

FLUKE®

Biomedical

10100AT

TRIAD™ TnT Field Service Kit

Operators Manual

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Section 1

General Information

1.1 Introduction

The TRIAD Service Kit can be used for government compliance testing, troubleshooting, repair of diagnostic x-ray equipment, installation and setup of new equipment, preventive maintenance, radiographic quality assurance measurements, and measurements required for JCAHO accreditation.

The TRIAD Service Kit performs measurements on all modalities: mammographic, cine, dental, radiographic, fluoroscopic, CT, and image intensifiers.

The Model 35050AT Dosimeter, as featured in the Model 10100AT TRIAD Field Service Kit, is both a sensitive, full-function dosimeter and a digital display for the Models 35080/80A/80B Non-invasive kVp Divider. It features a direct readout and simplified operator controls.

This manual contains all the information necessary for you to operate and service your Model 35050AT Dosimeter/kVp/Time Readout and the Model 10100AT TRIAD Field Service Kit components. This manual contains a description of usage of the Model 35080/80A/80B kVp Divider with the Model 35050AT Dosimeter as its readout. The operator is referred to the Model 35080/80A/80B kVp Divider Instruction Manual, though, for a complete coverage of specifications, general use, etc.

Some service kits may include a Model 35035 mA/mAs meter. The user is referred to its instruction manual for details of operation, specifications, and servicing.

Information on customizing the Model 35050AT Dosimeter using the Customization Software is contained in a separate manual (Model 35050A Customization Instruction Manual). Also, a separate Model 35050A Programmer's Instruction Manual contains a description of the protocol and commands used to operate the Model 35050AT Dosimeter via the RS-232 interface. The RS-232 interface also allows the user to capture kV waveforms obtained during simultaneous use of the Model 35050AT Dosimeter and the Model 35080/80A/80B kVp Divider. Refer to these instruction manuals as needed.

1.2 Features

Simplified Controls – automatic or manual exposure reset, autoranging, automatic offset and drift compensation, and automatic power down.

Battery or Line Current Operation - 6 AA alkaline batteries provide instrument power with an auto power-down feature to extend battery life and a 300 V electronic ion chamber bias. An AC adapter is provided which allows line current operation.

Direct Reading - readout in user-selected units: R, Gy, Sv, C/kg, A, C, /s, /min, /hr, /frame; pressure and temperature corrected readings. Temperature and pressure corrections may be made automatically using an internal temperature and pressure sensor or by manual entry.

Ion Chamber Flexibility - radiation units for any triaxial-BNC ion chamber with a known calibration factor, including CT ion chambers.

High Sensitivity - image intensifier measurements at 0.1 mR and 5 mR/min resolutions.

kVp+Dose+Time - kVp, dose, and exposure time measurements when used with the Model 35080/80A/80B Non-Invasive kVp Divider. Exposure time may be displayed in seconds or pulses (for single phase or pulsed outputs).

RS-232 Interface - remote operation, waveform capture, digital calibration, custom display units, customer specified ion chamber calibration factors, and Model 35080/80A/80B kVp Divider filter packs.

Self-Checking - the Model 35050AT Dosimeter and Model 35080/80A/80B kVp Divider battery voltage level, bias voltage level, ion chamber/cable leakage, and hardware/software checks.

1.3 Manual Addenda

Any improvements or changes concerning the instrument or manual will be explained in an addenda included with the manual. Be sure to note these changes and incorporate them into the manual.

1.4 Before You Start - Safety Precautions


This instrument is intended for use by qualified personnel who recognize radiation hazards associated with use of x-ray equipment.


Always turn off unit prior to connecting or disconnecting ion chamber or triaxial cable. Failure to do so could result in electrical shock or damage to the equipment.

Beyond the battery and fuse, this unit contains no operator serviceable parts. The operator should not attempt to gain access beyond the battery access cover. High voltage is generated internally and may remain on internal parts even after the batteries have been removed.

1.5 Safety Symbols and Terms

The following symbols and terms are found on the instrument and used in this manual.

The  symbol on the instrument indicates that the user should refer to the operating instructions located in the manual.

The  symbol on the instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The

WARNING

 heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The

CAUTION

 heading used in this manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

1.6 Specifications

Exposure and Exposure Rate Accuracy

The basic accuracy of the Model 35050AT Dosimeter is $\pm 1\%$ of reading ± 2 range resolution steps (see Table 1-1) over the range of 18 to 28° C and $\pm 2\%$ of reading ± 2 range resolution steps over the full operating temperature range of 0 to 50° C. This accuracy is guaranteed for a period of 1 year and is exclusive of all ion chamber effects. A 3% NIST traceable calibration is provided with each system and includes the effects of the Model 35050AT Dosimeter, Model 96035B Ion Chamber, and Model 96020C Ion Chamber.

Temperature and Pressure Accuracy

Temperature Accuracy: $\pm 2^\circ\text{C}$ (3.6°F)

Pressure Accuracy: $\pm 5\text{mm Hg}$

NOTE

The measured temperature is the internal temperature of the Model 35050AT, TRIAD TnT Dosimeter, which may not be the same temperature as the Ion Chamber that is in use. Adequate time must be allowed for the Dosimeter and Ion Chamber to reach thermal equilibrium before automatic temperature sensing is used.

At standard conditions of 22°C and 760mm Hg:

1°C ~ 0.36 % change in ADC

1 mm Hg ~ 0.13% change in ADC

Electrometer Measurement Ranges

Table 1-1. Electrometer Measurement Ranges

Ion Chamber	Units	Effective Range***	Threshold	Resolution Step Size	Units	Effective Range***	Threshold	Resolution Step Size
15 cc	R	100 μ to 20	60 μ	1 μ	Gy	1 μ to 0.2	.52 μ	0.01 μ
	R/s	100 μ to 20	60 μ	1 μ	Gy/s	1 μ to 0.2	.52 μ	0.01 μ
	R/min	5 m to 1200	3.6 m	50 μ	Gy/min	50 μ to 12	31.5 μ	0.5 μ
	R/hr	100 m to 72 k	216 m	1 m	Gy/hr	1 m to 720	1.89 m	0.01 m
	R/frame**	2 μ to 333 m	1 μ	0.02 μ	Gy/frame**	0.02 μ to 3.33m	.008 μ	0.2 n
150 cc	R	10 μ to 2	6 μ	0.1 μ	Gy	0.1 μ to 0.02	.052 μ	0.001 μ
	R/s	10 μ to 2	6 μ	0.1 μ	Gy/s	0.1 μ to 0.02	.052 μ	0.001 μ
	R/min	0.5 m to 120	0.36 m	5 μ	Gy/min	5 μ to 1.2	3.15 μ	0.05 μ
	R/hr	10 m to 7.2 k	21.6 m	0.1 m	Gy/hr	0.1 m to 72	.189 m	0.001 m
	R/frame**	0.2 μ to 33 m	0.1 μ	0.002 μ	Gy/frame**	0.002 μ to 0.33 m	0.8 n	0.02 n
150 cc VLDR	R/s	2 μ to 2*	N/A	0.1 μ	Gy/s	0.02 μ to 0.02*	N/A	0.001 μ
	R/min	0.1 m to 120*	N/A	5 μ	Gy/min	1 μ to 1.2*	N/A	0.05 μ
	R/hr	2 m to 7.2 k*	N/A	0.1 m	Gy/hr	0.02 m to 72*	N/A	0.001 m
	R/frame**	0.04 μ to 33 m*	N/A	0.002 μ	Gy/frame**	0.4 n to 0.33 m*	N/A	0.02 n
Electrical Units	C	1 p to 100 n	0.5 pC	0.01 p				
	A	1 p to 100 n	250 fA	0.01 p				

Values for ion chambers are calculated using nominal sensitivities:

15 cc: 2.4×10^8 R/C

150 cc: 2.4×10^7 R/C

* Very Low Dose Rate effective range at 5% resolution steps

** At 60 frames/s (1 to 120 frames/ selectable).

*** IEC 61674 effective range at 1% resolution steps

Measurement Modes

Dosimeter Operation Only: In use when the Model 35080/80A/80B kVp Divider is not connected or turned on.

Full-sensitivity Exposure: Automatic drift and offset compensation, and automatic post-exposure display hold are performed in this mode. Measurement range covers a span from low-level image intensifier inputs to unattenuated direct beams. Autoranging over five decades. Display updates at the end of each exposure. When the Automatic Reset option is enabled, exposure start and end detection are based on the exposure rate level crossing a 0.25 pA threshold. When the Automatic Reset option is disabled, exposure start detection is based on the exposure rate level crossing a 0.25 pA threshold but the exposure measurement is only reset by pressing the Reset/Measure key.

Full-sensitivity Exposure Rate: Automatic offset compensation and nonlinear digital filtering are performed in this mode. Autoranging provides five decades of sensitivity ranges. The measurement range covers a span from low-level image intensifier inputs to unattenuated direct beams. Display updates once per second. Differentiation between exposure on and off condition based on 0.25 pA threshold.

Very Low Dose Rate (VLDR): This mode is only for making very low dose rate measurements. Nonlinear digital filtering and autoranging provide five decades of sensitivity ranges. Display updates once per second. In this mode, automatic current offset and drift compensation is disabled. As a result, the system leakage (includes dosimeter, cable and ion chamber) is displayed and must be compensated for. This option should only be used with ion chambers suitable for very low dose rate measurements.

Dosimeter with kVp and Time Readout Operation: In use when the Model 35080/80A/80B kVp Divider is connected and a filter pack is selected from the Model 35050AT Dosimeter's front panel.

Tri-measurement Exposure: A single shot, direct beam measurement of exposure, kVp, and time. Autoranging across three-decade ranges and auto reset between exposures. Display updates following each exposure. Exposure start and stop based on detection of voltage from the Model 35080/80A/80B kVp Divider in excess of minimum kV for selected pack. A measurement delay of up to 999 ms may be used to skip over unwanted portions of an exposure. To prevent measurement of spurious signals, the 35050AT Dosimeter can be set to ignore exposures of less than 5ms.

Dual-measurement Exposure Rate: A simultaneous measurement of kVp and exposure rate. The display updates once per second. Autoranging across three-decade ranges provide adequate sensitivity for direct beam measurements. Display updates approximately once each second.

Customization

A customization program, contained on a compact disk, is included as part of a Model 10100AT TRIAD Field Service Kit.

The customization program runs on any IBM-PC or compatible computer. A cable and adapters are also furnished with the kit and provide means of interconnecting the computer's and the Model 35050AT Dosimeter's serial communications ports.

The program allows the user to modify the contents of the Model 35050AT Dosimeter's non-volatile memory, and thus determine a number of important operating parameters for the Model 35050AT Dosimeter. These are listed below:

1. All electrical calibration factors
2. All unit, ion chamber, and kV filter pack descriptions and conversion factors
3. Temperature and pressure unit types for use with air density corrections:

In degrees Fahrenheit, Celsius and Kelvin

In inches of Hg, mm of Hg, milliBars, hectoPascal, feet relative to sea level, and meters relative to sea level

4. Number of minutes to auto power-down, from 1 to 255
5. Optional Power-On and Test screen messages

Display

The display is a two-line, 20-character alphanumeric PLED (polymer light emitting diode) display with an approximate character height of 0.5 cm. The display shows all ion chamber/kV filter pack identification information, numerical measurement results, and other information such as battery level and calibration date.

Bias Voltage Supply

An electronic bias supply is fixed at a nominal 310 V. The bias voltage is removed from the triaxial input connector at instrument turnoff. Internal low and high bias voltage test limits are set at 300 and 325 V respectively.

Power

Continuous operational life of approximately thirty hours is provided by six “AA” alkaline batteries. Auto power-down feature turns off unit after user-selected period (1-255 min) of unattended operation.

An AC adapter allows line current operation. When the AC adapter is in use, no current is drawn from the batteries. When the AC adapter is in use, the auto power down feature is disabled, providing continuous operation. The AC adapter is an unregulated 9v, 200 mA adapter with a center negative, 2 .1 mm plug.

Note: before auto turnoff, unit stores selections of ion chamber, units, and kVp filter pack in nonvolatile memory. Eliminates manual reselection at next power-up. The default factory setting for the automatic power-down feature is 15 minutes.

Control Buttons

Power On/Off: initiates power-up and -down sequences

Detector Select: selection of ion chambers, kV filter packs

Units Select: selects measurement units, frame rates

Reset/Measure: starts measurement, provides manual reset (auto reset function is also available in the Model 35050AT Dosimeter)

Air Density: sets ambient temperature and pressure

Options: selects measurement options and displays diagnostic information such as supply level, ion chamber leakage, bias voltage, and other diagnostic information

Up, Down: scrolls through list of screen selections, increments / decrements numeric entries. Holding down the up or down key increases scroll speed.

Connections

Model 35080/80A/80B kVp Divider Interface: A coaxial-BNC connector used for measurement of kVp and exposure time.

Computer Interface: RS-232-C Serial Port offers full duplex communication with XON/XOFF handshaking. Connector is RJ-45 (female) with DCE configuration. Data format is 8 bits, no parity, and one stop bit. Data rate is fixed at 9,600 baud. Interface provides full instrument control, calibration, and automation.

Ion Chamber Input: A triaxial-BNC input connector: collector and guard positive-biased relative to ion chamber body/dosimeter chassis.

Power: 2.1mm DC Power Jack, power input for an unregulated 9v, 200 mA adapter with a center negative, 2.1 mm plug.

Models 96035B, 96020C Diagnostic Ion Chambers

Energy Range:

96035B: 25 kVp to 150 kVp

96020C: 30 kVp to 150 kVp

Calibration: pair of ion chambers with NIST-traceable calibration and 3% system calibration with Model 35050AT Dosimeter. Ion chambers are calibrated for use at 22°C and 760 mm Hg. Real time measurement or front panel selection of ambient temperature and pressure allow for corrected readings at other conditions.

Nominal Sensitivity:

96035B: 2.35×10^8 R/C (2.06×10^6 Gy/C). Flat response is suitable for both conventional diagnostic radiography and mammography.

96020C: 2.1×10^7 R/C (1.84×10^5 Gy/C), optimized for low-level image intensifier and cine measurements

Multiply values by 0.00876 to convert from R to Gy.

Construction:

96035B: Graphite-coated acrylic, parallel-plate, air-vented

96020C: Composite graphite-filled thermoplastic, parallel-plate, air-vented

Volumes:

96035B: --15 cc

96020C: --150 cc

NOTE

See Appendix B and C in this instruction manual for complete specifications on the Models 96020C and 96035B Ion Chambers.

Kit Accessories

Cable: (38208) 20 ft (6.1 m) Coax/Triax Cable

Test Stand: (37581) machined stainless steel upright rod with baseplate, ion chamber holder, Model 35080/80A/80B kVp Divider holder, and tray for HVL filters, which includes the ion chamber stem (32147).

Customization Kit: (37594) includes software on CD and a 6 ft (2 m) RS-232 interface cable with adapters for PC- and AT-type computers.

Instruction Manuals: Model 10100AT TRIAD Field Service Kit Operator's Instruction Manual (38651).

HVL Filter Set: (37668) set of nine aluminum filters for half-value layer measurements: one -- 2 mm, two - 1 mm, two -- 0.5 mm, three -- 0.1 mm, and one -- 0.2 mm.

Kit Carrying Case: (37500D) high-density polyethylene (HDPE) plastic absorbs impact to protect contents. Molded parallel ribs for strength. Corrosion-resistant hardware and locks. Custom-cut, high-quality foam interiors surround and protect standard kit equipment and accessories. The case is gasketed to exclude dust and moisture.

Environment

Operating: 0° to 50°C; relative humidity 20% - 80% non-condensing

Storage: -25° to 65°C

Kit Dimensions, Weight

Approximately 46 cm long x 33 cm wide x 15 cm deep (18 in x 13 in x 6 in); approximately 6.4 kg (14 lb).

kVp Measurement Accuracy and Method

The Model 35050AT Dosimeter will typically add an uncertainty of ± 2 mV to the voltage produced by the Model 35080/80A/80B kVp Divider for a well behaved (quiet and constant) voltage waveform. The accuracy of the peak detection method will be dependent upon both the shape of the kV waveform, and the amount of noise present in the signal produced by the kVp divider. Based on sampling the output of the kVp divider at a rate of 5 kHz, the peak voltage is determined by examining a 50 ms wide segment of these samples. In selecting the data segment to be analyzed, a delay of one-tenth of the total exposure time is inserted. When a measurement delay is used, this occurs after the measurement delay time elapses or with the first rising edge after the delay time elapses. Before peak detection occurs, the signal is passed through a digital filter with 1 ms time constant. The digital filter is not used with the Mobile filter pack

Exposure Time Measurement Accuracy and Method

When seconds are selected as exposure time units, the exposure time accuracy is $\pm 0.1\%$ of reading ± 0.2 ms. The measurement method is based on a kV threshold crossing. The threshold is set at 75% of the kVp, or the minimum kVp for the filter pack in use, whichever is greater. The maximum exposure time is six seconds and the measurement resolution is 0.2 ms.

When pulses are selected as exposure time units, the exposure time accuracy is ± 1 pulse. The measurement method is based on a kV threshold crossing; pulses are counted by detecting each passage through a threshold on the rising and falling edges each pulse in the output waveform.

When a negative measurement delay is specified, the TRIAD TnT Dosimeter does not include the delay time in the measured exposure time. A negative measurement delay should be used in cases when x-ray generator filament preheat pulses or other waveform anomalies should be excluded from kV and exposure time measurements.

When the measurement delay is positive, the TRIAD TnT Dosimeter includes the delay time in its measured exposure time. A positive measurement delay should be used in cases when the kV waveform contains leading edge overshoot or other waveform anomalies that should be excluded from kV measurements but included in the exposure time measurement.

** Specifications subject to change without notice.*

1.7 Unpacking and Inspection

The Model 10100AT TRIAD Field Service Kit was carefully inspected before shipment. Upon receiving the service kit, carefully unpack all items from the shipping carton and check for any obvious signs of physical damage that might have occurred during shipment. Report any damage to the shipping agent at once. Retain the original packing material in case reshipment becomes necessary. The following items are included with every Model 10100AT Service Kit shipment.

Standard System Components

- Model 35050AT Dosimeter/kVp Readout
- Model 10100AT TRIAD Field Service Kit Operator's Instruction Manual (38651)
- System Carrying Case (37500D)
- 15 cc and 150 cc Ion Chambers (96035B and 96020C)
- Test Stand (37581)
- 6.1 m (20 ft) Coax/Triax Cable (38208)
- Ion Chamber Stem (32147)
- HVL Filter Kit (37668)
- Spare Battery Holder (87-3)
- Customization Software Kit includes a compact disk, 2 m (6 ft) RS-232 Interface Cable, and adapters for PC- and AT-type computers (37594)
- AC Adapter

Optional Equipment

The Model 35080/80A/80B Non-invasive kVp Divider - is compatible with the Model 10100AT when used with the appropriate filter packs:

- Wide Range Filter Pack (37617)
- CT Filter Pack (33551)
- Cadmium K-Edge Mammo Filter Pack (37355)
- Linear Mammo Filter Pack (37351)
- Mobile Filter Pack Plus (37946)
- Low Range Filter Pack (38237)

Model 35035 mA/mAs Meter - measures anode current (mA) and anode current and time product (mAs) of x-ray generators.

TRIAD Toolkit for Excel (10500EXL) - is a complete software package for the TRIAD that includes an Excel Add-In, called TRIAD Tool and Excel templates that may be used to evaluate the performance of radiographic, mammographic, and fluoroscopic x-ray machines.

TRIAD QA Software (37978) - is a quality assurance software package for IBM-PC. It simplifies testing of exposure reproducibility, linearity, kVp, timer accuracy, and HVL.

Cable and Reel Assembly (38209) - is used to keep the 6.1 m (20 ft) coax/triax cable tangle free.

1.8 Getting Started

The Model 35050AT Dosimeter/kVp/Time Readout is a highly sophisticated instrument with many capabilities. Although there are a number of complex aspects about the instrument, you can use the following procedure to get your instrument up and running quickly. For more detailed information, you should consult section 2 of this manual.

1. Carefully unpack your Service Kit as described in section 1.7.
 - a. Connect the supplied triaxial cable to the case side input jack. Connect an appropriate ion chamber to the other end of the triaxial cable. Position the chamber where required.

WARNING

To prevent electrical shock, the Model 35050AT Dosimeter should always be turned off when connecting or disconnecting an ion chamber or triaxial cable.

2. a. If use of the Model 35080/80A/80B kVp Divider is intended, connect its output to input of the Model 35050AT Dosimeter using the coaxial cable provided. Position the kVp divider in the beam.

NOTE

Make certain that the color of the cable boot matches the color indicator around the connector of the instrument.

2. b. If using the AC adapter, plug the adapter into a suitable power outlet and plug the 2.1mm plug fully into the power jack on the side of the unit.

NOTE

Only use the supplied AC adapter. Use of AC adapters other than the one supplied with the unit may damage the unit and void the warranty.

3. a. Depress the front panel POWER ON/OFF button for approximately one second to apply power to the instrument. The instrument will power-up through a series of screens.
 - b. If a kVp divider is in use, set its switch to the RUN position and plug in desired filter pack.
4. a. At the Detector Select screen, make sure the ion chamber in use is indicated. If not, press the UP or DOWN buttons until it is. If air density corrections are desired, find an ion chamber with ADC in its description. If very low dose rate measurements are desired, find an ion chamber with VLDR in its description.
 - b. If using a Model 35080/80A/80B kVp Divider, press the DETECTOR SELECT button and then press the UP or DOWN buttons until the proper filter pack is selected.
 - c. If a kVp divider is not in use, press the DETECTOR SELECT button and then press the UP or DOWN buttons until the filter pack selection displays "35080/80A Not Used".

5. Press the UNITS SELECT button if an integrated exposure is to be measured. Or, if exposure rate is desired, these same units may be chosen with a timebase of seconds, minutes or hours. Additionally, per frame and amperes are available. Select desired units of measurement by pressing the UNITS SELECT button. Change the selection by pressing the UP or DOWN buttons. If exposure/frame units are selected, the user must set the frame rate at this screen.
6. If an ion chamber using air density corrections is selected, press the AIR DENSITY button to display the Air Density screen. If the temperature & pressure mode has been set to Automatic Sense, the measured ambient temperature and pressure will be displayed. If the temperature & pressure mode has been set to Manual Entry, the last used temperature and pressure will be displayed. Set temperature and pressure to match ambient conditions.

NOTE

When air density corrections are in effect, a "ADC" annunciator will appear on the Measurement screen.

7. Press and release the RESET/MEASURE button to place the dosimeter in the measurement mode.
8. Make the exposure. Following an exposure, the display will be updated with measurement results for the exposure. Additional exposures may be made at this point as the dosimeter will detect each exposure and automatically update the display.

