FLUKE®
Biomedical

Victoreen® 8000

NERO® mAx

Users Manual

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Section 1
General Information

1.1 Product Description

NOTE

To proceed directly to "Quick Start", go to Section 2.4.

To proceed directly to "Setup Mode", go to Section 2.5.9.

The Victoreen NERO™ mAx Model 8000, **Non-invasive Evaluator of Radiation Output**, uses an innovative system of menus and softkeys to provide an intuitive, user friendly operating environment. All measurement modes and options are displayed on the NERO mAx's LCD and all functions are controlled by the 5 softkeys beneath the display and the 3 keys to the right of the display.

The NERO mAx consists of the NERO mAx control console, detector, detector cable, filter slides, AC adapter, HVL plates, manual, Microsoft® Excel Add-in and carrying case.

The NERO mAx control console is compact and easy to use. The sophisticated electronics necessary to provide highly accurate, reproducible measurements while maintaining an intuitive, user friendly operating system are in the NERO mAx control console. The NERO mAx's rechargeable battery is also housed in the control console. The front panel of the control console contains a backlit 240 x 64 pixel, dot matrix LCD display and eight push buttons. Connectors for power input, RS-232, printer, scope output and the NERO mAx detector are located on the control console's rear panel.

Figure 1-1.Control Console Front Panel

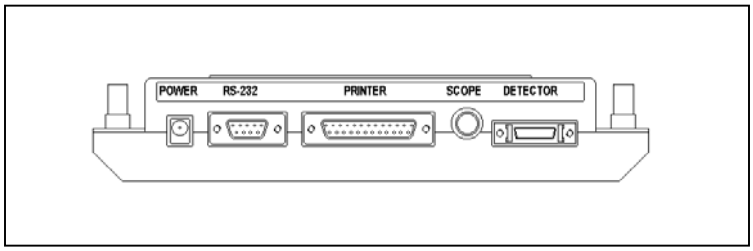
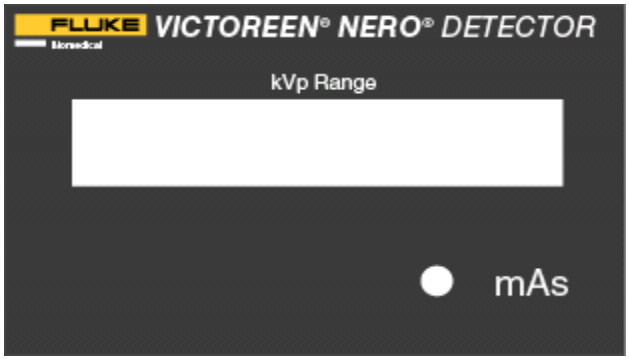
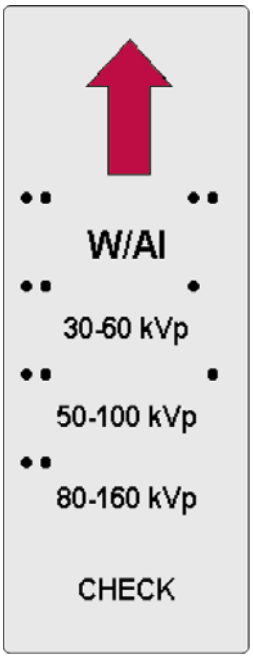


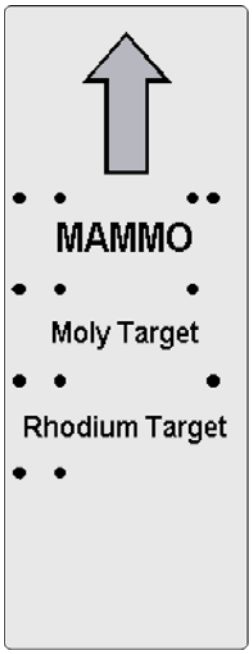
Figure 1-2. Control Console Rear Panel



The NERO mAx detector contains sensors for simultaneously measuring kV, exposure or rate and invasive mA or mAs. Solid-state detectors are used to measure kV. An ion chamber, located in the top of the detector, is used for exposure/rate measurements. In addition, connectors for an external ion chamber are provided on the rear panel of the 8000 detector. The NERO mAx detector's interface connector is also located on the detector's rear panel. The front panel has a keyed opening for the model 8000-filter slides and a connector for mAs leads.

The NERO mAx filter cards contain the various filters needed to accurately measure kilovoltage. Each filter card is coded so that the NERO mAx "knows" which filter is in use and its position. The NERO mAx also verifies that the filter card is valid for the selected measurement mode. In addition, the filter cards are keyed so that they may only be inserted one way. The W/Al filter card is labeled with the kVp ranges for which it is calibrated. The Mammo filter card is labeled for the x-ray tube targets for which it is calibrated.





The serial numbers of the NERO mAx control console unit, detector and filter cards must be matched in order to obtain accurate results. Since the control console unit, detector and filter cards are calibrated together, they must be used together for accurate measurements.

1.2 New Features of Firmware Release 2.3

This release adds several new features to the Radiographic mode that give the NERO mAx greater flexibility when making kV and exposure time measurements on all types of radiographic and dental x-ray machines.

1. The %kV setting provides more time measurement options:
   - Time measurements from 90%, 80%, and 75% of the peak kV.
   - Pulse counting and zero crossing settings for single-phase generator time measurements.
2. User settable measurement delay allows:
   - kV overshoot portion of waveform to be excluded from kV analysis.
   - Exclusion of x-ray generator preheat pulses from kV and time analysis.

More information on these new features may be found in "Using a Measurement Delay" and "Using %kV and Exposure Time Measurements" at the end of Section 2.5.1--Radio Mode.

