Radcal®

The Accu-Series -

Accu-Pro™
Accu-Dose
Accu-kV®

Radiation Measurement Systems

User Guide

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INTRODUCTION

The Accu-series instruments include the Accu-Pro™ for Dose and kV, the Accu-Dose for Dose only and Accu-kV for kV only measurements. This manual is applicable to all instruments in the Accu-series.

The Accu-Pro™ system measures the characteristics of a diagnostic x-ray machine. Measurements are processed and displayed by a microprocessor-based control unit. Sensors connect to the control unit via a 4m cable that carries only digital signals and operating voltages to eliminate cable noise. Dose is measured with ion chambers or solid-state detectors. Radcal Accu-kV sensors determine kV, filtration and half-value measurements (diagnostic sensor) using differential absorption and an array of solid state detectors. The mammographic (22-40kV) sensor Mo/Mo outputs can be corrected to W/Rh and W/Ag anode-filter combinations (Hologic Selenia x-ray machine only).

A 13 kHz sample rate for kV measurements is used with FFT-based ripple measurements for accurate kVp measurements on high-frequency generators.

Automatic compensation of kV measurements for filtration is available for diagnostic x-ray measurements. This also provides estimates for filtration and half-value layer.

Stand-alone exposure measurements can be made using the Ion chamber digitizer and an ion chamber or the dose diode digitizer and the DDX6-W or DDX6-M sensors. Using these sensors in conjunction with the kV sensors provides dose and dose rate measurements synchronized to an x-ray pulse.

Using 40X11-W and DDX10-W or 40X10-M and DDX10-M sensors allows simultaneous dose and kV waveform measurements

mA, mAs and mA waveform may be measured in conjunction with kV measurements using invasive or non-invasive mA sensors.

The Accu-Pro™ operates from rechargeable NiMH or alkaline C cells.
The figure on page 46 shows the Accu-Pro™ system in its carry case.

A USB interface allows a PC to control and process measurements performed by the Accu-Pro™ system . XLPRO, an Excel add-in, uses this capability to produce reports, graphs and to automate measurements.

The figure on page 40 shows the pushbutton controls and the 2-line display. The connectors for the mA sensor, USB and waveform are also visible. The battery charger interface is at the rear of the control unit. The in-beam sensor connector is on the opposite side.

The controls include *UP*-arrow, *DN*-arrow and ***select*** pushbuttons that are used to navigate the menu and to activate measurements. A ***test*** pushbutton provides a simulated x-ray signal so you can observe how the measurements work. The ***power*** pushbutton provides for orderly shutdown and startup.

Measurement results are presented on the display and are available in digital form on using the USB connection. The BNC provides calibrated real-time kV, dose or mA waveforms.

Accu-Pro™ Diagnostic Ion Chamber and kV Sensor Components

A. Accu-Pro™ (9096) Control Unit
B. 40x12-W Diagnostic Range kV Sensor
C. 10X6-6 Ion Chamber Sensor
D. Positioner
E. 9660 Ion Chamber Digitizer
F. 90C6-4 Sensor Cable

GETTING STARTED

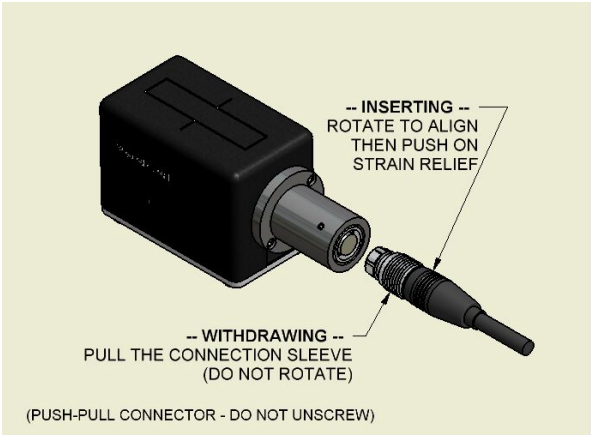
This describes initial assembly and operation of an Accu-Pro™ system comprising a control unit, sensor cable, diagnostic kV sensor and a 6cc ion chamber with an ion-chamber digitizer.

IMPORTANT: Stabilization is required before making any ion chamber measurements. Stabilization is best done by putting the unit in Dose Rate mode/High Sensitivity and waiting for 3 minutes. See page 11 for details.

Connect the sensor cable to the control unit:
Insert the rectangular connector on the sensor cable into the socket on the right side of the instrument with the Radcal logo facing you. It will click into place. To remove it, pinch the levers on the side of the connector and pull back.

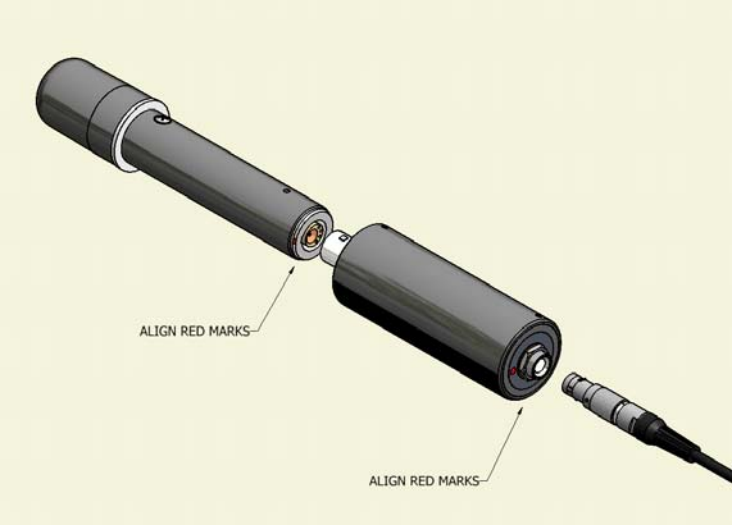
Sensor cable connection

Connect the kV sensor to the sensor cable:
Hold the round connector by the rubber strain relief and engage the kV sensor by rotating the connector until it aligns with the mating socket on the sensor and they move to engage, then press the connector. It should click into place. To disconnect, pull straight back on the ring, **not on the strain relief**, and the connector will unlatch. **Never attempt to unscrew the connector**.



kV sensor connection

Connect the Ion chamber
Connect the ion chamber to the larger circular connector on the Ion chamber digitizer. Align the red dots and push the connector until the mating surfaces contact one another. Connect the sensor cable to the smaller connector in the same fashion.



Ion chamber connection

Connect the battery charger:

Connect the charger to the control unit and plug it into an ac outlet. The charge indicator should turn on orange indicating the battery is being charged. The instrument can operate while the battery is being charged.

Turn on the Accu-Pro™:
Press the green ***power*** button. A set of vertical rectangles marches across the display to assure it is operating, the calibration date is displayed, and self-test is performed. During self-test the control unit reads the type and calibration factors of each sensor, measures the ion chamber temperature and the ambient pressure. When self-test completes, the display will show the chamber information:

6cc Corr 1.03
HV Stabilize 13s

while the ion chamber and bias supply stabilizes. When the stabilization times out, pressure and temperature display:

Press 99.2 kPa
Temp 20.1 deg C

The Corr value shown is the temperature and pressure correction that will be applied to the ion chamber readings.
The top line of the display will then show:

Change or SELECT

and the second line will show setup or whatever measurement mode was active the last time power off occurred.

If self-test is unsuccessful, a failure message is displayed. Pressing *UP* or *DN* allows operation to proceed, however you must resolve the problem before accurate measurements can be performed. See the discussion of error messages on page 37

Setup Defaults
The Accu-Pro™ has a number of options that are controlled from the Setup menu. The following procedure resets the setup functions to factory defaults. Use *UP* to get

Change or SELECT
Setup

and press **select** to enter *Setup* . Press *DN* twice. The display should show:

SELECT restores
setup defaults

Then press ***select***:

Accept changes ?
> OK

appears. Use *DN* until:

Press SELECT to
exit Setup:

appears. Press ***select***.

Accept changes?
> OK

appears again. Press ***select*** to return to the main menu with all settings at factory defaults.

Functional test

Now that the Accu-Pro™ is operating, you can use the ***test*** button to become familiar with the operation of the unit. The *UP* and *DN* arrows move through the main menu. The top line of the display continues to show

Change or SELECT

while the second line shows the function to be performed.

Dose Rate test

Use *UP* or *DN* to reach the Dose Rate function, and press ***select***.
The display will briefly show

6cc Corr 1.02
measuring zero

after which it will become

↑ Dose Rate
0.0 mR/min

The up arrow indicates low-sensitivity mode.
Press and hold ***test***
The display becomes:

↑ Dose Rate
999.5 mR/min

The dose rate value depends on the ion-chamber calibration factor. It lies between 940 and 1060 mR/min.

KV Pulse test - Diagnostic sensor 40-160kV

Press *UP* or *DN* until the display shows:

Change or SELECT
kV Pulse

Press ***select***.
After a few seconds, the display changes to:

kV Pulse
W

while the kV sensor zero is being determined. After another few seconds, the annunciator beeps, the W disappears and the system is ready to perform a measurement:

kV Pulse
A

The A indicates automatic filtration correction is active.

Press ***test.*** The kV sensor responds as if it had been exposed to a 100kV, 100 ms x-ray signal. When the kV sensor detects a signal, the display becomes:

kV Pulse

The arrow indicates a signal is being measured. The arrow is replaced by a ↓ when the pulse ends and kV calculations are being performed. Finally, a beep sounds, the W disappears and the measurement results are displayed:

98.4 kVp
A1.99mR I 100ms

The kVp reading results from the filtration correction for 10mm Al.

Pressing ***select*** displays filtration:

0.300 mm Cu HVL
A10.0mm AL 7.12

Pressing ***select*** again displays dose measurements:

1.993mR/pls
A1.196R/min C

The C indicates the radiation measurement comes from the dose sensor.

KV Pulse test - Mammographic sensor 22-40 kV

The factory default setting is for a Mo/Mo track filter combination. To change to another combination see MODE SELECT in *Setup* (page 19). See Appendix (page 47) for calibration example.

Attach the mammography kV sensor to the control unit.

Use UP DN to come to

Change or SELECT
kV Pulse

Press SELECT and have the display show

kV pulse

Press **test.** The kV sensor responds as if it had been exposed to a 30kV, 100 ms x-ray signal. The display shows for a Mo-Mo setting

30.0kVp
Dx.xxmR 100ms

The D stands for default filtration - 30µm Molybdenum for the Mammography sensor

For a Tungsten/Rhodium setting, you will see a T in the lower left of the display after you select kV pulse. On pressing the test button, you then have the display show

31.6kVp
Txx.xxmR 100ms

A Tungsten/Silver setting is different from the Tungsten/Rhodium setting. There is a range of calculated kVp's (25-33kV) that exceed a set error band and the instrument will show an error message as a result. The test button shows what this looks like. You will get two successive screens. The first reads

Exposure error
Bad W/Ag kV

The next screen reads

kV-try again
SError cleared

The S stands for silver

Once the measurement has been completed, the display retains the values. A subsequent exposure does not replace them until the measurement is complete The ⇢ and ⇊ appear to the left of the exposure value to indicate signal–present and kV– calculation respectively. When the ⇊ disappears, a beep sounds and the new reading is displayed. An exposure made when either ⇢ nor ⇊ are displayed will not be correctly analyzed.

MAKING ION CHAMBER MEASUREMENTS

1. Allow the system to reach equilibrium by selecting dose rate mode and waiting at least three minutes. Do not touch digitizer. One does not need to shut the system off when replacing chambers, however, do not disconnect the chamber when actual measurements are being made. Each time a new chamber is used, the system must re-stabilized

.

   Note: For changing environments, allow 10 minutes per 10 C for the sensor/electronics to equilibrate.

2. Ensure that the system is set to high sensitivity on (Setup->Mode SELECT->High sensitivity->On). This ensures that the system performs a fine zero (as opposed to a coarse zero) prior to every measurement.

3. Do not move or touch the digitizer or the ion chamber during the zero measurement interval. If low-level measurements are being made and there is a significant delay between measurements (> 2-3 minutes) it is prudent to force a full re-zero by exiting the mode and re-entering.

REFERENCE

Display

The 2-line 16-character LCD displays menu selections and measurement results.
Characters positioned at the left side of the display have special meaning:

→ in *Setup* indicates a parameter choice. Press ***select*** to chose the item.

For dose measurements:
? indicates dose-sensor signal was outside calibrated range .

→ indicates high-sensitivity mode measurement.

↑ indicates low -sensitivity mode measurement.

↓ indicates cumulative (zero-corrected) dose is negative.

For kV measurements:
W means Wait. The kV system is unable to process another exposure while W is displayed.

A indicates automatic filtration compensation is enabled.