Complete detailed operation concerning the Model 35050AT Dosimeter front panel operation may be found in section 2 of this manual, including the use of the Model 35080/80A/80B kVp Divider. If you wish to control these functions over the RS-232 Interface Cable, consult the Model 35050A Programmer's Instruction Manual.

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Section 2 Operation

2.1 Introduction

Operation of the Model 35050AT Dosimeter may be divided into two general categories: front panel operation and RS-232 bus operation. This section contains information necessary to use the instrument from the front panel. Note that many of these functions can also be programmed over the RS-232 bus, as described in the Model 35050A Programmer's Instruction Manual.

The following paragraphs contain a complete description of the Model 35050AT Dosimeter front panel operation. First a complete description of each front panel function is presented. Next the complete procedure for each of the measuring functions is presented.

2.2 Front Panel Familiarization

The front panel of the Model 35050AT Dosimeter is shown in Figure 2-1. The front panel may be divided into two sections: control buttons and display. The following paragraphs describe each of these items in detail.

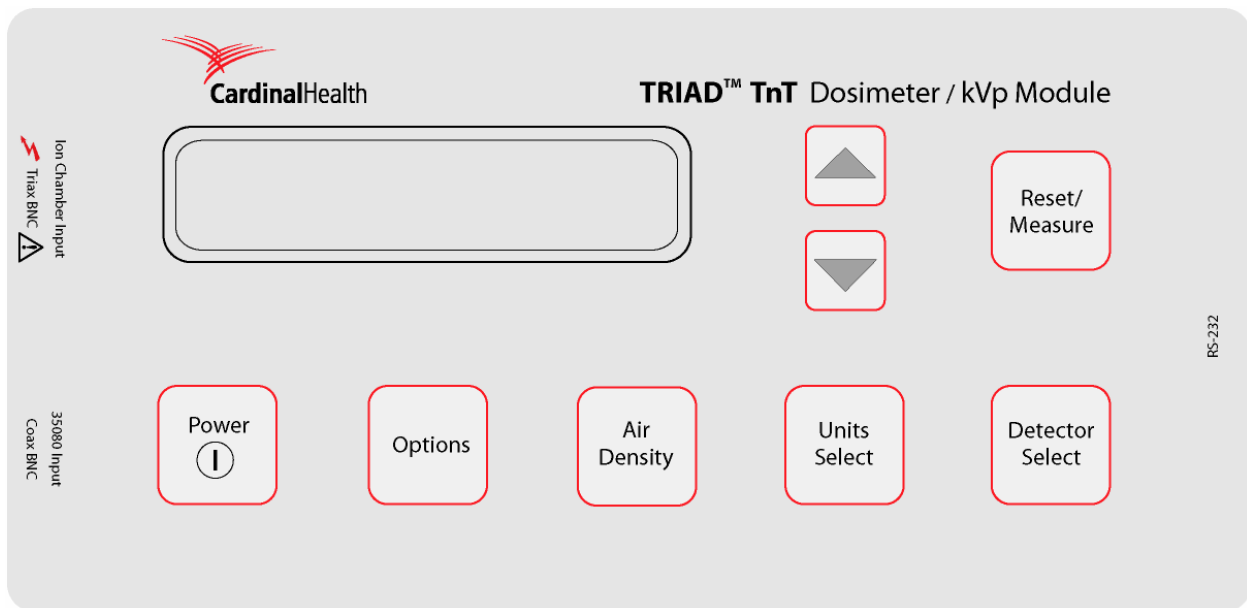


Figure 2-1. The Model 35050AT Dosimeter Front Panel

2.2.1 Control Buttons

All front panel control buttons are momentary contact switches, but their functions are firmware latched once depressed for even a short period of time. They are membrane type switches that provide a definite tactile indication of operation.

Power On/Off

This button controls the power to the instrument. Depressing this button for approximately one second turns the power on. Depressing and releasing the button a second time turns the power off.

NOTE

When the power-up screens sequence is still in progress, depressing any button will have no effect. Similarly, depressing any button during the power-down sequence will have no effect.

In the event of no button depression, no exposure, no operating kVp divider connected, or no RS-232 communication for a user-defined period; the instrument will automatically save its current settings and turn its power off. Note that any measurement values displayed at power down will be lost. For additional details on power-up screens, see section 2.4.

At next power-up, the unit will resume operation with these same selections. In addition, at power-up, the unit will automatically advance through four basic status or self-test screens and then automatically invoke the DETECTOR SELECT screen before returning control to the front panel buttons. This screen is shown in Figure 2-1.

Options

This button is used to select various measurement options and display of a series of test screens. For additional details on test screens, see section 2.5. The complete wraparound list may be examined by repeatedly pressing the Options button.

Air Density

This button causes display of the temperature and barometric pressure used for vented ion chamber corrections. When the temperature & pressure mode is set to Automatic Sense, pressing the Air Density button causes the ambient temperature and pressure to be displayed. When the temperature & pressure mode is set to Manual Entry, the button has a toggle function: momentarily depressing it selects whether temperature or barometric pressure may be adjusted. The current variable is indicated by the “greater than” symbol (>) as first character in the display line; hereafter, this is referred to as the cursor. The current variable may then be changed in value, if desired, by use of the UP and DOWN buttons. Air density corrections to the exposure and exposure rate displays will be made only if 1) radiological units (not A or C) have been selected, and 2) an ion chamber with air density corrections enabled has been selected. When air density corrections are in effect, an “ADC” annunciator will be displayed on the measurement screen. In the event that the temperature/pressure sensor becomes non functional, an error message, “Temp & Press Error Use Manual Entry” is displayed and only the manual temperature and pressure entry mode is available.


Units Select

This button causes display of the selected radiological or electrical units and cine frames per second. This button also has the toggle function to cursor select the units or frame rate for changing. Changes may then be made by means of the UP and DOWN buttons. The exposure and exposure rate displays will be affected by the frame rate setting only if units of exposure per frame (R/frame, Sv/frame, etc.) have been selected.

Detector Select

This button causes display of the identity of the ion chamber and kVp filter pack last used. This button also has the toggle function to cursor select which chamber and/or filter pack is to be currently used. If different, changes may then be made by means of the UP and DOWN buttons. The filter pack selection is used only when a Model 35080/80A/80B kVp Divider is connected.

Reset/Measure

This button is used to both begin and reset the measurement process. When the Exposure Reset option is set to Manual, indicated by  in the upper right corner, this button may be depressed between exposures to clear the display. When the Exposure Reset option is set to Automatic, this is not required because of the automatic reset feature of the Model 35050AT Dosimeter. The manual reset feature is only active in the Full-Sensitivity Exposure mode.

2.2.2 Display

The display, located on the upper left-hand corner of the front panel, is a two line, twenty character per line, alphanumeric PLED (polymer light emitting diode) display module. This module performs all visual indications for the manual operator.

Annunciators

The battery/supply level and ion chamber bias potential are measured regularly by the instrument in a background mode. Should either level go outside of preset limits, an annunciator is displayed. The preset limits are given below.

Bias voltage limits	300 to 325 volts
Power battery limits	5.9 to 9.6 volts

The low battery limit of 5.9 V has been chosen to provide approximately two hours of useful battery life following the initial display of the low battery annunciator.

NOTE

The battery voltage is measured at the input of the 5-volt regulator, after some drops in fuse, switch, wiring, etc. There will be a discrepancy of several tenths of a volt from the actual battery voltage.

2.3 Connector Familiarization

There are four external connectors provided on the Model 35050AT Dosimeter case sides. On the side left of the front panel (front view) is the ion chamber (marked by a yellow ring) and kVp divider connectors. The following paragraphs detail the purpose and use of these connectors. On the side right of the front panel is the DC power jack and the RS-232 connector. Information on RS-232 communication is in the Model 35050A Programmer's Instruction Manual that is available upon request.

2.3.1 Ion Chamber Connector

CAUTION

Never connect a coaxial-BNC type cable to the Model 35050AT Dosimeter's triaxial ion chamber input connector. Doing so may damage the ion chamber input connector.

WARNING

The central pin and inner shield shell of this connector are operated at 300 volts above the outer shell and instrument case. Although this potential is energy and current limited, care should be taken to avoid unnecessary and possibly hazardous shocks. Mating and unmating to this connector (or to the other end of a cable already connected to it) should be done only when the instrument is powered down. Within a few seconds of turnoff, the high voltage is internally discharged making such connections safe and convenient.

The connector is a triaxial-BNC female with dust cap and chain. It connects to the supplied coax/triax cable or other low-noise triaxial-BNC male cables. And, by means of which, the Models 96020C Ion Chamber, Model 96035B Ion Chamber, and other ion chambers can be operated with the Model 35050AT Dosimeter.

The connector is side-mounted to avoid contaminating spills and dust, but putting its dust cap in place whenever a cable is not connected will help assure long service without leakage problems.

2.3.2 kVp Divider Connectors

The connector is a BNC jack marked with a yellow ring. It is the opposite gender of the usual panel mounted BNC connector to prevent accidental connection of the triax cable to the BNC connector, and vice versa. Such a cable connector mix up will damage some or all connectors involved. The male to female BNC coaxial cable (as indicated by yellow boots) provides the connection between the Model 35080/80A/80B kVp Divider and the Model 35050AT Dosimeter / kVp Readout.

2.4 Power-Up Self-Test and Display Messages

When the instrument is powered up by pressing and releasing the POWER ON/OFF button on the front panel, the following sequence of screens will be displayed:

1. Pixel test
2. Last calibration and software revision date (5 seconds)
3. Instrument power level in volts and HI, LO or OK advisory (5 seconds). If the unit is operating on battery power, the displayed battery voltage will be between 5.9 and 9.6 volts. If the unit is powered by its AC adapter, the displayed battery voltage will be between 10 and 13 volts.

NOTE

If the AC adapter is plugged into the instrument, but is not plugged into an AC power source, the Supply Level will be reduced by several tenths of a volt. This is due to the additional components that are switched into the power circuit when the AC adapter is plugged into the unit. For best performance on battery power, unplug the AC adapter from the unit when not in use.

4. Optional power on screen displays user selected information (5 seconds):
This screen will be skipped if blank screen was specified using customization software.

During this opening screen sequence, pressing any front panel button will have no effect. The sequence ends in DETECTOR SELECT. The last selected detector will be displayed on the screen. Other functions or another detector may now be selected with the front panel buttons.

2.5 Using the Options Button

Pressing the OPTIONS button, when in any other function, will display one of the status/option screens. Repeatedly pressing the OPTIONS button again will move the display through twelve status/option screens as follows:

1. Last calibration and software revision dates
2. Optional test screen, can be skipped by customization
3. Supply Level in volts and HI, LO or OK advisory. When battery power is in use, the battery voltage is displayed. When the AC adapter is in use, the AC adapter voltage is displayed.
4. System leakage current measuring mode without offset current subtraction. Enables operator to directly see the ion chamber, cable, and dosimeter leakage current. See section 2.6.1 for more information.
5. System bias level in volts and HI, LO or OK advisory
6. Ion chamber calibration factor in use: 4 digits plus exponent, dimensioned in either Roentgens/Coulombs or Grays/Coulombs depending on option chosen during customization. Factor also includes air density correction if applicable.
7. Voltage measured at Data Terminal Ready (DTR) line of RS-232 port
8. Temperature & Pressure Mode selection. Pressing the up or down button toggles between Automatic Sensing of temperature and pressure or Manual Entry of temperature and pressure.
9. Short Exposure (< 5ms) selection. Pressing the up or down button toggles between Accept and Ignore. Accept allows the 35050AT to measure exposures that are less than 5 milliseconds in duration. When ignore is selected, the 35050AT ignores exposures that are less than 5 milliseconds in duration. This is useful when spurious signals trigger unintended measurements. This feature is only active when the 35050AT is in the Tri-measurement Exposure mode (when the 35080 is used).
10. kV Measurement Delay entry. Pressing the up or down buttons increments or decrements the measurement delay. The measurement delay range is -999 to +999 milliseconds and can be set in one-millisecond increments. The polarity of the measurement delay only affects how exposure time measurements are performed. When a negative measurement delay is specified, the 35050AT does not include the delay time in the measured exposure time. When the measurement delay is positive, the 35050AT includes the delay time in its measured exposure time. This feature is only active when the 35050AT is in the Tri-measurement Exposure mode (when the 35080 is used).

11. Exposure Reset selection. Pressing the up or down button toggles between Automatic and Manual. When the Exposure Reset option is set to Automatic, Model 35050AT Dosimeter automatically resets between exposures; exposure start and end detection are based on the exposure rate level crossing a 0.25 pA threshold. When the Exposure Reset option is set to Manual, this button may be depressed between exposures to clear the display. A \odot symbol appears in the upper right corner of the display when the Manual Reset option is active. Exposure start detection is based on the exposure rate level crossing a 0.25 pA threshold but the exposure measurement is only reset by pressing the Reset/Measure button. The manual reset feature is only active in the Full-sensitivity Exposure mode.
12. Exposure Time Units selection. Pressing the up or down button toggles between Seconds and Pulses. When Seconds are selected as exposure time units, exposure time is measured between the first and last passage through the kV threshold. The displayed units are milliseconds (ms) or seconds (s). The threshold is set at 75% of the kVp, or the minimum kVp for the filter pack in use, whichever is greater. When Pulses are selected as exposure time units, exposure time is displayed in pulses (P), and pulses are counted by detecting each passage through a threshold on the rising and falling edges each pulse in the output waveform.

2.6 Basic Measurement Techniques

2.6.1 General Considerations

It will be helpful to the user to understand the presence of several automatic compensations being performed during measurements and how they could affect the measurements under certain circumstances.

Automatic Voltage Offset and Drift Compensation

The instrument automatically measures the voltage offset of the electrometer and subtracts the value from the exposure and exposure rate measurement results.

Automatic Current Offset and Drift Compensation

In the usual situation, this feature is transparent and amounts to system leakage current being nulled from the measurements. In order to do this, both a short-term history of the leakage current and the establishment of a leakage/"real" current threshold must be made.

The threshold is set at 0.25 pA and only a few seconds are required for an accurate leakage level assessment. In the typical case, system leakage current is on the order of 10 fA and reasonably steady. It may be viewed at any time by going to the OPTIONS and scrolling to the System Leakage screen. When it approaches the current threshold level and/or becomes highly erratic, the system may improperly compensate the measurement value.

Another consideration of higher, but suppressed, leakage levels is that the automatic electrometer integrator reset frequency is raised. This increases the small, but finite possibility, that a reset may occur during an exposure and thereby lose some of its value. With low system leakage and manually resetting just before the exposure, this possibility is precluded. In the case where the Model 35050AT Dosimeter detects the start of an exposure immediately following an automatic reset, an error message will be displayed advising the user to repeat the exposure.

For several reasons, then, it is good operator practice to regularly check for a low system leakage level. Experience should serve as a guide to how often this needs to be done and in what circumstances.

Similarly, ten seconds or so should be allowed to elapse between the last triaxial cable or chamber movement or other disturbances to the high impedance part of the system before commencing an exposure--so that the "correct" history is applied to the measurement.

Important implications of the 0.25 pA threshold for exposure rate measurements and the 0.5 pC threshold for integrated exposure measurements in the case of integral exposure are the minimum radiological quantities that can be measured.

Table 2-1. Threshold Minimum Roentgen readings

Ion Chamber	Measurement Units	Minimum Reading
15 cc	R/s	60 μ
	R/min	3.6 m
	R/hr	.22
	R/frame	1 μ
	R	60 μ
150 cc	R/s	6 μ
	R/min	.36 m
	R/hr	22 m
	R/frame	0.1 μ
	R	6 μ

To find minimum readings in other radiological units, use the following multipliers of the roentgen factors:

0.000258 for Coulombs/kg air
0.00876 for Grays (in air)
0.01 for Sieverts (in air)

Ion Chamber Selection

The primary purpose of the Model 35050AT Dosimeter is to measure the ionizing radiation outputs of typical diagnostic x-ray machines. This will likely be done with either of the two ion chambers standard in the Model 10100AT TRIAD Field Service Kit: Model 96020C Ion Chamber, 150 cc or Model 96035B Ion Chamber, 15 cc. Typical units of use will be exposure, exposure rate or exposure per frame.

The choice of which ion chamber to use will depend upon the sensitivity required, the beam size, beam accessing port dimensions or the performance of a special function (e.g. CT probe).

Once a suitable ion chamber is selected, it is interconnected with the Model 35050AT Dosimeter by means of the 6.1 m (20 ft) low-noise triaxial cable supplied and stably positioned at the measurement point of interest by means of the test stand (see section 2.9) or ion chamber cable stem (see section 2.10) or other means. The dosimeter may be located where convenient and where both the dosimeter and the operator are out of the radiation field. The dosimeter may now be turned on.

Verify Ion Chamber Selection

After the opening screen sequence, the instrument will go to the DETECTOR SELECT screen and await a key press. If the ion chamber in use is not displayed, press the UP or DOWN buttons until it is.

Make sure that air density correction or no air density correction is what is desired--or required by the nature of the detector, e.g., sealed chamber. If air density corrections are desired see section 2.2.1 and 2.11.2.

If very low dose rate measurements are desired, find an ion chamber with VLDR in its description. This option should only be used with ion chambers suitable for very low dose rate measurements

Automatic Temperature & Pressure Sensing

The Model 35050AT Dosimeter contains an integrated temperature/pressure sensor. When using the automatic temperature and pressure sensing feature, the measured temperature is the internal

temperature of the Model 35050AT, TRIAD TnT Dosimeter. This temperature may not be the same temperature as the Ion Chamber that is in use. In normal use, the internal operating temperature of the 35050AT may be 1 to 2°C above ambient temperature. This operating temperature is normally achieved within 15 minutes of turn on.

Adequate time must be allowed for the Dosimeter and Ion Chamber to reach thermal equilibrium before automatic temperature sensing is used. For a large temperature differential, the thermal equilibrium time of the 35050AT may be up to 2 hours. If it is not possible to allow the instrument to reach thermal equilibrium, manual entry of temperature and pressure is recommended. A 3°C change in temperature results in approximately a 1% change in air density correction factor (ADC).

The housing of the Model 35050AT Dosimeter and its ion chambers are vented to atmospheric pressure; as a result, there should be no difference between the atmospheric pressure measured by Model 35050AT Dosimeter and the actual atmospheric pressure of the ion chamber.

A 3°C change in temperature results in approximately a 1% change in air density correction factor (ADC); an 8-mmHg change in barometric pressure results in approximately a 1% change in ADC.

In the event that the temperature/pressure sensor becomes non functional, an error message, "Temp & Press Error Use Manual Entry" is displayed and only the manual temperature and pressure entry mode is available.

kV Measurement Delay

A kV measurement delay may be used to postpone the start of data analysis in order to skip over waveform anomalies (such as overshoots or filament preheat effects), which may occur at the beginning of an exposure. This feature is only active in the Tri-measurement Exposure mode (when the 35080 is used).

When a delay is used, the 35050AT waits for the specified delay time after the beginning of an exposure before starting data analysis. If no radiation is detected after the delay time has elapsed, data analysis is delayed for up to one second after the delay time has elapsed. If no radiation is detected within one second after the delay time has elapsed, the 35050AT assumes that no exposure has occurred and displays the "-delay" message.

The delay range is from -999 to +999 milliseconds, and the polarity of the measurement delay only affects how exposure time measurements are performed.

When a negative measurement delay is specified, the 35050AT does not include the delay time in the measured exposure time. A negative measurement delay should be used in cases when x-ray generator filament preheat pulses or other waveform anomalies should be excluded from kV and exposure time measurements.

When the measurement delay is positive, the 35050AT includes the delay time in its measured exposure time. A positive measurement delay should be used in cases when the kV waveform contains leading edge overshoot anomalies that should be excluded from kV measurements but included in the exposure time measurement.

Exposure Time Units

When seconds are selected as exposure time units, the measurement method is based on a kV threshold crossing. The threshold is set at 75% of the kVp, or the minimum kVp for the filter pack in use, whichever is greater. The maximum exposure time is six seconds and the measurement resolution is 0.2 ms. Exposure time is displayed in milliseconds (ms) or seconds (s).

When Pulses are selected as exposure time units, the 35050AT counts the number of x-ray pulses in a pulsed or single-phase radiographic exposure. Pulses are counted by detecting each passage through a threshold on the rising and falling edges each pulse in the output waveform. Exposure time is displayed in pulses (P). This is primarily for use with single-phase full and half-wave rectified generators. Pulse counting will not function properly on single-phase generators employing output filter capacitors to smooth the generator's output because the generator's output does not drop to zero between pulses.

2.6.2 Making Exposure Measurements

Select Exposure Unit

The following integral exposure units are available for selection:

Exposure: Roentgens or Coulombs/kg air

Absorbed Dose: Grays (in air)

Dose Equivalent: Sieverts (x, gamma, or electron source and N=1 for air)

Charge: Coulombs (for the unlisted ion chamber)


Press UNITS SELECT button and use UP or DOWN buttons until the cursor is on the desired unit.

Taking the Exposure

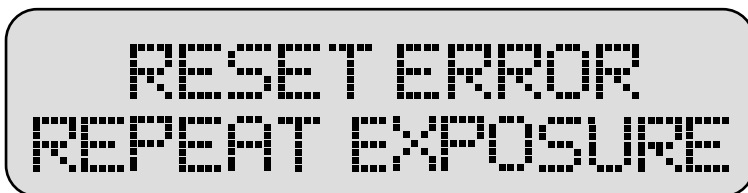
Press RESET/MEASURE just before the exposure. Make the exposure. The exposure value will be displayed.

Automatic / Manual Reset & Hold

When the Exposure Reset option is set to Automatic Reset, the electrometer is reset once the instrument senses the exposure is over. The final calculated value of the exposure is held on the display until either another above threshold exposure occurs, in which case the old value is discarded and the new value is displayed; or there is function change or power down. The instrument treats exposures separated by less than two seconds as single exposures.

When the Exposure Reset option is set to Manual Reset, the electrometer is only reset when the Reset/Measure button is depressed. The final calculated value of the exposure is held on the display until Reset/Measure button is depressed, in which case the old value is discarded and the display is reset to zero. When the Manual Reset option is active, the  symbol appears in the upper right corner of the display.

Resetting of the electrometer takes approximately 100 ms to complete. If an exposure starts while the electrometer is being reset, the result is an erroneous measurement. Instead of displaying the erroneous measurement, the display would read:



Simply repeat the exposure to clear the message and display a new measurement result.

2.6.3 Making Exposure Rate Measurements

For selection of ion chamber, verification of ion chamber with the instrument, minimum radiological quantities, and general considerations please refer to the discussions in section 2.6.1, as they apply here equally well. In addition, there are some aspects that are unique to exposure rate measurements.

