FLUKE ®

Biomedical

Victoreen® 440RF/D

Low Energy RF Shield Survey Meter

Operators Manual

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Section 1
General Information

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1.1Product Description

The Model 440RF/D Low Energy RF Shielded Survey Meter (Figure 1-1) is designed to measure low intensity gamma or x-ray radiation fields. In addition, it can be utilized as a beta detector. Response to gamma energy over a range of 6 keV to 1.2 MeV is achievable in fields as low as 0.1 mR/h. Upper limit measurable exposure rate is 100 mR/h.

The instrument is especially valuable when used for x-ray leakage detection, chiefly in the vicinity of electronic equipment with large electromagnetic fields.

The Model 440RF/D is a portable RF shielded, radiation exposure rate measuring system. The instrument is composed of a detector (or transducer) and electronics which provide amplification, meter response and computer interface (when used with a communicator device).

The detector is a guarded, unsealed air ionization chamber. The small DC signal produced by the ion chamber is monitored by a sealed, evacuated preamplifier and is processed using the latest CMOS microprocessor and support chip technologies.

The processed signal is then passed through a transistor-pulsing circuit to produce a standard analog meter readout.

Using the communicator option, data entry verification, test, or calibration can be performed. In addition, the instrument can be adjusted to meet environmental factors.

Figure 1-1.   Model 440RF/D Low Energy RF Shielded Survey Meter

1.2 Specifications

Full Scale Range	**Model 440RF/D:** 0 to 1, 0 to 3, 0 to10, 0 to 30 and 0 to 100 mR/h **Model 440RF/D-SI** 0 to 10, 0 to 30 and 0 to 100, 0 to 300 and 0 to 1000 µSv/h
Radiation Detected	Gamma, x-ray, and beta
Operating Range	**Model 440RF/D:** Exposure rate in five overlapping ranges: 0 to 1, 0 to 3, 0 to 10, 0 to 30 and 0 to 100 mR/h **Model 440RF/D-SI:** Dose equivalent in five overlapping ranges: 0 to 10, 0 to 30, 0 to 100, 0 to 300, 0 to 1000 µSv/h
Energy Response	**X and Gamma:** $\pm$ 10% from 12.5 keV to 42 keV effective, with a maximum peak of + 40% in the medium energy range. **Beta:** Energies above .15 MeV
Insensitivity	**RFI:** Operates properly in 10 mW/cm^2 fields **Magnetic:** Operates properly in a 200 gauss field
Accuracy	Maximum instrument inaccuracy, exclusive of energy dependence, is less than $\pm$ 10% of full-scale indication.
Response Time	**Range** **Response Time** 0 to 1 mR/h (0 to 10 µSv/h) 7 seconds 0 to 3 mR/h (0 to 30 µSv/h) 7 seconds 0 to 10 mR/h (0 to 100 µSv/h) 5 seconds 0 to 30 mR/h (0 to 300 µSv/h) 5 seconds 0 to 100 mR/h (0 to 1000 µSv/h) 5 seconds
Ion Chamber	**Chamber Window Area:** 10 cm^2 **Volume:** 60 cc **Chamber Window:** Approximately 1.5 mg/cm^2 aluminized mylar **Dimensions:** 2.5 in (6.4 cm) long; 1.5 in (3.8 cm) diameter
Case Window	13 mg/cm^2 magnesium
Batteries	Three 9 V alkaline transistor batteries for the electronics (9 V) and two 9 V alkaline transistor batteries for the chamber (-18 V) provide over 200 hours of continuous operation.
Weight	6 lb, 6.5 oz (2.9 kg)
Dimensions (H x W x L)	**Unit:** 8 in (includes handle) x 4 7/8 in x 10 7/8 in (20.3 cm x 10.4 cm x 25.7 cm) **Display:** 3.7 in (9.5 cm) Meter scale, marked 0 to 3 and 0 to 10
Environmental Dependence	**Operating Temperature:** -4° F to 104° F (-20° C to 40° C) **Relative Humidity:** 0 to 95% non-condensing

1.3 Getting Started

Receiving Inspection

Upon receipt of the unit:

1. Check the shipping carton(s) and their contents for in-shipment damage. If damage is evident, file a claim with the carrier and contact Fluke Biomedical, Radiation Measurement Services at 440.248.9300 immediately.
2. Check that all items listed on the packing slip are present and in good condition. If any items are missing or damaged, contact Fluke Biomedical.

Storage

If the unit is to be stored prior to use, pack it in the original container(s) if possible, and store in an environment free of corrosive materials, fluctuations in temperature and humidity, and vibration and shock.

Routine Cleaning

| NOTE |

Do not immerse the Model 440RF/D or Model 440RF/D-SI. The unit is not waterproof. Liquid could damage the circuits. The unit should be kept clean and free from dirt and contamination. The unit may be cleaned by wiping with a damp cloth using any commercially available cleaning or decontaminating agent.

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Section 2
Operation

2.1 Controls and Indicators

Function/Range Switch

Function/Range Switch positions include OFF, BAT, 100, 30, 10, 3 and 1 (Model 440RF/D) and OFF, BAT, 1000, 300, 100, 30 and 10 (Model 440RF/D-SI). The rotary switch is located below the handle. It turns the instrument OFF, provides a battery check function, and provides five operating ranges in mR/h or μSv/h, depending on user preference. The BAT position is also used with the communication option. Refer to Specifications, Section 1-2 for a list of operating ranges.

Zero Adjust

The Zero adjust, a screw centered just below the meter scale, zeroes the meter needle.

Meter

A panel meter, located on top of the instrument, displays the exposure rate (mR/h), dose equivalent rate (μSv/h), or battery condition.

Check Source

The check source, a hexagonal spring-loaded rotary switch positioned next to the chamber, verifies instrument operability.

2.2 Power, Battery Check, and Range Changing

A single rotary switch, located beneath the carrying handle provides function/range capability. In the OFF position, the 9 V electronic power supply is disconnected. The switch should be returned to the OFF position whenever the instrument is not in use to extend the battery usage period and to prevent possible damage to the battery compartment due to leaking or spent cells. Any other switch position will cause full battery current drain. If the instrument is placed in operation after a period of idleness, place the function/range switch in the BAT position and remain there. The function of the BAT position is to monitor the condition of the 9 V electronic supply and the -18 V chamber supply. This is accomplished through measuring the voltage (using the microprocessor) provided by the divider circuits directly across the battery supplies.

If both sets of batteries are at the voltages required for operation when the instrument is placed in the bat position from the OFF position, the meter should indicate full scale (9 V electronic supply), then drop to approximately half-scale (-18 V chamber supply), then return to the full scale position. If the instrument is in operation and battery check is performed, the meter will just indicate a full-scale reading. If either set of batteries is not at the voltage required for operation, the meter will drop to 0 V.

If the meter reads 0 V in the bat position, remove the batteries (one set at a time) and test them using a voltmeter to determine which batteries are bad. Replace the complete set for chamber voltage or electronic supply once the batteries have been located. Refer to Figure 2-1 for battery compartment location.

Once the battery check has been successfully completed, rotate the function/range switch to the first exposure rate range (100 mR/h) or dose equivalent range (1000 μSv/h). If the instrument has just been turned on, there may be an upscale indication on this range, but it should decay rapidly. When the indication on this range is, or has decayed to, less than one-third of full scale, switch to the 30 mR/h (or 300 μSv/h) range. Continue switching ranges until a steady indication greater than one-third full scale, or until the 1 mR/h (10 μSv/h) range is attained. If the instrument has not been in use for some time, this procedure may take a few minutes.

Series 9 V – 18 V Chamber
Voltage – Replace Both

Paralled 9 V for 9 V Electronics
Supply – Replace all Three
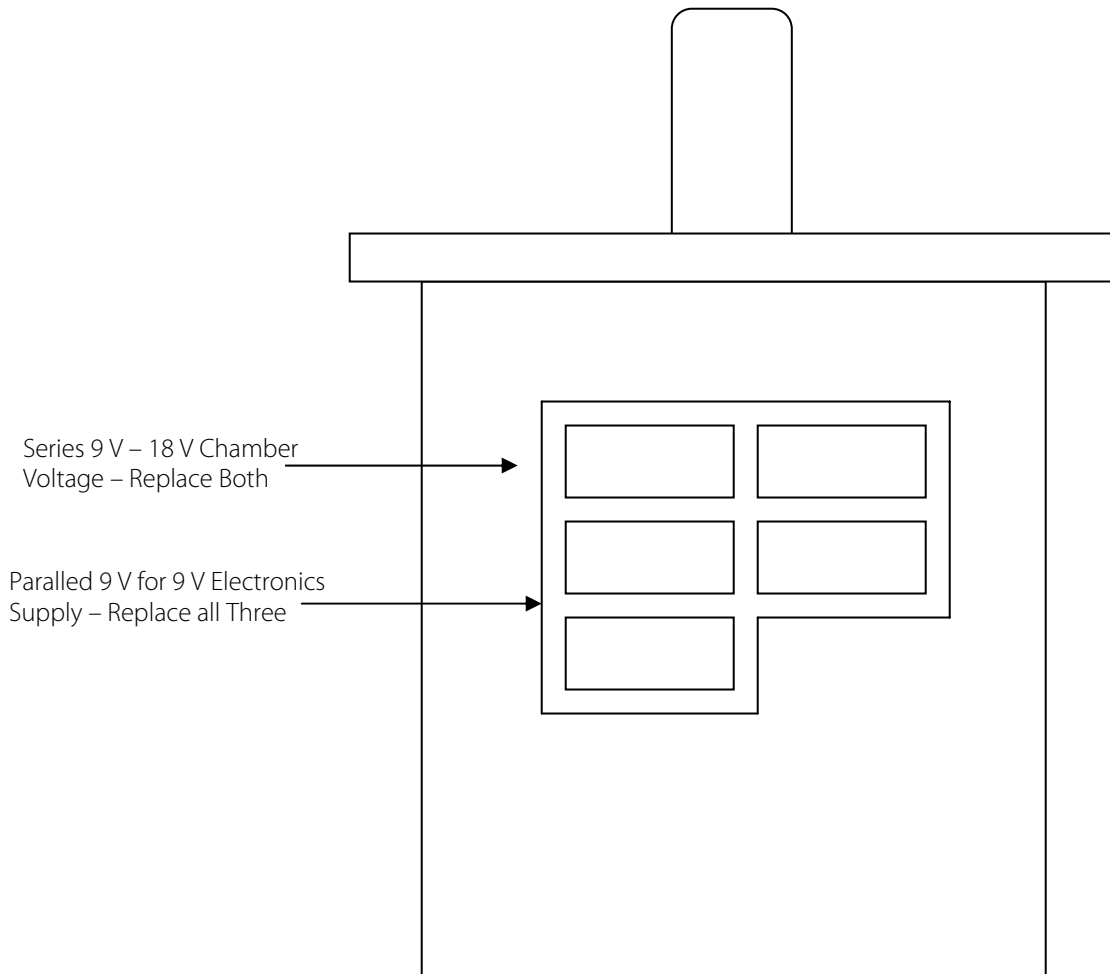
Figure 2-1.   Exposure Rate Measuring System 440RF/D Battery Compartment