D indicates default filtration will be used: 2.5 mm Aluminum for the diagnostic sensor.
30µm Molybdenum for the Mammography sensor

M indicates a user-selected filter (other than 2.5 mm Al).

T indicates a Tungsten/Rhodium anode/filter
S indicates a Tungsten/Silver anode/filter

In the lower right corner of the display:
C indicates a dose sensor (ion chamber or diode)
K indicates dose from the Accu-kV diode

The kV display may be configured in *Setup*. The following table shows the selections for each of the four locations on the display. *Default* values are underlined.

Location	Measurement			
Upper Left	*kVp*	kV practical	kV reduced	kV avg
Upper Right	*mAs*	width pulses	width ms	mA
Lower Left	*conv dose*	width pulses	width ms	mA
Lower* Right	*width ms*	kV diode dose rate	rel dose rate	pulses

* Readout not present if Lower Left is Conv Dose in kV

Fluoro Display Scrolling:
The kV displays provide filtration information by scrolling the display using ***select***. A second press of ***select*** in kV Pulse and Dental modes provides exposure information if a dose sensor or Accu-kV diode is connected and displayed.

Sounds

A brief(5ms) 4 kHz tone is produced whenever a key-press is recognized. A longer (100 ms) tone occurs when the kV measurement computation finished and a new reading is displayed. The longer sound also occurs when an error occurs.

Sensors

The Accu-Pro™ control unit can connect to various sensors to provide dose and x-ray beam information. The three main classes of sensors are the Accu-kV sensors that determine x-ray beam characteristics, the ion chambers that measure radiation dose and the diode-based radiation sensors. Also available are mA sensors used to determine x-ray anode current.

KV sensors

The Accu-kV sensors use differential absorbers and photodiodes to determine kV. You can select the filtration to be used for kV calculations in *Setup*. Automatic filtration correction is available for the diagnostic sensors. Both mammographic and diagnostic sensors are available that can accept a dose diode input for observing radiation waveforms and to provide dose measurements synchronized to with the kV pulse.
Diagnostic sensors are black; mammographic ones are purple.

40X9-M	- Basic mammographic Accu-kV sensor.
40X10-M	- Same as 40X9-M with provision for DDX-10M diode sensor to observe radiation waveform using oscilloscope or XLPRO. (Discontinued - see below)
40X9-W	- Basic diagnostic Accu-kV sensor. (Discontinued - see below)
40X10-W	- Same as 40X9-W with provision for DDX-10W diode sensor to observe radiation waveform using an oscilloscope or XLPRO (Discontinued - see below)
40X11-W	- Same as 40X9-W with provision for DDX-10W and automatic filtration compensation. (Discontinued - see below)
40X12-W	- Same as 40X9-W with automatic filtration compensation.

FFT kV SENSORS with FLASH HVL (diagnostic range)

The Diagnostic range sensor accuracy is ± 1 kV or ± 1 % whichever is largest. The mammo sensor has an Mo-Mo accuracy of ± 0.5 kV and < ± 1 kV for other track-filters.

40X12-W Accu-kV

✔ **The sensor for Diagnostic range (40 kV to 160 kV) measurements**
Besides **kVp**, also measures, displays, and compensates for **beam hardness** (add ± 1 % when on). Inherently correctly reads AMX4+ and AMX 700 portables. **Flash HVL**: ± 0.3 mm Al and ± 10 % of reading, 1-23 mm total equivalent thickness Al, 40-160 kVp.

40X9-Mo Accu-kV

The sensor for Mammographic range measurements
This versatile sensor is designed for 0.5 kV accuracy for Mo-Mo mammographic beams. It may also be used at < ± 1 kV accuracy for Tungsten-Silver / Rhodium tubes on Hologic Selenia mammography machines.

✔ Recommended for starter kit configuration.

Ion Chambers

Radcal ion chambers are recognized for reliable measurements They exhibit excellent energy response. Their omnidirectional response makes them suitable for leakage and scatter measurements as well an CT measurements. They are available in specialized configurations for particular systems. Ion chambers require care in handling, require a bias voltage which must stabilize after bias is applied, and are much larger than diode sensors.

ION CHAMBER DOSE SENSORS

The Ion Chamber Dose Sensors feature:
Calibration Accuracy ± 4%, Energy Dependence ± 5%. Plug-and-play.

10X6-6

✔ **The General Purpose, in Beam Chamber**
A well documented wide dynamic range chamber with many dose and rate applications.

10X6-6M
The Dedicated Mammography Chamber
A world standard for mammography.

10X6-60

✔ **The 'Service' Chamber**
This thin profile makes it ideal for low input dose at an image receptor and many other uses.

10X6-3CT
The Chamber for Computed Tomography Dose Index (CTDI)
Another industry standard.

10X6-180
The Leakage and Low Level Measurements Chamber
For leakage measurements. Cross-section of 100cm^2. Also for very low dose to image receptor.

10X6-1800
The Radiation Protection Chamber
For very low-level radiation measurements such as sheilding, leakage, and environmental. *Superior to typical survey meters for accuracy.*

✔ Recommended for starter kit configuration.

Diode dose sensors

Diode sensors are compact, rugged, insensitive to handling, “instant-on” and do not require temperature and pressure correction’ They are somewhat directional which reduces the effect of scatter. Their energy response is not as uniform as the 10X6 ion chambers. Their directional response makes them unsuitable for CT, scatter and leakage measurements. Temperature-dependent leakage current makes them unsuitable for long-term dose measurements.

Accu-kV diode sensors (DDX10) are available that work in conjunction with an Accu-kV sensor. They allow viewing radiation waveforms captured simultaneously with kV waveforms. They cannot make stand-alone radiation measurements. (Discontinued

DDX6 diode sensors connect to the DD60 diode digitizer. They are standalone dose sensors providing a full set of radiation measurements.

DIODE DOSE SENSORS

The Diode Dose Sensors feature:
Calibration Accuracy ± 4%, Energy Dependence and Filtration dependence: see below.

DDX6-W

✔ **The Diode Dose Sensor for Diagnostic range measurements**
Energy dependence ± 5 %, 40-150 kV at 2.5 mm Al. Filtration dependence + 5 % to -10 % for 2.5 to 23 mm Al.

DDX6-M
The Diode Dose Sensor for Mammographic range measurements
Energy dependence ± 5 %, 20-40 kV, 25-35 µm Mo. ± 5 % 25-35 kV 30 µm Mo + 2 mm Al. ± 10% 22-40 kV, 30 µm Mo + 2 mm AL.

✔ Recommended for starter kit configuration.

Relative dose:

The relative dose rate output is based on a single channel from the kV sensor. It is uncalibrated and uncompensated, however it can serve as a measure of relative output for consistency tests and the analog or USB waveform can assist in troubleshooting.

Main–Menu Functions

Italics indicate default functions. Using *Setup* you can add or remove functions to customize the main menu. A flow chart representation of the main menu is shown on the enclosed diagram.

Setup

Provides access to configuration settings. See **Setup–Menu Functions** on page 19.

Dose Rate

Measures and displays dose rate. Performs an auto-zero and measures environmental conditions when the mode is first selected. Applies that value to each reading. Measurement interval depends on dose rate and varies between 0.3 and 5 seconds. An arrow in the upper left corner is on when a measurement is in process. It points upward when low sensitivity mode is selected, and to the right the for high sensitivity.

Max Dose Rate

Measures Dose rate. Displays the result only if the measured rate is greater than that displayed. **select** resets the stored value.

Dose Accum/Hold

Measures total dose. Performs an auto-zero and measures environmental conditions when mode is first selected and applies those values to the measurements. A down-pointing arrow in the upper left of the display appears when accumulated zero-corrected dose is negative; up- and right-pointing arrows indicate measurements in normal and high-sensitivity modes respectively. Updates the display once per second.

Pressing ***select*** resets the accumulation but not the zero.

Auto Dose

Automatically measures the dose and duration of a single exposure. Displays the result until another exposure occurs. Starts when the dose rate exceeds 0.01% FS; stops accumulating dose 200 ms after the rate falls below 0.006% FS. Duration is measured between the trigger point and 50% of the peak rate. The ending delay allows collection of all the charge in the exposure.

Last Dose

Like Dose Accum/Hold except ***select*** doesn't reset the dose accumulator. The accumulator is updated every 500 ms.

Pulsed Cine

Accumulates dose and displays it in units of dose per pulse or dose rate. Use *Setup* to define 6 measurement conditions, each of which specifies pulse rate (pulses/s), delay(pulses) , acquisition(pulses) and threshold(varies with chamber). Available pulse rates include automatic (indicated as 0 pulses /s) that works up to approximately 16 pulses/s and selected values between 0.25 and 90 pulses/s. The x-ray machine must be operating during the entire time of the measurement.

kV Pulse

Measures and displays kVp and duration. If a dose sensor is connected measures and displays pulse dose and dose rate. If the mA sensor is connected integrates mA to obtain mAs. Displays mA or mAs. kVp measurements are calculated using a 100ms interval near the end of the pulse. Analyzes kV waveforms up to 5 sec. Use ***select*** to access filtration and additional dose measurements. See page 12 for a description of the display options. See Display discussion on page 12 for the meaning of special characters A, D and M (in filtration) and C and K (in dose).

kV Dental
Operates like *kV Pulse*. Disregards low-intensity preheat pulses if this feature is enabled in *Setup*. Duration can display in pulses for 50- and 60-Hz half-wave machines.

kV Fluoro
Operates like *kV Pulse*. Measures kV for 1 second, computes and displays the result and then repeats. Displayed values change slightly to adapt to a continuous waveform. Width measurements are omitted; dose and mAs become dose rate and average mA respectively.

Power off
Turns the unit off. Saves the operating mode and displays

```
Power off
```

for several seconds and then removes power.

Occurs automatically after 30 minutes of inactivity or when ***power*** is pressed during operation.

Setup–Menu Functions

Pressing ***select*** at the main menu display

Change or SELECT
setup

enters *Setup*. The following information and options are provided in this mode::

- Serial No. and firmware Version
  This manual applies to version 6.

- Pressure and temperature
  Values used for ion-chamber compensation. Prefixed with Std if measured not selected.

- SELECT restores setup defaults.
  Restores all items in *Setup* to default values. Default values are shown as *Default* in the following descriptions.
  See detailed instructions on page 8

- Mode SELECT

Parameter	Choices	Accu-Pro	Accu-Dose	Accu-kV
Pressure	*Measured*/Std 101.3 kPa	X	X	
Temperature	*Measured*/Std 22 deg C	X	X	
Len/area suffix	On(*cm or *cm2)/*Off*	X	X	
High sensitivity[1]	On/*Off*	X	X	
Radiation units	*Roentgens*/Grays/Coulombs	X	X	
Auto shutdown	*On*(30 min)/Off	X	X	X
Time units	Seconds/*Minutes*/Hours	X	X	X
Mammo anode/filter	*Mo/Mo,* W/Ag, W/Rh	X		X
DAC output	*kV*/mA/Rel. intensity/dose rate	X		X

[1]The Accu-Pro measures the background zero when you select a dose mode. If high sensitivity is set to off, the system will make a quick coarse zero measurement. Some fluctuations will be observed in dose rate mode and dose accumulate may exhibit drifting. If high sensitivity is set to on, the system will make a fine zero measurement which takes 3 to 5 seconds. The dose rate will fluctuate much less and the dose accumulate drift will be greatly reduced. It is recommended that high sensitivity mode is enabled for most dose measurements.

- Function SELECT
  Add/Remove functions from the main menu. See Page 17 for a list of functions

- kV disp(lay) SELECT
  See table on page 12

- Intrinsic filt(ration) SELECT
  Selects the filtration used to compute kV in the diagnostic range. Auto enables automatic calculation based on beam hardness.
  Auto, Cu (32 steps from 0 to 0.695 mm), Al (32 steps from 0 to 23 mm).

- Dent(al) thr(eshold) SELECT
  Raised threshold for *kV-Dental*. Values are multipliers of the kV pulse threshold. 1, 10, 25, 50, 100, *250*, 600, and 1500.

- Pulsed Rad Mod Index no. SELECT
  Set up presets 0 thru 5 for Pulsed/Cine mode. For each, select four parameters:

Pulse Frequency							
0	0.25	.5	1	2	3	4	5
6	6.25	7	7.5	8	9	10	12.5
15	25	30	40	50	60	75	90

Trig threshold. Number is relative dose rate. () is dose rate in nR/sec for 10X6-6				
3 (55)	5(92)	10 (184)	18 (330)	30 (550)
55 (1000)	100 (1840)	182 (3300)	300 (5500)	500 (9200)

Acquire Delay
Number of frames: 1 - 256 converted to time based on selected pulse frequency

Acquire Interval
Number of frames: 1 - 256 converted to time based on selected pulse frequency

- Press SELECT to exit Setup
  If any changes have been made, you then will see

  Accept Changes?
  > OK

  select accepts the changes and returns to main menu.
  UP or *DN* changes OK to Cancel and then ***select*** returns to the main menu discarding the changes.