Nonlinear Filter

Incorporated in the instrument's firmware is a digital nonlinear filter that responds quickly to significant changes in exposure rate, but possesses a much larger time constant for small changes, such as measurement system noise.

Realtime Display

While operating in the exposure rate mode, the display is updated at an approximate rate of once per second. Each new display value corresponds to the average exposure rate present since the previous

display update. This differs from operation in the exposure mode where the display is updated and held following each exposure.

Very Low Dose Rate Measurements

Very low dose rate measurements are selected by pressing Detector Select and selecting an ion chamber with VLDR in its description. This option should only be used with Ion Chambers suitable for very low dose rate measurements. To add this measurement option to an ion chamber, using the Customization Software, add "VLDR" to the chamber's description. This option is only active in the Exposure Rate mode (35080 not used).

In order to display very low dose rates in the VLDR measurement mode, automatic current offset and drift compensation is disabled. As a result, system leakage (dosimeter, cable and ion chamber) is displayed and should be subtracted from the rate reading. For instance, if the displayed leakage rate is 0.2 uR/sec (beam off) and the rate with the beam on is 6.9 uR/sec, the actual rate is 6.7 uR/sec.

Allow at least five minutes of settling time after connecting the ion chamber and cable to the dosimeter before making very low dose rate measurements. Settling time must also be allowed after moving the ion chamber, cable or dosimeter. When making very low dose rate measurements, the ion chamber, cable and dosimeter must be stationary; any movement can induce currents.

2.6.4 Use of the Model 35050AT Dosimeter as a kVp Divider Readout

For a full discussion of the Model 35080/80A/80B kVp Divider, the reader is referenced to its instruction manual. The information given here only concerns the combined operation of the two instruments.

There are some general considerations that apply to both the Exposure Rate/kVp mode and the Exposure/Time/kVp mode.

Interconnection & Power-Up Sequence

Use the supplied coaxial-BNC cable to connect the Model 35080A kVp Divider to the Model 35050AT Dosimeter. (Take note of the color-coding of BNC cable boots and respective connectors on the instruments.)

CAUTION

Never connect a coaxial-BNC type cable to the Model 35050AT Dosimeter's triaxial ion chamber input connector. Doing so may damage the ion chamber input connector.

Always power-up the Model 35050AT Dosimeter first and power it down last. Both instruments may now be turned on.

kVp Divider Battery Check

With the Model 35050AT Dosimeter turned on, set the function selector of the Model 35080/80A/80B kVp Divider to the BAT CHK position. The kVp divider battery measurement screen will be displayed by the dosimeter. A battery voltage display between 7 and 9.6 volts will carry an advisory of OK with it. Below 7 volts, LO will be indicated. If a kVp value is displayed in the BAT CHK position, the battery is indeed exhausted. Since the kVp divider is not under control of the readout, the operator must remember to check battery voltage manually.

Filter Pack Selection & Verification

Select an appropriate kVp filter pack for the x-ray machine involved and plug it into the Model 35080/80A/80B kVp Divider. Position the kVp dividers long dimensional axis at right angles to the x-ray tube axis, to avoid "heel" effect. The filter pack area can be placed as close to the beam axis as the ion chamber allows. Neither the ion chamber nor the kVp divider should shadow the other.

Pushing DETECTOR SELECT should display the name of the filter pack installed on the kVp divider. If it does not, scroll through the filter packs until it does.

NOTE

Filter packs should not be exchanged between kVp dividers. Each instrument and its filter pack(s) have been carefully calibrated together as a unit. Always check the calibration sheet serial numbers against the actual combination. A mismatch can impact measurement accuracy.

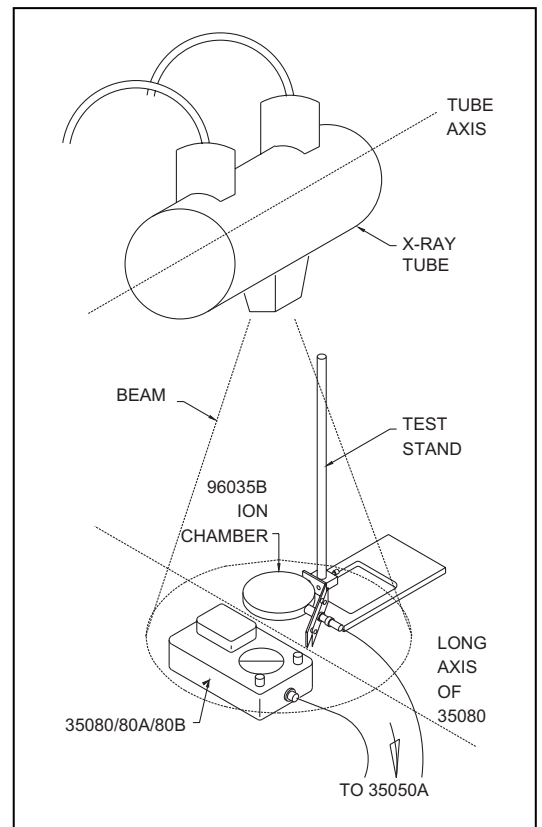


Figure 2-3. The Model 35080/80A/80B kVp Divider and Ion Chamber X-ray Shot

Internal Calibration Check

To use the cal check feature of the Model 35080/80A/80B kVp Divider, set the Model 35050AT Dosimeter for exposure rate units (A, R/s, etc.). Set the function selector of the Model 35080/80A/80B kVp Divider to the CAL position. After the Model 35050AT Dosimeter's RESET/MEASURE button is pressed the filter pack cal level will be displayed in kVp. The Linear Mammo Filter Pack cannot show the calibration check kVp, since it falls outside the specified kVp range.

Because the Model 35050AT Dosimeter automatically performs filter pack linearization corrections when the Wide Range, CT, or Mobile Filter Pack is selected, the kVp level displayed by the Model 35050AT Dosimeter will differ from the calibration kV level printed on the face of the filter pack. Table 2-2 gives the Printed Calibration kV Level for each filter pack as well as the Corrected kVp Reading that should be displayed by the Model 35050AT Dosimeter.

Table 2-2. Corrected kVp Readings for kV Filter Packs with Automatic Linearization Corrections

Filter Pack Type	37617C Wide Range	3351C CT	37946C Mobile
Printed Calibration kV Level	80 kV	124.4 kV	100.0 kV
Corrected kVp Reading	79.4 kVp	123.6 kVp	98.8 kVp
Nominal Calibration Voltage	0.400 V	0.644 V	0.600 V

The Nominal Calibration Voltage levels listed in Table 2-2 are also printed on the faces of the filter packs, and may be read directly and without the effect of the Model 35050AT Dosimeter's automatic linearization correction scheme by selecting the Test Pack from the Model 35050AT Dosimeter's Detector Select screen.

Dosimeter Range Reduction in kVp Modes

Because of the higher exposure rates associated with kVp determinations, the dosimeter is automatically desensitized when in either kVp mode. This changes the minimum detectable quantities as follows below.

An important implication of the 5-picoampere threshold in the case of kVp/Exposure Rate is that there are minimum radiological quantities that can be read, depending on the ion chamber being used. Once above the threshold, though, there will be good value resolution.

Table 2-3. Reduced Range, Minimum Roentgen Readings

Ion Chamber	Measurement Units	Minimum Reading
15 cc	R/s	1.2 m
	R/min	72 m
	R/hr	4.3
	R/frame*	20 μ
150 cc	R/s	120 μ
	R/min	7.2 m
	R/hr	.43
	R/frame*	2 μ

* at 60 frames/second

To find minimum readings in other radiological units, use the following multipliers to the roentgen factors found above.

0.000258 for Coulombs/kg air
0.00876 for Grays (in air)
0.01 for Sieverts (in air)

kVp Out-of-Range Indications

If the peak kilovoltage during an exposure falls short of the filter pack's specified kVp range, the display will indicate 0.0 kVp; if it exceeds, the display will indicate ---. kVp.

2.7 Simultaneous Measurement Mode

The Model 35050AT Dosimeter can be configured to perform simultaneous exposure and kVp measurements. The simultaneous measurement option can be enabled through the TRIAD Customization Software. In this measurement mode, a delay of up to 999 ms may be used to skip over unwanted portions of an exposure. To prevent measurement of spurious signals, the 35050AT Dosimeter can be set to ignore exposures of less than 5ms.

2.7.1 Making Combined Exposure Rate and kVp Measurements

The Model 35050AT Dosimeter can be used with the Model 35080/80A/80B kVp Divider as its kVp readout while at the same time measuring exposure rate. The operating instructions for measuring exposure rate in this mode are the same as without a kVp divider with the exception that the Model 35080/80A/80B kVp Divider must be placed in the x-ray beam with the ion chamber see section 2.9.

When in this mode, a typical display might look like this:



Exposure rate measurements are entirely independent of the kVp measurements, even if the kVp measures outside the specified range.

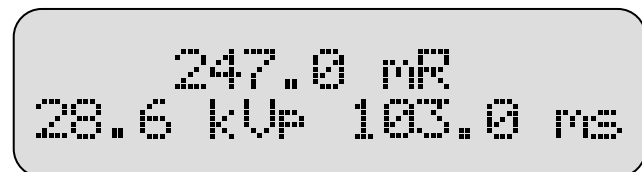
2.7.2 making Combined Exposure, kVp, and Time Measurements

If an exposure unit or coulombs is selected, and kVp filter pack is selected, this measurement mode is entered. For general operating information, see section 2.6.4 and 2.7.1. The exposure measurement is conducted the same as in section 2.6.2 with the following exception.

If the peak kilovoltage falls short of entering the filter pack's kVp range, a zero (0.00 R) exposure value will be displayed. Under this condition, the displayed kVp value will be 0.0 kVp and the displayed time value will be 0.2 ms.

For the case where the peak kilovoltage enters or exceeds the filter pack's kVp range, exposure and time will be displayed correctly. If the range is exceeded, ---. kVp will be displayed.

Waveform storage and the value of time is limited to six seconds. If an exposure is longer than six seconds, the time overrange indication -... s, is displayed.



After the exposure is over, which is defined as the waveform having dropped below the filter pack's kVp range and not having returned to it in 100 ms, the instrument performs an analysis of the stored waveforms to calculate the exposure time.

2.7.2.1 Advanced Measurement Options

When in the Combined Exposure, kVp, and Time Measurements mode, several measurement options are available that enhance the usability of the 35050AT. These features are available via the options button.

Measurement Delay – Allows the user to specify a measurement delay to skip over unwanted portions of an x-ray output waveform. The measurement delay range is from –999 to 999 milliseconds. When a negative measurement delay is selected, the 35050AT does not include the delay time in the measured exposure time. When a positive measurement delay is selected, the 35050AT includes the delay time in its measured exposure time. If the selected delay time is longer than the exposure time, a “-delay” message will be displayed.

When no measurement delay is used, time measurement starts either when the waveform first attains 75% of its peak value, or when the waveform first enters the kVp range, if 75% of its peak value lies below the range. Time measurement ends when the waveform last attains this value.

Exposure Time Units – Allows the user to select exposure time units of seconds (milliseconds) or pulses.

When seconds are selected as exposure time units, exposure time measurement method is based on a kV threshold crossing. The threshold is set at 75% of the kVp, or the minimum kVp for the filter pack in use, whichever is greater. Exposure time is measured between the first and last passage through this threshold.

When Pulses are selected as exposure time units, the 35050AT counts the number of x-ray pulses in a pulsed or single-phase radiographic exposure. Pulses are counted by detecting each passage through a threshold on the rising and falling edges each pulse in the output waveform.

Short Exposures <5 ms - To prevent measurement of spurious signals, the 35050AT Dosimeter can be set to ignore exposures of less than 5ms. Use of this option does not affect exposure time measurements.

2.7.2.2 Time Corrections

For a pulsed single-phase x-ray unit operating on a power supply frequency of 60 Hz, division of the pulse count by 120 for full-wave rectified units yields the exposure time in seconds (divide by 60 for half-wave of self-rectified systems). Because the Model 35050AT Dosimeter measures exposure-time as the time between the first and last crossings of the 75% of the kVp level, the values obtained from the Model 35050AT Dosimeter will be less than those marked on the generator. The following table gives values that may be added to the Model 35050AT Dosimeter's results to correct for this effect.

Line Frequency/Machine Type	Add to Displayed Time
60 Hz/Half Wave	12.8 ms
60 Hz/Full Wave	4.5 ms
50 Hz/Half Wave	15.4 ms
50 Hz/Full Wave	5.4 ms

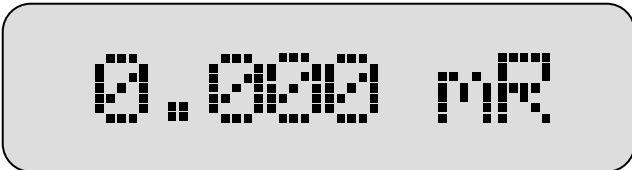
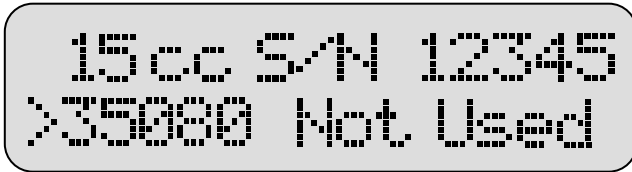
It has been assumed that 75% of kVp lays within the filter pack's specified measurement range.

2.7.3 Making kVp and Time Measurements without an Ion Chamber

kVp and time measurements can be made without the use of an ion chamber. Simply follow the procedures in sections 2.7.1 and 2.7.2. When the ion chamber is not connected, disregard the displayed value of exposure or exposure rate.

2.7.4 Making Exposure or Exposure Rate Measurements without a Model 35080/80A/80B kVp Divider

The Model 35050AT Dosimeter can be setup to make only exposure measurements by selecting the filter pack type “35080/80A Not Used”. This filter pack selection turns off the Model 35050AT Dosimeter’s kVp divider port, and causes only the exposure line to be displayed on the measurement screen.



Selecting any one of the other filter packs enables simultaneous exposure and kVp measurements.

2.7.4.1 Advanced Measurement Options

Exposure Reset – Allows the user to turn the Automatic Exposure Reset feature on or off.

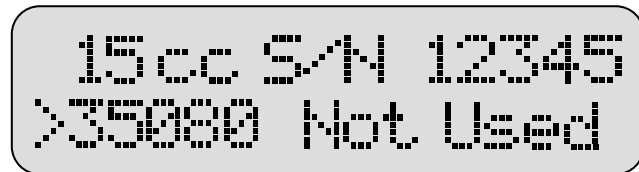
When the Exposure Reset option is set to Automatic, Model 35050AT Dosimeter automatically resets between exposures; exposure start and end detection are based on the exposure rate level crossing a 0.25 pA threshold. The instrument treats exposures separated by less than two seconds as single exposures.

When the Exposure Reset option is set to Manual, the Reset/Measure button may be depressed between exposures to clear the display. When the Manual Reset option is active, the ϕ symbol appears in the upper right corner of the display. Exposure start detection is based on the exposure rate level crossing a 0.25 pA threshold but the exposure measurement may only be reset by pressing the Reset/Measure button. The manual reset feature is only active in the Full-sensitivity Exposure mode.

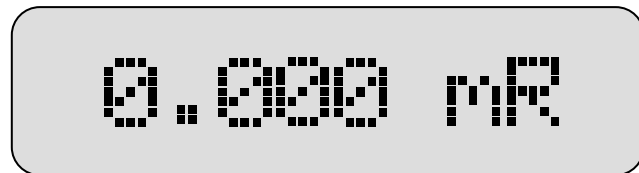
2.8 Exclusive Measurement Mode

The firmware allows a Model 35050AT Dosimeter to be setup to perform exclusive exposure and kVp measurements. This exclusive option can be enabled through the Customization Software. When a Model 35050AT Dosimeter configured to perform exclusive measurements, the operator selects whether an exposure or kVp measurement is to be made from the dosimeter's front panel.

The Model 35050AT Dosimeter contains the filter pack type "35080/80A Not Used". This filter pack selection turns off the Model 35050AT Dosimeter's kVp divider port. The Model 35050AT Dosimeter ignores the 35080 Input when this filter pack is selected, and displays only the exposure line on the measurement screen.



15 cc S/N 12345
>35080 Not Used

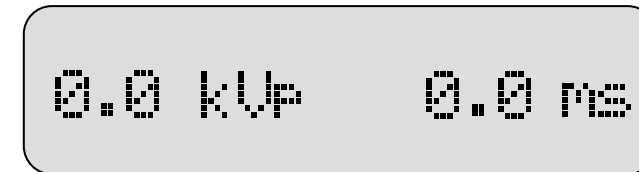


0.000 mR

Selecting any one of the other filter packs causes the dosimeter to monitor the kVp divider port and present only the kVp line on the measurement screen:



15 cc S/N 12345
>50 to 150 kV Pack



0.0 kVp 0.0 ns

2.9 Using the Ion Chamber Test Stand and Accessories

The purpose of the test stand is to provide an easily reproducible central x-ray beam alignment of both the Model 35080/80A/80B kVp Divider and the Model 96035B ion chamber. The test stand achieves this goal for both over-table and under-table x-ray tube configurations. Features of the test stand are described in more detail below (refer to Figure 2-3).

1. A beam port has been provided in the baseplate. This port allows the x-ray beam from under-table tubes to pass up to the ion chamber and kVp Divider without attenuation. Notches in this port also facilitate correct positioning of the kVp divider on the baseplate when using the test stand with over-table tubes.
2. This test stand is supplied with a square rod for easy alignment of components.
3. The test stand includes a holder tray for the kVp divider. Its purpose is to hold the kVp divider in an inverted position above the ion chamber when using the system with under-table tubes.
4. Wire safety clips are provided on each interface cable. The user should always use these clips to fasten the interface cables to the test stand near its baseplate. This practice will greatly reduce the likelihood of tipping the test stand during use.
5. The test stand rod is made of stainless steel for added rigidity. In addition, a pair of scribe marks are made to the rod to allow vertical reproducibility of the test setup. Their use is optional but highly recommended.

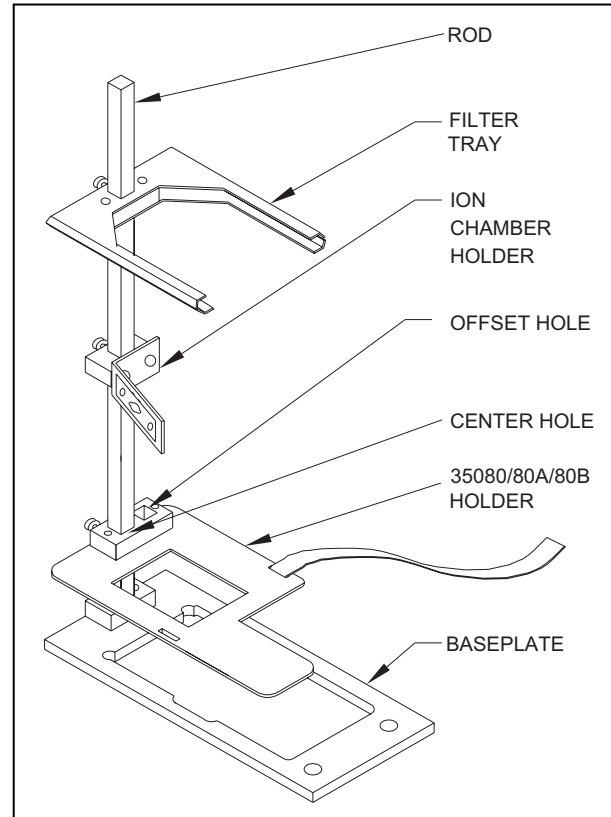


Figure 2-3. The Model 10100AT TRIAD Field Service Kit Test Stand (This figure shows components only, not an actual setup.)

2.9.1 Using the Test Stand for Over-Table Tubes

For over-table tubes, follow the assembly steps below and refer to Figure 2-4.

1. Remove the test stand from the case, slide the HVL filter tray up the test stand rod and position it just below the rod's upper scribe mark. The scribe mark should align with the topside of the filter tray. Tighten thumbscrew.
2. Slide the ion chamber holder up the test stand rod and position it just below the rod's center scribe mark. The scribe mark should align with the topside of the ion chamber holder. Tighten thumbscrew.
3. Place Model 96035B ion chamber in its holder and attach the triaxial cable. Route the cable down the rod and secure it to the test stand near its base by snapping the wire cable clips around the rod.

CAUTION

Failure to secure the cable near the base of the test stand may result in tipping the test stand and damage to the equipment.

4. If not already in place, position the kVp divider on the test stand baseplate with filter pack facing upward. Make sure the square rod is placed in the center hole on the holder as shown in Figure 2.4. The kVp divider's rubber feet must be inserted fully into the half circle cutouts in the baseplate for proper alignment.

NOTE

Failure to properly align the kVp divider may result in an incorrect kVp reading.

5. Place the test stand in an upright position at the center of the x-ray beam.
6. Attach the interface cable to the kVp divider. Route the cable around the side of the instrument and secure it to the test stand rod near the baseplate using the attached cable clip.
7. Verify that both cables have been routed in such a way that they will not interfere with the x-ray beam as it travels to the ion chamber and kVp divider.

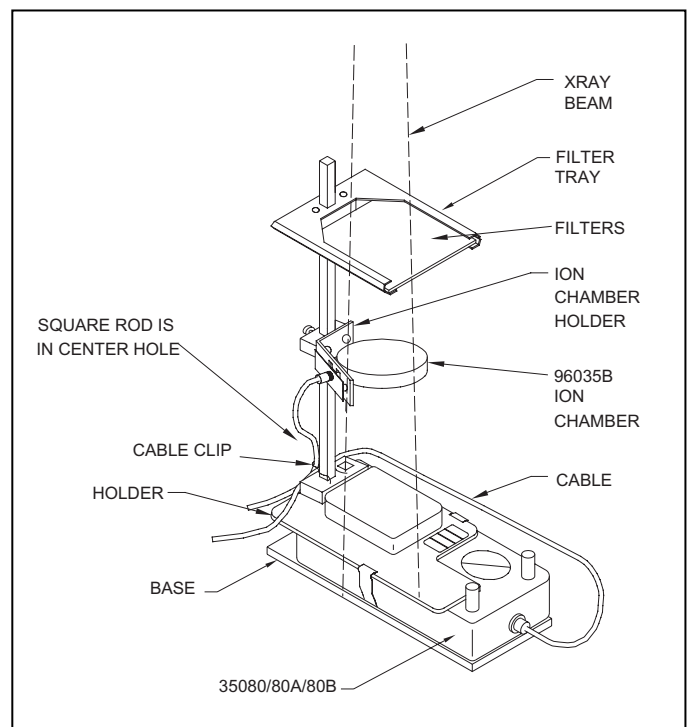


Figure 2-4. Over-Table HVL Setup

8. During HVL testing, the HVL filters can be positioned on the test stand filter tray.

NOTE

The kVp and exposure time measurement value may be affected by the presence of HVL filtering in the x-ray beam. Be sure to remove the HVL filters from the “filter tray” when making these measurements.