1.3 Specifications

Kilovoltage

Measured during the first 480 ms of exposure

Accuracy:	0.5 kV or ± 1%	
Reproducibility:	0.5 kV or ± 1%	
Range:	W/Al	30 - 60 kV
		50 - 100 kV
		80 - 160 kV
	Mo/Mo	22 - 35 kV
	Mo/Rh	22 - 40 kV
	Mo/Al	22 - 49 kV
	Rh/Rh	25 - 49 kV
	Rh/Al	25 - 49 kV

Time To Display

Radio & Mammo:	3 seconds for 0.1 second exposure
	1 second for each 32 ms of exposure time
Fluoro & AMSE:	15 seconds for all exposures

Time

Measured during entire exposure at 90% rise/fall of waveform.

Accuracy:	1 ms
Range:	1 ms to 60 sec

Exposure/Exposure & Rate

Measured during entire exposure; kVp corrected.

Accuracy:	± 5%
Reproducibility:	(Radio & Mammo Modes) ± 2% or 2 mR
Range:	1 mR minimum

mAs and mA

Measured during entire exposure

Accuracy:	± 2%
Reproducibility:	± 1% or 0.2 mAs
Range:	1 - 1000 mA

HVL

Accuracy:	± 5%
Range:	.1 - 99.9 mmAl

Physical

Display:	240 x 60 pixel, super twist LCD w/ccfl backlight
Power:	115 or 230 VAC External Supply. Rechargeable internal batteries supply more than 4 hours of continuous service with overnight charge.

Size:

Console:	9.00" x 9.12" x 3.25" (22.86 mm x 23.17 mm x 8.26 mm)
Detector:	6.56" x 3.70" x 2.58" (16.66 mm x 9.4 mm x 6.55 mm)
Slides Only:	2.4" x 6.25" x 0.31" (6.1 mm x 15.88 x 0.8 mm)

Operating Conditions:

10° C to 40°C (50° F to 104° F)

Maximum 90% relative humidity (non-condensing)

Weight:

Console:	4 lbs. 9.0 oz. (2.067 kg)
Detector:	1 lb. 10.4 oz. (with slide) (.747 kg)
Slides Only:	2.9 oz. & 3.2 oz. (.090 kg & .094 kg)

HVL Set

2.30 mm, 1.0 mm, 0.3 mm

Calibration

W/Al	calibrated with 4.5 millimeters of Aluminum total filtration
Mo/Mo	calibrated with 30 microns of Molybdenum filtration
Mo/Rh	calibrated with 25 microns of Rhodium filtration
Mo/Al	calibrated with 1 millimeter of Aluminum filtration
Rh/Rh	calibrated with 25 microns of Rhodium filtration
Rh/Al	calibrated with 1 millimeter of Aluminum filtration

1.4 Battery Operation and Charging

The NERO mAx has an internal rechargeable battery which provides up to four hours of continuous operation depending upon usage. The NERO mAx draws twice as much power from its from its battery when it is actively making measurements than it does when in an idle state with its backlight off. To conserve and extend battery life, the NERO mAx incorporates several power saving features. The display backlight automatically turns off after one minute of inactivity. The backlight turns on when any key is pressed or an exposure is made while in any measurement mode. In addition, the NERO mAx exits from any measurement mode after five minutes of no activity. Pressing the ENTER key restores the NERO mAx to its previous measurement mode.

The NERO mAx utilizes two levels of protection to assure reliable operation when the battery charge becomes low. The first level of protection is a warning that is displayed when there is approximately 20 minutes of battery life remaining. During this time, the AC adapter may be plugged into the NERO mAx to continue operation without interruption. The second level occurs when the battery charge is insufficient to guarantee proper operation. When this occurs, the low battery indicator in the lower left corner of the front panel illuminates and the instrument shuts down, becoming inoperable. When this happens, the AC adapter can be plugged into the NERO mAx to restore operation. The NERO mAx “remembers” what mode it was in before it shut down and returns to that mode upon power up. Pressing the ENTER key returns the NERO mAx to its measurement mode.

The battery is charged whenever the NERO mAx is connected to its AC adapter and the adapter is plugged into a suitable power source. When the power switch is on, the battery is charged at a low rate that is enough to sustain the battery’s charge. When the power switch is off, the battery is charged at a high rate.

To fully charge the battery, make sure that the NERO mAx is turned OFF, plug the AC adapter into the rear of the NERO mAx console and plug the adapter into a suitable power source. The green battery

charge indicator on the front panel of the NERO mAx console illuminates when the battery is charging. When the battery charge indicator is off, the battery is charged. It may take up to 16 hours to fully recharge a severely discharged battery.

1.5 Printing

All of the exposure results displayed by the NERO mAx may be printed automatically if desired. The data that is sent to the printer includes the NERO mAx's mode of operation and selected options, the current time and date, and the measured data. The NERO mAx uses a standard IBM compatible PC printer cable.

With the NERO mAx turned off, plug the computer end of a standard IBM compatible PC printer cable into the printer port at the rear of the NERO mAx then plug the printer end of the cable into the printer and turn the printer on. Plug the AC adapter into the 8000 if needed (see Section 1.4--Battery Operation and Charging) and turn the instrument on. From the readout menu, select setup screen and turn the automatic printing on as follows:

SETUP	**CLOCK - >**	**OFF**		
CAL	**PRINT - >**	**ON**		
HVL	**UNITS - >**	**R**		
EXP	**AIR --- >**	**20.5 C**	**734 mmHg**	
CT EXP	**DATE -->**	**Oct.**	**10,**	**1996**
AMSE	**TIME -->**	**10**	**30**	**45**
MODE	**SELECT**	**ON/OFF**		

From the SETUP screen, use the SELECT softkey (under column 1) to select PRINT. When PRINT is selected, the print selection blinks and a highlight (reverse video) extends across the other display field. Press the ON/OFF softkey (under column 2) to turn automatic printing to ON. Now, whenever a measurement is made, all of the measured results that are displayed on the NERO mAx's screen will also be sent to the printer.

If the printer is off line, out of paper or is otherwise non functional, the NERO mAx will display a printer error message and printing will be disabled. If the printer becomes functional and returns to an on line status with no errors, the NERO mAx will resume printing with the next exposure.

To turn automatic printing off, follow the procedure outlined above and toggle PRINT to OFF.