Batteries

The Accu-Pro™ is powered by 2 C cells located behind a removable cover at the lower rear of the control unit. Rechargeable nickel-metal-hydride (NimH) C-cells (Energizer NH35-2500) batteries are supplied from the factory. Alkaline batteries (IEC LR14) may also be used. Operating time depends on the measurement mode and battery but is usually in excess of 8 hours. Effective operating time is extended by a timer that turns off the instrument after 30 minutes of inactivity.

"***Battery LOW***" appears when the battery voltage falls to where recharging or replacement will soon be needed. When the battery voltage is too low for proper measurement, "Battery LOW" appears and the system will not respond to ***select..*** The instrument turns off when the batteries are depleted.

1000 to 6000 mAh NiMH cells are recommended. It takes approximately 3.5 hours to recharge fully-depleted 2500 m Ah cells. The system can operate while the battery is charging or with the charger connected and no cells installed.

The charge indicator is orange while charging, green when the battery is charged, and red if a fault occurs. Disconnect the charger power supply to clear the fault indication. The most common fault is attempting to charge an alkaline battery.

The charger power supply plugs into the rear of the control unit as shown. Refer to the charger label for input power requirements.

The figure on page 7 shows the charger connector and the charge indicator.

USB Interface

The Accu-Pro™ includes a USB interface for communication with a PC. USB driver software required to implement this communication is automatically installed with XLPRO 4. A virtual serial-port driver is available; contact Radcal for details

Connect a USB cable from the PC to the Accu-Pro™. If the driver is installed the green LED adjacent to the USB connector will illuminate.

PERFORMANCE

Environmental conditions

Operating temperature:
15°C to 35°C
(30°C for 40X9,10-M sensors)
Pressure
60 to105 kPa
Humidity:
Up to 80% RH or 20 g/m^3
Storage Temperature:
-20°C to +50°C

kV Sensors

40X W Sensors:

Potential	40 kV - 160 kV
Accuracy	1 kV or 1% of value
Repeatability (COV of 10 150 ms exposures)	0.2kV
Long-term drift:	1 kV for 1 yr
Rotation (normal to source-detector line)	
about sensor long axis:	1 kV for 6 º
about sensor short axis:	1 kV for 5 º
Alignment (tube anode-cathode vs sensor long axis)	1 kV for 10º
Width accuracy (2 ms - 5 sec):	0.1% of value + 0.2 ms
Ripple Error (Displayed kVp):	0.8 kV for 10%, 0-to-peak, ripple < 4 kHz

Filtration

kV, uncorrected	0.7kV/mm
kV, manual entry	1 kV
kV, automatic	1 kV 1 to 23 mm Al, 0.030 - 0.695 mm Cu For combined thicknesses, the Al equivalent thickness is 33 times the Cu value.
HVL (mm Al)	10% of value + 0.3 mm

Reference conditions:

21 - 23 C
Varian A192M tube (W-Re Anode)
HVL at 70 kV 2.9 mm Al
Anode current: 50 mA, < 1% ripple
Focus - Sensor distance 50 cm
Sensor long axis perpendicular to anode-cathode axis
Sensor plane normal to focus-sensor line
Width measured at 75% of kV waveform

40X M Sensors:

Potential	22 kV - 40 kV
Accuracy	0.5 kV for Mo/Mo
	±1 kV for Hologic Selenia x-ray machines with W anode and Rh filter
Repeatability (COV of 10 150 ms exposures)	
	0.2kV for Mo/Mo
	0.1kV for Hologic Selenia x-ray machines with W anode and Rh filter
Rotation (normal to source-detector line)	
about sensor long axis:	0.5 kV for 6º
about sensor short axis:	0.5 kV for 5º
Alignment (tube anode-cathode vs sensor long axis)	
	0.5 kV for 10º
Long-term drift:	0.5 kV for 1 yr
Width accuracy (2 ms - 5 sec):	0.1% of value + 0.2 ms
Ripple Error (Displayed kVp):	0.5 kV for 10%, 0-to-peak, ripple < 4 kHz

Filtration

25 - 35 µm Mo	0.1kV/µm Mo
28 - 40 kV	0.8 kV/mm Al

Reference conditions:

Temperature	21 - 23 C
Mo Anode, 30 µm Mo total filtration	
Anode current	50 mA, <1% ripple
Focus - sensor distance	30 cm

Sensor long axis perpendicular to anode-cathode axis
Sensor plane normal to focus-sensor line
Width measured at 75% of kV waveform

Diode Sensors

DDX10 W, DDX6-W diode sensors:
Energy dependence of sensitivity: +5% to -5% from 40 kVp to 120 kVp at 2.5 mm Al
Filtration dependence of sensitivity: +5% to -10% from 2.5 mm Al to 23 mm Al
Typical zero-level dose fluctuations: 1.5 µR, rms, for a 1-s pulse; 0.5 µR, rms, for a 0.1-s pulse

DDX10 M, DDX6-M diode sensors:
These sensors are calibrated for Mo/Mo. No corrections are applied for other anode/filter combinations.
Energy dependence of sensitivity: ± 5% from 25 kVp to 30 kVp at 30 µm Mo
Energy dependence of sensitivity: ± 5% from 25 kVp to 35 kVp at 30 µm Mo + 2 mm Al
Typical zero-level dose fluctuations: 1.8 µR, rms, for a 1-s pulse; 0.8 µR, rms, for a 0.1-s pulse

Ion chambers

Radcal ion chambers are unsealed. The control unit provides automatic correction for temperature, pressure and chamber calibration using a memory chip and temperature sensor located in the chamber stem and pressure measured at the control unit.
Overall ion chamber accuracy is ± 5% at reference conditions.

Ion Chamber Dose Timing Specifications

Measuring time (pulse width)
The Auto-Dose mode provides a pulse width (time) measurement capability when you use either ion chambers or dose diodes.

For ion chambers, the 10X6-6 and 10X6-6M are recommended. The range of pulse width extends from 10 ms to 9999s. The uncertainty is 4 ms (or 50 ms for the 10X6-1800 only) plus 0.1% of width.
The minimum dose rate for the 6cc Chamber is 650 mR/min or 95 µGy/s.
Minimum total dose for the 6cc Chamber is 0.54 mR or 4.7 µGy.
For other 10X6-series chambers, these minimums are inversely proportional to chamber volume.

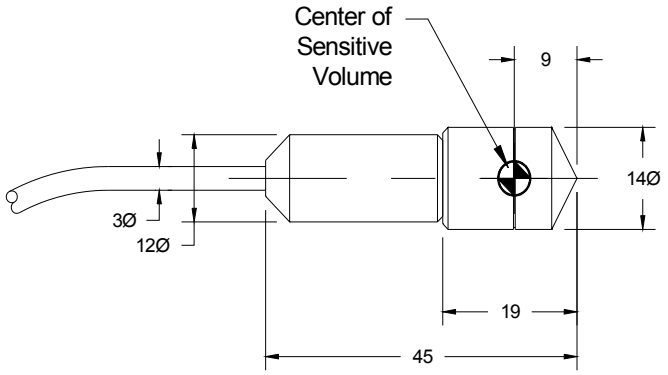
When using adapters for 10X5 or 10X9 chambers, time measurements are valid for the -6 and -6M chambers only.

For time less than 10ms, the dose diode or kV sensors are recommended.
For the DDX6 diodes in Auto Dose the width uncertainty is 1.2 ms plus 0.1% of width over a range from 5 ms to 9999 s. Minimum dose rate is 102 µGy/s or 700 mR/min.

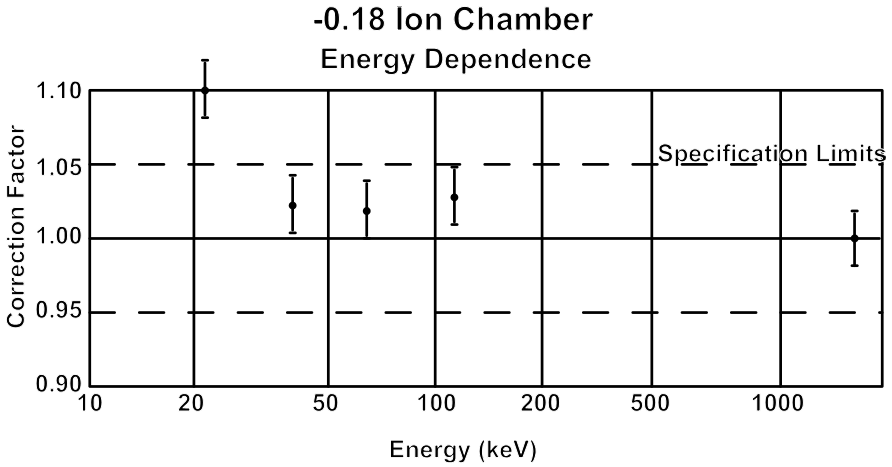
The kV Pulse mode provides pulse width measurement starting even lower at 2 ms and going up to 5.03 s when you use the 40X12-W and 40X9-M sensors. Over this range the uncertainty is 0.2 ms plus 0.1% of the width.

10X6-0.18

Exposure Rate	50 µR/s - 180 R/s	500 nGy/s - 1.58 Gy/s
Dose	200 µR - 2.0 MR	2 µGy - 17 kGy
Auto Dose Threshold	72 mR/s	631 µGy/s
Calibration	4% @ ^{60}Co	
Rate Dependence	2%, 3 mR/s - 180 R/s	
Energy Dependence	5%, 45 keV - 1.33 Mev	
Construction	C552 air-equivalent walls & electrode, 0.18 cm^3 active volume. 3 m cable	
Application	High-intensity gamma radiation in-beam measurements. Irradiators.	

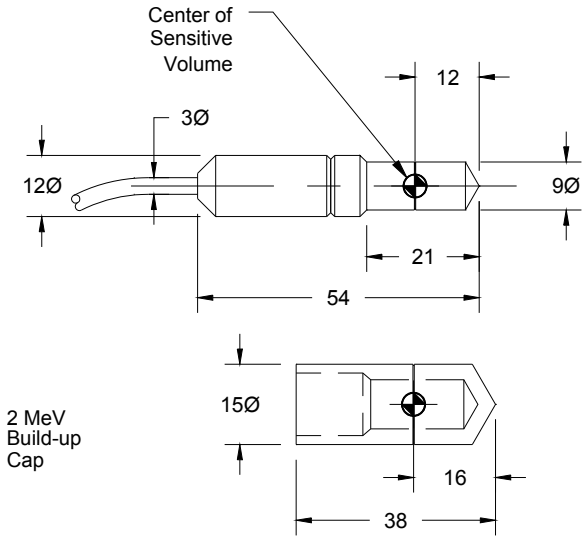


Dimensions in millimeters

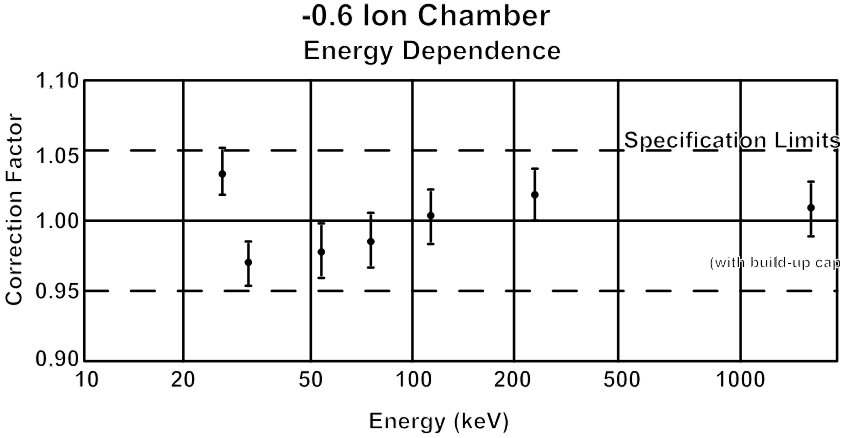


10X6-0.6

Exposure Rate	20 µR/s - 133 R/s	200 nGy/s - 1.17 Gy/s
Dose	100 µR - 589 kR	1 µGy - 5 kGy
Auto Dose Threshold	22 mR/s	189 µGy/s
Calibration	4% @ ^{60}Co	
Rate Dependence	2%, 10 mR/s - 100 R/s	
Energy Dependence	5%, 40 keV - 1.33 Mev (with buildup cap)	
Construction	C552 air-equivalent walls & electrode, 0.6 cm^3 active volume. 12 m cable	
Application	High-intensity gamma radiation in-beam measurements. Irradiators.	