2.9.2 Using the Test Stand for Under-Table Tubes

For under-table tubes, follow the assembly steps below and refer to Figure 2-5.

1. Remove the test stand from the case, slide the HVL filter tray up the test stand rod and position it just below the rod's upper scribe mark. The scribe mark should align with the topside of the filter tray. Tighten thumbscrew.
2. Slide the ion chamber holder up the test stand rod and position it just below the rod's center scribe mark. The scribe mark should align with the topside of the ion chamber holder. Tighten thumbscrew.
3. If not already in place, position the kVp divider on the test stand baseplate with filter pack facing upward. Make sure the square rod is placed in the center hole on the holder as shown in Figure 2.4. The kVp divider's rubber feet must be inserted fully into the half circle cutouts in the baseplate for proper alignment.
4. Loosen thumbscrew that is securing the base plate to the test stand rod. Grasp firmly the kVp divider's holder and kVp divider and lift the assembly away from the base plate. Now, the assembly can be turned upside down and re-attached to the baseplate. Tighten thumbscrew.
5. Place the Model 96035B ion chamber in its holder and attach triaxial cable. Route the cable down the rod and use the cable clip to secure cable to the test stand rod near the baseplate.

CAUTION

Failure to secure the cable near the base of the test stand may result in tipping the test stand and damage to the equipment.

6. Place the test stand in an upright position and center it in x-ray beam.
7. Attach the interface cable to the kVp divider. Route the cable up and over the top of the kVp Divider and secure it to the rod near the test stand baseplate using the attached cable clip.

CAUTION

Failure to secure the cable near the base of the test stand may result in tipping the test stand and damage to the equipment.

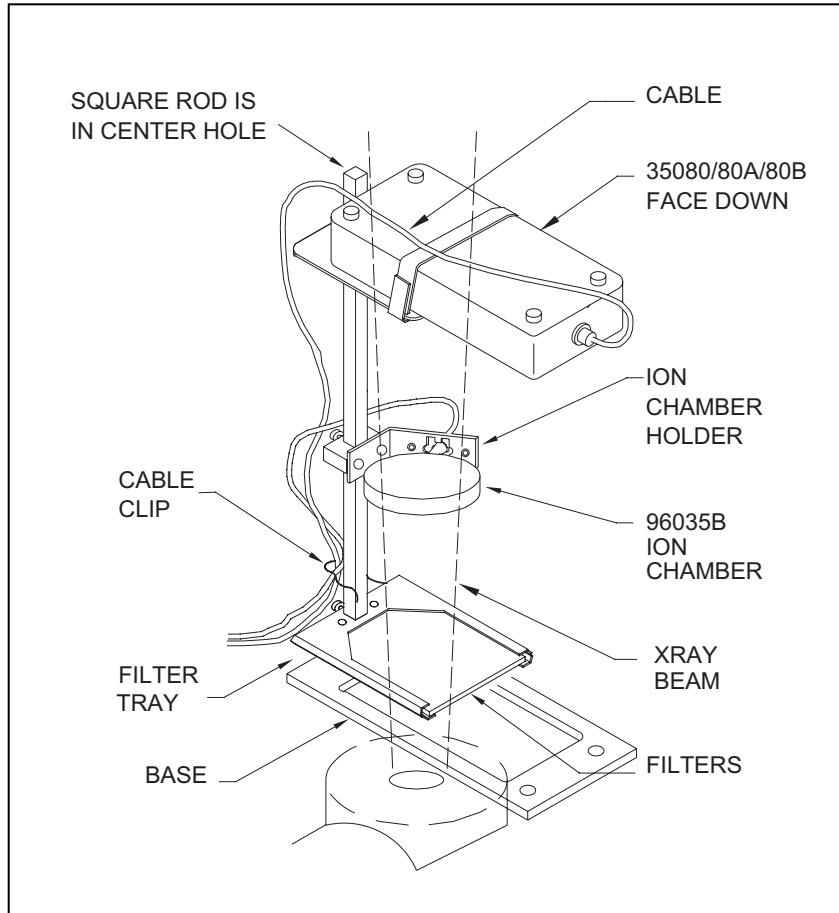


Figure 2-5. Under-Table HVL Setup

8. During HVL testing, the HVL filters can be positioned on the test stand filter tray.

NOTE

The kVp and exposure time measurement value may be affected by the presence of HVL filtering in the x-ray beam. Be sure to remove the HVL filters from the “filter tray” when making these measurements.

2.9.3 Using the Test Stand for Horizontal X-ray Beams

For horizontal x-ray beams, refer to Figure 2-6 below.

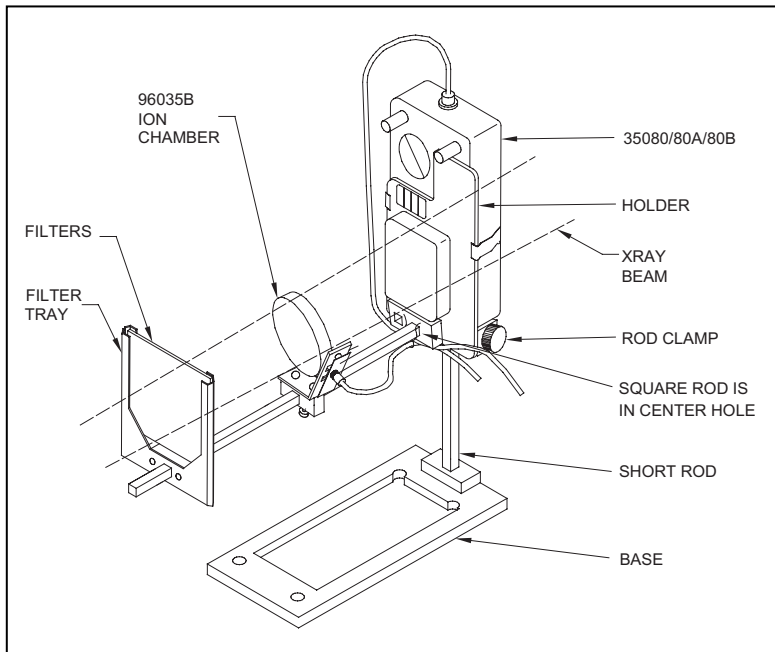


Figure 2-6. Test Stand Configuration for Horizontal Beam/Chest Stand

2.9.4 Using the Test Stand for Mammo kVp Measurements

For mammo kVp measurements, refer to Figure 2-7 below.

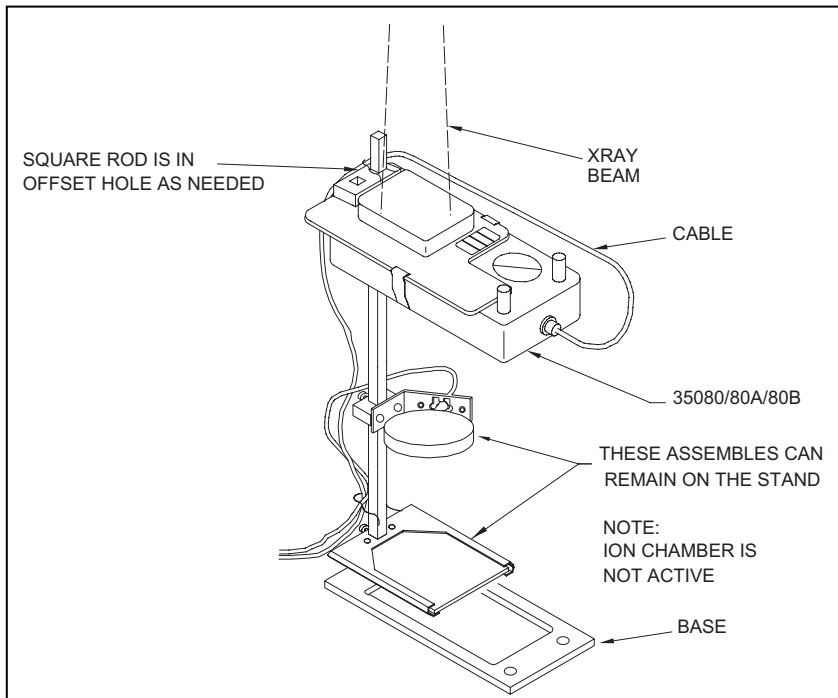


Figure 2-7. Test Stand Configuration for Mammo kVp Measurements

2.10 Using the Ion Chamber Cable Stem

To accurately remote position the ion chamber in an image intensifier housing or other limited access situation, the plastic cable stem may be slipped firmly over the rear of the triaxial cable connector nearest the ion chamber. This will give about five inches more position control than the ion chamber itself.

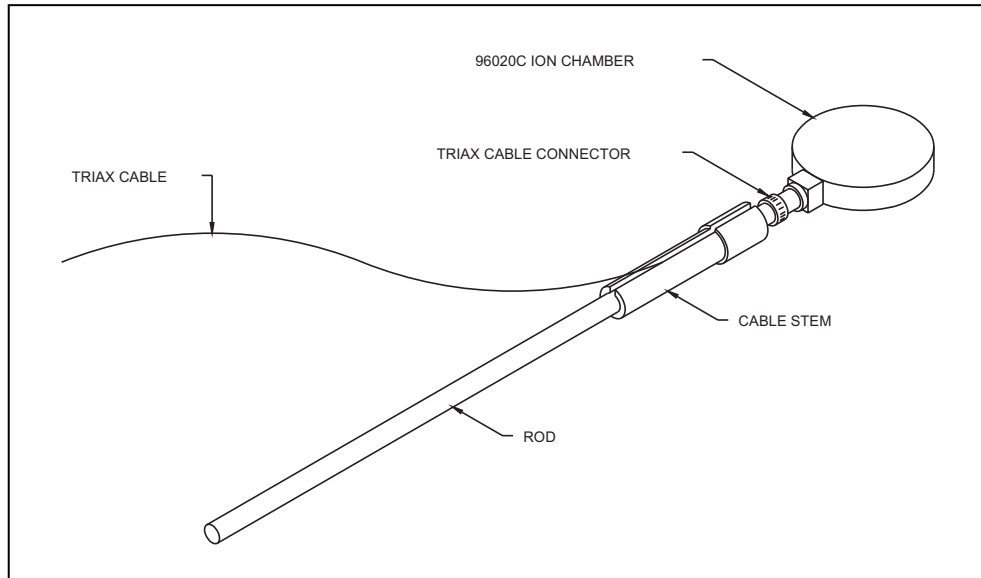


Figure 2-8. The Model 96020C Ion Chamber, Stem, Rod, and Cable

If greater maneuvering distance is required, the vertical rod may be screwed into the threads provided at the rear of the cable stem. This will provide an additional fifteen inches of rigid control.

2.11 Measurement Considerations

2.11.1 Using Other Ion Chambers

There is a choice of two methods: 1) either load the calibration factor for the ion chamber into non-volatile memory, via the RS-232 link to a computer running the customization program; 2) Run the Model 35050AT Dosimeter in coulombs or amperes and hand calculate radiological values from known chamber factors. Whenever the instrument has electrical units selected, i.e. coulombs or amperes, air density corrections are disabled. Therefore, any corrections will have to be done by hand also.

2.11.2 Using Air Density Corrections

Select Detector

If air density corrections are desired, during DETECTOR SELECT the chamber identification line on the display must end with the letters ADC. During measurements "ADC" will be displayed at top right of the measurement screen as a reminder that air density corrections are being applied.

Air Density Parameters

The standard units are altitude in feet relative to sea level and degrees Celsius. Units available through the customization software are as follows:

Temperature: Choice of Fahrenheit, Kelvin, and Celsius

Barometric Pressure: Choices are inches of mercury (inHg), millimeters of mercury (mmHg), feet (ft), meters (m), millibars (mbar), and hectoPascals (hpa)

Temperature & Pressure Mode

Two modes are available for supplying temperature and pressure values to the 35050AT Dosimeter for air density corrections. In the Automatic Sensing mode, the Dosimeter's internal temperature/pressure sensor provides the temperature and pressure values. In the Manual Entry mode, the user must select temperature and pressure values.

To select either of these modes, press the Options button until Temp & Press Mode is displayed, then press the UP or Down button to toggle between Automatic Sense and Manual Entry.

If Automatic Sense has been selected, pressing the Air Density button displays the measured temperature and barometric pressure to be used for air density corrections. In the event that the temperature/pressure sensor becomes non functional, an error message, "Temp & Press Error Use Manual Entry" is displayed and only the manual temperature and pressure entry mode is available.

If Manual Entry has been selected, press the Air Density button to display the screen containing the selected temperature and pressure values. Pressing the Air Density button again toggles the cursor (>) between the temperature and pressure values. The UP and DOWN buttons may be used to change the value adjacent to the cursor.

Table 2-4. Air Density Adjustment Ranges

Air Density Units Adjustment Range and Step Size			
Unit	Minimum Value	Maximum Value	Size Step
°F	32	120	0.5
°C	0	50	0.5
°K	273	323	0.5
mm Hg	522	795	1.0
in Hg	20.55	31.30	0.05
mbar	697	1060	1.0
hPa	697	1060	1.0
feet	-1200	10,000	25
meters	-360	3,050	10

2.11.3 Using Exposure/Frame Units

Cine x-ray machines can be measured directly in units of exposure per frame by the dosimeter. The steps are simple:

1. Physically set-up the desired chamber with the x-ray machine and turn on the dosimeter.
2. Select ion chamber at the DETECTOR SELECT screen.
3. Select radiological exposure unit per frame on UNITS SELECT screen. On the same screen select the desired frame rate.
4. Make the exposure. The Model 35050AT Dosimeter will display the exposure rate in units of exposure per frame.

Simultaneous kVp determinations can be done while measuring exposure per frame. See section 2.6.4 for general information.

2.11.4 Making Mammo kVp Measurements

This section follows the recommendation that the Linear Mammo Filter Pack be used in conjunction with the Cadmium K-edge Filter Pack. The Model 35050AT will automatically apply corrections based on the k-edge measurement.

The operator should read the mammographic filter pack sections of the Model 35080/80A/80B kVp Divider Instruction Manual to become familiar with the specifications, theory of operation, and application of corrections for these filter packs. Also see section 2.6.4 of this manual for instruction on using the Model 35050AT Dosimeter as a readout for the Model 35080/80A/80B kVp Divider.

The following procedure requires the ability to select the k-edge and linear mammo filter packs using the DETECTOR SELECT button. Press the DETECTOR SELECT button to display the name of the filter pack installed. The cursor '>' should be the left most character on the bottom line of the display. If not press, the DETECTOR SELECT button again. To scroll through the available filter packs, use the UP or DOWN buttons. Stop scrolling when the desired filter pack name appears on the display. If the desired filter pack name does not appear, the instrument must be customized. See the customization manual for details.

The two-exposure method of k-edge kVp determination precludes any combined exposure RATE measurements. Therefore, if units of exposure rate, exposure per frame, or current are selected with the K-edge Filter Pack, the following error message will be displayed:



Error: Incompatible
filter and units

Select units of either charge or dose (C, R, Gy, or Sv). Although the Model 35050AT Dosimeter has the capability to do a combined exposure dose, kVp, and time measurement, the distance and beam limitations on mammographic generators make this impractical. Therefore, the Model 35050AT Dosimeter will only display the kVp and time.

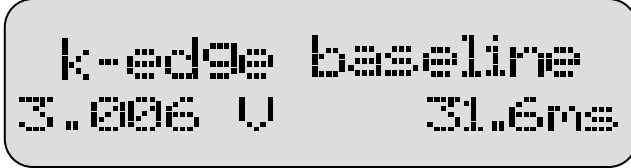
2.11.4.1 Cadmium K-edge Filter Pack Use

1. **K-edge Measurement Setup:** Install the Cadmium K-edge Filter Pack in the Model 35080/80A/80B kVp Divider. Place the kVp divider in the x-ray beam on the compression paddle or other suitable support with the long axis of the kVp divider perpendicular to the axis of the x-ray tube. Raise the kVp divider as close as possible to the x-ray tube. The x-ray beam should cover the entire filter pack. Select the K-edge filter pack using the DETECTOR SELECT button and the UP or DOWN button on the Model 35050AT Dosimeter. Press the RESET/MEASURE button. The display should show the following message:



Ready for baseline
k-edge exposure

2. **25 kVp Measurement Procedure:** Set the x-ray generator for 25 kVp and 100 mA. If not available, use at least 50 mA and a minimum time of 50 ms or a mAs setting that provides these tube currents. Select the molybdenum (Mo) filter on the generator. Make an exposure. A message similar to the one below will appear.



3. **26 kVp Measurement Procedure:** Repeat the baseline measurement at a slightly higher kV setting that should still be below the k-edge (26.7 kV). Set the generator for 26 kVp. Press the RESET/MEASURE button. The display should read:



Make an exposure. The new voltage should be the same as the previous voltage ± 0.020 V as in the following representative display.



If the voltage is within the limits, this is the base voltage. Proceed to step 4. If the voltage is outside the limits, repeat steps 2 and 3 at 24 kVp and 25 kVp respectively.

4. **29kVp Measurement Procedure:** Do NOT press RESET/MEASURE. Set the generator for 29 kVp. Make an exposure. If the exposure is within the range 27.5 to 29.5 kVp, the reading is accurate. If ---.kVp is displayed, set the generator for 28 kVp and repeat step 4. If 0.0 kVp is displayed, set the generator to 30 kVp and repeat step 4. The last displayed k-edge kVp is used to determine linear correction as in the following example.



Once an accurate determination of kVp has been made do not disturb the x-ray generator settings. Proceed to linear mammo filter pack use.

2.11.4.2 Linear Filter Pack Use

If the Model 35080/80A/80B kVp Divider changes position in the x or y axis with respect to the x-ray generator during the linear kVp measurements, you must repeat the determination of the k-edge kVp and the correction value since this measurement is position sensitive.

1. **Linear filter pack Setup:** Select the linear filter pack using the DETECTOR SELECT button and the UP or DOWN button on the Model 35050AT Dosimeter. Remove the k-edge filter pack and replace it with the linear mammo filter pack. Increase the target to filter pack distance to about 15 inches (38cm). Press the RESET/MEASURE button. If the last kVp measured in step 4 is an acceptable value for the k-edge, the instrument will proceed to step 6. If the kVp is not acceptable, the instrument will proceed to step 8 with kVp correction turned off.

2. **Linear Correction Exposure:** The display reads:

```
Ready for linear  
correction exposure
```

Make an exposure using the same generator settings as those used to make the last k-edge exposure. Proceed to step 7. If you do not want your linear kVp measurements automatically corrected, press the RESET/MEASURE button. kVp correction is turned off. The automatic correction factor is set to zero. You must make any corrections manually. Proceed to step 8.

3. **Corrected exposure:** The top line of the display shows the correction factor for the current setup. The correction may be either positive or negative. The kVp, by definition, is the same as the kVp measured with the k-edge filter pack. If you would like to determine the repeatability for this measurement, press RESET/MEASURE and repeat step 6. To make additional measurements, make an exposure and proceed to step 9.

```
Correction 1.5 kVp  
28.5 kVp 1.576 s
```

4. **Measurement Reset:** The display will show either of the following:

```
Correction applied  
0.0 kVp 0.0 ns
```

```
kVp NOT Corrected  
0.0 kVp 0.0 ns
```

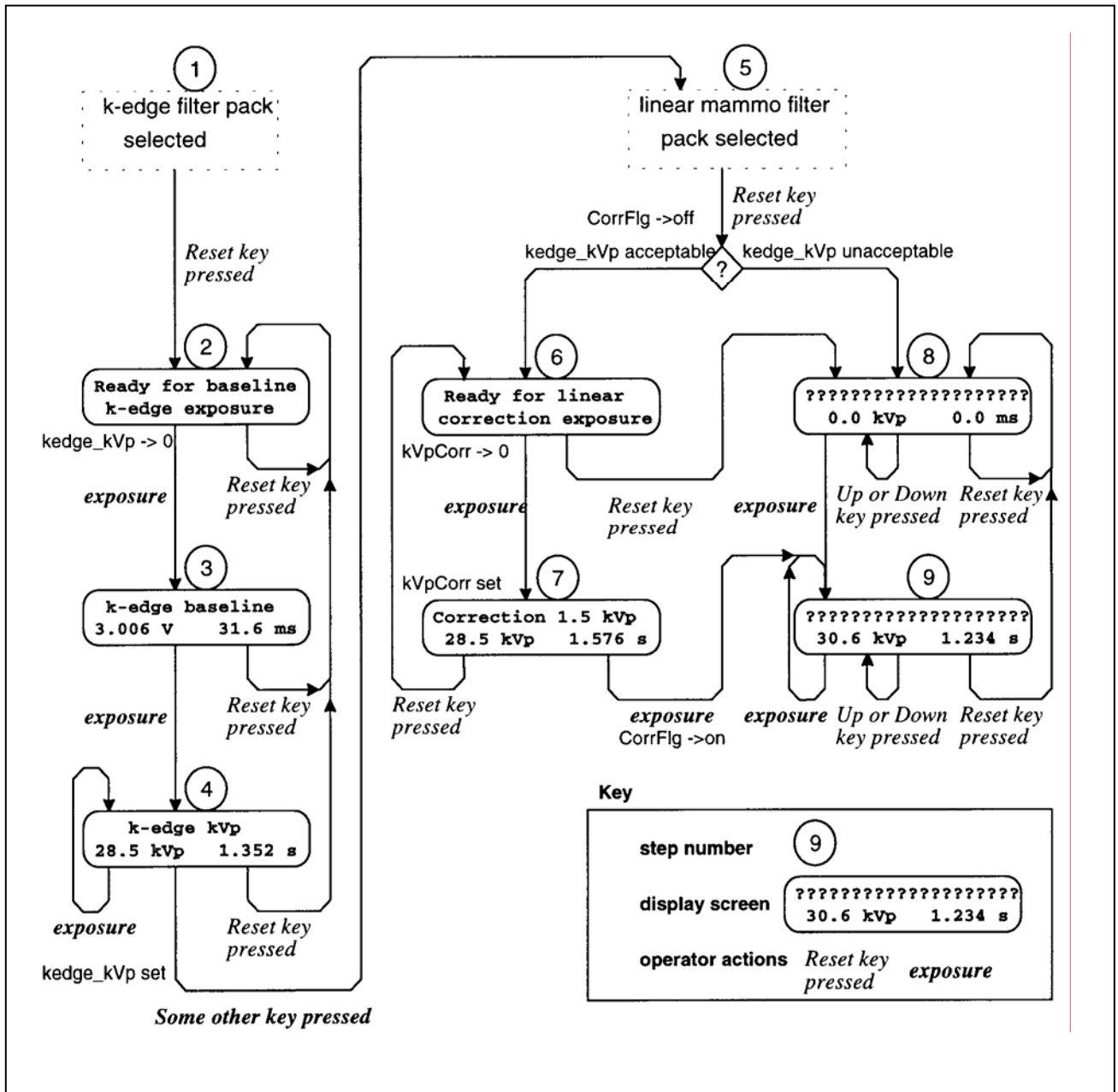
You may turn the automatic correction on or off by pressing the UP or DOWN button.