1.6 Scope Output

The NERO mAx scope output provides a real time output of the radiation waveform from the NERO mAx detector. This output is from the less filtered detector; "channel A". This signal can have a maximum amplitude of approximately 5 volts. This signal is always available at the scope output BNC connector. The NERO mAx does not need to be in a kVp measurement mode to provide a real time scope output, but the NERO mAx detector must be in the beam.

To use the real time scope output, connect the NERO mAx's scope output to an oscilloscope input using a suitable BNC cable. Set the oscilloscope horizontal deflection controls to the desired sweep period and adjust the scope to trigger on a positive slope. Some experimentation will be necessary to get the trigger level and the vertical deflection adjusted properly. Generally, exposures made at the top of the selected kV range will have signals above one volt and exposures made near the bottom of the selected kV range will have signals in the tens of millivolts.

1.7 Procedures, Warnings, and Cautions

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

Although the equipment described in this manual is designed and manufactured in compliance with all applicable safety standards, certain hazards are inherent in the use of electronic and radiometric equipment.

WARNINGS and **CAUTIONS** are presented throughout this document to alert the user to potentially hazardous situations. **A WARNING** is a precautionary message preceding an operation that has the potential to cause personal injury or death. **A CAUTION** is a precautionary message preceding an operation that has the potential to cause permanent damage to the equipment and/or loss of data. Failure to comply with **WARNINGS** and **CAUTIONS** is at the user's own risk and is sufficient cause to terminate the warranty agreement between Fluke Biomedical and the customer.

Adequate warnings are included in this manual and on the product itself to cover hazards that may be encountered in normal use and servicing of this equipment. No other procedures are warranted by Fluke Biomedical. It shall be the owner's or user's responsibility to see to it that the procedures described here are meticulously followed, and especially that **WARNINGS** and **CAUTIONS** are heeded. Failure on the part of the owner or user in any way to follow the prescribed procedures shall absolve Fluke Biomedical and its agents from any resulting liability.

Indicated battery and other operational tests must be performed prior to each use to assure that the instrument is functioning properly. If applicable, failure to conduct periodic performance tests in accordance with ANSI N323-1978 (R1983) **Radiation Protection Instrumentation Test and Calibration**, paragraphs 4.6 and 5.4, and to keep records thereof in accordance with paragraph 4.5 of the same standard, could result in erroneous readings or potential danger. ANSI N323-1978 becomes, by this reference, a part of this operating procedure.

Warning Summary

The following WARNINGS are provided for your reference and may appear throughout the NERO mAx manual:

WARNING

Extreme caution should be used when making connections to the mAs terminals of the X-ray generator or detector. Improper connections may result in injury, damage to the NERO mAx, and/or damage to the x-ray generator. Tube current (mA and mAs) measurements should only be made by persons familiar with the calibration and repair of x-ray machines.

WARNING

An electric shock hazard exists between the ion chamber bias connector and ground.

Caution Summary

The following CAUTIONS are provided for your reference and may appear throughout the NERO mAx manual:

CAUTION

Use extreme caution when connecting to the mAs terminal of the detector.

CAUTION

If line voltage surges beyond 15% of normal, a power line conditioner must be used, otherwise damage to the charging circuit will occur.

Note Summary

NOTE

In the event of a transient induced lockup of the Model 8000 NERO mAx, it is necessary to reset the unit by cycling its power (turning it off then on). After reset, the unit will power up in its normal operating mode.

1.8 Receiving Inspection

Upon receipt of the package:

1. Inspect the carton(s) and contents for damage. If damage is evident, file a claim with the carrier and notify Fluke Biomedical at 440.248.9300.
2. Remove the contents from the packing material.
3. Verify that all items listed on the packing list have been received and are in good order.

1.9 Storage

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

Prior to use, check the condition and functionality of the device. Also check that the calibration is still valid. Periodic recalibrations are usually required by individual radiation safety and/or quality assurance programs. Please consult your local radiation safety or quality assurance office if you have any questions.

Section 2
Operation

2.1 Description

The NERO mAx consists of the NERO mAx control console, detector, detector cable, filter slides, AC adapter, HVL plates, manual, Microsoft Excel Add-in and carrying case.

The NERO mAx control console is compact and easy to use. The sophisticated electronics necessary to provide highly accurate, reproducible measurements while maintaining an intuitive, user-friendly operating system are contained in the NERO mAx control console. The NERO mAx's rechargeable battery is also housed in the control console. The front panel of the control console contains a backlit 240 x 64 pixel, dot matrix LCD display and eight push buttons. Connectors for power input, RS-232, printer, scope output and the NERO mAx detector are located on the control console's rear panel. The ON/OFF switch is located on the right side of the control console.

The NERO mAx detector contains sensors for simultaneously measuring kV, exposure or rate and invasive mA or mAs. Solid-state detectors are used to measure kV. An ion chamber, located in the top of the detector, is used for exposure/rate measurements. In addition, connectors for an external ion chamber are provided on the rear panel of the 8000 detector. The NERO mAx detector's interface connector is also located on the detector's rear panel. The front panel has a keyed opening for the model 8000-filter slides and a connector for mAs leads.

The NERO mAx filter cards contain the various filters needed to accurately measure kilovoltage. Each filter card is coded so that the NERO mAx "knows" which filter is in use and its position. The NERO mAx also verifies that the filter card is valid for the selected measurement mode. In addition, the filter cards are keyed so that they may only be inserted one way. The W/Al filter card is labeled with the kVp ranges that it is calibrated for. The Mammo filter card is labeled for the x-ray tube targets that it is calibrated for.

The serial numbers of the NERO mAx control console unit, detector and filter slides must be matched in order to obtain accurate results. The control console unit, detector and filter slides are calibrated together, and must be used together for accurate measurements.