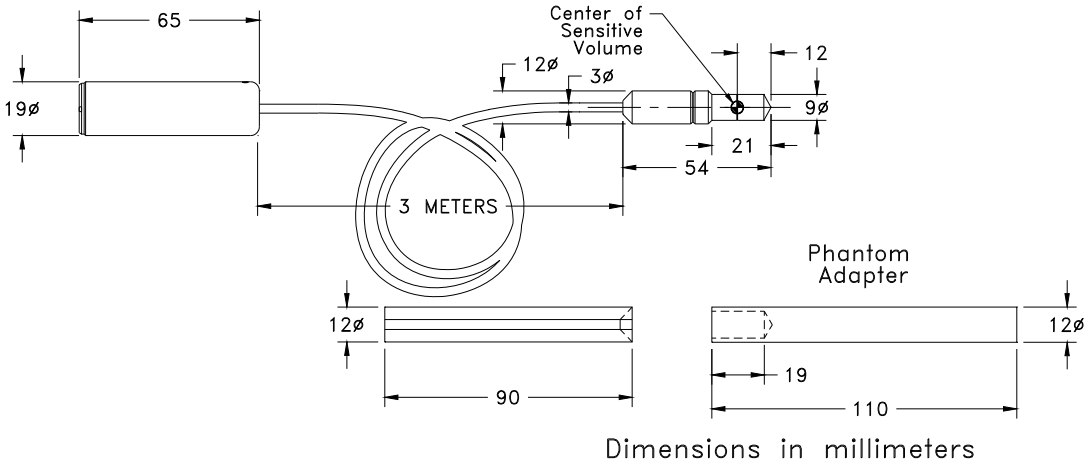


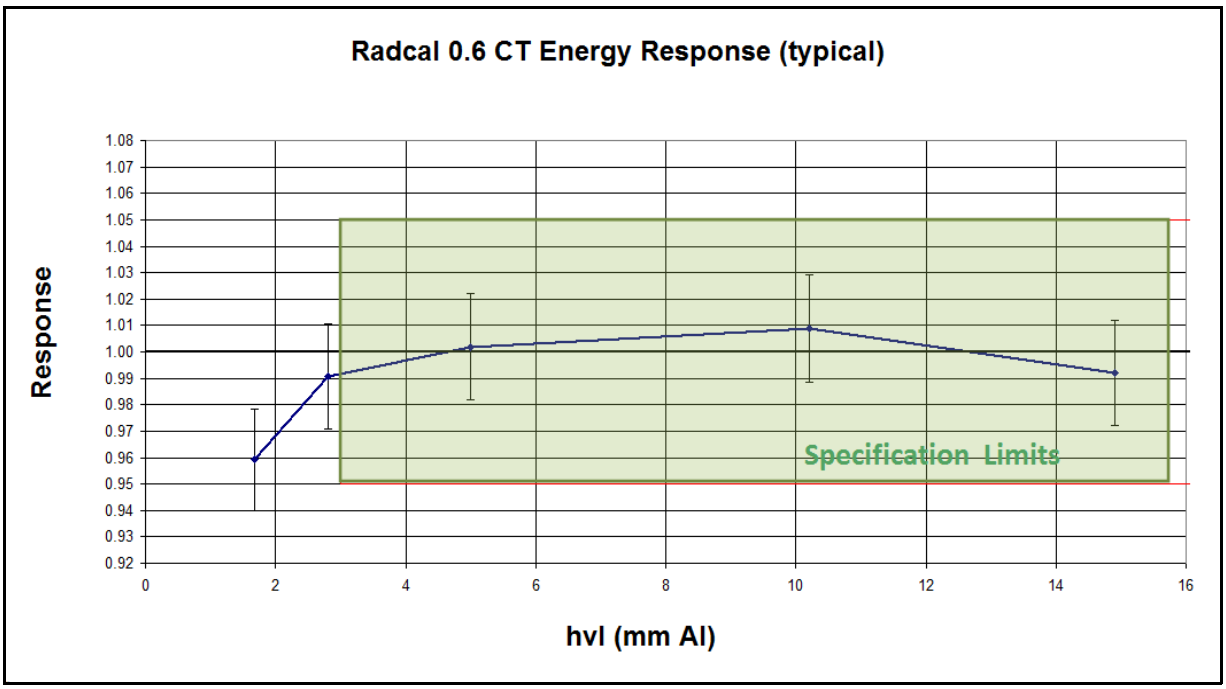
Dimensions in millimeters



10X6-0.6CT

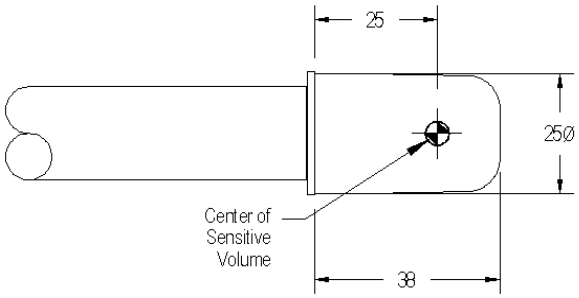
Exposure Rate	20 µR/s - 133 R/s	200 nGy/s - 1.17 Gy/s
Dose	100 µR - 589 kR	1 µGy - 5 kGy
Auto Dose Threshold	22 mR/s	189 µGy/s
Calibration	4% @ 150 kV,10.2 mm Al HVL	
Rate Dependence	2%, 10 mR/s - 100 R/s	
Energy Dependence	5%, 3 - 20 mm Al HVL	
Construction	C552 air-equivalent walls & electrode, 0.6 cm^3 active volume. 3 m cable	
Application	CT measurements.	



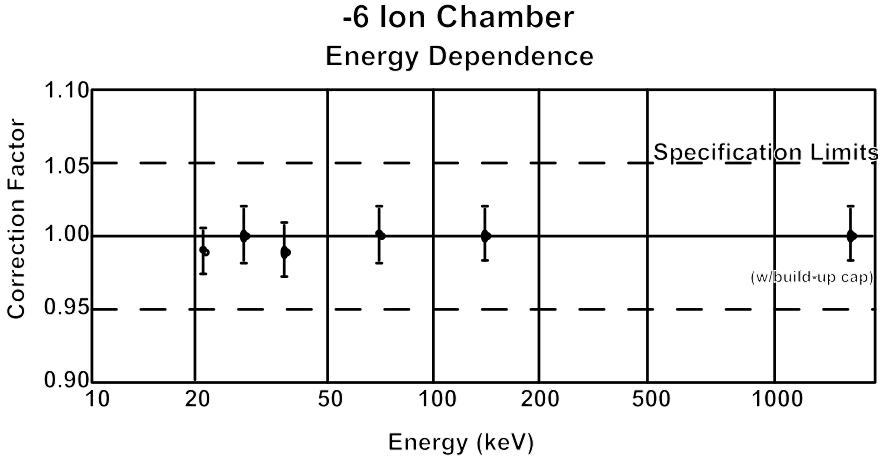


10X6-6

Exposure Rate	2 µR/s - 17 R/s	20 nGy/s - 149 mGy/s
Dose	10 µR - 59 kR	100 nGy - 516 Gy
Cine (per frame)	0.1 µR - 1 R	1 nGy - 10 mGy
Auto Dose Threshold	2 mR/s	19 µGy/s
Calibration	4% @ 60 kV, 2.8 mm Al HVL	
Rate Dependence	5%, 0.4 mR/s - 80 R/s Pulse: 500R/s, 50µs	
Energy Dependence	5%, 30 keV - 1.33 Mev (with buildup material)	
Construction	Coaxial cylinder, 25mm dia X 27mm active area. 6cm^3.	
Application	General purpose in-beam measurement Compatible with CDRH geometry.	

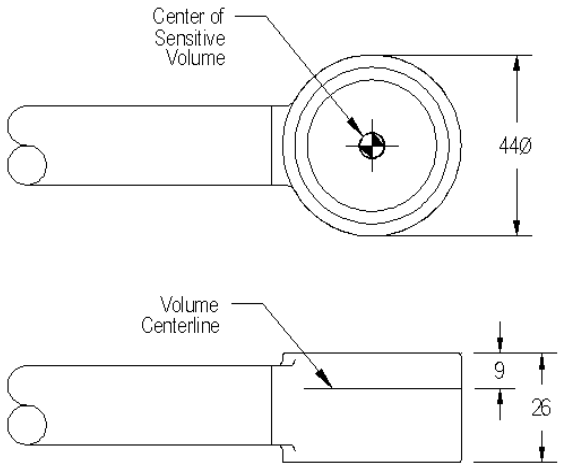


Dimensions in millimeters

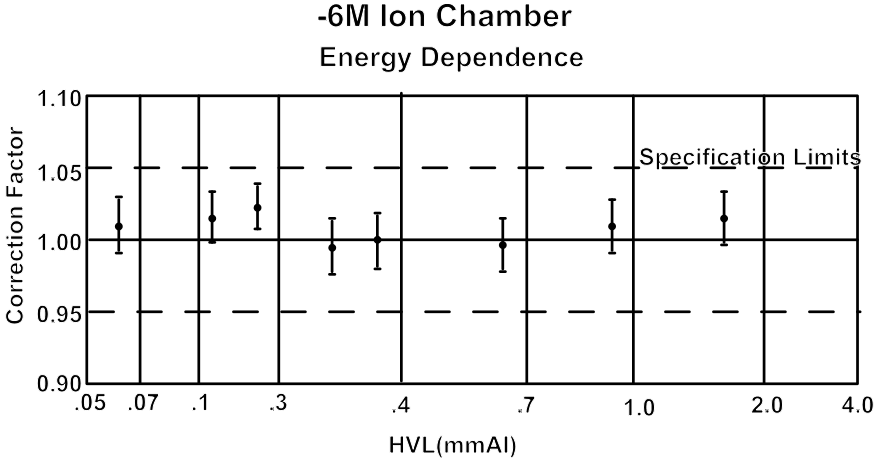


10X6-6M

Exposure Rate	2 µR/s - 10 R/s	20 nGy/s - 88 mGy/s
Dose	10 µR - 59 kR	100 nGy - 516 Gy
Auto Dose Threshold	2 mR/s	19 µGy/s
Calibration	4% @ 20 kV,0.26 mm Al HVL	
Rate Dependence	5%, 20 mR/min - 600 R/min	
Energy Dependence	5%, 10 keV - 40 keV	
Construction	Parallel plate with 0.7 mg/cm ^{2} metallized polyester entrance window. 44 mm dia 26 mm thick. 6cm^3.	
Application	Mammographic x-ray measurements	

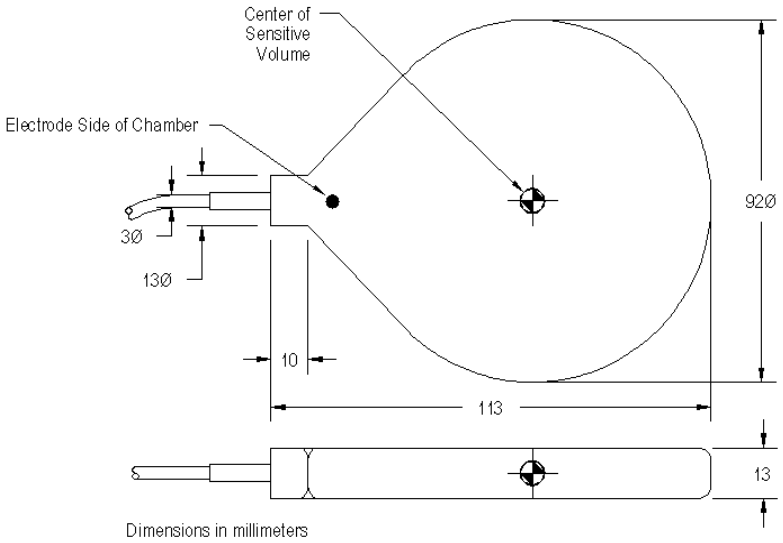


Dimensions in millimeters



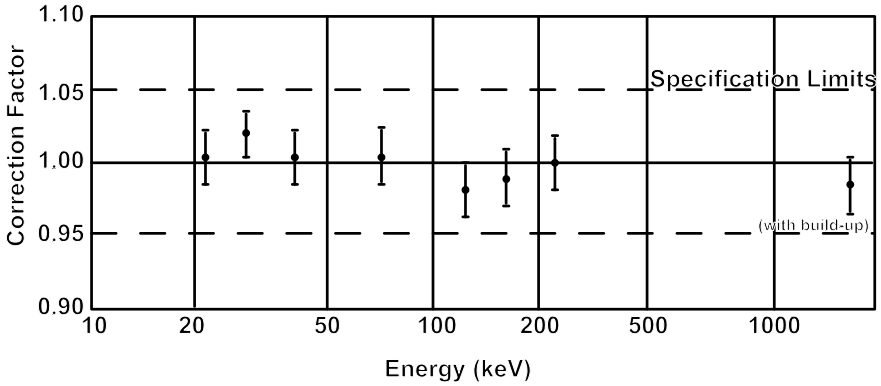
10X6-60

Exposure Rate	200 nR/s - 2 R/s	2 nGy/s - 19 mGy/s
Dose	1 µR - 5.9 kR	10 nGy - 52 Gy
Cine (per frame)	0.01 µR - 100 mR	0.1 nGy - 1.0 mGy
Auto Dose Threshold	216 µR/s	2 µGy/s
Calibration	4% @ 150 kV,10.2 mm Al HVL	
Rate Dependence	5%, 2 mR/min - 199 R/min	
Energy Dependence	5%, 20 keV - 1.33 MeV (with buildup material)	
Construction	Parallel plate. 13 mm thick x 92 mm dia 60 cm^3, 0.5 m cable	
Application	General purpose for x-ray service Use 8231 holder	