5. **Measurement:** You may turn the automatic correction on or off by pressing the UP or DOWN button. You may reset the displayed values to zero by pressing the RESET/MEASURE button. The following are representations of what might be seen.

```
Correction applied  
32.1 kVp 1.234 s
```

```
kVp NOT Corrected  
30.6 kVp 1.234 s
```

The following diagram illustrates the steps involved in this measurement sequence and the possible paths through the procedure.



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Section 3

Theory of Operation

3.1 Introduction

The Model 35050AT Dosimeter/kV Readout, when used in conjunction with the Model 35080/80A/80B kVp Divider and the Model 96035B / 96020C Ion Chambers, forms a complete microcomputer-based diagnostic radiological test system capable of measuring radiographic exposure, kVp, and exposure time.

This section will describe the basic theory of operation of the Model 35050AT Dosimeter/kVp Readout. Information pertaining to the theory of operation for the Models 35080/80A/80B kVp Divider may be found in their respective instruction manuals. This section will begin with the presentation of a simplified hardware function block diagram accompanied by a description of each block. It will end with a description of the internal measurement techniques used in conjunction with the electrometer to achieve offset and drift nulling. Descriptions of the methods for kV peak detection and exposure time measurements are also included.

As a dosimeter, the Model 35050AT Dosimeter effectively automates all of the error correction and unit conversion functions that were manually performed by the operator in earlier dosimeters. These corrections may optionally include those for air density. Exposure and exposure rate measurement results may be directly displayed in the radiological units of choice, or as electrical charge and current if preferred. The peak voltage output of the kVp divider may be directly displayed in units of kVp with corrections for filter pack offset and gain taken into account. The ability to measure exposure time is based on the use of a threshold set at 75% of the kVp. The Model 35050AT Dosimeter includes an RS-232 serial communication port that allows complete computer control of the measurement system. The communications port, in conjunction with an internally located non-volatile memory (EEPROM), also provides a means of customization and calibration of the Model 35050AT Dosimeter.

3.2 Overall Functional Description

Figure 3-1 represents a simplified hardware function block diagram for the Model 35050AT Dosimeter. While the most important interblock connections have been shown, many interconnections have been omitted in order to maintain clarity. Three external connections are illustrated: RS-232 Computer Interface, Ion Chamber Input Connector, and Model 35080/80A/80B kVp Divider Input Connector.

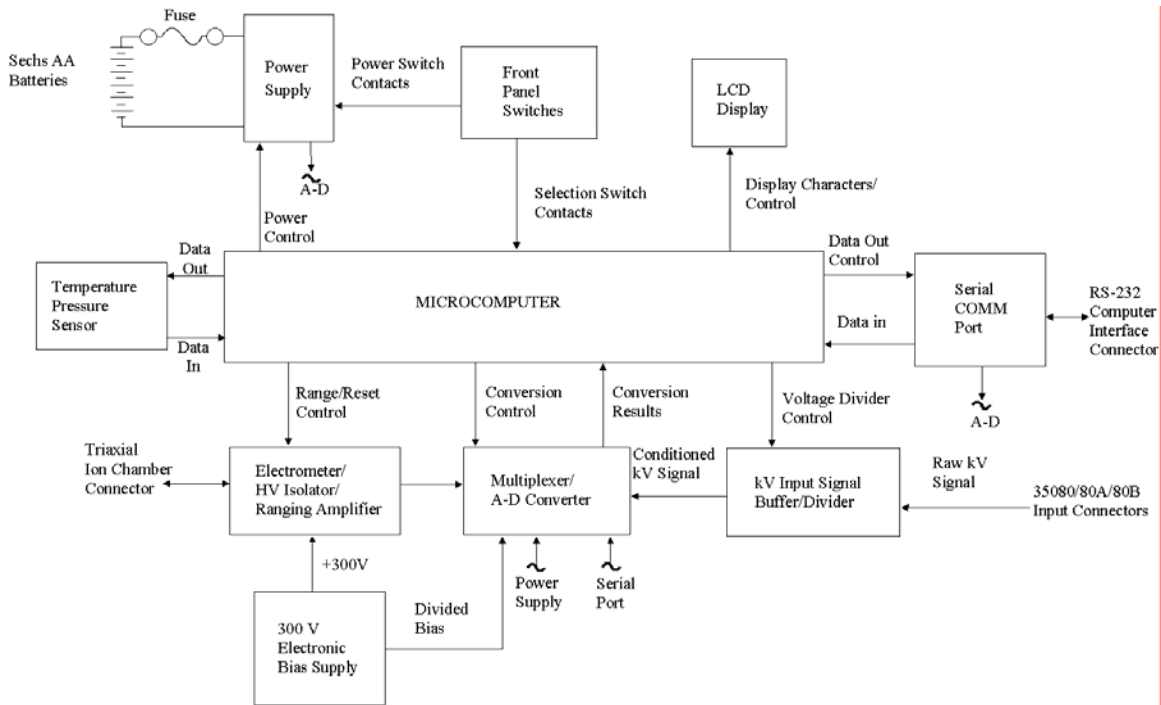


Figure 3-1. Hardware Block Diagram of the Model 35050AT Dosimeter

3.3 Power Supply

All power for the unit is derived from either the supplied AC Adapter or 6 “AA” alkaline batteries. When operating on battery power, the batteries will normally provide a continuous operational life of approximately 30 hours. An automatic turn off feature will power down the unit after a period of inactivity (no key presses or exposures are detected). This period may be set by the user during the customization procedure (see the Model 35050AT Customization Instruction Manual for details). A low battery annunciator is displayed when less than 2 hours of the useful battery life remains, and automatic power-down occurs when the battery is completely exhausted. Battery voltage may be checked by scrolling through the Options menu until the Battery Voltage is displayed.

When operating with the AC Adapter, the batteries no longer provide any power to the unit. The automatic turn off feature is disabled when the AC adapter is in use. When checking the battery voltage, via the Options menu, while the AC adapter is in use, the voltage displayed is the AC adapter voltage which is approximately 12 volts. The AC adapter provided with the 35050AT is rated at 9 volts at 200mA (0.2A). It is an unregulated adapter, and as such its output voltage displayed from the Options menu will normally be between 10 and 13 volts. This is because the unit does not draw 200 mA from the adapter; it normally draws approximately half as much. This causes the output voltage to rise.

An in-line fuse located within the battery compartment has been provided for safety. Fuse failure would normally indicate a fault within the unit. The function of the power supply block is to first regulate the battery voltage, and second to transform it to the various levels required by the system. The power supply provides power to all of the other blocks in the system. These interconnections have been omitted for clarity.

Although the power supply is under the control of the microcomputer during normal operation, it is forced to turn on when the operator presses the front panel POWER ON/OFF button. The connection between the Power Supply and the Multiplexer/A-D Converter provides the means by which the microcontroller can monitor the battery voltage and thus detect low and exhausted batteries. This voltage is also displayed during the power-up sequence and on one of the Test screens. Since the measurement point is not

directly at the battery terminals (it is separated from the terminals by the fuse and other components not shown), the measured value will be several tenths of a volt below that measured directly at the terminals.

3.4 Front Panel Switches

The eight front panel switches are of the momentary contact type and are continuously monitored by the microcomputer for detection of contact closure. At the detection of any contact closure, the microcomputer scans the switch set to determine which key was pressed and then takes the appropriate action. The dedicated function of each key is described in section 2 of this manual and will not be repeated here.

3.5 Microcomputer

The microcomputer is based on the Motorola 68HC11 microcontroller and includes 64 k-bytes of factory-programmed memory (EPROM). The EPROM contains all of the executable code (firmware) as well as the descriptions of all built-in customization items (including the standard filter packs, nominal ion chambers, and standard radiographic units). Also contained within this functional block are 8 k and 64 k byte blocks of RAM memory.

These are used to hold the data variables required for execution of the internal program, and the storage of 32,000 kV data points (6.4 s worth at a sampling rate of 5 kHz), respectively.

A 512-byte block of nonvolatile memory (EEPROM) is provided. A portion of the EEPROM is automatically reprogrammed during each power-down sequence to hold all front panel selections made by the user. Thus, the ion chamber, filter pack, units, temperature, pressure, and frame/second settings in effect at power down are automatically restored at the next power up. The EEPROM is also used to hold all of the internal electrical calibration factors for the unit, as well as all of the customization selections installed by the user over the RS-232 via the customization program (see the Model 35050A Programmer's Instruction Manual).

3.6 Display

All display functions are handled by a 2 line by 20-character alphanumeric PLED (polymer LED) module. The module is under the direct control of the microcomputer and is capable of displaying all ion chamber/kV filter pack identification strings, numerical measurement results with their appropriate units, as well as other informational items including the battery voltage, calibration date, etc. Multiple informational items may be displayed simultaneously (e.g., exposure, time, and kVp measurement values). The display of kV waveform is left to an external computer.

3.7 Serial Communications Port

A computer interface has been provided in the form of a DCE configured RS-232 port. This port is configured for operation at 9600 baud and uses a standard Xon/Xoff handshaking protocol (described in the Model 35050A Programmer's Instruction Manual). The connector type is RJ-45. This interface facilitates production testing and calibration of the unit, and provides to the user a method of achieving fully programmable operation as well as waveform display from a PC.

Since there is a power requirement associated with operating the serial communications port, a mechanism for automatically sensing the presence of an external computer has been provided. The sensing method involves the detection of a nonzero voltage at the data terminal ready line (DTR) on the RS-232 connector. The RS-232 interface circuits are powered only when it is sensed that an external computer is connected.

3.8 Multiplexer/A-D Converter

This block consists of an 8-channel analog multiplexer and 12-bit analog to digital converter, and operates under direct control of the microcomputer. Its function is to convert the analog voltage signals produced by the Electrometer and kV Signal Conditioning blocks into digital signals for use by the microcomputer. In addition, signals from the Power Supply, 300 Volt Electronic Bias Supply, and the Serial Communications Port are available for measurement. These measurements are used by the microcomputer in its various control functions as described throughout this section. The A-D operates in a bipolar mode, and all conversions are done relative to a 4.6 Volt full scale. The effective measurement resolution is 2.25 mV and the A-D is capable of performing conversions at the approximate rate of 5 kHz.

3.9 kVp Input Signal Buffer/Divider

The Model 35050AT Dosimeter is equipped with a coaxial-BNC input connector for use in connecting to the output of the Model 35080/80A/80B kV Divider. When a kVp divider is connected, the output of the kV Input Signal Buffer/Divider is sampled at the rate of 5 kHz. During normal use, this block simply acts as a unity gain buffer passing the kVp divider's kV signal directly through to the A-D. When the kVp divider is placed in battery check, an out of range voltage is detected and the kVp Input Signal Buffer/Divider is switched to its 1/2 gain configuration. Thus, the battery voltage from the kVp divider is brought back into the measurement range of the A-D. All normal kVp measurements are carried out with this block in its unity gain configuration.

3.10 Ion Chambers

3.10.1 Basic Theory

The Model 96035B and Model 96020C Ion Chambers supplied with the Model 10100AT TRIAD Field Service Kit are the Model 35050AT Dosimeter's sensors of exposure and exposure rate. The ion chambers are of parallel plate geometry, constructed of air equivalent plastic, and vented to the atmosphere.

They may be depicted as plastic containers of air, whose inside surfaces have been given a conductive coating. Located centrally in the air volume is a plastic disc (collector) that is conductively coated. The collector is electrically well insulated from the other surfaces, however connected to the electrometer input.

X-ray photons (rays) from the generator pass through and are absorbed into the chamber's materials and internal air volume. The primary absorption takes place in the windows, collectors, and wall because it is of much higher density than air.

When absorption occurs (photons interact with atoms), high-energy electrons are emitted from the interacting atoms. The high-speed electrons, spraying from the solid chamber materials into the air volume, produce many ionized tracks consisting of lower velocity electrons and "air" ions.

It is the role of the bias voltage to separate and sweep these ion and electron clouds out of the air volume and into the electrometer, before they recombine. The ion chamber, bias supply, and electrometer are connected electrically in series. With both the electrometer and bias supply offering low impedances, the ion chamber's charge or current is captured by the electrometer.

Thus, radiation is converted into electrical charge or current, by the international definition of exposure or exposure rate, for measurement.

3.10.2 Air Density Corrections

The dosimeter corrects exposure and exposure rate readings and adjusts the displayed ion chamber calibration factor according to the temperature and barometric pressure settings chosen while in the Air Density screen, if applicable. The reference calibration conditions are:

Temperature: 22° C, 71.6° F, 295.2° K or 20° C, 68° F, 293.2° K

Sea Level Pressure: 760 mm Hg, 29.92 in Hg, 1013.25 mB or 1013.25 hPa

The calculations and methods are based on the following formulas:

$$\begin{aligned} \text{calculated exposure or exposure rate} & \times \text{air density correction factor} = \text{corrected exp. or exp. rate displayed} \\ \text{air density correction factor} & = \frac{\text{sea level pres. pressure setting}^*}{\text{temp. setting converted to Kelvin}} \times \frac{\text{RefTemperature}}{\text{RefTemperature}} \end{aligned}$$

* If chosen unit is in terms of altitude relative to sea level:

$$\begin{aligned} \frac{54041 - \text{feet}}{54041 + \text{feet}} \times \text{sea level pressure} & = \text{effective pressure setting} \\ \frac{16471.7 - \text{meters}}{16471.7 + \text{meters}} \times \text{sea level pressure} & = \text{effective pressure setting} \end{aligned}$$

3.11 Electrometer/HV Isolator/Ranging Amplifier

The Model 35050AT Dosimeter is equipped with a triaxial-BNC ion chamber input connector. This connector serves a dual purpose. First it supplies the 300 V bias potential to the ion chamber. It is this bias potential which causes the radiation induced ionization of the air within the ion chamber to result in the collection of an electrical charge. As its second function, the connector provides a guarded path for the extremely small ionization charge that is produced within the ion chamber to be carried to the electrometer measurement circuit. It is the primary function of the Electrometer / HV Isolator / Ranging Amplifier to transform these small electrical charges to signals which can be easily measured by the A-D converter.

The electrometer is a dual range resettable integrating amplifier. Both the reset and the integrator ranging functions are performed by reed relays under control of the microcontroller. By dosimeter convention, and for operator safety, the outermost conductor of the triaxial interconnect system is maintained at instrument case (or ground) potential. This arrangement requires that the electrometer's input be elevated to the 300 Volt bias potential above ground for proper ion collection.

An analog isolator performs the functions of powering the electrometer at this elevated potential and returning the signal produced by the electrometer to ground level. Under control of the microcomputer, a final analog ranging amplifier stage provides three voltage gains (X1, X10 and X100).

This combination of a dual range electrometer with a three range amplifier results in 6 possible ranging combinations. The system has been set up so that the middle pair of ranges are completely overlapping. Thus, the result is a signal-conditioning block that can be ranged over 5 decades under control of the microcomputer. The most sensitive range has a full scale of 10 pC and an effective resolution of 5 fC. Similarly, the least sensitive range has a full scale of 100 nC and an effective resolution of 0.5 pC.

In order to eliminate the need for resistive feedback elements and the associated low level switching, all current measurements are derived by measuring the quantity of charge integrated over a 1 second interval. Thus, five decade current measurement ranges are derived. The most sensitive range has a full

scale of 10 pA and an effective resolution of 5 fA. Similarly, the least sensitive range has a full scale of 100 nA and an effective resolution of 0.5 pA.

3.12 300 Volt Electronic Bias Supply

The 300 Volt ionization potential is generated internally by an electronic bias supply circuit. The supply eliminates the need for the Model 35050AT Dosimeter to contain high voltage batteries. As explained previously, the ion chamber collector and guard are positively biased relative to the ion chamber body, which is maintained at the same potential as the chassis of the dosimeter for operator safety. A readout of the bias potential is facilitated by a divided bias signal generated within the bias supply block and connected to the A-D converter.

The output of the electronic bias supply is highly regulated and filtered. In addition, the output energy and current have been limited should the operator come in contact with the input or guard points while connecting or disconnecting an ion chamber. As a further safety feature, the bias voltage at the ion chamber input connector is automatically discharged at power-down. The operator should always power down the instrument before attempting to make or break a connection of the triaxial system.

3.13 Measurement Technique

The Model 35050AT Dosimeter can be operated in four basic measurement modes. These are automatically selected by the microcomputer and are differentiated from one another by the use (non-use) of a Model 35080/80A/80B kVp Divider, and the use of integrating (non-integrating) measurement units. The subsections that follow contain brief descriptions of the measurement techniques utilized during operation in these four measurement modes.

3.13.1 High Sensitivity Dose

This mode is activated when “35080/80A Not Used” is selected from the Detector Select screen and the operator has selected integrating exposure units such as C, R, or Sv. During operation in this mode, the 35080 Input is ignored and the microcomputer provides automatic drift and offset compensation, as well as automatic post exposure display hold. Autoranging across all five-charge ranges provides a span covering from low-level image intensifier input measurements to the measurements of unattenuated direct beams.

When operating in this mode, the rate of change of the integrator output level is monitored at 1-second intervals. Any rate of change corresponding to an input current of less than 0.25 pA is considered a leakage drift and correspondingly nulled at the display. The start of an exposure is designated by the first crossing to above this threshold level. An exposure is assumed to have ended when the signal remains below the threshold level for 2 seconds.

At the end of each exposure, the integrator will be reset and a new measurement sequence initiated. The displayed value of integrated exposure will be held until the beginning of the next exposure is detected or until the operator presses the RESET/MEASURE button.

The instrument, when in this measurement mode, resets the electrometer's integrator whenever 5 pC of charge has accumulated due to system leakage. At .01 pA leakage, reset would occur every eight minutes. The reset is performed at this level to preserve the necessary “headroom” on the 10 pC full-scale range for a true exposure.

During the automatic reset, the instrument is insensitive to any exposure. A very short exposure occurring during this interval would be completely lost, and a long exposure only slightly reduced in value. At the .01 pA leakage level, there is less than a 0.2% chance of the reset and the exposure coinciding. As the leakage current increases, the chance of a coincidence increases proportionately. In the case where the start of an exposure is detected immediately following the automatic reset, an error message is displayed. This message will be cleared when the operator presses the RESET/MEASURE button or repeats the exposure.

3.13.2 High Sensitivity Rate

This mode is activated when “35080/80A Not Used” is selected from the Detector Select screen and the operator has selected non-integrating exposure units such as A, R/s, or Sv/min. During operation in this mode, the 35080 Input is ignored and the microcomputer again provides automatic drift and offset compensation. The display is updated at a rate of once each second. Autoranging across all five current ranges provides a span covering from low-level image intensifier input measurements to the measurements of unattenuated direct beams.

When operating in this mode, the rate of change of the integrator output level is monitored at 1-second intervals. Any change corresponding to an input current of less than 0.25 pA will be considered as leakage drift and correspondingly nulled at the display. Any value above 0.25 pA will result in the display of an offset corrected value. If the charge stored during any 1-second measurement interval reaches a level of 1.2 pC, the integrator feedback capacitors will be automatically reset prior to the beginning of the next interval.

3.13.2.1 Very Low Dose Rate

This mode is the same as High Sensitivity Rate, except the measurement threshold of 0.25 pA is not used. This effectively turns off leakage suppression, so any low level input current (including leakage) will be displayed. This mode is activated when “35080/80A Not Used” and an ion chamber displaying VLDR in its description are selected from the Detector Select screen and the operator has selected non-integrating exposure units such as A, R/s, or Gy/min.

3.13.3 kVp/Dose/Time

This mode is activated when one of the Model 35080/80A/80B kVp Divider filter packs is selected from the Detector Select screen and the operator has selected integrating exposure units such as C, R, or Sv. During operation in this mode, direct beam exposure levels are assumed. Thus, the automatic drift and offset compensation are not required and autoranging is limited to the upper three sensitivity ranges. In this mode, kVp and exposure time measurements are performed along with the basic exposure measurement. Automatic reset and display hold is provided following each exposure.

While operating in this mode, the burden placed upon the microcomputer by the kVp divider data acquisition task inhibits its ability to continuously monitor the rate of change of the integrator output level, and thus prohibits the use of a 0.25 pA start/end exposure threshold. Instead, the start of an exposure is designated as the first time the kVp divider output's crosses to above the minimum kV level for the filter pack in use. Furthermore, the end of the exposure has been designated as the last time the kVp divider's output level drops below this threshold and remains there for a minimum of 100 ms. At the end of each exposure, the display is updated with new kVp, dose, and time measurement values; and the electrometer is reset in preparation for the next exposure. The display values are held until the end of the next exposure, or until the operator presses the RESET/MEASURE button.

The displayed kVp value is derived by scanning a 50 ms wide segment of kV data. The data is first smoothed by a digital filter using a 1 ms wide rectangular filter function. The digital filter is disabled when using the Mobile filter pack. The smoothed data is then scanned for its peak value. This peak value is corrected for the gain and offset of the filter pack in use, and then displayed as the kVp.

The position of the 50 ms wide segment of kV data is selected based on a delay from the start of the exposure. This delay is fixed at one-tenth of the exposure time.

The exposure time calculation is based on the first and last crossings of the kV signal above the 75% of the kVp value. In cases where the 75% value is less than the minimum kV for the filter pack in use, the minimum kV for the filter pack is used.

3.13.4 kVp/Rate

This measurement mode is activated when one of the Model 35080/80A/80B kVp Divider filter packs is selected from the Detector Select screen and the operator has selected a non-integrating exposure units

such as A, R/min, or Sv/s. During operation in this mode, direct beam exposure levels are assumed. Thus, the automatic drift and offset compensation are not required, and autoranging is limited to the upper three sensitivity ranges. In this mode, a kVp measurement is performed along with the basic exposure rate measurement. The display is updated at a rate of approximately once per second.