2.2 General

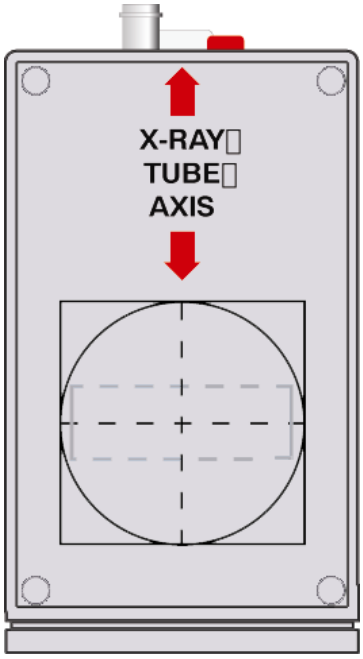
Positioning the Control Console

Position the NERO mAx control console on a stable, flat surface within 25 feet of the detector. If a printer is to be used with the NERO mAx it should also be placed on a stable, flat surface.

Positioning the Detector

Correct and reproducible positioning of the NERO mAx detector in the x-ray beam is very important in obtaining accurate and reproducible results from the NERO mAx. Fluke Biomedical has printed several alignment marks on top of the detector to assure correct, reproducible positioning of the detector.

The black circle is the minimum collimated beam size required for accurate exposure, rate and kVp measurements. This circle defines the diameter of the NERO mAx's internal ion chamber.



NOTE

The dashed gray rectangle is the minimum collimated beam size required for accurate kVp measurements only. This rectangle outlines the NERO mAx's kV detectors. Exposure and rate results from an x-ray beam collimated to this area will be incorrect because the beam is not illuminating all of the internal ion chamber.

The black square and the dashed black crosshairs are alignment marks to aid in positioning the NERO mAx detector in the x-ray beam.

The red arrows on the detector indicate the axis of the detector that should be aligned with the x-ray tube axis for the most accurate measurements. This minimizes any heel effect.

Radiographic

Install the W/Al filter slide in the detector and set the filter slide to the desired kVp range. Position the detector under the x-ray tube with the top of the detector facing up. Align the detector along the axis of the x-ray tube to minimize heel effect. Set x-ray tube SDD (normally 26 inches) and collimate the beam size to the round or square alignment marks on the top of the detector. Align the x-ray beam by making the light field crosshairs coincident with the crosshairs on the top of the detector.

Dental

Set the detector on a flat, stable surface and position the x-ray tube so that the cone is just above the detector's top surface.

NOTE

Do not rest the cone on the detector. This may depress the top of the ion chamber and cause incorrect exposure measurements.

Make sure that the detector is aligned along the axis of the x-ray tube and that the tube is perpendicular to the detector's top surface and is centered over the detector crosshairs.

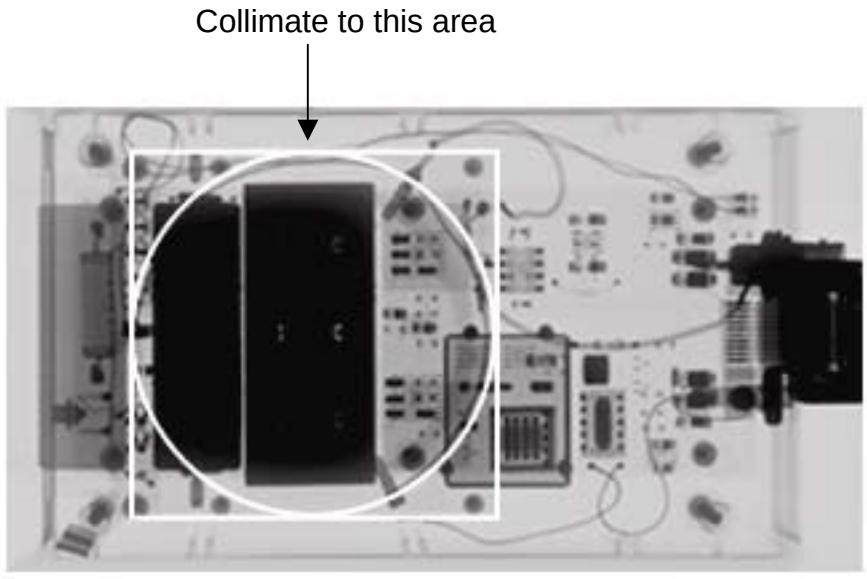
Mammography

Install the Mammo filter slide in the detector and set the filter slide for the x-ray machine's target material. Position the detector under the x-ray tube with the top of the detector facing up. Align the detector along the axis of the x-ray tube to minimize heel effect. Set x-ray tube SSD (normally 26 inches) and collimate the beam size to the square alignment marks on the top of the detector. Line up the front edge of the square alignment mark on the top of the detector with the front edge (toward the chest wall) of the collimated x-ray beam.

Fluoroscopy

Install the W/Al filter slide in the detector and set the filter slide to the desired kVp range. The kVp range is the range closest to the detector front panel.

Position the detector **upside down** on the table (the top of the detector must be positioned toward the x-ray tube) and align the detector along the axis of the x-ray tube to minimize heel effect. Using the centering marks provided on the table (or other centering methods), center the detector over the x-ray beam. Don protective clothing and energize the fluoroscope to view the detector on the fluoro screen. Move the fluoroscope so that the lead shield containing the NERO mAx's detector diodes (opaque rectangle) is centered on the screen.



Fluoro Detector Positioning

For automatic brightness control machines, place appropriate shielding over the detector to drive the output to its maximum. A folded lead apron, gloves or a lead sheet may be used. For manual systems, set the machine for its maximum output and use appropriate shielding to protect the image intensifier.

Other Applications

The basic principles are the same for other applications. In general, the detector should be located 18 to 40 inches from the x-ray source. The detector should be aligned with the x-ray tube axis with the top of the detector facing the x-ray source. The detector should be in the center of the x-ray beam and the beam should be collimated to the round or square alignment marks on the top of the detector.

For chest x-ray machines, the detector may be strapped or taped to the table in front of the film cassette.

For panoramic dental machines, the detector may be strapped or taped to the film cassette holder.