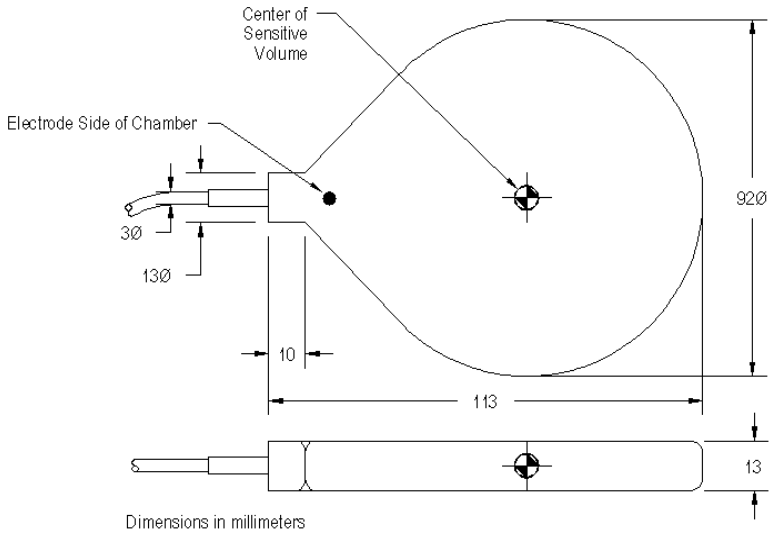
-60 Ion Chamber

Energy Dependence

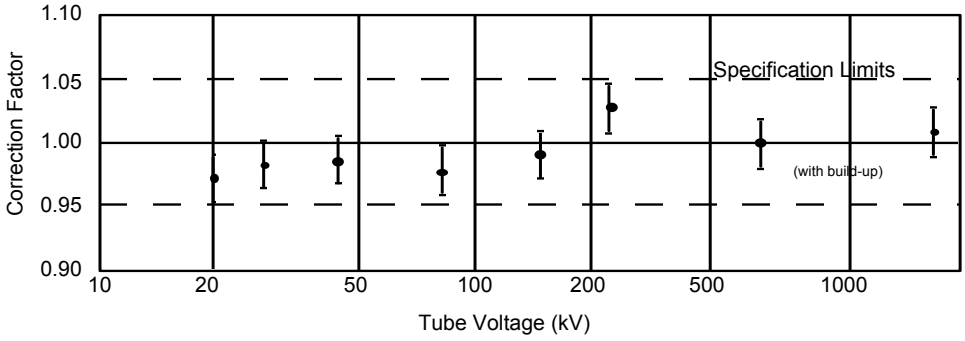


10X6-60E

Exposure Rate	200 nR/s - 2 R/s	2 pGy/s - 19 mGy/s
Dose	1 µR - 5.9 kR	10 nGy - 52 Gy
Cine (per frame)	0.01 µR - 100 mR	0.1 nGy - 1.0 mGy
Auto Dose Threshold	216 µR/s	2 µGy/s
Calibration	4% @ 50 kV, 0.88 mm Al HVL	
Rate Dependence	5%, 2 mR/min - 199 R/min	
Energy Dependence	5%, 0.2 mm Al HVL - 1.33 MeV (with buildup material)	
Construction	Parallel plate. 13 mm thick x 92 mm dia 60 cm^3, 0.5 m cable	
Application	Extended range. General purpose for x-ray service Use 8231 holder	

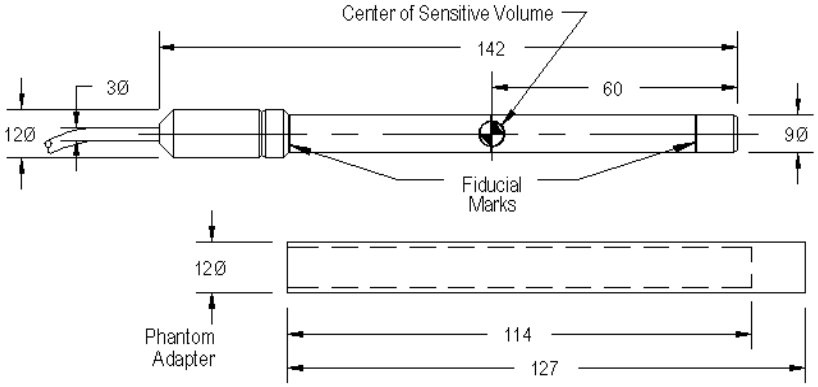


Chamber Energy Dependence



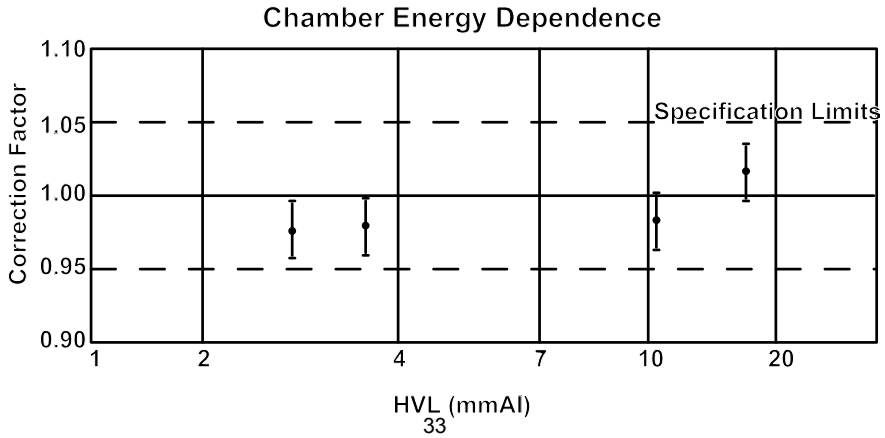
10X6-3CT

Exposure Rate	2 µR/s - 40 R/s	20 nGy/s - 350 mGy/s
Dose	20 µR - 118 kR	200 nGy - 1.0 k Gy
Auto Dose Threshold	4 mR/s	38 µGy/s
Calibration	4% @ 150 kV,10.2 mm Al HVL	
Rate Dependence	2%, 2 mR/s - 40 R/s	
Energy Dependence	5%, 3 - 20 mm Al HVL	
Construction	Concentric cylinder. 9 mm dia x 142 mm. 10 cm active length. 5% uniformity of response over central 95mm of active length for a constant volume slice. 3 cm^3 C552 air-equivalent walls and electrode. 1.5 m cable.	
Application	CT measurements.	



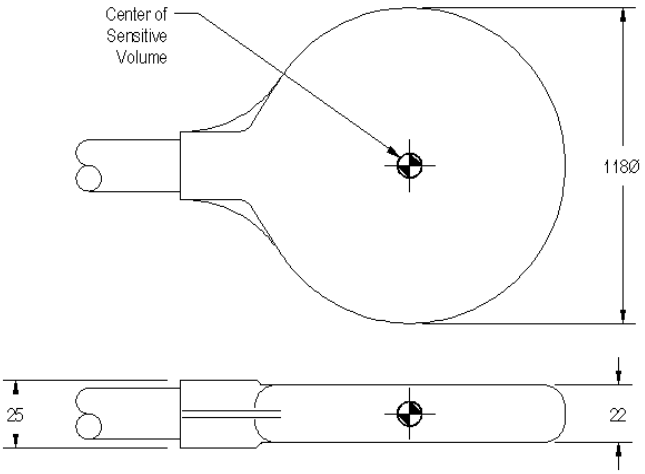
Dimensions in millimeters

3CT Ion Chamber

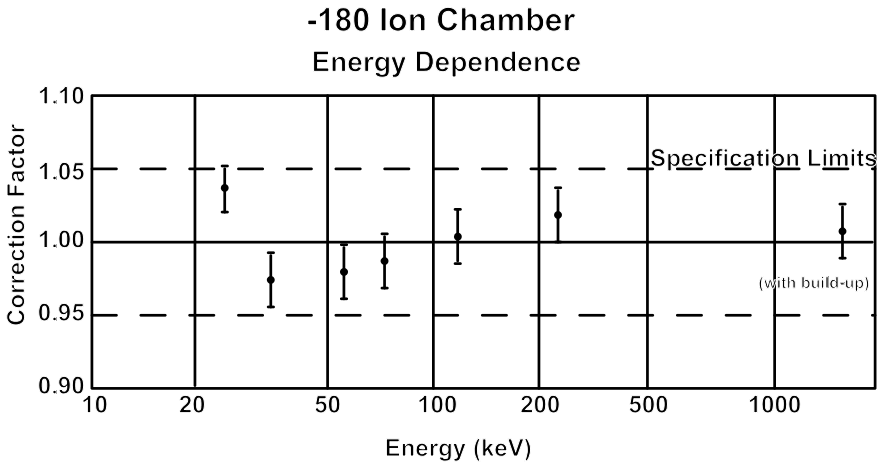


10X6-180

Exposure Rate	100 nR/s - 600 mR/s	1 nGy/s - 4.9 mGy/s
Dose	200 nR - 2 kR	2 nGy - 17 Gy
Auto Dose Threshold	72 µR/s	1 µGy/s
Calibration	4% @ 150 kV,10.2 mm Al HVL	
Rate Dependence	5%, 20 mR/hr - 2 kR/hr	
Energy Dependence	5%, 30 keV - 1.33 MeV (with buildup material)	
Construction	Parallel plates. 118 mm dia x 22 mm 180 cm^3	
Application	Leakage measurements. 100 cm^2 effective area.	

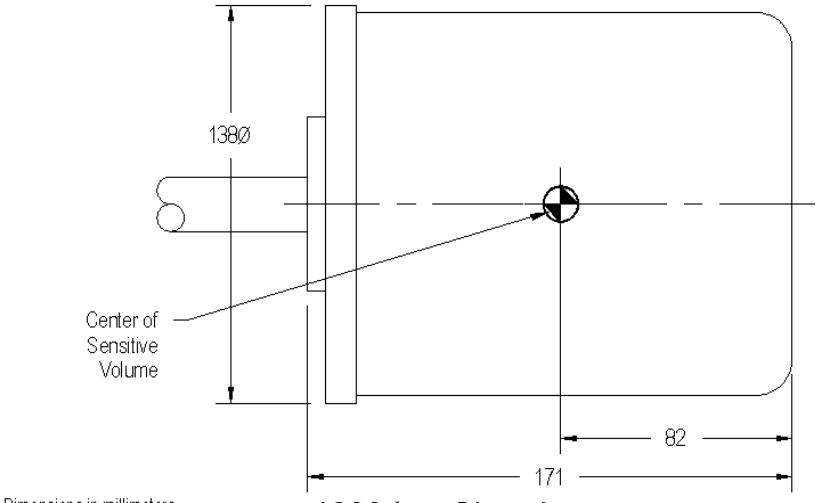


Dimensions in millimeters



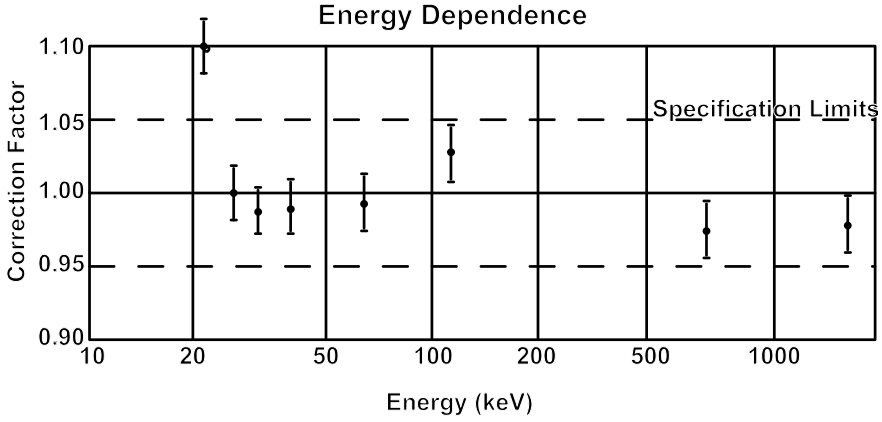
10X6-1800

Exposure Rate	5 nR/s - 18 mR/s	50 pGy/s -200 µGy/s
Dose	20 nR - 196 kR	200 pGy -1.7 Gy
Auto Dose Threshold	7 µR/s	63 pGy/s
Calibration	4% @ 150 kV,10.2 mm Al HVL	
Rate Dependence	+0, -5% 0.1 mR/hr - 20R/hr -10 % @ 65 R/hr	
Energy Dependence	5%, 30 keV - 1.33 MeV (with buildup material)	
Construction	Concentric cylinder. 138 mm dia x 171 mm. 1800 cm^3	
Application	Shield leakage, low-level irradiators, environmental measurements.	