If the instrument is brought closer to a radiation source, or if radiation is intensified until the meter needle pegs above full scale, the function/range switch can be rotated to less sensitive operating positions. To enable accuracy, set the function/range switch so that the maximum on-scale indication is visible.

2.3 Instrument Positioning and Scanning

In general, after warm-up and range selection, the measuring system is placed is some specific location and attitude to obtain a reading. Operator knowledge of radiation source locations, special geometry applications, physical placement problems, etc., will affect exactly how and where the instrument is positioned. Because the instrument's low energy response is best when photons enter the case through

the magnesium window, an operator should keep the window facing the field of increasing intensity (or toward the source).

The instrument responds to the effective exposure rate or dose equivalent rate averaged throughout the chamber volume. An exposure rate or dose equivalent rate 10 or 100 cm away cannot be predicted without knowledge of the shape, direction, and contours of the radiation field involved. If this concept of measuring a local field, rather than a general area, is remembered, confusion can be avoided.

Operator knowledge regarding the location of radiation sources can be divided into several classifications which include precise location, general vicinity, and no specific location. Each classification requires a specialized approach.

Precise Location

When positioning the instrument in a field where a nominal indication will occur, no position adjustments are necessary. When placing the instrument in a field where maximum indication is desired, minor position adjustments may be necessary.

General Vicinity

A small amount of careful scanning, less than a few square feet, can be employed so that a small indication will be visible on the scale and so that fatigue will not occur. See Figure 2-2. Maximum scan line speed should be between 2 and 4 feet/minute depending upon how low the source intensity encountered.

The scanning motion should be slow, smooth, and uniform. If any upscale indication is encountered, the scan should be stopped immediately in order to determine whether the instrument detected a cosmic ray or a tiny intense beam.

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NOTE
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Scanning should be performed with minimum jostling or jarring of the instrument, particularly when a low exposure rate or dose equivalent rate is underway.

No Specific Location

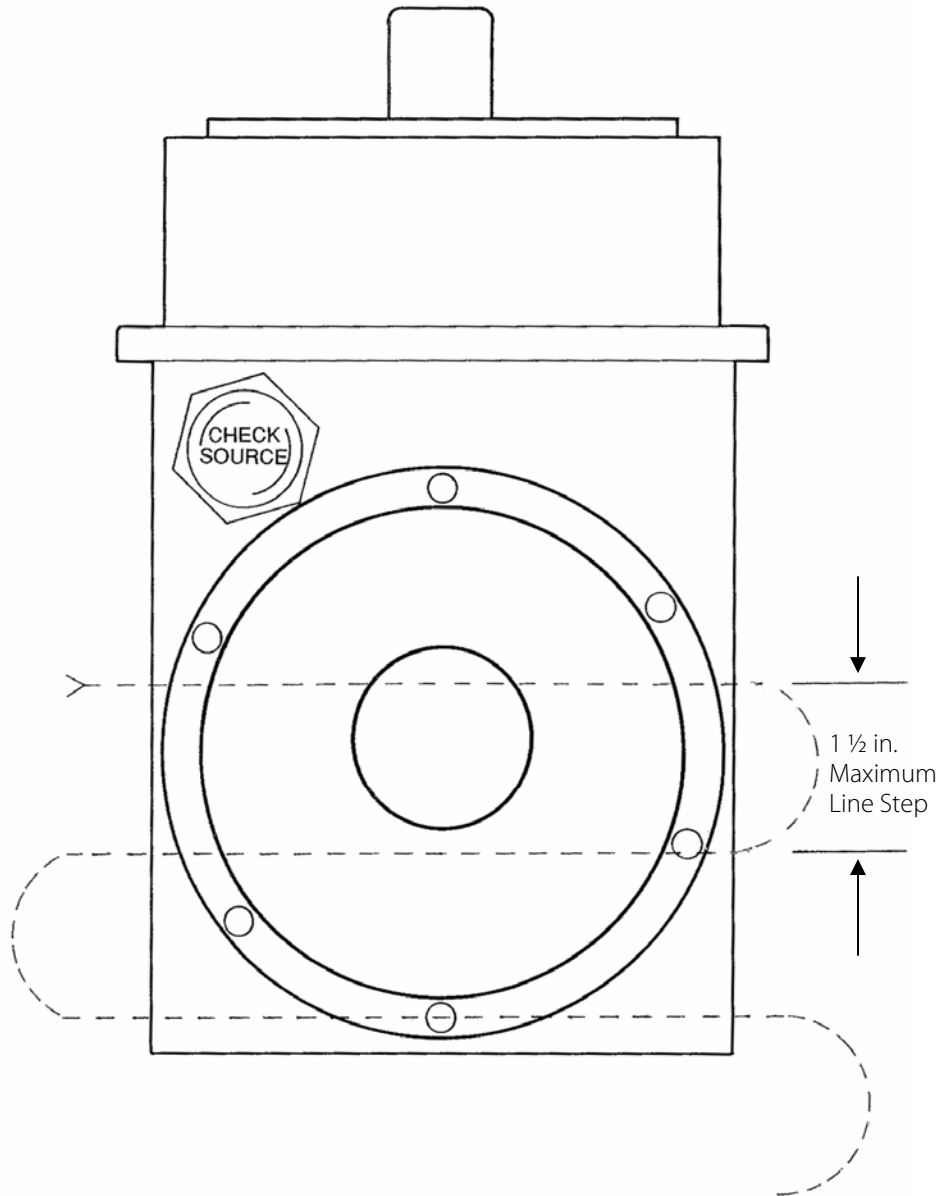Scanning of large areas at low exposure or dose equivalent rates is not recommended for this instrument.
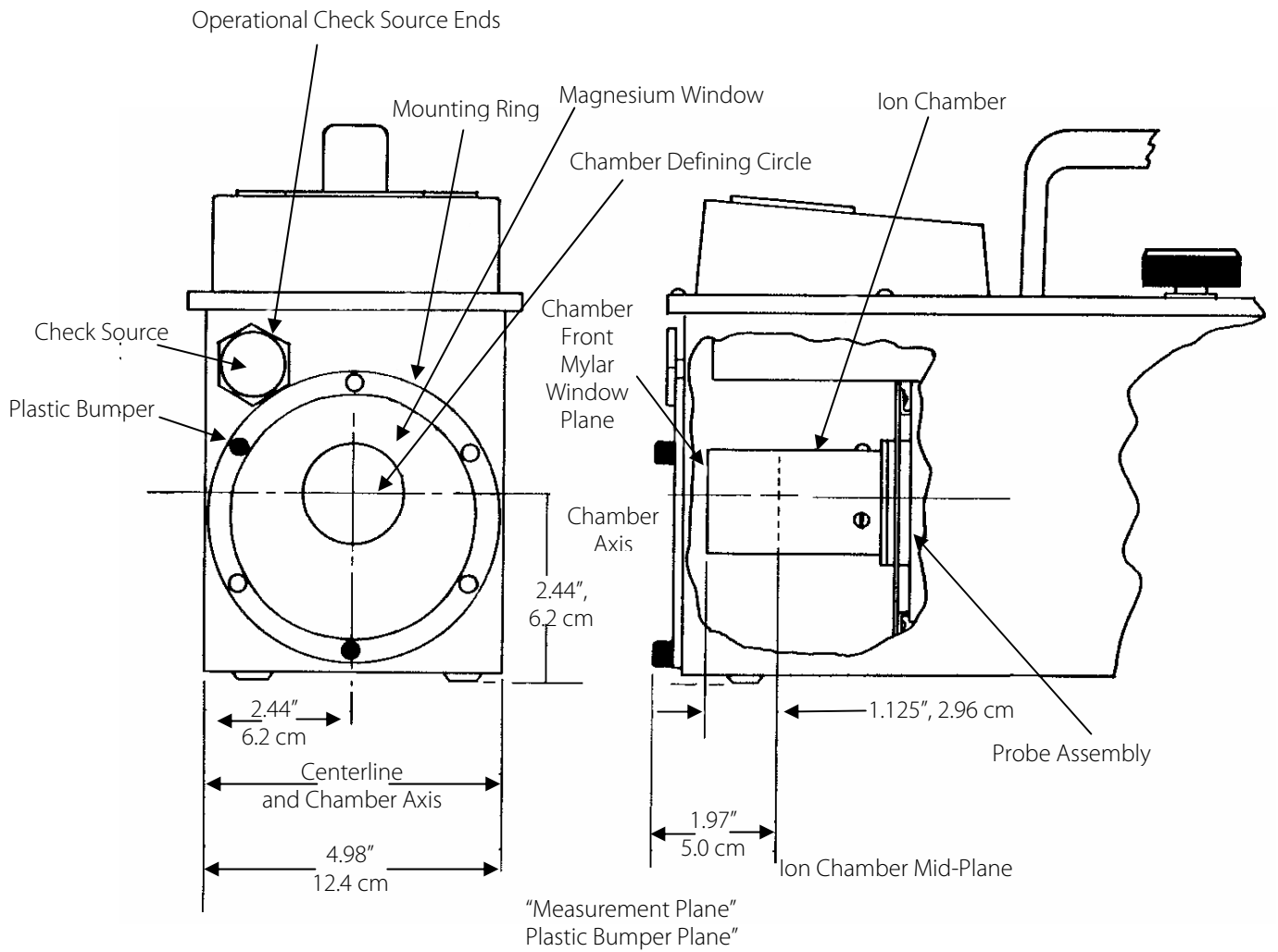
Figure 2-2.   General Vicinity Scanning