Inserting the Filter Slide

The NERO mAx filter slides are inserted into the front of the detector. The filter slides are keyed so that they may only be inserted one way. To insert the filter slide, place the filter slide in the opening in the front of the detector and gently push. The slide will click into place at each of its positions. Move the filter slide until the desired kVp range (W/Al) or target material (Mammo) is closest to the detector front panel (below “kVp RANGE”).

Connections to the NERO mAx

The NERO mAx detector and control console are connected to each other via a 25-foot cable. The NERO mAx power should be turned **off** when connecting the detector to the control console, connecting an external ion chamber to the detector or connecting the mAs leads.

mAs Connections

WARNING

Extreme caution should be used when making connections to the mAs terminals of the X-ray generator. Improper connections may result in injury, damage to the NERO mAx, and/or damage to the x-ray generator. Tube current (mA and mAs) measurements should only be made by persons familiar with the calibration and repair of x-ray machines.

Two mAs cables are provided with the NERO mAx; 12-ft. long mAs leads and 12-ft. long mAs extension leads. The mAs leads are black, with a miniature phone plug at one end and alligator clips at the other end, the mAs extension leads have clear insulation with two banana plugs at one end and alligator clips at the other end. The miniature phone jack of the black mAs leads plugs into the mAs jack on the front panel of the NERO mAx detector. The alligator clips may then be connected to the generator’s mAs terminals. If the black mAs leads have insufficient length, the mAs extension leads may be used to provide additional length. The mAs extension leads may be used in two ways; the extension lead banana jacks may be plugged into the generator’s mAs terminals (if the generator has banana jacks) or the extension leads may be reversed and the alligator clips can be clipped to the generator’s mAs terminals.

The opposite end of the mAs extension leads are to be connected to the alligator clips at the end of the black mAs leads. When using the mAs extension leads, care should be used to make sure that the leads are not shorted together when they are connected.

The mAs leads should always be connected in the ground return of the high voltage transformer. Damage to the generator or the NERO mAx or inaccurate measurements may result if the mAs leads are connected to any point other then the ground return of the x-ray tube current. Tube current measurements should only be made on generators providing open and short circuit protection of the metering circuit and where the circuit operates near ground potential. The polarity of the mAs input signal is not important because a full wave bridge is used in the NERO mAx mAs input circuit.

Printer Connections

When using the NERO mAx with a printer, both the printer and the NERO mAx should be turned off prior to connection. The NERO mAx uses a standard IBM PC printer cable. For more information on printing with the NERO mAx, see Section 1.5--Printing.

AC Adapter

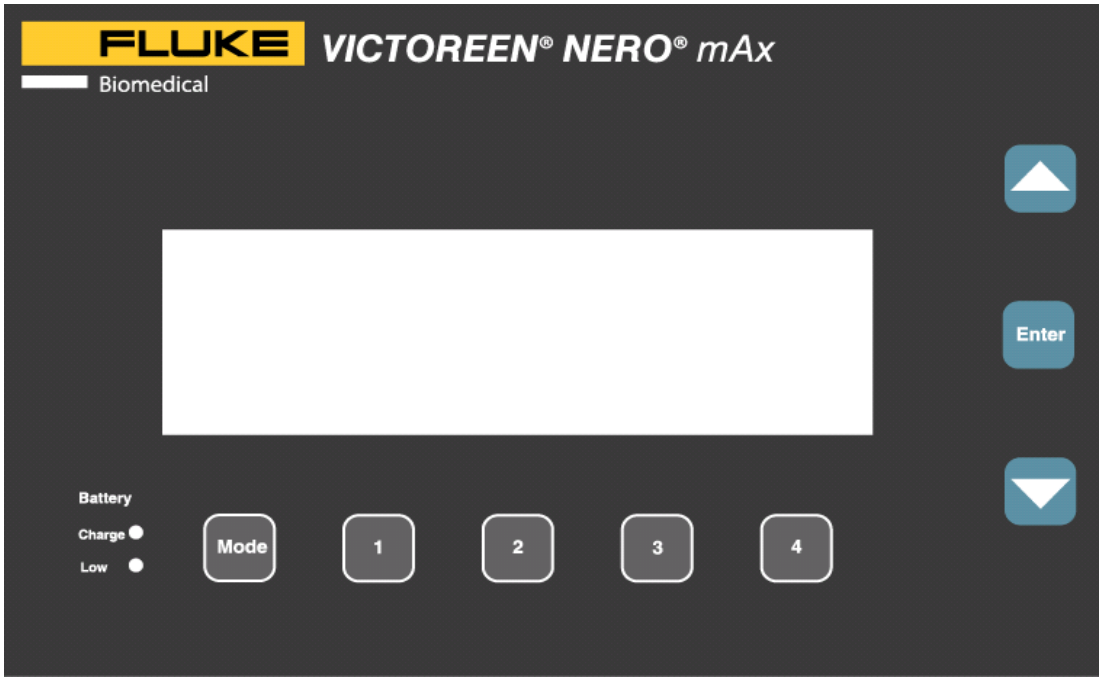
The AC adapter may be plugged into the NERO mAx at any time. For more information on using the AC adapter with the NERO mAx, see Section 1.4--Battery Operation and Charging.

Scope Output

The NERO mAx's scope output may be connected to a suitable oscilloscope at any time. For more information regarding the real time scope output, see Section 1.6--Scope Output.

2.3 Using The NERO mAx

The NERO mAx uses an innovative system of menus and softkeys to provide an intuitive, user-friendly operating environment. All measurement modes and options are displayed on the NERO mAx's LCD and all functions are controlled by the 5 softkeys beneath the display and the 3 keys to the right of the display.



The NERO mAx display is divided into 5 columns, each column corresponds to the push button (softkey) directly beneath it. The left most column is the “MODE” column that is used to select the NERO mAx’s operating mode. The remaining four columns (1 through 4) display various options for each mode.

A highlight (reverse video block) denotes the selected menu element in each column. A blinking highlight (reverse video block) locates the “active” menu column and highlights the selected menu element in that column.

Legends, which describe the function of each softkey, appear along the bottom of the display. These legends are separated from the rest of the display by a horizontal line. The time and date may be displayed in the upper right corner of the display.