Dimensions in millimeters

-1800 Ion Chamber



Waveform Output[1]

Sensitivity	20mV/kV 200mV/R/s[2] 0.5mV/mA[3]
Full scale	4V
Output impedance	100 Ω
Sample Rate	77 µs
0.5 db frequency	1.0 kHz
3 db frequency	2.3 kHz

[1]Waveform only available in kV modes
[2]Requires 40X11-W and DDX10 -W or 40X10-M and DDX10-M
[3]Requires mA sensor 90M9 or 90M10

Part number reference

Part numbers

Description	Part Number
Control Unit	9096
Sensor Cable (4m)	90C6-4
Diagnostic Accu-kV sensor (with auto compensation)	40X12-W
Mammographic Accu-kV sensor	40X9-Mo
Dose diode digitizer	DD60
Diagnostic Dose diode sensor	DDX6-W
Mammographic Dose diode sensor	DDX6-M

Description	Part Number
Ion Chamber digitizer	9660
6cc Ion Cham ber	10x6-6
Mammographic Ion Chamber	10x6-6M
60cc Ion chamber	10x6-60
CTDI Ion chamber	10x6-3CT
180 cc Ion chamber	10X6-180
1800 cc Ion Chamber	10X6-1800
Extension cable (2m)	90E6-2
Invasive mA Sensor	90M9
Noninvasive mA sensor	90M10

OPERATOR MESSAGES

Messages are displayed and a beep sounds when the Accu-Pro™ is unable to perform a measurement. Pressing SELECT generally proceeds. Pressing *UP* or *DN* exits to the main menu.

Self-test

"Battery LOW"	Replace or recharge battery
"Analog volt fail"	Precision voltages are out of tolerance. Measurement accuracy is questionable.
"Logic volt fail"	Logic supply voltage is out of tolerance. May shutdown or operate erratically.
"No converter"	No dose converter connected. Proceeds after 3 seconds.
"No dose sensor"	Press SELECT to proceed.
"EPROM error"	Press SELECT to proceed.
"Temp Error 1,2"	Unable to read temperature sensor.
Temp Error 3	Temperature out of range.
"No kV sensor"	Proceeds after 3 s or SELECT.
"Std 22 deg C"	Standard temperature was selected.
"Std 101.3 kPa"	Standard pressure was selected.
"Bias failed"	Bias voltage is out of tolerance. Measurements may be in error.

Accu-kV

These messages result from operations involving the Accu-kV sensor. They are displayed for at least two seconds. The underlined header in the following is the first line of the message.

<u>"Exposure Error"</u>

These errors arise from problems with the x-ray signal.
After two seconds, the messages become "kV - try again" and "Error cleared", and a new measurement can be performed.

"Too narrow 1,2,3"	Waveform was too narrow.
"Too weak 1,2"	Intensity was too low.
"Too strong"	High intensity caused saturation.
"kV too small"	Measured kV was too small.
0.00 kV	Measured kV too large. Allows dose outputs.

<u>"KV - wait"</u>

These arise form problems that often clear themselves. If the error condition clears, the messages become "kV - try again" and "Error cleared", and a new measurement can be performed.

W	Accu-kV zero level is unstable.
"Bad kV zero"	Zero level too small.
"Measure abort"	Processing was interrupted.
"Bad W/Ag kV"	Measured kV is in bad-accuracy range for W/Ag correction.

<u>"kV failure"</u>

These arise from a faulty or missing Accu-kV sensor
If connecting a working Accu-kV sensor clears the error condition, the messages become "kV - try again" and "Error cleared", and a new measurement can be performed.

"ADC error"	Analog-to-digital converter problem. May be an Accu-Pro™ fault.
"EPROM error"	The sensor EPROM did not respond properly.
"No sensor"	EPROM not found or zero level too large.
"Zero failed"	Zero didn't stabilize within 2 minutes. Unstable zero values cause "W" to appear in the lower-left corner of the display.

“Dose diode fail”
These errors arise from problems with the DDX10 kV dose diode. If connecting a working diode clears the error condition, the messages become “kV - try again” and “Error cleared”, and a new measurement can be performed.

"No kV diode"	The diode was not connected to the Accu-KV sensor and a dose-related measurement is specified.
“Wrong kV diode”	The wrong diode is connected to the Accu-kV sensor.
"EPROM error"	The diode EPROM did not respond properly.

“System error”
The top line of the display shows “System error”, with the bottom line showing one of several messages. Exits to the main menu after displaying the message for two seconds. Contact Radcal if it persists.

Ion chambers and dose diodes

These messages arise when measuring dose and dose rate using ion chambers or the DDX6 dose diodes.

Starting a measurement:

“Dose sync fail”	Press SELECT to retry.

While measuring zero:

“Zero too small”	Press SELECT to continue. Measurements near minimum dose rate for the selected sensor may be inaccurate.
“Zero too small”	
“Zero unstable”	

While measuring dose or dose rate:

“?”	In the upper left corner. Indicates the sensor is operating above its specified maximum rate.

While measuring dose-rate
Automatic retry after 3 s.

“Input negative”	The converter output reached zero.
“Conv overload”	The input current overloaded the converter.

While measuring dose
Displayed until user presses SELECT, then function exits.

“Input negative”	The sensor signal was negative..
“Conv overload”	The sensor signal exceeded full-scale.
“Dose overflow”	The total dose was too large.
“Time overflow”	The dose-accumulation time was too large.

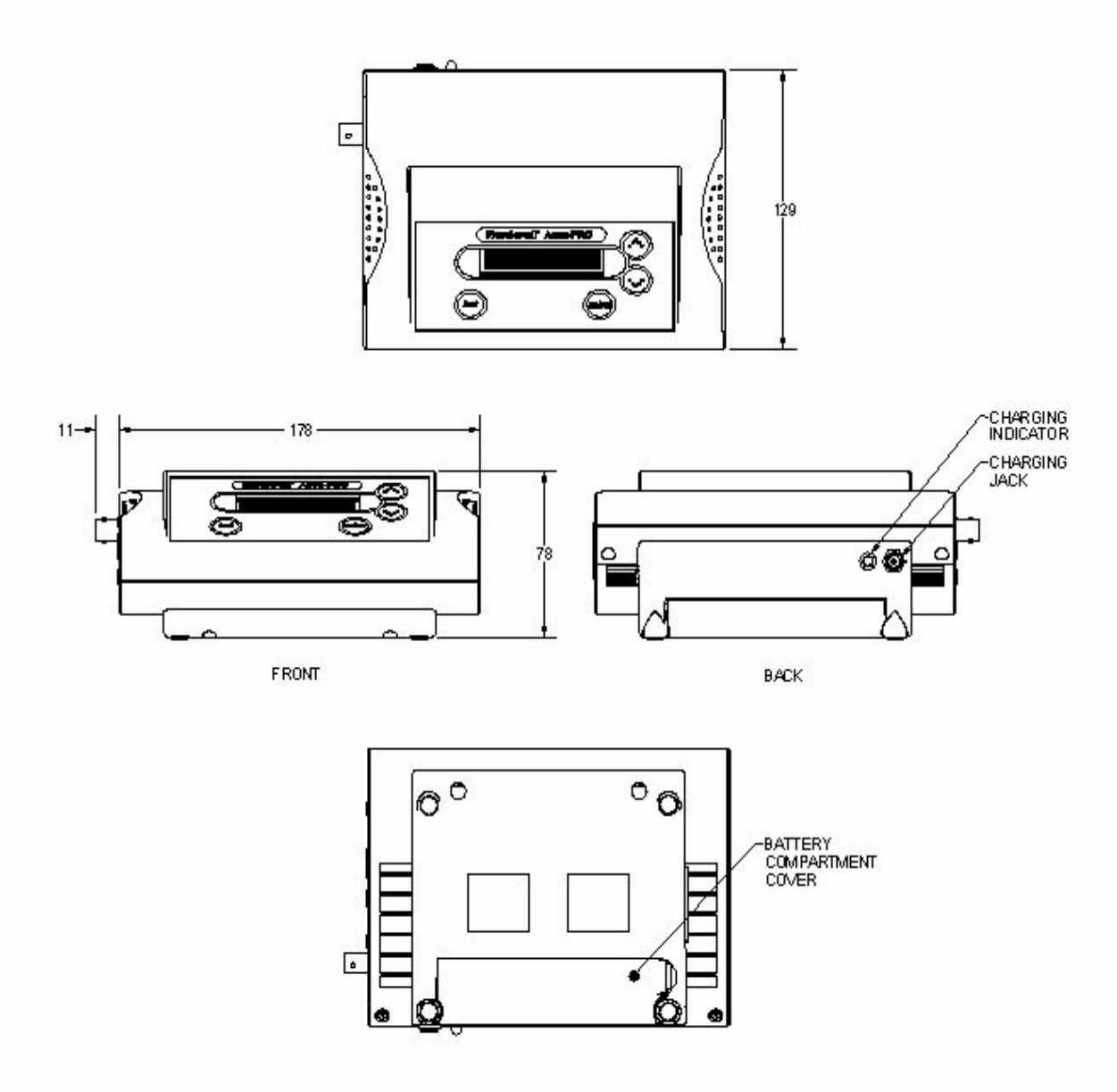


Figure 24 - Control Unit Configuration

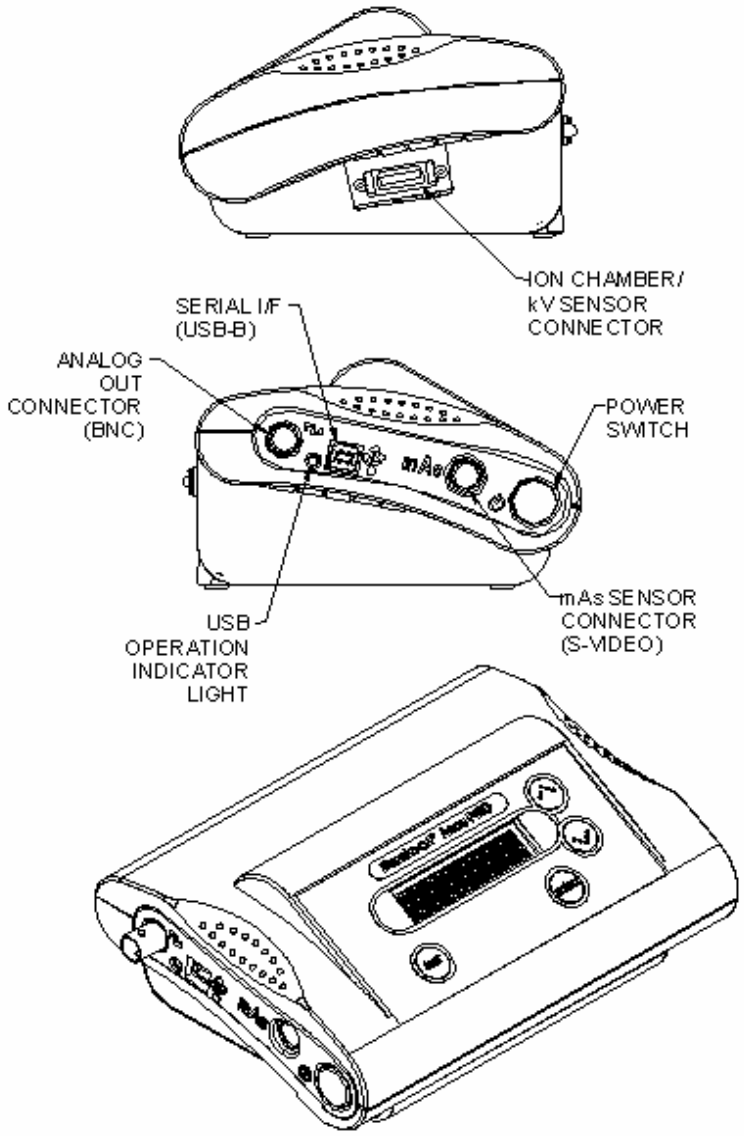


Figure 25 - Connector Locations

ACCESSORIES

XLPRO Excel add-in

XLPRO is a Microsoft Excel add-in that provides control and communication within Excel via the USB connection. It uses the computational and display capabilities of Excel to record, analyze and display Accu-Pro™ measurement results on a PC. XLPRO can control the Accu-Pro™ system as well, so test protocols can be automated to provide consistent results and guided operation.