When operating in this mode, the integrator output level is monitored at 1-second intervals. The exposure rate measurement value is based upon the amount of charge integrated during each 1-second update period. The integrator is reset at the beginning of each sampling period. During each 1-second period between display updates, a new 50 ms wide kV data set is acquired. The data set is analyzed using the prefiltering and peak detection described in the previous section.

3.14 Temperature and Pressure Sensor

The Model 35050AT Dosimeter contains an integrated temperature/pressure sensor. When using the automatic temperature and pressure sensing feature, the measured temperature is the internal temperature of the Model 35050AT, TRIAD TnT Dosimeter. This temperature may not be the same temperature as the Ion Chamber that is in use.

Adequate time must be allowed for the Dosimeter and Ion Chamber to reach thermal equilibrium before automatic temperature sensing is used. For a large temperature differential, the thermal equilibrium time of the 35050AT may be 2 hours. A 3°C change in temperature results in approximately a 1% change in air density correction factor (ADC).

The housing of the Model 35050AT Dosimeter and its ion chambers are vented to atmospheric pressure; as a result, there should be no difference between the atmospheric pressure measured by Model 35050AT Dosimeter and the actual atmospheric pressure of the ion chamber.

In the event that the temperature/pressure sensor becomes non functional, an error message, "Temp & Press Error Use Manual Entry" is displayed and only the manual temperature and pressure entry mode is available.

Section 4

Maintenance

4.1 Introduction

This section gives step-by-step procedures on how to replace the Model 35050AT Dosimeter's battery and fuse. This section also gives instructions on how to order replaceable parts or arrange for service if necessary.

WARNING

Disconnect the instrument from other equipment and turn off power before continuing to section 4.3, Battery Replacement, and section 4.4, Fuse Replacement.

4.2 Cleaning the Instrument

To clean the exterior of the instrument, follow these steps:

1. Turn off the instrument and disconnect all input connectors.
2. Place the cap on the triaxial-BNC connector.
3. Moisten a soft cleaning cloth with a solution of three parts water and one part liquid dishwashing detergent.

Do not soak the cloth in the solution; you must not let the solution drip inside the instrument.

4. Use the moistened cloth to wipe the instrument's exterior cover.
5. Let the instrument dry completely before using.

4.3 Battery Replacement

Use the following procedure to replace the battery pack in the Model 35050AT Dosimeter and refer to Figure 4-1.

1. Turn off power.
2. Twist off the four rubber feet on the bottom of the instrument with finger friction; remove the bottom cover plate and set aside.
3. Invert and tap the instrument into the palm of the hand until the battery pack falls out.
4. Using a small screwdriver or fingernail, remove all six exhausted batteries from the battery pack; dispose of them properly.
5. Replace with six fresh AA alkaline batteries -- spring side connects to negative end of battery. Press all six batteries firmly to make sure contacts have been made at both ends.
6. Install the battery pack back into the instrument with the output terminals facing the direction of the notch cutout provided for easy replacement (see Figure 4-1).
7. Put the bottom cover plate back on the instrument in the proper position. Screw the rubber feet back on and finger tighten.

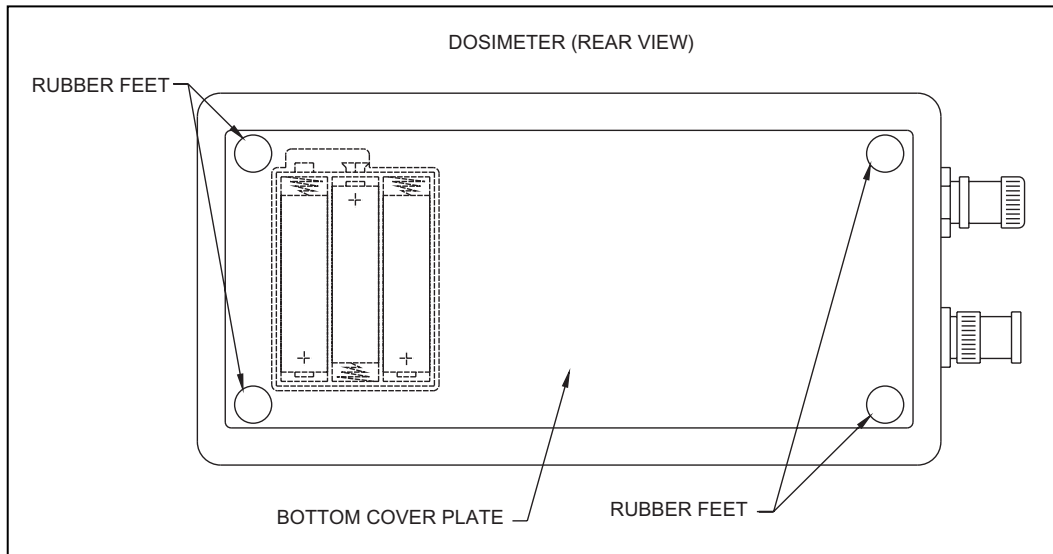


Figure 4-1. The Model 35050AT Dosimeter Battery Replacement

4.4 Fuse Replacement

1. Twist off the four rubber feet on the bottom of the instrument with finger friction. Remove the bottom cover plate and set aside.
2. Invert the instrument and tap into the palm of the hand till the battery pack falls out.
3. Look inside the battery pack compartment and find the fuse extractor. It is a loop of plastic tubing held captive by the fuse body & fuse clips (see Figure 4-2). Grasping the fuse extractor tightly between your index finger and thumb and as close to the fuse as possible, push away from you until the fuse pops out. Pull the fuse out of the instrument.

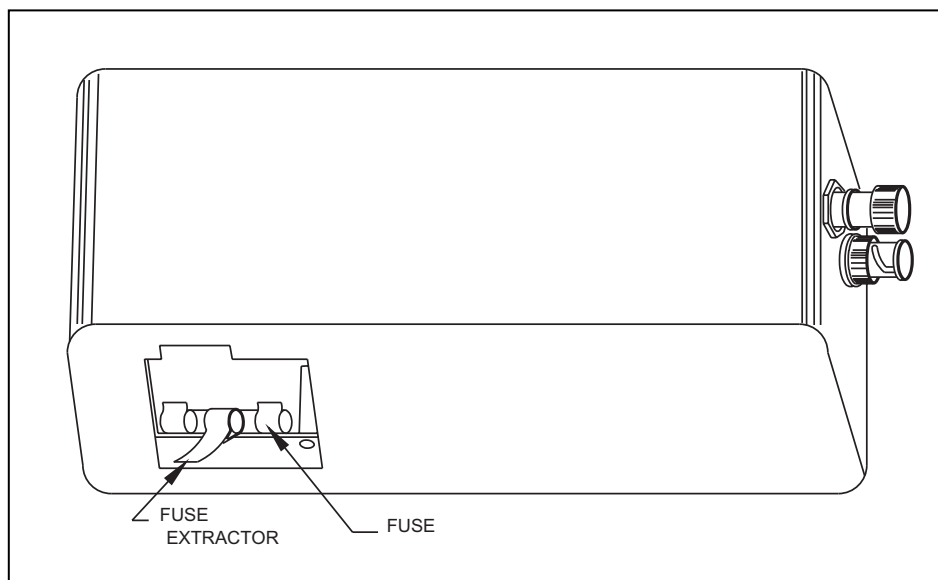


Figure 4-2. The Model 35050AT Dosimeter Fuse Replacement

4. Replace the fuse with P/N FU-83.

CAUTION

Use of a different fuse could cause damage to the instrument.

5. Install the new fuse with the fuse extractor into the instrument by reversing the procedure.

4.5 Replaceable Parts Information

Fluke Biomedical, Radiation Management Services maintains a complete inventory of all normal replaceable parts (see Table 4-1). To place an order, or to obtain information concerning replaceable parts, contact the Fluke Biomedical at 440.248.9300.

Table 4-1. Replaceable Parts List

Description	Part Number
20 ft (6.1 m) Coax/Triax Cable	38208
Ion Chamber Stem	32147
Battery Holder	87-3
HVL Filter Kit	37668
Carrying Case, Fitted	37500D
Chamber Holder	37582
HVL Filter Tray	37586
Test Stand Rod	37589
Test Stand Base	37590
Thumbscrew	2715-E-BLACK
Rubber Feet	38471
Bottom Cover Plate	34067
Fuse	19-5
Fuse Extractor	38486
Dust Cap and Chain	878-11-63
Customization Kit with 2 m Cable & Adapters	37594
A.C. Adapter	Call for P/N

4.6 Temperature / Pressure Sensor Adjustment

The measurements from the internal temperature / pressure sensor may be adjusted using the front panel buttons. Allow the unit's temperature to equilibrate for at least 1 hour before calibrating the sensor. Verify that only calibrated thermometers and barometers are used to adjust the 35050AT internal temperature / pressure sensor. To adjust the sensor measurements:

1. Make sure that the Auto Sense Temperature & Pressure option has been selected.
2. Momentarily depress the Options and Air Density buttons simultaneously.
3. The adjusted/measured temperature and adjusted/measured pressure will be displayed and the cursor (>) appears next to the value to be adjusted.

4. Momentarily depressing the Options and Air Density buttons simultaneously again toggles the cursor to the other value. Holding down the Options and Air Density buttons simultaneously causes the cursor to toggle between temperature and pressure values.
5. Press the Up or Down buttons to increment or decrement the adjusted temperature or pressure readings until they agree with the calibrated thermometer or barometer. Setting the adjusted values equal to the measured values restores the adjusted values to the measured sensor values.
6. Pressing any other button exits the adjustment mode.

4.7 Recalibration and Repair Information/Technical Assistance

If your instrument needs recalibration or repair, we request that you consult the Fluke Biomedical, Radiation Management Services Repair Department at 800.850.4606, 440.498.2564, or Fax 440.542.3682.

More information concerning the operation, application, or service of your instrument may be obtained from the applications engineer at the numbers listed above.

4.8 Warranty Information

Should your instrument require warranty service, contact Fluke Biomedical at 440.248.9300.

NOTE

This warranty does not cover battery replacement or damage caused by battery leakage.

Appendix A

Model 35050AT Default Ion Chamber Selection Screens

A.1 Introduction

The standard calibration for your Model 10100AT TRIAD Field Service Kit includes two calibration points for the Model 96035B ion chamber and one calibration point for the Model 96020C ion chamber. If you received the standard calibration (which you did unless you requested otherwise), these calibration factors have been entered into the Model 35050AT Dosimeter. Each calibration factor has been linked to two Ion Chamber Selection screens, one with air density corrections active, and one with air density correction inactive. Choosing the proper Ion Chamber Selection screen in the Model 35050AT Dosimeter ensures that the correct calibration factor for the ion chamber being used is active. Below is a description of the three default Ion Chamber Selection screens and their meanings.

A.2 Model 96020C (150 cc) Ion Chamber

The standard calibration for the 150 cc Model 96020C ion chamber is performed at the Fluke Biomedical, Radiation Management Services equivalent of NIST beam quality H60. The calibration factor of your Model 96020C at this beam quality has been entered into the Model 35050AT Dosimeter and linked to two Ion Chamber Selection screens which read as follows:

150 cc xxxxx ADC

150 cc xxxxx

150 cc refers to the volume of the Model 96020C ion chamber.

xxxxx is replaced in your selection by the serial number of your Model 96020C.

ADC indicates that air density correction are active.

NOTE

Both of these selections use the same ion chamber calibration factor (which can be viewed using the OPTIONS button). However, using the top selection results in automatic air density corrections being applied to your measurements, while the bottom selection results in no air density correction being applied.

A.3 Model 96035B (15 cc) Ion Chamber

The standard calibration for the 15 cc Model 96035B ion chamber includes one mammographic point (the Fluke Biomedical, Radiation Management Services equivalent of NIST beam quality MoMo28) and one diagnostic point (the Fluke Biomedical, Radiation Management Services equivalent of NIST beam quality L100). Each of these calibration factors is entered into the Model 35050AT Dosimeter and linked to two Ion Chamber Selection screens (for a total of four screens) that read as follows:

15 cc xxxxx MAM ADC
15 cc xxxxx MAM
15 cc xxxxx DIA ADC
15 cc xxxxx DIA

15 cc refers to the volume of the Model 96035B ion chamber.

xxxxx is replaced in your selection by the serial number of your Model 96035B.

MAM indicates the selection for the mammographic calibration point (MoMo28).

DIA indicates the selection for the diagnostic calibration point (L100).

ADC indicates that air density correction are active.

The selection containing MAM should be used for all measurements on the mammographic side of the chamber, while the selection containing DIA should be used for all measurements on the diagnostic side of the chamber. The selections containing ADC indicate that automatic air density corrections will be applied, while the selections without ADC indicate that no air density corrections will be applied.

Appendix B

Model 96020C Ion Chamber Specifications

B.1 Introduction

The Model 96020C parallel-plate ion chamber is optimized for low-level intensity measurements. The chamber has a flat energy response suitable for both attenuated and unattenuated diagnostic beam qualities. Complete physical, electrical, and energy response specifications are given in this appendix.

B.2 Physical Specifications

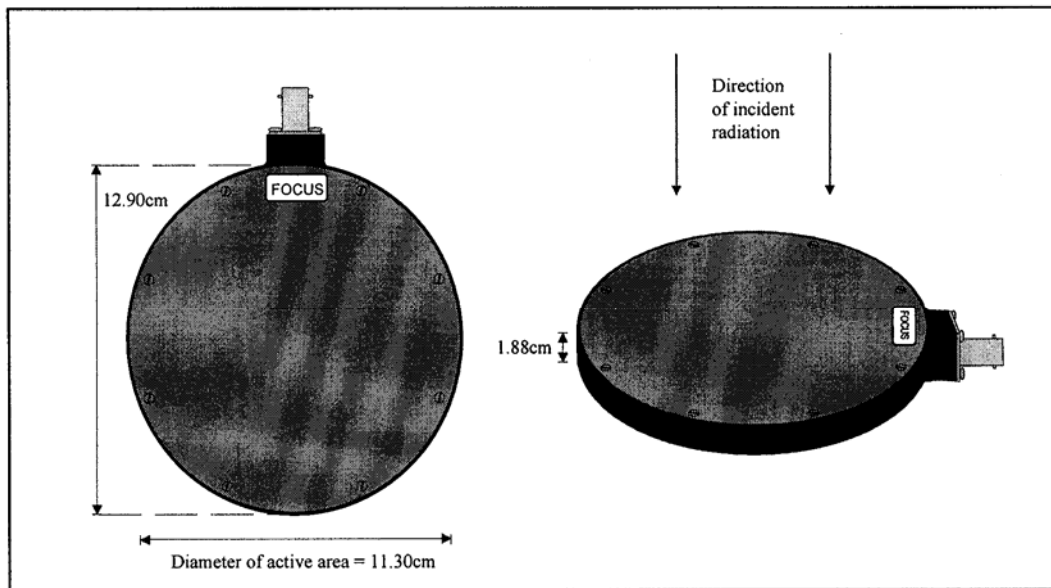


Figure B-1. The Model 96020C Ion Chamber

Description: vented volume, parallel-plate air ionization chamber

Overall Dimensions: 12.90 ± 0.03 cm diameter by 1.88 ± 0.01 cm thick

Nominal Volume: 150cc, 11.30 cm diameter by 1.50 cm thick active volume

Wall Material: composite graphite-filled thermoplastic

Window Material: 0.76 mm thick, graphite-coated polycarbonate (lexan). A 3.5 by 4 cm piece of 0.0025 cm thick aluminum is attached to the back of the window to improve the energy response.

Window Density: 91 mg/cm²

Active Window Area: 100 cm², centered within the chamber body

Connector: side-mounted triaxial two-lug BNC connector

Collector Plate: centrally mounted collector is a 0.8 mm thick graphite-coated acrylic plate, 10.80 cm in diameter. Thirty-five, 6.4 mm diameter holes are drilled through the plate. A 2.16 x 2.85 cm guard region is electrically isolated from the collector area.

Foam Supports: Two, 1.30 x 1.30 x 0.94 cm pieces of styrofoam DB are used to support the collector plate and provide mechanical stability.

B.3 Electrical Specifications

Sheet Resistivity: All areas sprayed with graphite conductive coating measure less than 6 k /square but greater than 3 k /square.

Leakage Current: With 300 volt bias in effect and 0.1 volt potential imposed between the guard and collector, at 20°C and 50% relative humidity, the leakage current is < 10 fA within 60 seconds of applying the voltage. The leakage under the above bias conditions is < 100 fA within 60 seconds of applying the voltage over both the full operating temperature range of 8 - 38°C and for 20 - 80% relative humidity, but only for conditions in which the absolute humidity is 20 g/m³ (the equivalent R.H. is 75% at 25°C, 60% at 30°C, and 50% at 35°C).

B.4 Radiological Specifications

Energy Range: 30 to 150 kVp

Nominal Sensitivity:

H60: 2.08 x 10⁷ R/C (1.82 x 10⁵ Gy/C) at 22°C and 1013 hPa

DV70: 2.12 x 10⁷ R/C (1.86 x 10⁵ Gy/C) at 20°C and 1013 hPa

DH70: 2.07 x 10⁷ R/C (1.81 x 10⁵ Gy/C) at 20°C and 1013 hPa

Multiply values by 0.00876 to convert from R to Gy.

Sensitivity Range: sensitivity range is ± 5% of nominal

Reference Point: The reference point of measurement for the chamber is 1.05 cm directly below the center of the top of the entrance window. This corresponds to the center of the active region.

Incident Beam Direction: A small sticker with the word "FOCUS" is secured to the top, entrance window of the chamber. The reference direction of incident radiation is perpendicular to this surface.

Angular Dependence: The ion chamber response to radiation incidence variations up to ± 5° of normal is within ± 1% of the response to incident radiation striking perpendicular to the entrance window surface.

Ion Transit Time: Maximum of 1.0 ms in the center of the chamber at STP with a bias voltage of 300 volts.

Collection Efficiency: The collection efficiency for both continuous intensity and 120 Hz half wave rectified intensity is theoretically calculated using Boag's equations. An ionization potential of 300V is used in both cases. An effective plate separation distance of 0.8 cm was determined experimentally and used to generate the curves below.

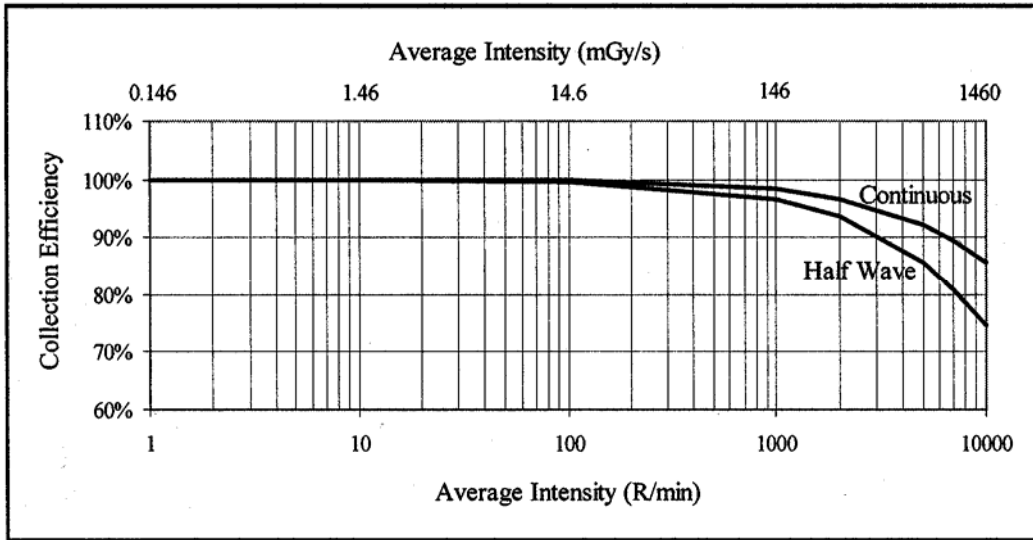


Figure B-2. Collection Efficiency of the Model 96020C Ion Chamber

Air Density Correction: To perform air density corrections when using a calibration factor with a reference temperature of 22°C, multiply the ion current by the following correction factor, F:

$$F = \frac{(273.15 + T)}{295.15 \times P}$$

where T is the actual temperature in °C, and P is the pressure expressed as a fraction of a standard atmosphere (1013 hPa). For chambers with a calibration factor normalized to 20°C, the denominator is 293.15 x P.

B.5 Calibration and Verification

Calibration or calibration verification is performed by comparison of each 96020C ion chamber with a reference chamber calibrated at either the National Institute of Standards and Technology (NIST) or PTB. Specifications for all PTB equivalent beam qualities are given in Tables B-1 and B-2 in the energy correction factor section.

Standard Calibration

The standard calibration is performed at the Fluke Biomedical, Radiation Management Services equivalent of H60 (NIST defined as 60 kVp, first HVL of 6.0 mm Al, homogeneity coefficient of 94). The calibration factor is normalized to 22°C and 1013 hPa of atmospheric pressure.

European Calibration Option

This calibration option replaces the standard calibration for units sold in Europe, or when specifically requested by a customer. This calibration is performed at the Fluke Biomedical, Radiation Management Services equivalent of DH70 (PTB defined as 70 kVp, first HVL of 6.77 mm Al). The calibration factor is normalized to 20°C and 1013 hPa of atmospheric pressure.

PTB Calibration Option

This calibration option replaces the standard calibration when PTB requirements must be met, or when specifically requested by a customer. This option includes calibration at both of the beam qualities listed below. Calibration factors are normalized to 20°C and 1013 hPa of atmospheric pressure.

Unattenuated beam: Calibration is performed at the Fluke Biomedical, Radiation Management Services equivalent of DV70 (PTB defined as 70 kVp and first HVL of 2.45 mm Al).

Attenuated beam: Calibration is performed at the Fluke Biomedical, Radiation Management Services equivalent of DH70 (PTB defined as 70 kVp and first HVL of 6.77 mm Al).

Other Calibration Options

Optional calibration points are the Fluke Biomedical, Radiation Management Services equivalent of L100, M50, S75, DV30, DV40, DV50, DV60, DV80, DV90, DV100, DV120, DV150, DH40, DH50, DH60, DH80, DH90, DH100, DH120, and DH150. Calibration factors at these points may be normalized to either 20°C or 22°C, as specified by the customer.

Calibration Accuracy

NIST traceable: NIST traceable reference chambers are accurate to within $\pm 1\%$ at each beam quality. Matching between the reference and unknown chamber is accurate to $\pm 1\%$. Thus, NIST traceable calibrations are accurate to within $\pm 2\%$.

PTB traceable: PTB traceable reference chambers are accurate to within $\pm 1.5\%$ at each beam quality. Matching between the reference and unknown chamber is accurate to $\pm 1\%$. Thus, PTB traceable calibrations are accurate to within $\pm 2.5\%$.