Figure 2-3.   *Chamber Reference Dimensions*

2.4 Chamber Location

Some information regarding the actual location of the ion chamber within the case, in terms of outside markings and dimensions, will aid in using the instrument for precision or special geometry applications.

The ion chamber is in the form of a right cylinder. It is located directly below the panel meter end of the case with the axis parallel to the case length. Refer to Figure 2-3 for exact dimensions. Three plastic bumpers are arranged in a triangle on the outside mounting ring of the magnesium window. Their tops define a plane. This plane will include any flat surface that all three bumpers contact. The midplane of the ion chamber is exactly 5 cm deep from the bumper plane.

> NOTE
>
> The ion chamber midplane is defined as; that plane, at right angles to the axis, which separates the total effective volume of the chamber into two equal volumes.

A black ring (1-½ inch diameter) is located on the outside surface of the magnesium window. It serves as a guide to ion chamber size and location.

The ion chamber end window is aluminized mylar. It is parallel to, congruent with, and directly behind the ring on the magnesium end window.

2.5 Measurement of Exposure Rate

Unit of Measurement

The Model 440RF/D is used to measure ionizing radiation in terms of exposure rate, whose unit is Roentgen per unit time.

An exposure rate of one Roentgen per unit time is that intensity of X- or gamma radiation which produces ion pairs amounting to one electrostatic unit of charge per unit time in each cubic centimeter of air at standard conditions.

> NOTE
>
> Exposure rate is not really defined for beta particles. Any indications should be indications of relative beta particle intensity and not indications of exposure rate (or milliroentgen per hour).

This instrument indicates in thousandths of a Roentgen per hour or milliroentgen per hour (mR/h).

The following characteristics are implied when any ionization chamber is used to determine exposure rate as defined above.
1. Total collection of all ion pairs created,
2. Relative independence of ion pair generation on the energy of photons.

In many real measurement situations, some of the above conditions will be difficult to meet. In order to approach a true value, a correction factor is necessary.

Obtaining Readings from Indications

The instructions supplied here generally apply to high and low level measurements.

RESPONSE TIME
The measuring system requires a certain amount of time to respond to a change in exposure rate. The response times supplied in Table 1 are times required to reach 90% of the final value. A 10% error, due to response time, remains. If twice the quoted response time is allowed, the time error will fall to less than 1%. Therefore, in all measurements, sufficient time must be allowed before obtaining a reading from the meter.

METER ARCS AND RANGE POSITION CORRESPONDENCE

The 0 to 10 meter arc contains 10 major and 50 minor divisions. It corresponds to the 0-1, 0-10 and 0-100 mR/h (0-10, 0-100, 0-1000 μSv/h) range positions.

The 0 to 3 meter arc contains 6 major and 30 minor divisions. It corresponds to the 0-3 and 0-30 mR/h (0-30 and 0-300 μSv/h) range positions.

READING THE METER INDICATION

Using the formula provided in Figure 2-4, it should be relatively simple to set the decimal point and make interpolations.

Applying Corrections To Readings

After a reading has been obtained, the operator should be able to determine if the correction factors described in Sections 3.6 and 3.7 apply. If no correction factors apply, or if a relative indication is desired, the readings can be accepted as final data. If there are correction factors that apply and accuracy is required, then those factors must be applied before readings can be accepted as final data.

Correction factors are numbers, ranging around unity, which are multiplied with the reading to give a corrected reading. They are employed to correct for errors contained in the initial reading due to some non-standard measurement condition.

Corrections are not required when a maximum inaccuracy of 25 to 30% can be tolerated, e.g., during a casual survey. However, when the highest possible accuracy is desired, all likely sources of inaccuracy should be considered with corrections and compensations applied where necessary.

Arbitrary Standards

Government and/or industrial agencies may adopt a standardized measurement or set of conditions for measurement. When this is done, it is helpful to know which correction factors will apply and which will not apply. Generally, when a specific detector cross-sectional area and an external surface to center of effective volume spacing is used, the geometry factors are fixed and correction factors related to geometry are not required. Energy and air density corrections, will apply when maximum accuracy is desired.

2.6 Source Geometry Corrections

Proximate Source

In the exposure rate definition (refer to Section 2.5, Unit of Measurement) the need for a constant radiation intensity throughout the chamber volume or for a suitable correction factor can be perceived.

Since ionizing radiation follows the inverse square law in the same manner as visible light, radio waves, gravitational forces, etc.; the field is relatively constant throughout the chamber only at several times the maximum dimensions of the chamber. In Figure 2-5, a calculated correction curve is supplied for point sources of radiation which closely approach the chamber.

Small Cross-Section Beam

As described earlier (refer to Section 2.6, Proximate Source), constant radiation intensity throughout the volume, or a correction factor, is required. This is the sole practical manner in which chamber calibration can be performed.

If a small cross-sectional beam ionized only a fraction of the chamber volume, as shown in Figure 2-6, the resulting indication will reflect an overall average value instead of the beam cross-sectional value. In order to correct for this type of measurement condition, the actual cross-sectional area of the beam must be known.

The Model 440RF/D cannot be used to determine beam cross-sectional areas. To determine such an area, one possibility includes the use of photographic sheet film. If the cross-sectional area is well defined (rather than diffuse) on the film, the cross-sectional area can be scaled off. This will allow for the computation of a rough correction factor. For example, the Small Cross Section Beam Correction Factor is equal to:

$$\frac{\text{Cross-Sectional Area of Chamber}}{\text{Total Cross Sectional Area of Beam}} = \frac{10 \text{ cm}^2}{X \text{ cm}^2}$$

Most beams found associated with color television receivers are on the order of 1 cm^2 cross-sectional area, or larger.

Skew Beams

Just as the cross-sectional areas of X-ray beams vary, so does the three-dimensional angle, at which the beam leaves the apparatus where it is generated.

Normally, the Exposure Rate Measuring System should be positioned so that its magnesium window is parallel to the external surface of the apparatus being surveyed. This positions the ion chamber axis parallel to any beams that leave the apparatus normal, or at right angles, to the surface. It is likely that some beams will not follow this pattern. If the angle is small with respect to the normal, little or no error occurs. In addition, if the beam has a large cross-section (compared to the chamber), the error is slight. However, for small cross-sectional beams at significant angles from normal, the error will be large (see Figure 2-7). The Model 440RF/D can be tipped off its normal axis in the direction and angle which yields the maximum indication. This will reduce the error associated with the small cross-sectional area at significant angles.

Plane Source

A plane source of radiation presents a unique measurement situation. A color television picture tube face plate can be treated for all practical purposes as a plane source due to the speed of scan and frame rate. The bulk of the X-ray photons are generated when the electron beam strikes the shadow mask. This thick glass face plate functions in a manner similar to a low energy filter or absorber. In Figure 2-8, the geometry of the tube and measurement system is shown.

The most important characteristic of a plane source is that it attempts to illuminate the chamber volume from a large oblique angle. Therefore, instrument centering becomes meaningless.

At higher energies, the case and chamber wall are almost as transparent to photons as the magnesium and mylar windows. However, in the energy range expected for a color television receiver, this is not the situation; and some oblique angle contribution is lost in the case wall. Matters are moderately improved due to the increased absorption for oblique angle photons which have a longer travel path in the glass faceplate.

Range Position: 100 mR/h

Indication (On "0-10" meter arc): Four (4) major divisions plus two and one-half (2½) minor divisions.