Using XLPRO

- Connect a USB cable between the PC and the Accu-Pro™ control unit. If the green LED illuminates (it is not very bright) the Radcal USB software is installed on the PC; otherwise you need to install XLPRO version 4 or later.
- Turn on the Accu-Pro™, wait for self-test to completed, and then start XLPRO.
- XLPRO is now in control of the Accu-Pro™. ***select****, UP* and *DN* are disabled. The display reads:

Control locked
by PC over USB

While XLPRO is making measurements the display will show measurement results in default units: R, /min, fixed Temperature and Pressure . Unit conversion and environmental correction is handled within XLPRO. The user selections are restored when the USB is disconnected or when XLPRO ends. While the USB is active, the power-off timer is disabled.

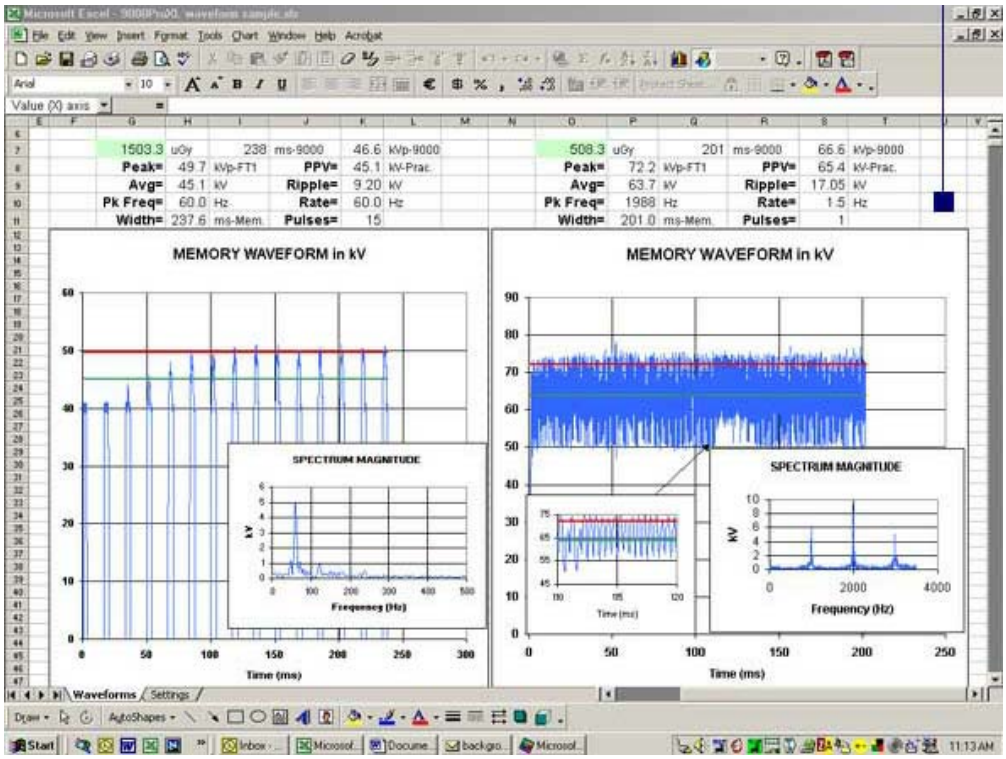
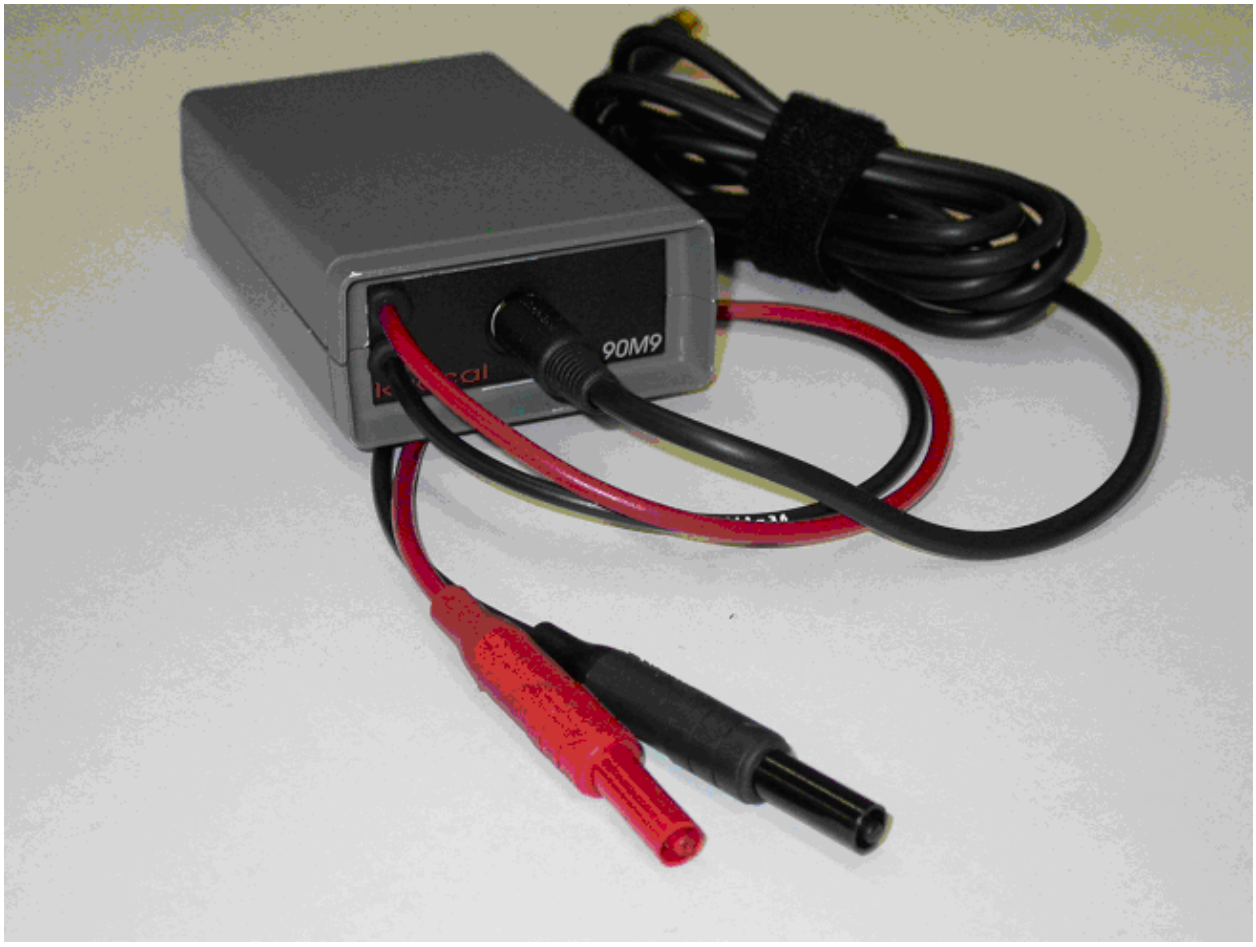


Figure 26 - XLPRO sample

90M9 mAs Sensor

Battery-powered, isolated, Invasive mA sensor
Synchronized to Accu-kV measurement
Real-time waveform.
Automatic zero and no range switching.
2000 mA or 9999 mAs full-scale
Measures absolute value of mA.
0.2% mA accuracy
5 µAs or 0.2% mAs accuracy (1-s pulse)
Input impedance: Fixed, resistive, 1 ohm plus fuse and wiring.
Withstands1500 vac between input leads and control unit.
77 µs sample rate
-2.6% at 720Hz, -3 dB at 2.33 kHz.
Digital waveform sent over the USB port to XLPRO
Automatic turn-on only when kV function is active
Battery lifetime: Approximately 30 operating hours.



90M10 mAs Sensor

Battery-powered, isolated, clamp-on non, invasive mA sensor
Aperature 23mm.
Synchronized to Accu-kV measurement
Real-time waveform.
Automatic zero and no range switching.
2000 mA or 9999 mAs full-scale
Measures absolute value of mA.
Resolution greater of 3-4 digits or .015mA
mA accuracy:
    ±4% of reading (Limited by 0.6mA RMS noise below 15mA).
mAs accuracy (1-s pulse):
    ±4% of reading (Limited by 0.6mAs RMS noise below 15ma).
77 µs sample rate.
-2.6% at 720Hz, -3 dB at 2.33 kHz.
Digital waveform sent over the USB port to XLPRO
Automatic turn-on only when kV function is active
Battery lifetime: Approximately 35 operating hours.

Caution: In the presence of strong electromagnetic fields, performance may degrade up to 1 Amp.

10A96 Ion chamber Adapter

This adapter adapts the 10X5 ion chambers to the 9660 ion chamber digitizer. It contains a microprocessor that translates between the jumpers, resistors and potentiometer located within the probe stem of 10X5-series ion chambers into signals that mimic the EAROM that holds calibration and chamber-type information the Accu-Pro™ requires. A temperature sensor is included to provide that information also. Its diameter is slightly larger than that of the chamber stem, with a hard-mounted microdot connector on one end and a 9096-style connector on the opposite end. It draws power from the 9660 Ion Chamber digitizer.

90E6-2 - Extension cable

The extension cable allows one to place the ion chamber up 2 meters away from the digitizer. (Other lengths available)

Chamber Positioner

The chamber positioner locates an ion chamber at a fixed height from the x-ray table. Holes in the base of the chamber positioner locate the kV sensor relative to the ion chamber to control the effect of backscatter from the kV sensor on exposure measurements. Because mammography measurements using th 6M chamber are less affected by backscatter, the mammography kV sensor may be positioned closer to the chamber. The Figure 29 shows suggested arrangements.