Calibration Verification

NIST traceable: For NIST traceable calibrations, a chamber will be reported to be outside of its calibration accuracy specification when a new calibration value differs from the old calibration value by more than $\pm 4\%$. This includes the $\pm 2\%$ accuracy specification plus $\pm 1\%$ for the verification reference plus $\pm 1\%$ for the verification match.

PTB traceable: For PTB traceable calibrations, a chamber will be reported to be outside of its calibration accuracy specification when a new calibration value differs from the old calibration value by more than $\pm 5\%$. This includes the $\pm 2.5\%$ accuracy specification plus $\pm 1.5\%$ for the verification reference plus $\pm 1\%$ for the verification match.

B.6 Energy Correction Factors

B.6.1 Attenuated Beam (Behind the phantom)

The energy correction factors for the 96020C are determined for the attenuated diagnostic beam using the PTB defined DN series of beam qualities given in Table B-1.

Table B-1. Specifications for PTB Defined Attenuated Beam Qualities

PTB Denomination	kVp	Added Filtration in mm Al	First HVL in mm Al	First HVL in mm Cu
DN40	40	6.5	2.2	0.07
DN50	50	12.5	3.4	0.123
DN60	60	18.5	5.0	0.207
DN70	70	23.5	6.2	0.289
DN80	80	29.5	7.8	0.403
DN90	90	32.5	9.0	0.501
DN100	100	36.5	10.1	0.609
DN120	120	42.5	12.0	0.839
DN150	150	52.5	14.1	1.245

Typical energy correction factor curves are obtained by dividing the calibration factor at each beam quality by the calibration factor at a reference point and plotting the result versus first HVL. The first HVL at H60 is chosen as the reference point for chambers receiving the standard calibration while the first HVL at DH70 is chosen for chambers receiving the PTB calibration option. DH70 is a new calibration point defined by PTB with a first HVL of 6.77, which falls between DN70 and DN80 in the table above. The correction factor charts normalized to these two points are shown below (Figures 3 and 4). All 96020C ion chambers must have an actual correction factor within $\pm 1.5\%$ of the value shown in the curves at any point.

The energy correction factors are multiplicative, such that multiplying the measured ion chamber output at any beam quality by the appropriate value from the curve will correct readings not made at the calibration factor beam quality.

The numerical value shown beside each point is the kVp value of that point in the DN series of beam qualities. Users making measurements in an attenuated beam with characteristics similar to the PTB DN series may use these values to easily obtain the appropriate correction factor. For a more precise correction factor value, or when making measurements in an attenuated beam not similar to a DN series point, the user may calculate the actual first HVL and locate the proper correction value on the curve.

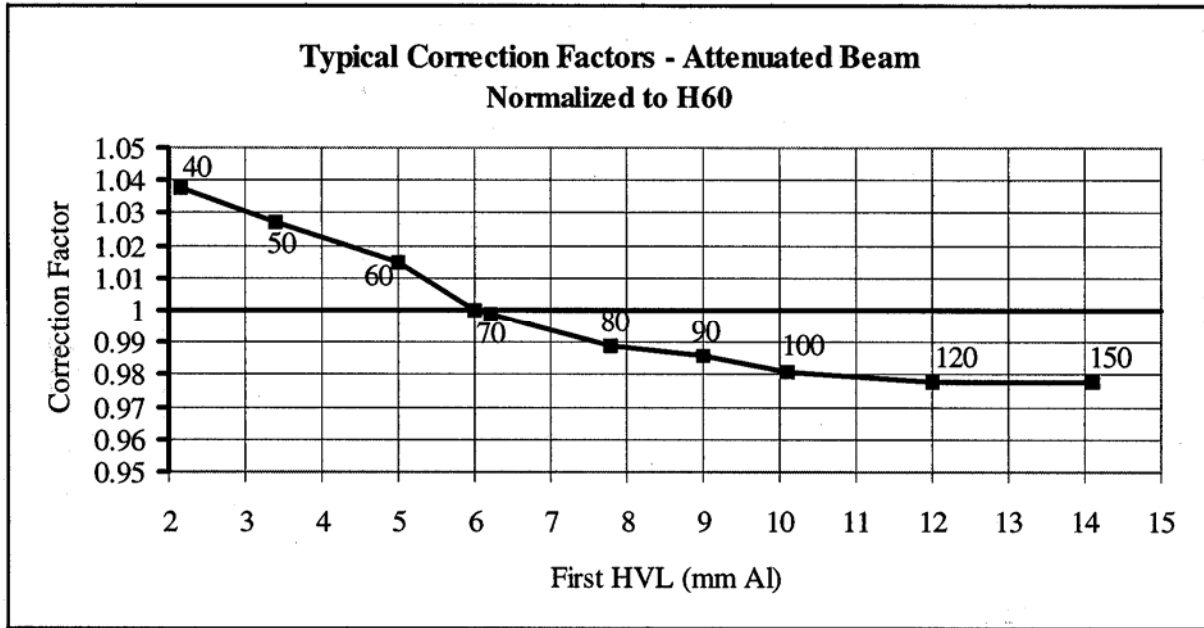


Figure B-3. Energy correction factors for Model 96020C in attenuated beam normalized to H60

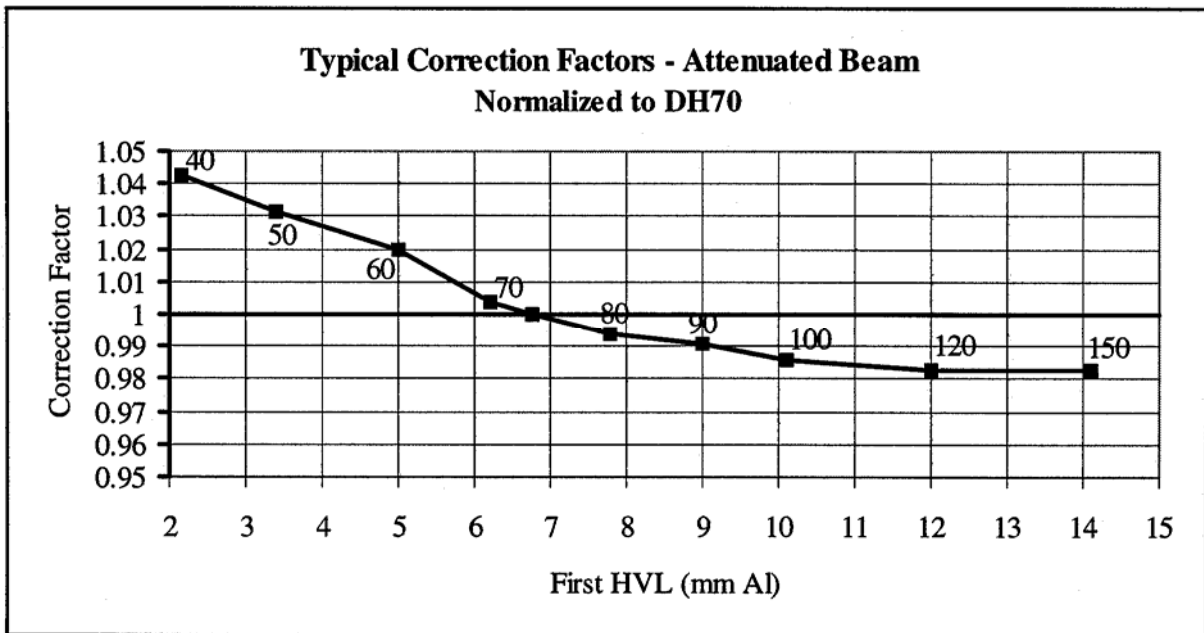


Figure B-4. Energy Correction Factors for Model 96020C in Attenuated Beam Normalized to DH70

B.6.2 Unattenuated Beam (In front of the phantom)

The energy correction factors for the 96020C are determined for the unattenuated diagnostic beam using the PTB defined DV series of beam qualities given in Table B-2.

Table B-2. Specifications for PTB Defined Unattenuated Beam Qualities

PTB Denomination	kVp	Added Filtration in mm Al	First HVL in mm Al	First HVL in mm Cu
DV30	30	2.5	1.05	0.031
DV40	40	2.5	1.42	0.045
DV50	50	2.5	1.82	0.059
DV70	70	2.5	2.45	0.081
DV90	90	2.5	3.10	0.112
DV100	100	2.5	3.60	0.126
DV120	120	2.5	4.30	0.165
DV150	150	2.5	5.40	0.231

Typical energy correction factor curves are obtained by dividing the calibration factor at each beam quality by the calibration factor at a reference point and plotting the result versus first HVL.

The typical correction factor curves for the unattenuated beam are shown below normalized to L100 in Figure 5 and DV70 in Figure 6. All 96020C ion chambers must have an actual correction factor within $\pm 1.5\%$ of the value shown in the curves at any point. Users receiving the standard calibration must request a calibration factor at either L100 or DV70 to use the correction factors in these curves.

The numerical value shown beside each point is the kVp value of that point in the DV series of beam qualities. Users making measurements in an unattenuated beam may use these values to easily obtain the appropriate correction factor. For a more precise correction factor value, the user may calculate the actual first HVL and locate the proper correction value on the curve.

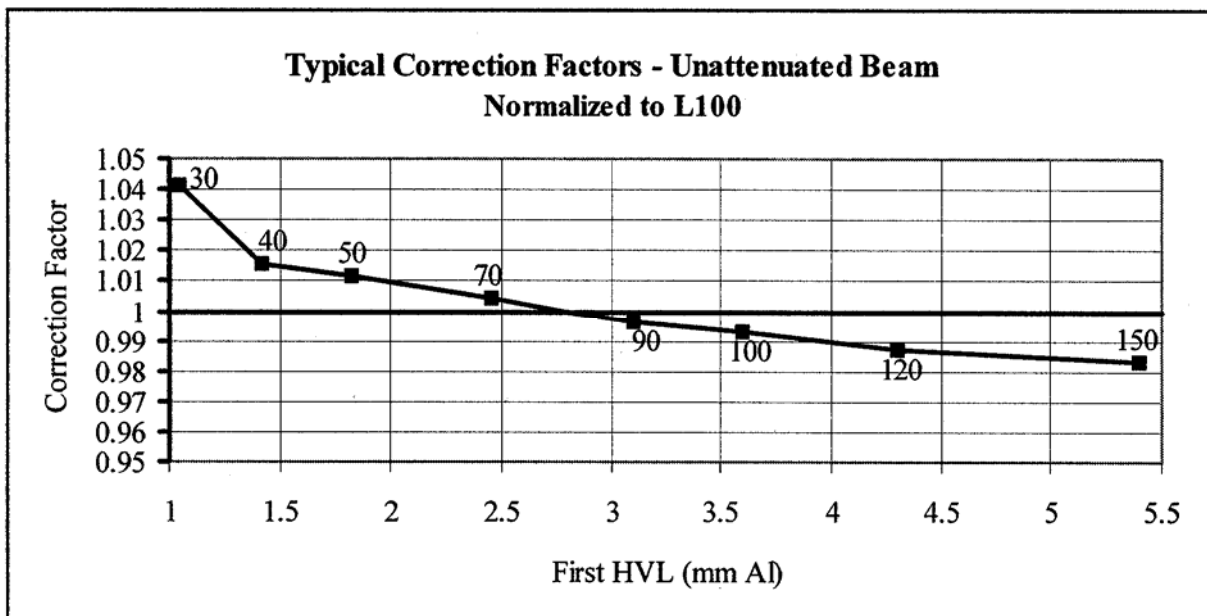


Figure B-5. Energy Correction Factors for Model 96020C in Unattenuated Beam Normalized to L100

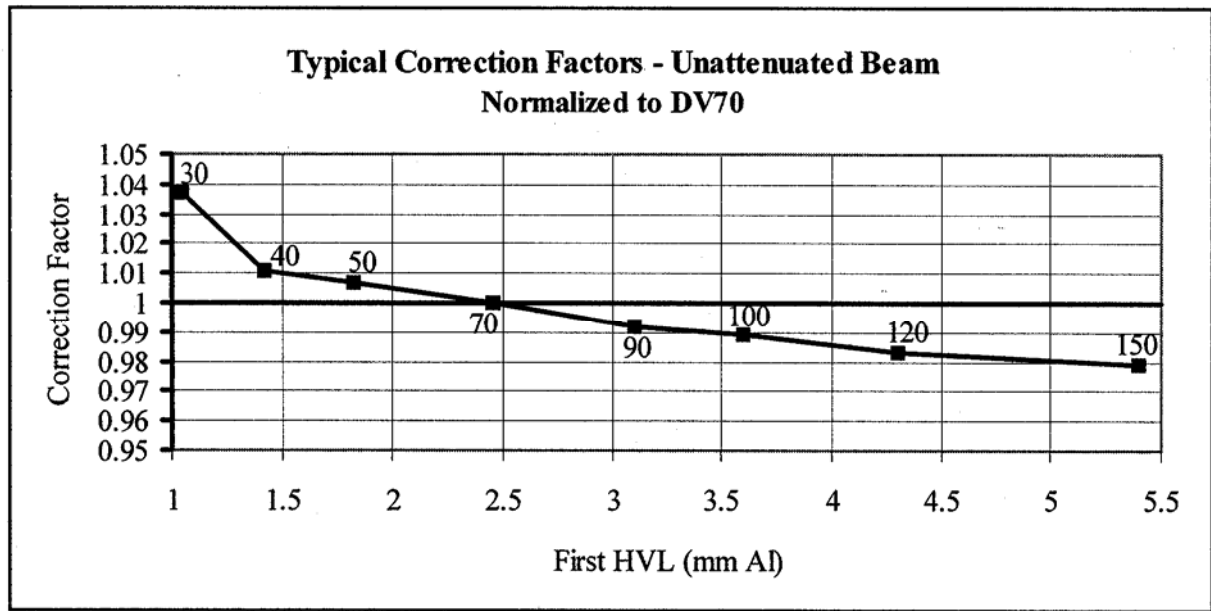


Figure B-6. Energy Correction Factors for Model 96020C in Unattenuated Beam Normalized to DV70

Appendix C

Model 96035B Ion Chamber Specification

C.1 Introduction

The Model 96035B dual entrance window parallel-plate ion chamber has a flat response suitable for both diagnostic radiography and mammography. One entrance window is provided for diagnostic measurements and one for mammographic measurements. The fully guarded, centrally located collector plate provides excellent collection efficiency. This appendix provides complete physical, electrical, and energy response specifications.

C.2 Physical Specifications

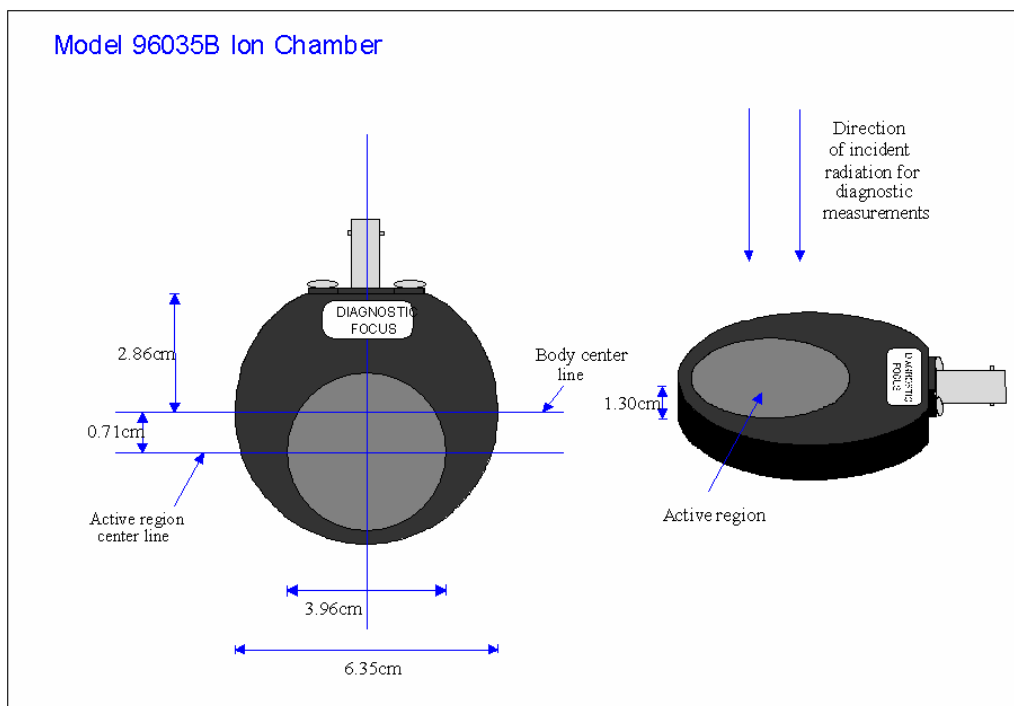


Figure C-1. The Model 96035B Ion Chamber

Description: vented volume, parallel-plate air ionization chamber. This is a dual entrance window ion chamber. Diagnostic measurements are made using one side of the chamber as the entrance window and mammographic measurements are made using the other side as the entrance window.

Dimensions: 6.35 ± 0.04 cm diameter by 1.30 ± 0.01 cm thick

Nominal Volume: 15cc, 3.96 cm diameter by 1.22 cm thick active volume

Wall Material: graphite-coated acrylic (methyl-methacrylate)

Window Material: Both entrance windows are made of 0.25 mm graphite-coated polycarbonate (lexan). A 1.5 by 1.6 cm piece of 0.0025 cm thick aluminum is attached to the back of the window with the "DIAGNOSTIC FOCUS" sticker to improve the energy response for diagnostic measurements.

Window Density: 32 mg/cm^2

Active Window Area: Each side of the chamber has a circular active window region centered 7.1 mm further from the BNC connector than the center of the chamber body. These regions are centered in the other direction (see Figure C-1). The active window regions have an area of 12.32 cm^2 .

Connector: side-mounted triaxial two-lug BNC connector

Collector Plate: The collector is a 0.25 mm thick, centrally mounted, graphite-coated, polycarbonate (lexan) plate. The diameter is 3.18 ± 0.01 cm. A 1.27×0.89 cm guard region is electrically isolated from the collector area.

C.3 Electrical Specifications

Sheet Resistivity: All areas sprayed with graphite conductive coating measure less than 6 k /square but greater than 3 k /square.

Leakage Current: With 300 volt bias in effect and 0.1 volt potential imposed between the guard and collector, at 20°C and 50% relative humidity, the leakage current is $< 10 \text{ fA}$ within 60 seconds of applying the voltage. The leakage under the above bias conditions is $< 100 \text{ fA}$ within 60 seconds of applying the voltage over both the full operating temperature range of 8 - 38°C and for 20 - 80% relative humidity, but only for conditions in which the absolute humidity is 20 g/m^3 (the equivalent R.H. is 75% at 25°C, 60% at 30°C, and 50% at 35°C).

C.4 Radiological Specifications

Energy Range: 30 to 150 kVp for diagnostic measurements; 20 to 50 kVp for mammographic measurements.

Nominal Sensitivity:

L100: $2.00 \times 10^8 \text{ R/C}$ ($1.75 \times 10^6 \text{ Gy/C}$) at 22°C and 1013 hPa

MV30: $2.21 \times 10^8 \text{ R/C}$ ($1.94 \times 10^6 \text{ Gy/C}$) at 22°C and 1013 hPa

DV70: $2.01 \times 10^8 \text{ R/C}$ ($1.76 \times 10^6 \text{ Gy/C}$) at 20°C and 1013 hPa

DH70: $1.89 \times 10^8 \text{ R/C}$ ($1.66 \times 10^6 \text{ Gy/C}$) at 20°C and 1013 hPa

MH30: $2.16 \times 10^8 \text{ R/C}$ ($1.89 \times 10^6 \text{ Gy/C}$) at 20°C and 1013 hPa

L100, DV70, and DN70 nominal sensitivities apply to the diagnostic side of the chamber, while MV30 and MH30 apply to the mammographic side. Multiply values by 0.00876 to convert from R to Gy.

Sensitivity Range: sensitivity range is $\pm 8\%$ of nominal

Reference Point: The reference point is located 6.5 cm directly below the center of the either active window region. This corresponds to the center of the active volume.

Incident Beam Direction: For diagnostic measurements, the reference direction of incident radiation is perpendicular to the entrance window with the “DIAGNOSTIC FOCUS” sticker attached, and with this window facing the x-ray source. For mammographic measurements, the reference direction of incident radiation is perpendicular to the entrance window with the “MAMMOGRAPHY FOCUS” sticker attached, and with this window facing the x-ray source.

Angular Dependence: The ion chamber response to radiation incidence variations up to ± 8° of normal is within ± 1% of the response to incident radiation striking perpendicular to the entrance window surface.

Collection Efficiency: The collection efficiency for both continuous intensity and 120 Hz half wave rectified intensity is theoretically calculated using Boag’s equations. An ionization potential of 300V is used in both cases. An effective plate separation distance of 0.73 cm was determined experimentally and used to generate the curves shown in Figure C-2.

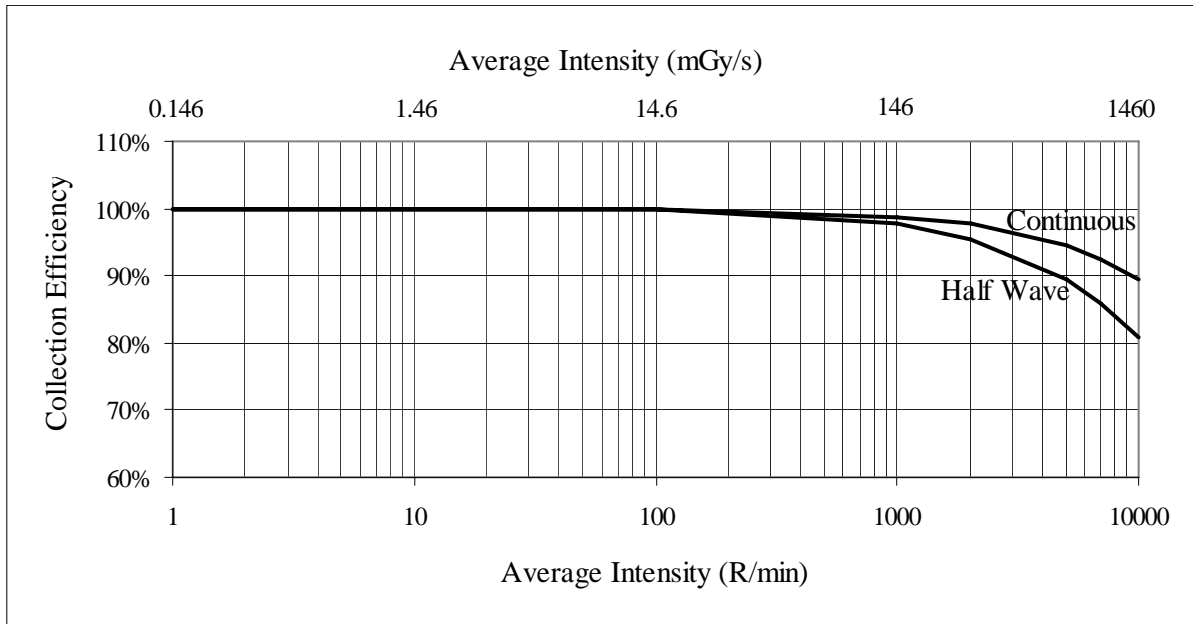


Figure C-2. Collection Efficiency of Model 96035B Ion Chamber

Ion Transit Time: Maximum of 0.67 ms in the center of the chamber at STP with a bias voltage of 300 volts.