	Major Divisions		**Minor Divisions**		
Reading:	$\dfrac{4}{10}$	+	$\dfrac{2.5}{50}$		
	$\dfrac{40}{100}$	+	$\dfrac{5}{100}$	=	$\dfrac{45}{100}$
	$\dfrac{45}{100}$	X	100 mR = 45 mr/h		
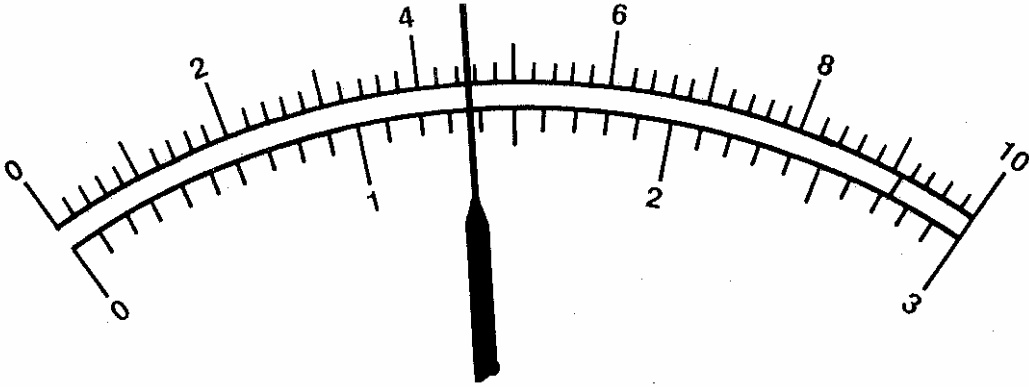
Figure 2-4   Reading Meter Scale Indications

Distance in Inches from "Measurement Plane" to Source

Distance in Centimeters from "Measurement Plane" to Source
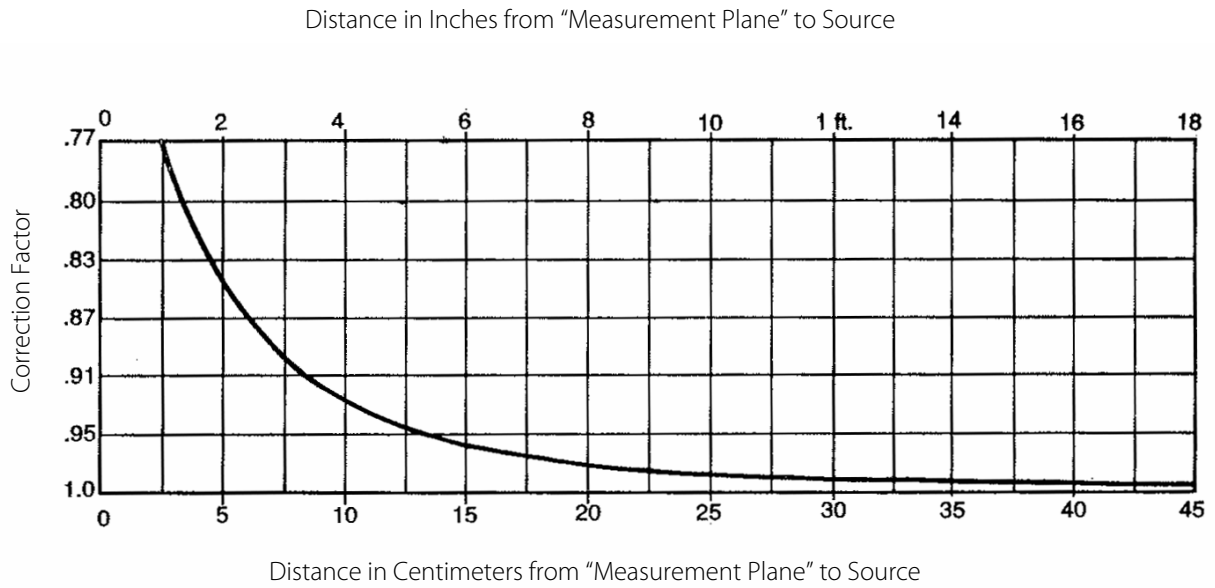
Figure 2-5.   Proximate Source Correction Curve

Small Beam

Window

Ion Chamber

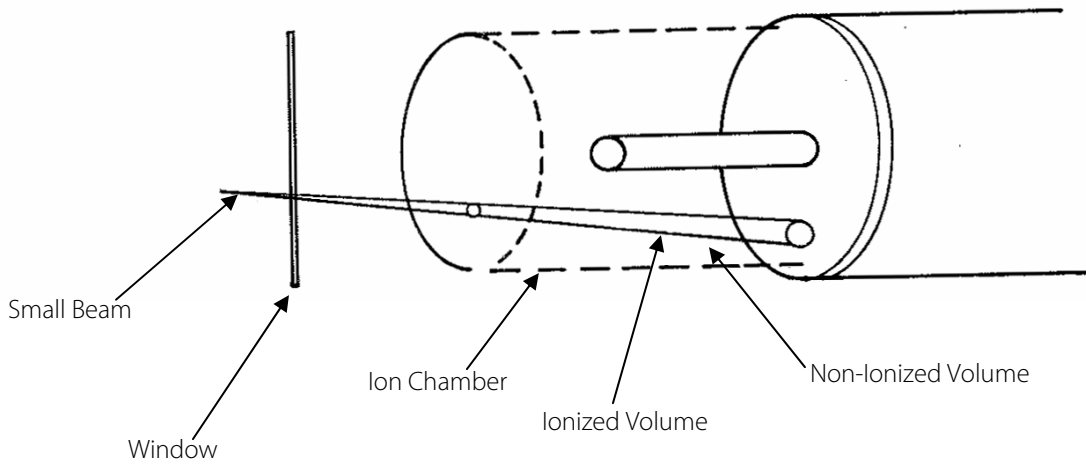Ionized Volume

Non-Ionized Volume

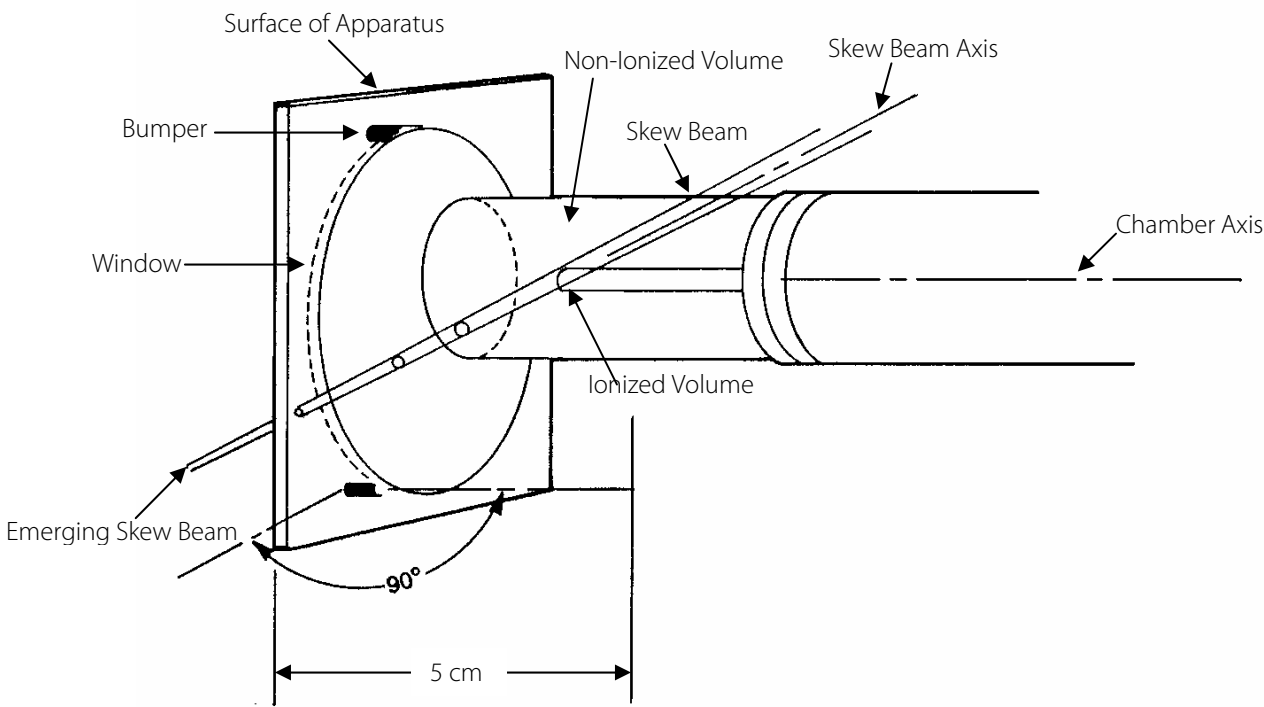*Figure 2-6.   Small Cross Section Beam*
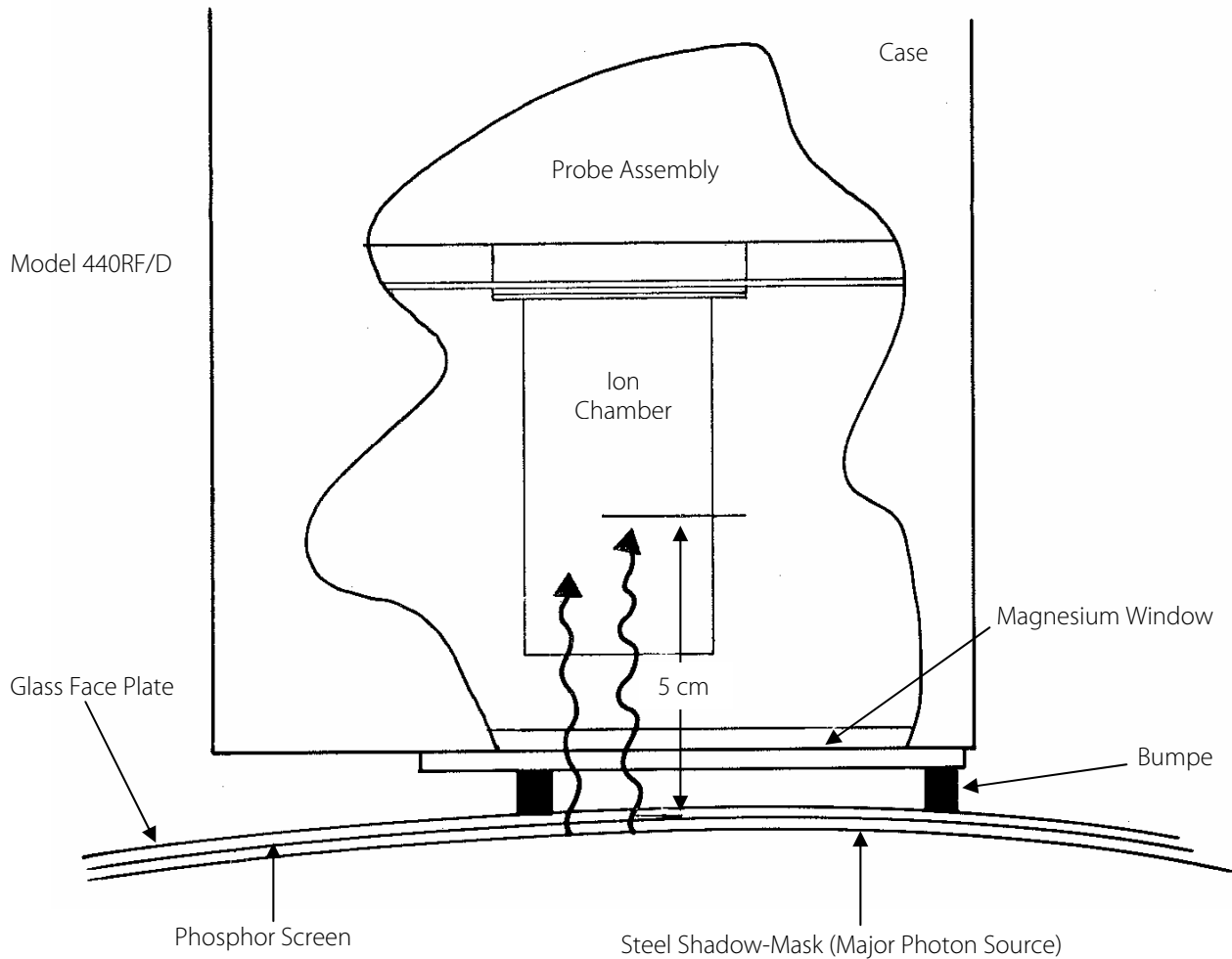
Figure 2-7.   Skew Beam