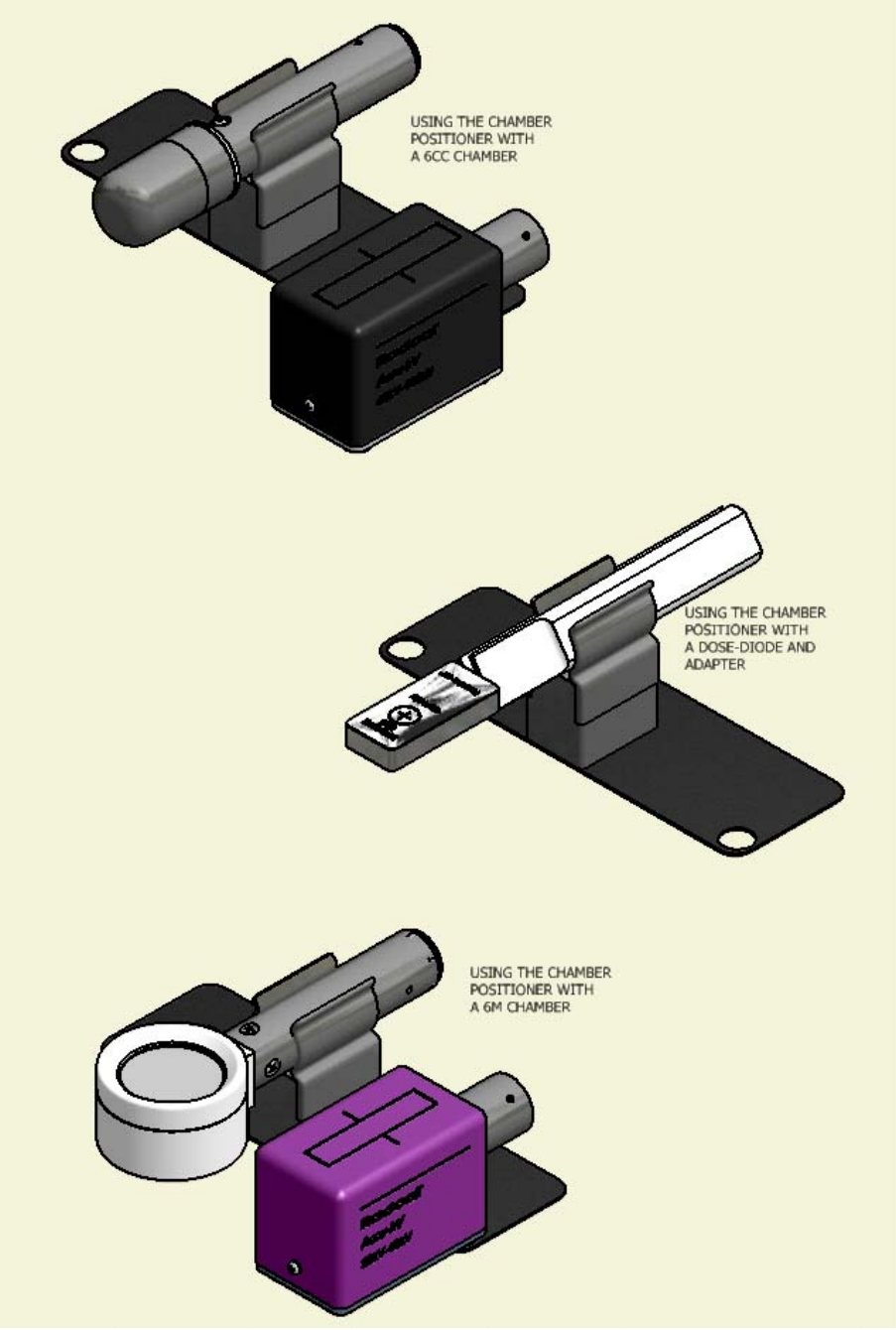
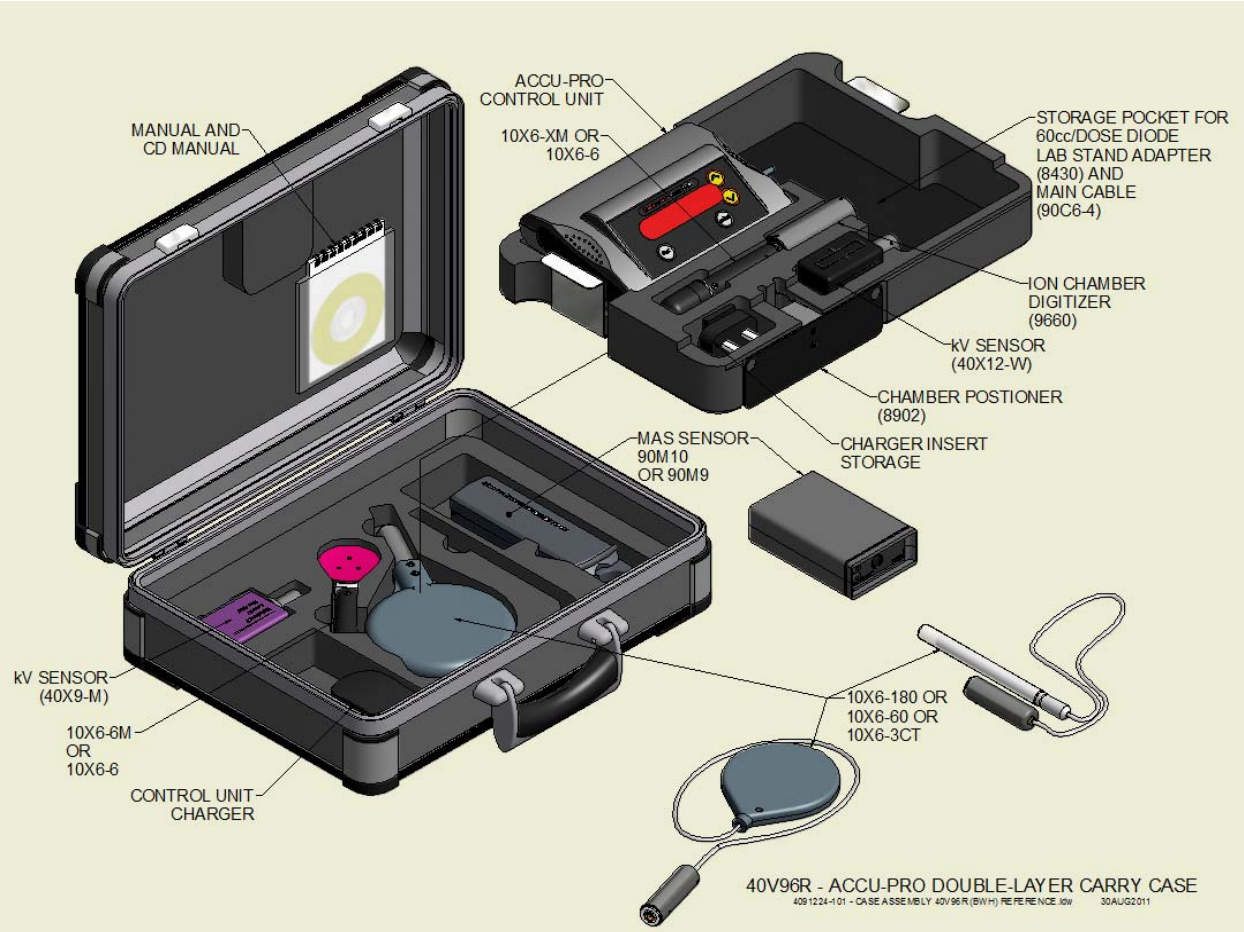
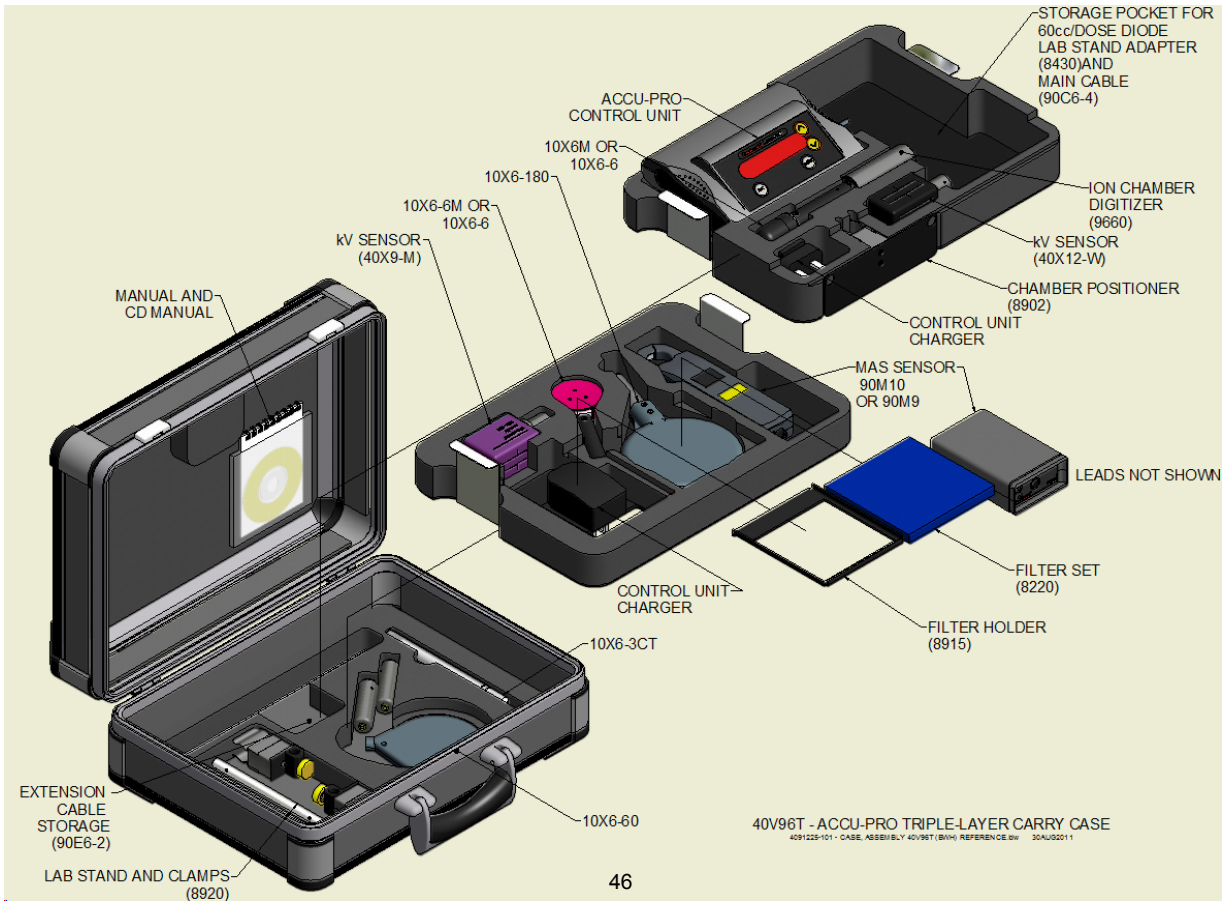


Figure 29 - Positioner/Chamber relationship

Accu-Pro™ System Carrying Cases





APPENDIX - Mammography kVp measurements on Hologic Selenia

Using a Radcal kVp Meter to Measure kVp's on Hologic Selenia Mammographic X-ray Machine Equipped with a Tungsten-Rhodium, Silver Tube Option

A Radcal kV meter with a 40X series Mo sensor may be used with a look-up correction algorithm to obtain Selenia W-Rh, Ag kVp's with an accuracy of +/- one kVp. Radcal recommends the Selenia Tungsten-Ag/Rh tube be calibrated as follows.

After going into manual mode on the Hologic machine and selecting large focal spot,100mAs, place the Radcal 40X9-Mo kV sensor on top of the Bucky table. The small compression paddle may be left in-beam. Align the Radcal kV sensor so that its long axis is 90 degrees to the tube anode -cathode axis so as to eliminate heel effect. Move the sensor about one inch in from the table edge. Center the sensor right to left. Do not to forget to protect the imaging plate by placing and then smoothing out a lead apron over it.

Use the Rhodium track to calibrate the 22 to 39 kV Selenia range and the Silver track to refine the 22 to 24 kV range to obtain a few more tenths accuracy if required from 22 to 24 kV. An example Selenia calibration is shown below.

A Tungsten/Silver setting is different from the Tungsten/Rhodium setting. There is a range of calculated kVp's (25-33 kV) that exceed a set error band and the instrument will show an error message as a result.

The data used to construct the correction algorithm were recorded by comparing a kVp's obtained with Radcal Dynalyzer High Voltage Divider (True kVp) and the kVp's displayed on Radcal kVp meters during Selenia exposures with the small compression paddle in-beam. These data were obtained from five Selenia machines during Acceptance testing in manual mode.

Example of a Selenia calibration

	Dynalyzer	Ag	Rh	Ag	Rh
Set kVp	True kVp	9096 kVp	9096 kVp	Radcal-True	Radcal-True
22	22.0	22.5	22.5	0.5	0.5
23	23.0	23.0	23.5	0.0	0.5
24	24.0	24.2	25.0	0.2	1.0
25	25.0		25.6		0.6
26	26.0		26.1		0.1
27	27.0		27.3		0.3
28	28.0		28.1		0.1
29	29.0		29.3		0.3
30	30.0		30.1		0.1
31	31.0		30.9		-0.1
32	32.0		32.1		0.1
33	33.0		33.2		0.2
34	34.0	34.4	34.2	0.4	0.2
35	35.0	35.4	35.1	0.4	0.1
36	36.0	36.3	36.1	0.3	0.1
37	37.0	37.3	37.1	0.3	0.1
38	38.0	38.4	38.1	0.4	0.1
39	39.0		39.4		0.4

Warranty for the Accu-Pro™ Measurement System

Radcal warrants that, in the event that any defects in material or workmanship should develop within one year of the date of shipment, the company assumes full responsibility for servicing equipment of its manufacture without charge upon return of the equipment to Radcal, with shipping costs prepaid by the customer. Costs to return-ship to customer by ground transportation will be paid by Radcal if the repairs are warranty-applicable. This warranty excludes batteries.
Radcal shall not be held liable for damages or delays caused by defects beyond making repairs or furnishing replacement parts, nor shall Radcal be liable for any defective material replaced without Radcal's consent during the period of this warranty. Radcal reserves the right to perform warranty services at its own factory.

Non-Warranty Repairs

The calibration of this instrument was correct within specified limits when the instrument left our factory. Radcal cannot be responsible for injury or damage resulting from improper use or calibration errors which develop subsequent to our shipment of the instrument.
If Radcal determines that a fault has been caused by misuse, abnormal operating conditions, or repairs by unauthorized personnel during the warranty period, repairs and shipping costs will be billed at normal rates.
If the equipment is found to be in proper working condition, Radcal will return-ship the equipment at customer expense.

Declaration of Conformity
According to ISO/IEC 17050 and EN 45014

The Radcal declares, under our sole responsibility, that the **Accu-Pro™** Measurement System conforms to the following product specifications.

EMC: EN 50081-2 / EN 555011 Class A
EN 50082-1 / IEC801-2, 4 kVcd, 8 kVAD
EN 50082-1 / IEC801-3, 3V/m

Note: The Analog Output is intended for use by trained users. Observe proper ESD precautions when using this connection.

QA Manager
Date: 2007 September 27

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