pF}$$

Although the calculated capacitance is 50% lower than that measured, the agreement is close enough to verify good contact with both chamber electrodes.

SAMPLE #2
Given a PTW 0.6 cc Farmer Type probe. The measured charge with a bias voltage of 700 V is 0.46×10^{-9} pF. For this chamber, $r_a = 5 \times 10^{-4}$m, $r_b = 3 \times 10^{-3}$m, and $1 \approx 0.021$m. Therefore, the calculated capacitance is found as follows:

$$C = 0.021 \ [2\pi \ 8.85 \times 10^{-12} / \ln (3 \times 10^{-3} / 5 \times 10^{-4})]$$
$$= 0.652 \text{ pF}$$

The measured capacitance is actually

$$\frac{0.46 \times 10^{-9}}{700}$$

$$= 0.657 \text{ pF}$$

This is unusally good agreement, much better than can be expected most of the time. An error of $\pm 50\%$, as shown in Sample #1, is much more usual, and is acceptable for purposes of this continuity verification.

The example chambers of Samples 1 and 2 are fully guarded chambers; that is to say, the guard extends right into the chamber volume. Furthermore, the charges transferred to the electrometer would be small. Reversing the bias again in the above examples would show a net charge of zero meaning the charge flowing in one direction exactly cancelled the charge flowing in the other. For much larger chamber capacitances, the instantaneous current flow may be too great for the slow rate of the electrometer, and the reading will show a net loss on the reversal. However, in spite of gross variations caused by improper guarding, or large capacitance. The demonstration that the charge on the capacitor drives the electrometer proves continuity. If the capacitance is high enough to drive the electrometer off scale, the 40% bias switch can be used.

2 Correction for Recombination Losses - The 40% bias option makes a convenient method of determining percent of loss caused by incomplete saturation of the ion chamber. The solution can be determined graphically or mathematically.

2.1 Graphical Method - A method is needed for plotting an easily extrapolated curve of reading versus bias voltage. The vertical scale of the graph can be a direct reading of the digital readout. If a parameter which is the product of the reading and the inverse of the square of the bias voltage ($\frac{R}{V^2}$) is applied to the horizontal axis, then all of the readings for a given input, for any bias voltage up to saturation, will fall in a straight line.

As the bias voltage increases, $\frac{R}{V^2}$ comes closer to zero. Theoretically, zero is never reached, but for practical purposes, a line can be established that is close to zero. This is the location of the optimum bias voltage that theoretically will completely eliminate recombination. The point where the straight line graph crosses this line, as shown in the accompanying illustration, indicates the correct reading for the exposure in question. The reading at this point, R_∞, divided by the reading at the instrument full-bias voltage point will produce a correction factor that can be used with that electrometer-chamber combination for that voltage.