Figure 2-8.   Plane Source (Color TV Screen)

2.7 Chamber Corrections

Energy Dependence

The definition of exposure rate (refer to *Unit of Measurement*) did not reference any specific photon energy. Any ion chamber has a certain energy dependence. If the exposure rate is held constant, the chamber will respond differently to slightly different energy photons. The Model 440RF/D has been calibrated at an effective energy of 21 keV. The response is fairly independent in the low-energy region. For accurate usage at middle and high-energy regions, the energy response correction curve shown in Figure 2-9 must be used.

For example, a monochromatic source of X-ray known to have an effective energy of 100 keV indicates 42 mR/h on the instrument. Figure 2-9 indicates that a correction factor of about 0.67 is required. This will convert the reading to 28.1 mR/h.

Additional Equilibrium Wall Material

For effective energies above 250 keV, additional equilibrium wall material should be used. When the energy response correction curve was generated, a ¼ inch thick plastic plate was used. The plate area was approximately the same area as the magnesium window and it was placed directly in front of the window.

NOTE

Any plastic may be used. It is not critical.

Temperature and Pressure

Air, at standard temperature and pressure, is the ionized medium in our exposure rate definition. The density of air directly determines the ionization rate with all other factors held constant. The density is, in turn, a function of barometric pressure and Kelvin temperature. Since the ion chamber is not sealed, correction must be made for temperatures and barometric pressures different from those used during calibration.

Standard temperature, 0° C, is rarely encountered in practice. The Model 440RF/D is calibrated and corrected to 22° C and 760 mmHg. The instrument will automatically compensate for temperatures and pressures different from those used during calibration using a pressure transducer and temperature sensor located inside the case. Correction factors for changes sensed by these elements are stored in memory. They are also software controlled.
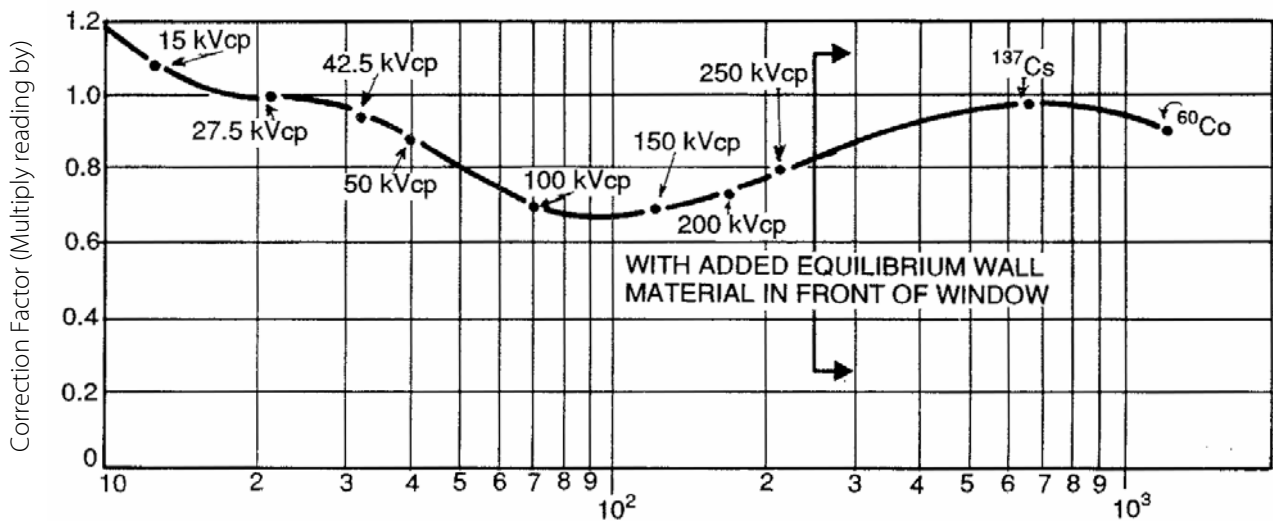

Figure 2-9.   440RF/D Energy Response Correction Curve

2.8 Low Level Measurements

Non-zero and Fluctuating Indications

If the instrument is set to the 1 mR/h or the 3 mR/h range and there is no external radiation, the meter will not show a zero indication; but will continuously fluctuate slightly upscale from 0. Occasionally, the needle will move to the ½ mR/h range on the scale. This is to be expected in an instrument with this sensitivity and response time. The needle fluctuations in the 1 mR/h or the 3 mR/h range can be attributed to four sources.

External Background Radiation

Even in the absence of an artificial external radiation field, an external field exists due to building materials which contain minute quantities of naturally occurring radioactive elements and due to cosmic radiation. These two sources are termed background. Over any short space of time, they are static or noisy because of the activities involved.

The average value of background ranges between 0.01 and 0.1 mR/h depending upon the location. Because the instrument does not differentiate between background and any other low intensity source, background must be indicated.

Internal Radiation

There is a less than 0.01 mR/h contribution due to trace quantities of radiation in the chamber materials and due to residual scatter emitted by the check source.

Amplifier Leakage

Leakage current originating in the dual mosfet electrometer and in the shorting transistor comprise the major source of fluctuation on the bottom ranges. It has been reduced to the lowest value possible. A leakage correction routine in the software aids in reducing the effect of the leakage current.

Insulator Strain Charges

After rough handling and during transportation, the insulators in the probe assembly of the instrument may have developed strain charges on their surfaces. If this has occurred, rest the instrument until the charges bleed off. If the strain charges are upscale and relatively steady, a measurement can be made. Then a non-zero compensation should be applied (refer to *Non-zero Compensations*).

As a preventative measure, subject the instrument to as little shock, vibration, and abrupt motion as possible.

Statistics Of Radiation

 Another limitation associated with the measurement of low-level radiation to any degree of accuracy, in any short period of time, is the statistics of the source. Statistics refer to the idea that there is a lower level of radiation flux per unit time intercepted by the chamber volume. Beneath this level, the radiation flux is measured more as a series of individual photons and less as a smooth flow.

This effect can be observed when measuring the exposure rate of radiation sources on the 1 mR/h range. For instance, the reading will fluctuate more frequently at 0.8 mR/h than it will when background only is present. The amount of electrical filtration or signal averaging employed is a compromise between small fluctuations and long response times.

Obtaining Readings from Fluctuating Indications

In order to differentiate background, the operational check source, and low intensity external radiation from the slightly fluctuating display on the 1 mR/h and 3 mR/h ranges, some repeatable and unambiguous method of evaluating the fluctuations should be employed. The following method is recommended.

While studying the fluctuations for approximately ½ minute, select an upper and a lower limit that most (approximately 80%) of the fluctuations remain in. Mentally note or record these limits.

NOTE

On positive (upscale) indications, disregard occasional (5 to 30 mR/h) large fluctuations and decays. These are believed to be cosmic rays or chamber alphas.

Take the arithmetic mean, by adding the two values and dividing by two.