Air Density Correction: To perform air density corrections when using a calibration factor with a reference temperature of 22°C, multiply the ion current by the following correction factor, F:

$$F = \frac{(273.15 + T)}{295.15 \times P}$$

where T is the temperature in °C, and P is the pressure expressed as a fraction of a standard atmosphere (1013 hPa). For chambers with a calibration factor normalized to 20°C, the denominator is 293.15 x P.

C.5 Calibration and Verification

Calibration or calibration verification is performed by comparison of each 96035B ion chamber with a reference chamber calibrated at either the National Institute of Standards and Technology (NIST) or PTB. Specifications for all PTB equivalent beam qualities are given in the tables in the energy correction factor section.

Standard Calibration

The standard calibration is performed at one diagnostic and one mammographic beam quality as given below. Calibration factors are normalized to 22°C and 1013 hPa of atmospheric pressure.

Diagnostic Unattenuated beam: Calibration is performed at the Fluke Biomedical, Radiation Management Services equivalent of L100 (NIST defined as 100 kVp, first HVL of 2.8 mm Al, homogeneity coefficient of 59).

Mammographic beam: Calibration is performed at the Fluke Biomedical, Radiation Management Services equivalent of MoMo28 (NIST defined as 28 kVp, first HVL of 0.332 mm Al, homogeneity coefficient of 74.3).

European Calibration Option

This calibration option replaces the standard calibration for units sold in Europe, or when specifically requested by a customer. This option includes one diagnostic and one mammographic beam quality, as given below. Calibration factors are normalized to 20°C and 1013 hPa of atmospheric pressure.

Diagnostic Unattenuated beam: Calibration is performed at the Fluke Biomedical, Radiation Management Services equivalent of DV70 (PTB defined as 70 kVp, first HVL of 2.45 mm Al).

Mammographic beam: Calibration is performed at the Fluke Biomedical, Radiation Management Services equivalent of MV30 (PTB defined as 30 kVp, first HVL of 0.337 mm Al).

PTB Calibration Option

This calibration option replaces the standard calibration when PTB requirements must be met, or when specifically requested by a customer. This option includes two diagnostic points and one mammographic point as given below. Calibration factors are normalized to 20°C and 1013 hPa of atmospheric pressure.

Diagnostic Unattenuated beam: Calibration is performed at the Fluke Biomedical, Radiation Management Services equivalent of DV70 (PTB defined as 70 kVp, first HVL of 2.45 mm Al).

Diagnostic Attenuated beam: Calibration is performed at the Fluke Biomedical, Radiation Management Services equivalent of DH70 (PTB defined as 70 kVp, first HVL of 6.77 mm Al).

Mammographic Beam: Calibration is performed at the Fluke Biomedical, Radiation Management Services equivalent of MH30 (PTB defined as 30 kVp, first HVL of 0.67 mm Al).

Other Calibration Options

Optional calibration points are the Fluke Biomedical, Radiation Management Services equivalent of M50, S75, H60, MoMo35, DV30, DV40, DV50, DV60, DV80, DV90, DV100, DV120, DV150, DH40, DH50, DH60, DH80, DH90, DH100, DH120, and DH150. Calibration factors at these points may be normalized to either 20°C or 22°C, as specified by the customer.

Calibration Accuracy

NIST Traceable: NIST traceable reference chambers are accurate to within $\pm 1\%$ at each beam quality. Matching between the reference and unknown chamber is accurate to $\pm 1\%$. Thus, NIST traceable calibrations are accurate to within $\pm 2\%$.

PTB traceable: PTB traceable reference chambers are accurate to within $\pm 1.5\%$ at each beam quality. Matching between the reference and unknown chamber is accurate to $\pm 1\%$. Thus, PTB traceable calibrations are accurate to within $\pm 2.5\%$.

Calibration Verification

NIST traceable: For NIST traceable calibrations, a chamber will be reported to be outside of its calibration accuracy specification when a new calibration value differs from the old calibration value by more than $\pm 4\%$. This includes the $\pm 2\%$ accuracy specification plus $\pm 1\%$ for the verification reference plus $\pm 1\%$ for the verification match.

PTB traceable: For PTB traceable calibrations, a chamber will be reported to be outside of its calibration accuracy specification when a new calibration value differs from the old calibration value by more than $\pm 5\%$. This includes the $\pm 2.5\%$ accuracy specification plus $\pm 1.5\%$ for the verification reference plus $\pm 1\%$ for the verification match.

C.6 Energy Correction Factors

C.6.1 Diagnostic - Unattenuated Beam (In front of the phantom)

The energy correction factors for the 96035B are determined for the unattenuated diagnostic beam using the PTB defined DV series of beam qualities given below in Table C-1.

Table C-1. Specifications for PTB Defined Unattenuated Beam Qualities

PTB Denomination	kVp	Added Filtration in mm Al	First HVL in mm Al	First HVL in mm Cu
DV30	30	2.5	1.05	0.031
DV40	40	2.5	1.42	0.045
DV50	50	2.5	1.82	0.059
DV70	70	2.5	2.45	0.081
DV90	90	2.5	3.10	0.112
DV100	100	2.5	3.60	0.126
DV120	120	2.5	4.30	0.165
DV150	150	2.5	5.40	0.231

Typical energy correction factor curves are obtained by dividing the calibration factor at each beam quality by the calibration factor at a reference point and plotting the result versus first HVL. L100 is chosen as the reference point for chambers receiving the standard calibration while DV70 is chosen for chambers receiving the PTB calibration option.

The energy correction factors are multiplicative, such that multiplying the measured ion chamber output at any beam quality by the appropriate value from the curve will correct readings not made at the calibration factor beam quality.

The typical correction factor curves for the unattenuated beam are shown below normalized to L100 in Figure C-3 and DV70 in Figure C-4. All 96035B ion chambers must have an actual correction factor within $\pm 1.5\%$ of the value shown in the curves at any point.

The numerical value shown beside each point is the kVp value of that point in the DV series of beam qualities. Users making measurements in an unattenuated beam may use these values to easily obtain the appropriate correction factor. For a more precise correction factor value, the user may calculate the actual first HVL and locate the proper correction value on the curve.

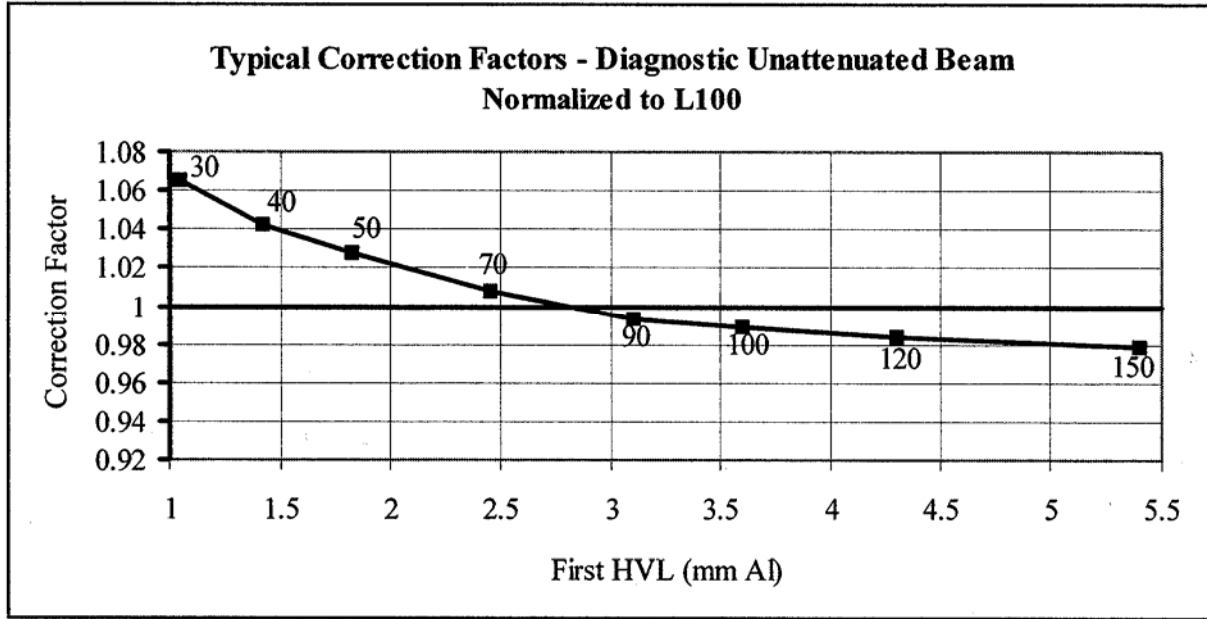


Figure C-3. Energy correction factors for Model 96035B in unattenuated beam normalized to L100

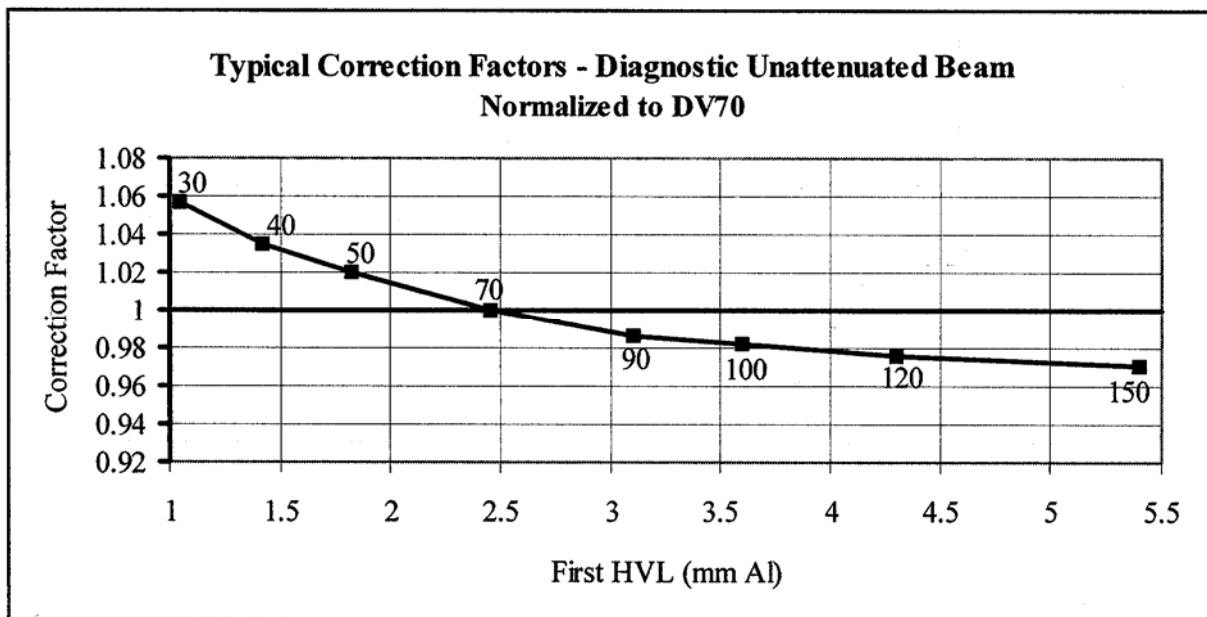


Figure C-4. Energy Correction Factors for Model 96035B in Unattenuated Beam Normalized to L100

C.6.2 Diagnostic - Attenuated Beam (Behind the phantom)

The energy correction factors for the 96035B in the attenuated diagnostic beam are determined using the PTB defined DN series of beam qualities given below in Table C-2.

Table C-2. Specifications for PTB Defined Attenuated Beam Qualities

PTB Denomination	kVp	Added Filtration in mm Al	First HVL in mm Al	First HVL in mm Cu
DN40	40	6.5	2.2	0.07
DN50	50	12.5	3.4	0.123
DN60	60	18.5	5.0	0.207
DN70	70	23.5	6.2	0.289
DN80	80	29.5	7.8	0.403
DN90	90	32.5	9.0	0.501
DN100	100	36.5	10.1	0.609
DN120	120	42.5	12.0	0.839
DN150	150	52.5	14.1	1.245

Typical correction factor curves are obtained by dividing the calibration factor at each beam quality by the calibration factor at a reference point and plotting the result versus first HVL.

The typical correction factor curve for the attenuated beam is normalized to DH70 in Figure C-5. DH70 is a new PTB beam quality with an HVL of 6.77, which falls between DN70 and DN80. Since the response of the chamber at H60 is virtually identical to the response at DN70, this curve is also considered normalized to H60. Users receiving the standard calibration must request a calibration factor at either H60 or DH70 to use the correction factors in this curve.

All 96035B ion chambers must have an actual correction factor within $\pm 1.5\%$ of the value shown in the curve at any point.

The numerical value shown beside each point is the kVp value of that point in the DN series of beam qualities. Users making measurements in an attenuated beam with characteristics similar to the PTB DN series may use these values to easily obtain the appropriate correction factor. For a more precise correction factor value, or when making measurements in an attenuated beam not similar to a DN series point, the user may measure the actual first HVL and locate the proper correction value on the curve.

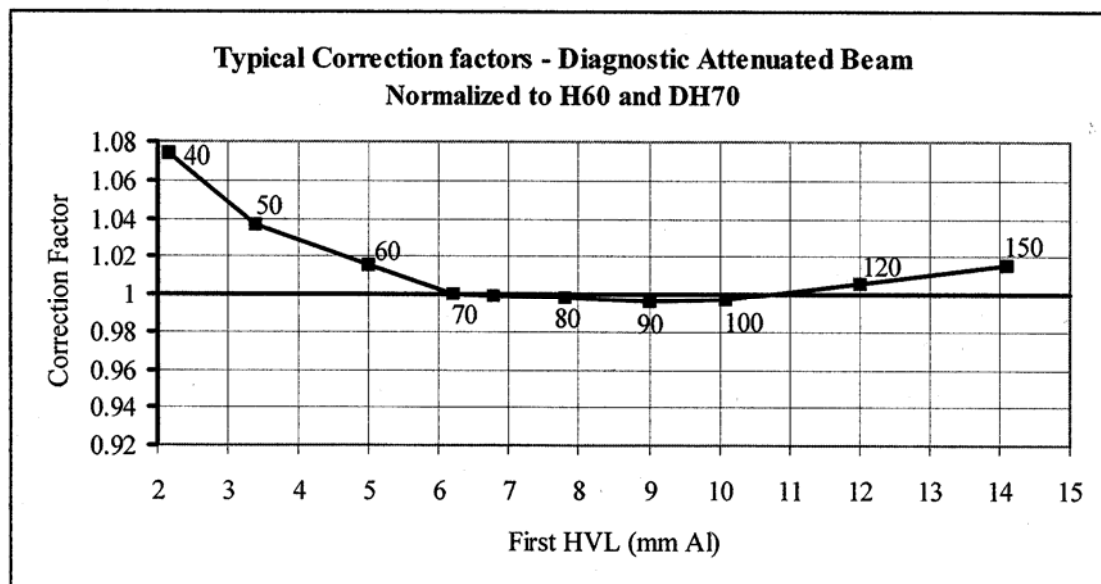


Figure C-5. Energy Correction Factors for Model 96035B in Attenuated Beam

C.6.3 Mammographic Beam Qualities

The energy correction factors for the 96035B are determined for the mammographic beam using the PTB defined MV and MH series of beam qualities given in Tables C-3 and C-4, respectively.

Table C-3. Specifications for PTB Defined Unattenuated Mammographic Beam Qualities

PTB Denomination	kVp	Added Filtration	First HVL in mm Al
MV20	20	30 μ m Mo	0.223
MV25	25	30 μ m Mo	0.282
MV30	30	30 μ m Mo	0.337
MV35	35	30 μ m Mo	0.374
MV40	40	30 μ m Mo	0.402
MV50	50	30 μ m Mo	0.440

Table C-4. Specifications for PTB Defined Attenuated Mammographic Beam Qualities

PTB Denomination	kVp	Added Filtration	First HVL in mm Al
MH20	20	30 μ m Mo + 2.0 mm Al	0.45
MH24	25	30 μ m Mo + 2.0 mm Al	0.58
MH30	30	30 μ m Mo + 2.0 mm Al	0.67
MH35	35	30 μ m Mo + 2.0 mm Al	0.75
MH40	40	30 μ m Mo + 2.0 mm Al	0.83
MH50	50	30 μ m Mo + 2.0 mm Al	0.97

Typical energy correction factor curves are obtained by dividing the calibration factor at each beam quality by the calibration factor at a reference point and plotting the result versus first HVL. MV30 is chosen as the reference point for chambers receiving the standard calibration while MH30 is chosen for chambers receiving the PTB calibration option. Since the response of the chamber at MoMo28 is equivalent to the response at MV30, the first curve is also considered normalized to MoMo28.

The typical correction factor curves for mammography are shown below normalized to MV30 and MoMo28 in Figure C-6 and MH30 in Figure C-7. All 96035B ion chambers must have an actual correction factor within $\pm 1.5\%$ of the value shown in the curves at any point.

The actual points plotted in the graphs below correspond to the points in the MV and MH series of beam qualities. Users making measurements at a beam quality similar to one of the PTB mammographic beams may easily obtain the appropriate correction factor by assuming the HVL of the most equivalent PTB beam. For a more precise correction factor value, the user may calculate the actual first HVL and locate the proper correction value on the curve.

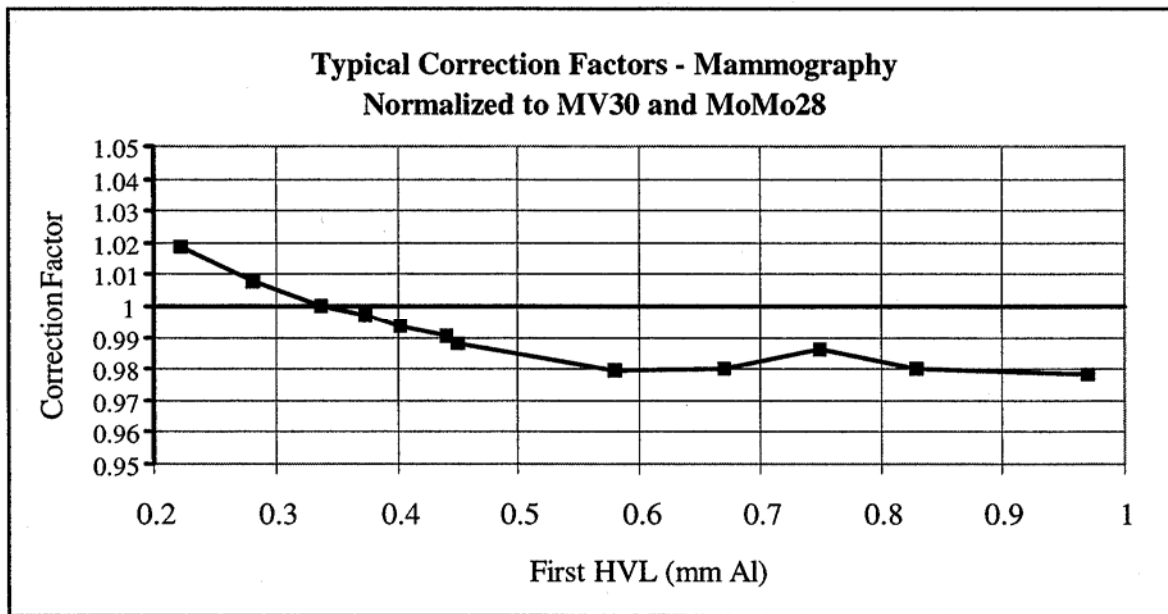


Figure C-6. Energy Correction Factors for Model 96035B for Mammography Normalized to MV30 and MoMo28

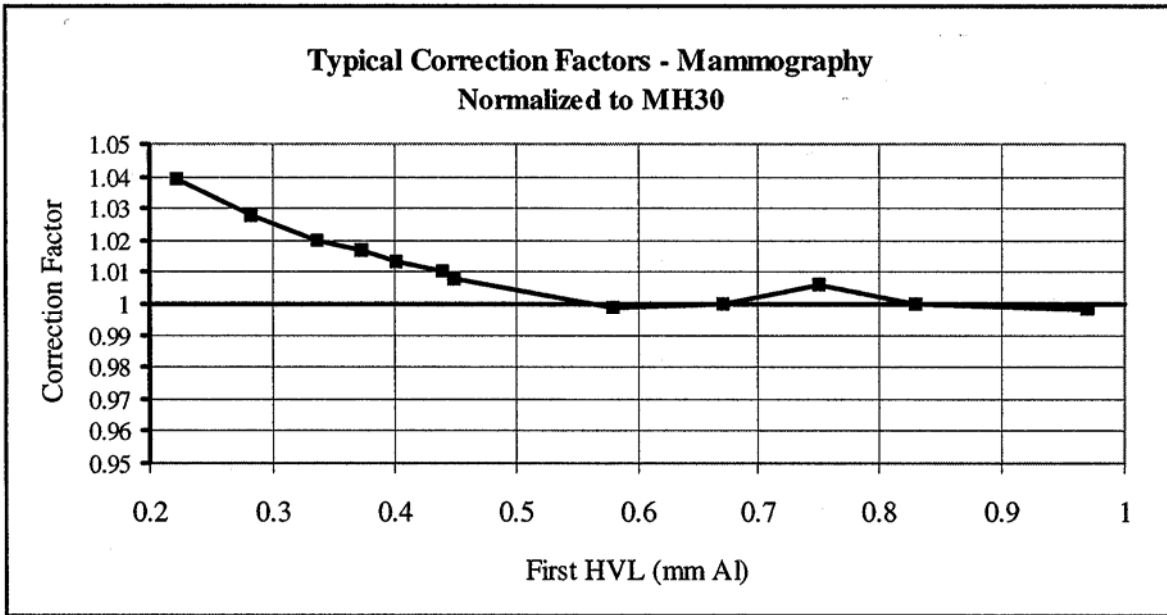


Figure C-7. Energy Correction Factors for Model 96035B for Mammography Normalized to MH30

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