There are eight push buttons on the front panel of the NERO mAx. The five buttons directly beneath the display are “softkeys”, their functions change according to the NERO mAx’s mode of operation. These softkeys are used to select the NERO mAx’s mode of operation and various options within each mode. These softkeys are also used to increment numerical values such as time or date. The “MODE” softkey has two functions. First, it may be used to select the NERO mAx’s operating mode. Second, it may be used to exit from any active measurement mode.

The “UP” and “DOWN” keys to the right of the display are also used to select the NERO mAx’s mode of operation and various options within each mode. The “UP” and “DOWN” buttons move the highlight up and down within each selected column to select various options. When the “UP” button is pressed, the highlight moves up one menu element and wraps around when it reaches the top of the column and returns to the bottom. When the “DOWN” button is pressed, the highlight moves down one menu element and wraps around when it reaches the bottom. If only two options are available, the highlight toggles between the two selections. In the calibration and setup modes, the “UP” and “DOWN” buttons are used to toggle between options or to increment and decrement numeric values.

The “ENTER” button to the right of the display is used to initiate data acquisition and measurement with options that have been selected. It also is used to accept numeric data in situations requiring data entry.

Each of the NERO mAx’s operating modes has a menu. All available menu options for each mode are displayed in columns 1 through 4 above each softkey. All menus are left justified. This means that changes made in columns on the left (such as the MODE column) may affect the columns of options to the right. Softkey legends appear along the bottom of the display and as the menu options change, the softkey legends change. The left most menu column is the ‘mode’ column, which displays the available operating modes. The legend above the “MODE” softkey never changes, as this key always selects the mode of operation of the NERO mAx.

Pressing the softkey under any column (MODE, 1 - 4) moves the blinking highlight into that menu column, thereby selecting that column, and moves the highlight up through the available options. The highlight wraps around when it reaches the top of the column and returns to the bottom. If only two options are available, the highlight toggles between the two selections. In the calibration and setup modes, some of the softkeys are used to toggle between options or to increment numeric values.

To make a measurement with the NERO mAx, simply highlight the desired measurement mode and options and press the enter button. For more information on a specific measurement mode, see the manual section that applies to that mode or x-ray generator type.

All of the NERO mAx’s operating modes are described in "Modes of Operation", following "Quick Start".

2.3.1 LCD Backlight Control

As a power saving feature, the NERO mAx LCD backlight turns off after one minute of no activity. The backlight turns back on when any button is pressed. When the NERO mAx backlight turns off while exposure results are being displayed, the backlight may be restored without affecting the displayed exposure results by pressing any key except the MODE key. Pressing the mode key exits from the active measurement mode and returns to the menu screen, erasing all exposure data.

2.3.2 Measured Quantities

kV

The NERO mAx calculates kVp from the ratio between two differentially filtered detector channels (A&B). When an x-ray exposure is made, the NERO mAx samples the two detector channels simultaneously at a rate of 100,000 samples per second. The detector waveforms are digitized by a pair of 100 kHz 16 bit A/D converters and stored in memory.

The NERO mAx has sufficient memory to store up to 480 milliseconds of waveform data. For radiographic exposures that exceed 480 milliseconds in length, the NERO mAx stores the first 320 milliseconds of the waveform and the last 160 milliseconds. This method allows storage of both the rising and falling edges of the x-ray waveform. In the fluoro and AMSE modes, the NERO mAx stores a 480-millisecond sample of the x-ray waveform after the SAVE key is pressed.

A delay of up to 999 milliseconds may be used to delay the start of kV data acquisition in the Radio and Mammo modes. This delay may be used to skip events that occur at the beginning of an exposure, such as an overshoot or undershoot. When a delay is used, only the kV data acquisition is effected. Exposure, mAs and time measurements are not delayed and are measured over the entire exposure.

After the exposure is complete, the NERO mAx searches the stored channel A and B waveforms for ratio peaks, when a peak is found it is stored. These peaks are then averaged and the average kVp is calculated. While the NERO mAx searches for ratio peaks, it also looks for the highest peak, when the highest peak is found it is stored and peak kV is calculated. Effective kV is calculated from the ratio of the integrated A and B waveforms which is analogous to the density ratio in the kVp film cassette.

When calculating kVp average in the radiographic mode, the NERO mAx only includes peaks that are above the selected %kV in its kVp average calculation. When ZERO or 1ØPULSE are selected, the NERO mAx includes all detected peaks in the kVp average calculation.

The NERO mAx calculates kV as a function (F) of the ratio between the two detector channels, A and B (r). The calculations used to calculate kV peak, kV effective and kVp average are summarized below:

kVp Average = F (r), where r is the average peak ratio B/A

kV Peak = F (r), where r is the peak ratio B/A

kV Effective = F (r), where r is the ratio $_{\Sigma}B/A_{\Sigma}$

The calibration information that the NERO mAx uses to calculate kV is stored in nonvolatile memory in the NERO mAx control console.

Time

The NERO mAx measures exposure time by determining the time between the first and last passage through a preset percentage of kVp average. To accomplish this, the NERO mAx calculates the detector ratio that corresponds to the preset percentage of the exposure's kVp, then measures the time between those points on the rising and falling edges of the ratio waveform. In the Radiographic mode, the percentage of kVp average over which the NERO mAx measures radiographic exposure time may be selected using the %kV key. In the Mammographic mode, the percentage is fixed at 90% of kVp average.

In the radiographic mode, when 75%, 80%, or 90% kV is selected, the NERO mAx measures exposure time between the 75%, 80%, or 90% points on the kV waveform. When zero crossing (ZERO) is selected, the NERO mAx measures radiographic exposure time from the moment x-rays are detected until they are no longer detected. When 1ØPULSE is selected, the NERO mAx counts the number of x-ray pulses in a pulsed or single-phase radiographic exposure. This is primarily for use with single phase full and half wave rectified generators.