For example, in Figure 2-10, a portion of the meter scale is shown and a certain fluctuating indication is represented.

UPPER LIMIT - 0.16 mR/h

LOWER LIMIT - 0.08 mR/h

$\underline{0.24\ \text{mR/h}}$ = 0.12 mR/h average

2

Non-Zero Compensations

In the event that local background radiation becomes, or is, an objectionable percentage of the indicated value, it should be subtracted out in order to maintain maximum accuracy at low intensities. The value used for background can be stated as described in *Obtaining Readings from Fluctuating Indications*, as well as the value of external radiation or the operational check source. The value used for background should be measured regularly, as there can be short-term variations and possible strain charges included in the readings. For example, an indicated and averaged reading of 0.80 mR/h, less an indicated and averaged background of -0.03 mR/h is equal to a compensated reading of 0.77 - mR/h.
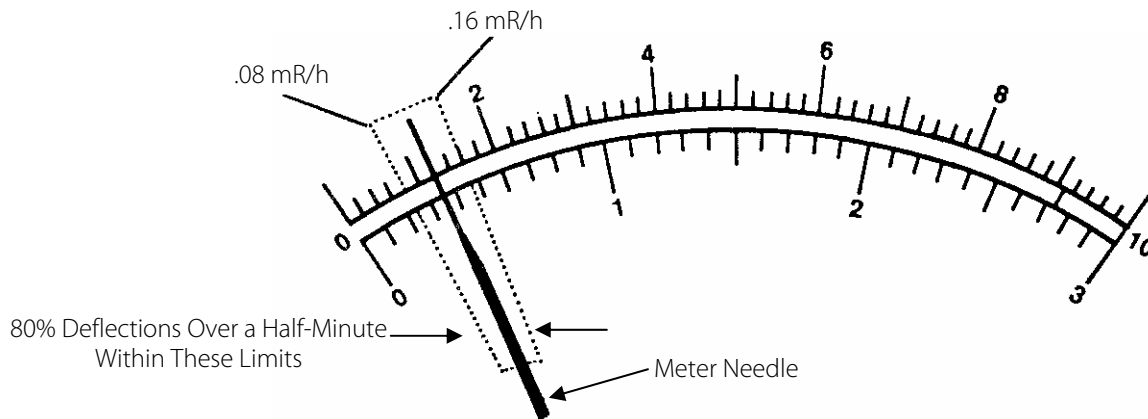

Figure 2-10.   Interpreting Fluctuations

2.9 Operational Check Source

This built-in source enables the operator to verify instrument operational status. A hexagonal knob is located on the front surface of the case, above and to one side of the magnesium window (refer to Figure 2-3).

To operate the check source, rotate the knob in the direction indicated by the arrows until a mechanical stop is reached. This is the check source position. Place enough torque on the knob so that the return spring does not return the check source to rest position during this procedure. Place the function/range switch in the 3 mR/h position. The source supplied with this instrument will indicate in the range of 1.2 to 1.8 mR/h. Wait approximately 15 seconds for the final value indication.

To stop check source operation, return the check source knob to rest position; the return spring will retract the source back into a shielded position.

NOTE

Use of the operational check source constitutes a low level measurement. The information provided in Section 2.8 regarding interpretation and evaluation of fluctuations and background in the indication apply.

There is a variation in activity from one check source to another. The nominal reading is 1.4 mR/h, but a range of 1.2 to 1.8 mR/h will be found. The exact check source value for your instrument is stamped on a special tag located on the case bottom.

Due to the extremely long half-life of the check source material, there will be no measurable decay in source activity over the life expectancy of the instrument.

Section 3
Theory of Operation

3.1 General

When the ion chamber is exposed to radiation, the internal air volume becomes ionized. A DC potential applied between the outer shell and center electrode separates the newly formed ion pairs before they can recombine, and collects them.

The ions, upon reaching the electrodes are restored to neutral gas atoms, through the process of taking on (or giving up) electrons. This causes a DC current flow in the external circuit.

The ion chamber can be considered a constant current generator whose output current is directly proportional to the rate of internal air ionization (or exposure rate). However, these currents are extremely small and special electrometer circuitry is required to measure them.

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Section 4
Circuit Description

4.1 Ion Chamber

The ion chamber serves as the input transducer of the instrument. It responds to an ionizing radiation field with the generation of a small direct current.

X or gamma radiation is comprised of photons, or electromagnetic packets of radiation. When the photon strikes atoms of chamber wall material (or air), some or all of the photon energy is transferred into ejecting a high-speed electron from one of the inner orbits of the target atom. This electron speeds off through space striking the shells of other atoms, until all of the original high-speed electron energy is converted into a long jagged track of ionized atoms. Collection potential, applied between the chamber electrodes, collects the ions and electrons generated in the air volume before they can locally recombine and delivers them to the external circuit. Due to electrode geometry and spacing, and the chamber collection voltage, less than 0.1% of the ions are not collected at the maximum measurable exposure rate.

The ion chamber behaves in a bandpass manner. This means it will respond evenly only for a specific range of photon energies.

At very low energies, photons are unable to penetrate the chamber wall material, so there are no internal high-speed electrons or ion chamber current. In practice, the wall is made of the thin, low-density material necessary to achieve the desired low energy response.

At very high energies, the situation is reversed and a minimum wall thickness is necessary to prevent high-speed electrons generated outside the chamber entering and adding spurious contributions to the ion current. As a condition of measurement, all high-speed electrons are generated in the chamber wall or the internal air volume. Therefore, above a certain energy (about 250 keV), additional wall material must be added to insure non-response to outside electrons.

The electrometer preamplifier circuit receives the current from the ion chamber. At typical temperatures and pressures, the ion chamber delivers about 5×10^{-15} A when a uniform exposure rate of 1 mR/h permeates the chamber volume.

An -18 V collection potential is supplied by two 9 V alkaline transistor batteries, connected in series. This potential is always present in the circuit.

Refer to Figure 4-1 for a block diagram of the 440RF/D Exposure Rate Measuring System.

4.2 Probe

The electrometer and buffer amplifier are located in the probe assembly. The signal from the ion chamber is applied to the electrometer and buffer amplifier. The amplified signal is applied to circuitry on the analog board.

4.3 Analog Board

The analog board contains circuitry for two programmable gain amplifiers, an analog multiplexer, and $\pm$ 5 V voltage regulators. (See Figure 4-2.)

The output of the buffer amplifier is applied to one programmable gain amplifier, while a sample of the -18 V chamber voltage is applied to the other. The gain of each amplifier is determined by the operating program. Output from each amplifier drives an input of the analog multiplexer. Signals from the pressure amplifier and the temperature sensor are also applied to inputs on the multiplexer. Under program control, any one of these inputs can be applied to the CPU board.
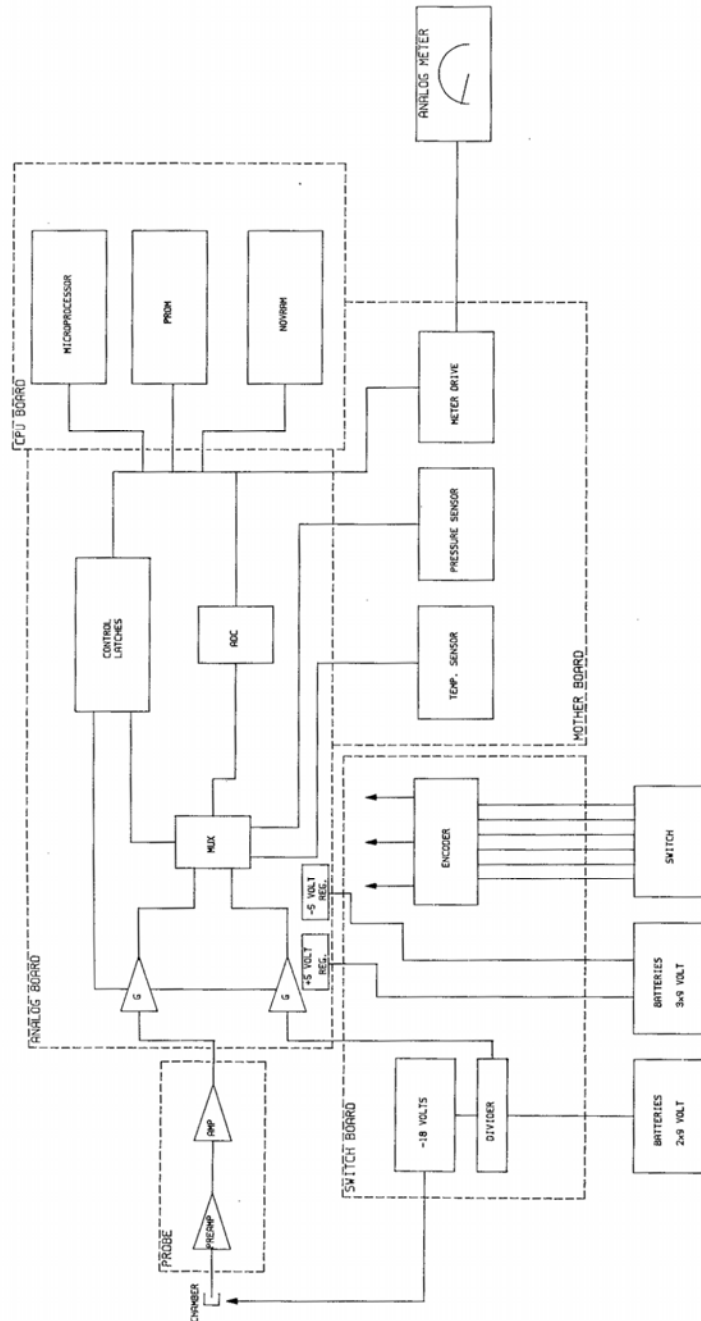

Figure 4-1.   Exposure Rate Measuring System Block Diagram

Operating power for the instrument is provided by three 9 V alkaline transistor batteries. The $\pm$ 5 V sources required for operation of the digital circuitry are provided by two voltage regulator circuits.