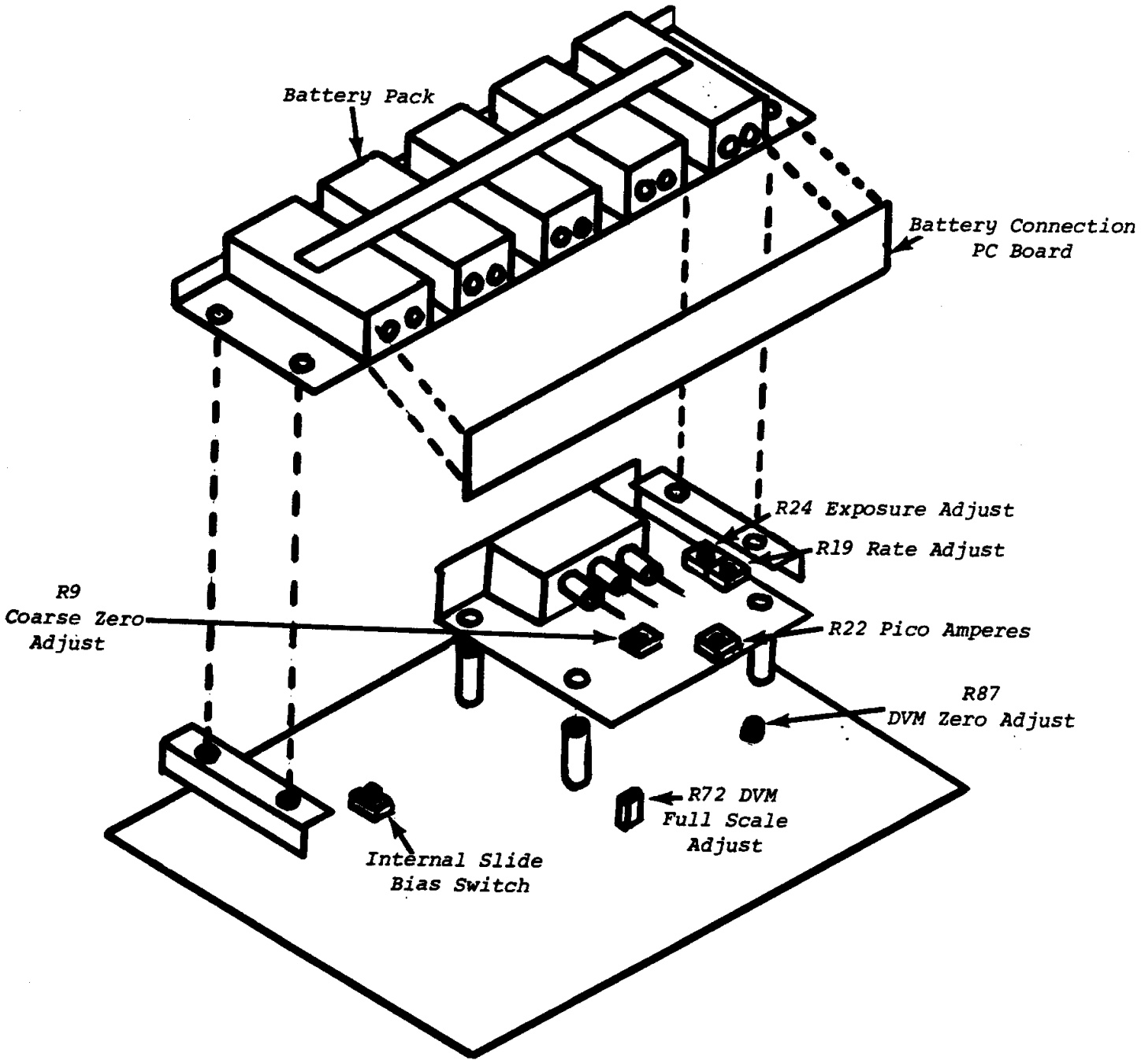
2.2 Mathematical Method - Starting with the following equation for R^{∞}

$$R = R_F \frac{\frac{1}{V_{40}^2} - \frac{1}{V_F^2}}{\frac{1}{V_{40}^2} - \frac{R_F/R_{40}}{V_F^2}}$$

substitute $V_{40} = 0.4\ V_F$:

$$R^{\infty} = \frac{5.25}{R_F\ 6.25 - R_F/R_{40}} = \text{correction factor to be applied}$$

$$\frac{R^{\infty}}{R_F} = \frac{5.25}{6.25 - R_F/R_{40}}$$


Battery Pack
Battery Connection
PC Board
R24 Exposure Adjust
R19 Rate Adjust
R9
Coarse Zero
Adjust
R22 Pico Amperes
R87
DVM Zero Adjust
R72 DVM
Full Scale
Adjust
Internal Slide
Bias Switch

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(To be used when return of material has been authorized by VICTOREEN)

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VICTOREEN REGISTER NUMBER OR INVOICE NUMBER _____

DATE PURCHASED _____

MODEL OR TYPE NUMBER _____ SERIAL NUMBER _____

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REASON FOR RETURN _____

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CUSTOMER ORDER NUMBER _____

VICTOREEN REGISTER NUMBER OR INVOICE NUMBER _____

DATE PURCHASED _____

MODEL OR TYPE NUMBER _____ SERIAL NUMBER _____

WARRANTY REPAIR Yes ☐ No ☐

REASON FOR RETURN _____

RETURN AUTHORIZED BY _____
VICTOREEN Sales Department

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