In pulsed and single-phase applications when time is measured in pulses (1ØPULSE), use of a measurement delay may introduce errors in the pulse count because the NERO mAx does not count pulses during the delay time. In pulsed and single-phase applications when time is measured at a

percentage of kV, use of a measurement delay can also introduce errors. If the delay terminates between pulses, when no x-rays are present, the NERO mAx waits until the beginning of the next pulse to begin timing. If the delay terminates during a pulse, when x-rays are present, the NERO mAx begins timing immediately.

When a delay is used in making measurements in the Radio and Mammo Modes, the NERO mAx calculates exposure time differently. If a positive measurement delay is used in making a measurement, the NERO mAx includes the delay time in its calculated exposure time. In addition, the exposure time may be slightly longer than the exposure time between the selected %kV points on the kV waveform. This is because the Model 8000 does not store the leading edge of the x-ray output waveform; it waits for the specified delay time before acquiring kVp data. Because of this, the %kV point on the rising edge of the kV waveform is not stored and the rise time of the waveform appears to be instantaneous. The difference between the actual and measured exposure times is the rise time between zero and the specified %kV. When a negative measurement delay is specified, the NERO mAx does not include the delay time in the measured exposure time. The measured exposure time is from the beginning of data acquisition or the %kV point on the first rising edge after the delay until passage through the %kV point on the falling edge of the kV waveform.

More information on using the %kV function or using a measurement delay may be found at the end of the Radio Mode section under "Using %kV and Exposure Time Measurements" or "Using a Measurement Delay".

Exposure and Exposure Rate

The NERO mAx measures exposure by integrating the signal from an ion chamber (either internal or external) and applying the proper conversion factor(s) to calculate exposure (R or Gy). Exposure rate is calculated by sampling the integrated charge from the ion chamber at one-second intervals and dividing the integrated charge by the sample period and applying the proper conversion factor(s). In the Pulsed Fluoro and AMSE modes, the NERO mAx calculates exposure per pulse or frame by sampling the integrated charge from the ion chamber at one second intervals and dividing by the number of pulses or frames that it counts in a one second interval and applying the proper conversion factor(s). The NERO mAx's ion chamber is internally vented and all exposure and rate measurements are corrected for air density based upon user entered temperature and pressure.

The NERO mAx’s internal ion chamber is factory calibrated to provide accurate exposure and rate measurements over the entire kVp range of the NERO mAx. These exposure and rate measurements are adjusted by applying energy dependent correction factors that are determined by comparison to applicable N.I.S.T. techniques.

In addition to the factory calibration, a user entered multiplier is available for exposure and rate measurements made with the NERO mAx’s internal ion chamber.

When using external ion chambers, exposure and rate are calculated using the user entered calibration factor (R/nC or Gy/nC) for the selected chamber. When making measurements in the CT Exposure mode with a CT chamber, user entered beam width is also used in calculating exposure and rate.

mAs and mA

The NERO mAx measures mAs by integrating the signal from the mAs input during an x-ray exposure. To calculate mA, the integrated signal from the mAs input is sampled at one-second intervals and divided by the sample period. In the Pulsed Fluoro and AMSE modes, the NERO mAx calculates mAs per pulse or frame by sampling the integrated signal from the mAs input at one second intervals and dividing by the number of pulses or frames that it counts in a one second interval. The mA(s) circuitry is factory calibrated using a calibrated current source and is not user adjustable.

HVL

In the HVL mode, the NERO mAx calculates half value layer based upon a series of exposure or rate measurements made with varying thicknesses of aluminum absorbers placed in the x-ray beam. The exposure or rate measurements may be made using the NERO mAx’s internal ion chamber or an external

ion chamber. HVL is calculated using a linear regression of the natural log of the normalized exposure versus absorber thickness in millimeters of aluminum. Below is the formula used by the NERO mAx to calculate half value layer.

$$HVL = A * \ln(x) + B$$

Where: x = Normalized dose at Half Value Layer (0.5)

A = Slope of ln(x) vs. mmAl

B = Intercept of ln(x) vs. mmAl (Usually very close to zero)

2.4 Quick Start

Locate a suitable radiographic x-ray generator. Set the generator for approximately 80 kV, 100 mA, .1 seconds or 10 mAs.

CAUTION

Make sure the NERO mAx is turned off.

Plug the detector cable into the back of the NERO mAx at the connector marked DETECTOR.

Plug the other end of the detector cable into the NERO mAx detector.

Insert the W/Al filter slide into the front filter slot of the NERO mAx detector at the 50 - 100 kVp position. The filter slide will click into place.

Place the detector on the x-ray table at approximately 26” SDD. Make sure that the top of the detector is facing the x-ray tube and the detector is aligned with the x-ray tube axis.

Plug the AC adapter into the NERO mAx and plug the adapter into a suitable AC power outlet.

Turn on the NERO mAx.

After the NERO mAx performs its power up diagnostics, the main menu screen is displayed.

EXP			
CT EXP	**1Ø PULSE**		
AMSE	**ZERO**		
FLUORO	**75%**		
MAMMO	**80%**	**LOW**	
RADIO	**90%**	**HIGH**	**+10 ms**
MODE	**%kV**	**SENS**	**DELAY**

a. Press the MODE button, the reverse video highlight in the mode column of the display (far left column above the mode key) will start blinking.
b. Press the down arrow key until RADIO is highlighted.
c. Press the "1" key until 75% is highlighted.
d. Press the "2" key to toggle sensitivity between high and low, set the sensitivity to LOW.
e. Press the "3" key to change the measurement delay. Using the up and down arrow keys, set the delay to +10 milliseconds.
f. Press the ENTER button.

Please wait a moment while the NERO mAx prepares to measure an exposure.

When the NERO mAx beeps and displays MAKE EXPOSURE, make an exposure.

Wait a moment while the 8000 analyzes the exposure then displays the measured kVp, exposure, time and mAs (mAs will be zero because the mAs input was not used).