4.4 CPU Board

The CPU board contains the microprocessor, programmable read only memory (PROM), a user programmable NOVRAM, and an analog-to-digital converter (ADC). (See Figure 4-2.)

ADC accepts analog data from the multiplexer and converts it to a digital format which is compatible with the microprocessor. A Texas Instruments TMS70C00 microprocessor performs all control functions. The operating program is permanently stored in the 27C256 programmable read only memory (PROM) which contains 32,000 eight-bit words. Additional data are stored in the 6116 RAM.

4.5 Switchboard

The switchboard contains battery inputs, the 18 V divider circuit and a 74HC147 eight line to three-line priority encoder. (See Figure 4-3.)

The encoder communicates the function/range switch position to the microprocessor. Battery voltages and encoded data are then transferred to the motherboard.

4.6 Motherboard

In addition to providing interconnections between the Model 440RF/D circuit boards, the motherboard contains the pressure sensor, temperature sensor, and meter driver circuit. (See Figure 4-3.)

The meter driver is a transistor pulsing circuit which accepts digital data from the microprocessor and converts it to a format capable of driving the analog meter readout.

4.7 Analog Meter Readout

Meter Signal Filtration

A 300 µF capacitor, in shunt with the meter's internal resistance, provides a long time constant RC filter which reduces the displayed amplitude of source statistics and electronic noise.

4.8 Meter and RF Filtration

The insensitivity of the instrument to RF and electrostatic fields is obtained by completely enclosing the instrument in a conducting, metal case. The magnesium window provides a low energy radiation entrance to the case, while maintaining the metal shield integrity. The leads to the panel meter, which are not included within the main shielded cavity, are routed through double-pi section filters, with each section isolated in a separate shielded compartment. The basic case and filter design has been tested successfully in high intensity RF fields including the microwave region on down.

Magnetic insensitivity is achieved through the use of solid-state circuitry, and a magnetically insensitive radiation detector.
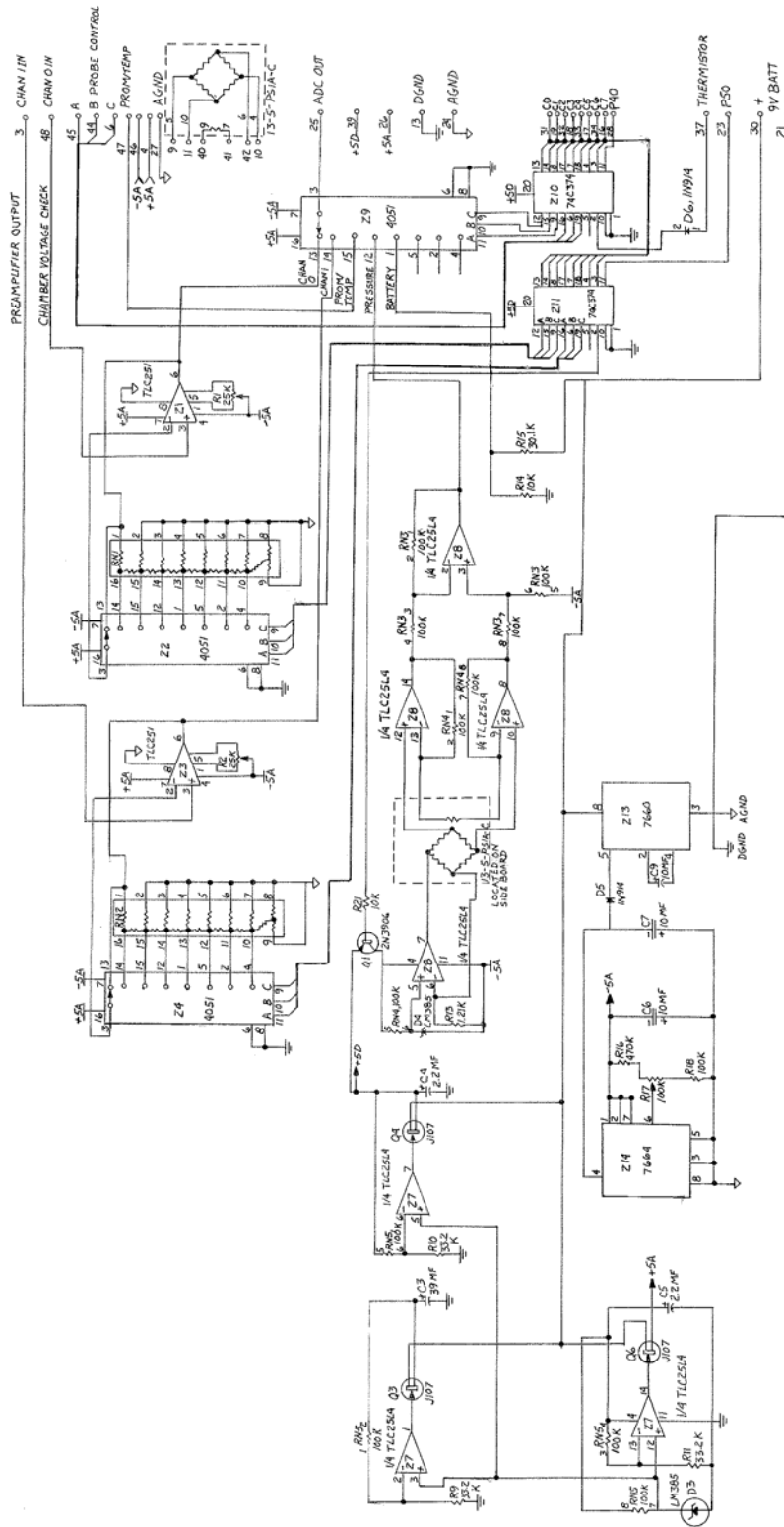
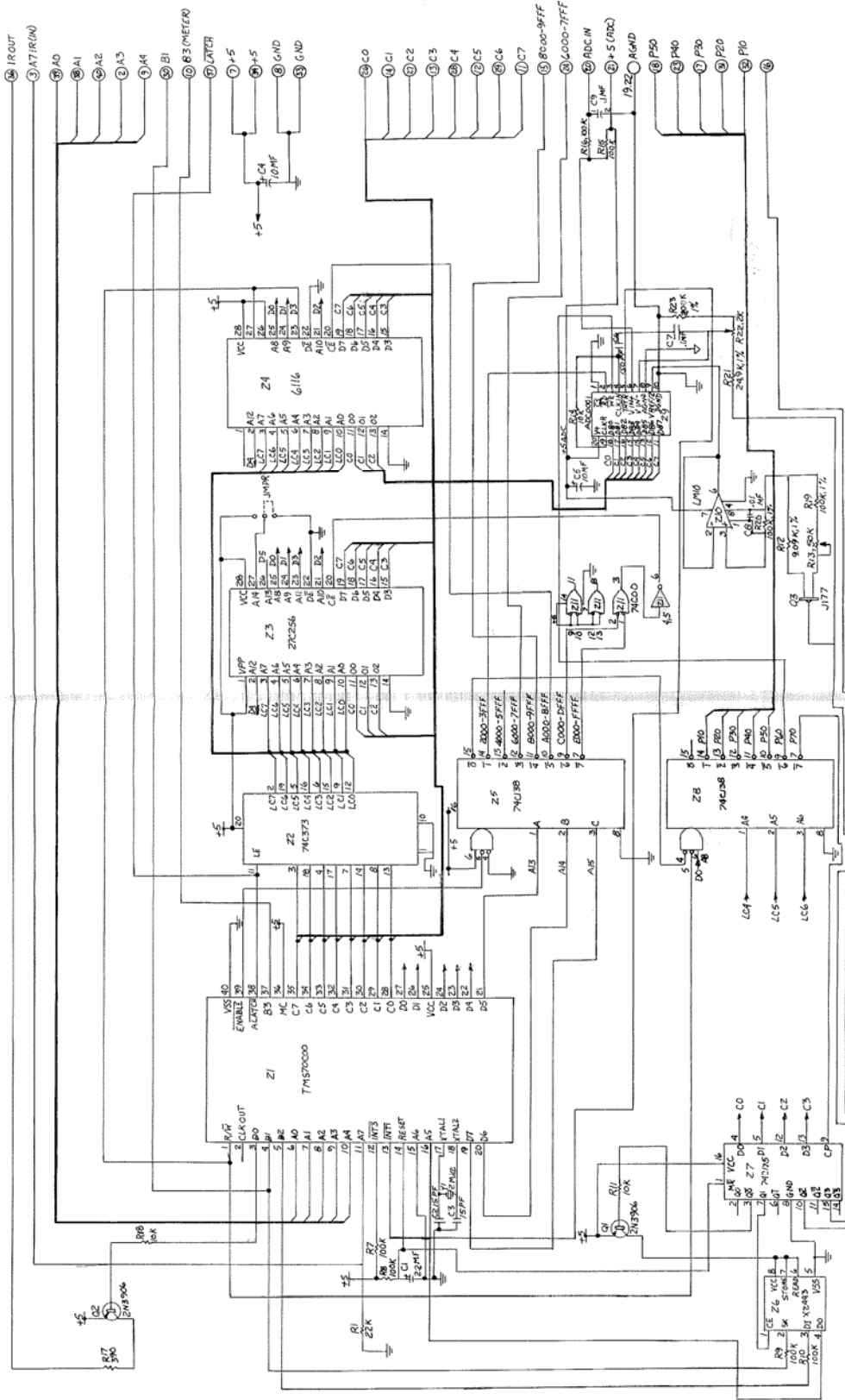*Figure 4-2. Analog Board Schematic Diagram*
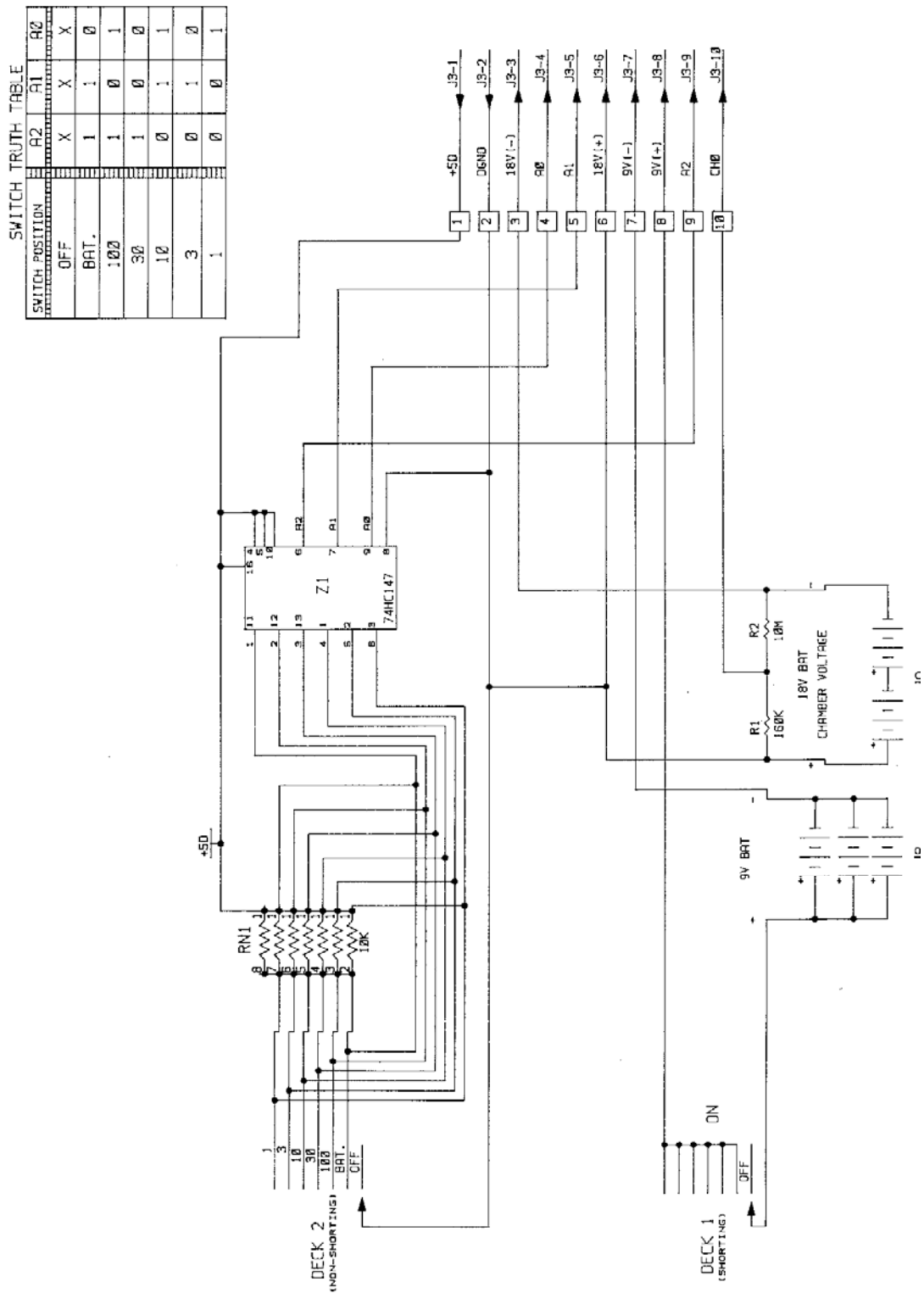
Figure 4-3. CPU Board Schematic Diagram

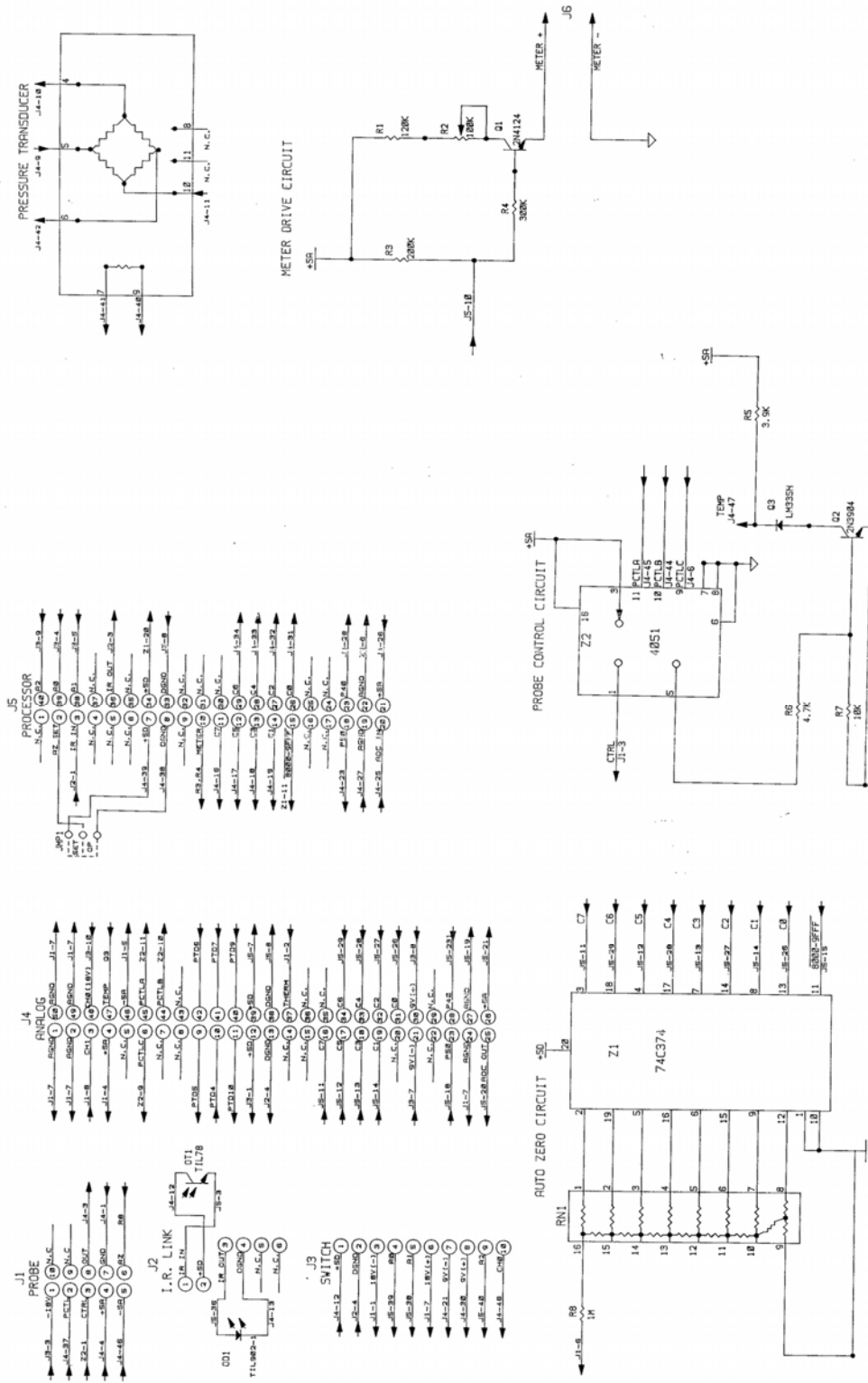*Figure 4-4. Switchboard Schematic Diagram*

Figure 4-5. Motherboard Schematic Diagram

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Section 5
Maintenance, Repair and Calibration

5.1   Maintenance

The only maintenance necessary for this instrument is battery removal and replacement

5.2 Battery Replacement

The battery holder is located in the instrument rear, just below the carrying handle.

Remove the two thumbscrews holding the battery compartment cover in place by turning them in a counter-clockwise direction until the cover plate can be removed from the case. Replace the batteries as shown in Figure 2-1 making sure that polarity is correct. Then replace the cover plate using the thumbscrews. Ensure that the cover plate is   snug.

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┌──────────┐
│   NOTE   │
└──────────┘
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The battery cover plate must be flush and snug against the outer surface of the case. This is to ensure proper battery contact with the spring-loaded contact block in the battery compartment.

5.3 Repair & Calibration

Due to the sensitive nature of this instrument, it should be returned to the factory for repair and calibration.

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Section 6
Replacement Parts

6.1 Replacement Parts

Part No.	Description	Qty.
16-29	9 V Battery ALK	5
440-587	Battery Drawer Polarity Decal	1
440-637	Battery Cover Plate	1
440-545	Decal	1
440-638	Cover, Acrylic	1
440-410	Spacer, Delrin Black	3
9-88	Knob	1

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