	80.0	**kVp Avg**			**100**	**msec**	
	79.2	**kV Eff**			**392**	**mR**	
	81.1	**kV Peak**			**0.0**	**mAs**	
RADIO	**75%**		**LOW**	**+ 10 ms**			**Please**
MODE	**%kV**		**SENS**	**DELAY**			**Wait…**

The 8000 will immediately display Please Wait… in the lower right corner of its screen while it prepares to take another exposure.

After the 8000 beeps and displays Make Exposure in the lower right corner of the display, another exposure may be made.

To stop making exposures and return to the main menu screen, press the MODE button.

2.5 Modes of Operation

The NERO mAx Nero has ten modes of operation as listed below (in selection order):

1. RADIO
2. MAMMO
3. FLUORO
4. AMSE
5. CT EXP
6. EXP
7. HVL
8. CAL
9. SETUP
10. UNIT ID

UNIT			
SETUP			
CAL			
HVL			
EXP			
CT EXP	**1Ø PULSE**		
AMSE	**ZERO**		
FLUORO	**75%**		
MAMMO	**80%**	**LOW**	
RADIO	**90%**	**HIGH**	**10 mS**
MODE	**%kV**	**SENS**	**DELAY**

The NERO mAx's mode of operation is controlled from the main screen. When the menu cursor (blinking reverse video) is moved to a mode selection, by pressing the mode key or using the up and down arrow keys, all of the options available for that mode are displayed. Pressing a softkey (1 thru 4) moves the menu cursor into the selected menu column and starts it blinking. Pressing the softkey again will move the blinking menu cursor up through the column of available options. Pressing the up and down arrow keys moves the blinking menu cursor up or down through the selected column of available options. After options have been highlighted, the enter key is pressed to start the selected mode with the selected options. Pressing the mode key at any time returns to the mode select screen.

NERO mAx Operating Modes

Radio Mode

Radio mode is used to make measurements on tungsten target, aluminum filtered radiographic x-ray generators. Radio mode simultaneously measures kVp, exposure, exposure time and mAs from a single radiographic exposure. Radiographic mode may also be used to verify the NERO mAx's kV calibration.

Mammo Mode

Mammo mode is used to make measurements on mammographic x-ray generators. Mammo mode simultaneously measures kVp, exposure, exposure time and mAs from a single mammographic exposure.

Fluoro Mode

Fluoro mode is used to make measurements on fluoroscopic x-ray generators. Fluoro mode supports both continuous fluoro and pulsed fluoro measurements. In the continuous fluoro mode, the NERO mAx measures kVp, exposure rate (R/min) and mA. In the pulsed fluoro mode, the NERO mAx measures kVp, exposure rate (R/min and mR/pulse) and mAs/pulse.

AMSE Mode

AMSE mode is used for Automated Measurement of Sequential Exposures. This mode is used to measure the output of CINE X-ray generators. In AMSE mode, the NERO mAx measures kVp, exposure rate (mR/frame), mAs/frame and time/frame (mS/frame).

CT Exposure Mode

CT Exposure mode is used to make CT exposure measurements using the Victoreen 6000-100 or 6000-200 CT ion chamber. A CT probe must be connected to the NERO mAx detector's external ion chamber input in this mode. The exposure is calculated using the user entered beam width (in mm) and the CT probe's calibration factor (Rcm/nC). This mode functions in the same manner as the Exposure Mode with the addition of beam width entry.

Exposure Mode

Exposure mode is used to make exposure and rate measurements using the NERO mAx's internal ion chamber or an external ion chamber. The exposure is calculated using the selected ion chamber's stored calibration factor.

HVL Mode

In the HVL mode, the NERO mAx calculates half value layer based upon a series of exposure or rate measurements made with varying thicknesses of aluminum absorbers placed in the x-ray beam. A minimum of two exposures are required and up to ten exposures may be used. The exposure or rate measurements may be made using the NERO mAx's internal ion chamber or an external ion chamber. Exposure and rate are calculated using the selected ion chamber's calibration factor and when using a CT chamber, beam width.

Calibrate Mode

The Calibrate mode is used to enter and store calibration factors for ion chambers used with the NERO mAx. Calibration factors are available for the NERO mAx's internal chamber and external chambers, including the Victoreen CT chamber.

Setup Mode

The Setup Mode is used to setup various features of the NERO mAx. From the setup screen the user can set the instruments internal real time clock, set the temperature and pressure used in air density correction of exposure measurements, select exposure units of either Roentgens or Grays, turn automatic printing on or off, turn the clock display on or off and select normal or reverse video on screen clock display.

Unit ID

Displays the NERO mAx's serial number, firmware part number and revision.

2.5.1 Radio Mode

Radio mode is primarily used to make measurements on tungsten target, aluminum filtered radiographic x-ray machines. Radio mode simultaneously measures kVp, exposure, exposure time and mAs from a single radiographic exposure. A measurement delay of up to 999 milliseconds may be used to delay the start of kV data acquisition in order to skip over waveform anomalies at the beginning of an exposure. See "Using a Measurement Delay" (at the end of this section) for more information on using a measurement delay. The percentage of peak kV over which exposure time is measured may be selected from 90%, 80%, or 75% of the kV peak. In addition, exposure time may be measured between zero crossings or x-ray pulses may be counted (for single-phase generators). See "Using %kV and Exposure Time Measurements" (at the end of this section) for more information about using %kV.

Generally, to measure radiographic exposures, choose a filter card (kV) setting such that the measured (or expected) kV is in the upper end of the filter range. For instance, use the 50 - 100 kVp range instead of the 80 - 160 kVp range to make measurements at 80 kVp. Staying in the upper end of the filter's kVp range improves the signal to noise performance of the NERO mAx and allows the NERO mAx to "receive" more of the radiation output that improves its measurements accuracy. Also, start out in low sensitivity, if a channel A or B overrange occurs, switch to the next kVp filter range. If the NERO mAx does not respond to an exposure and displays "MAKE EXPOSURE", switch to high sensitivity.

Radio mode may also be used to make measurements on dental x-ray generators. When using the NERO mAx with dental x-ray machines, follow the instructions in section "Positioning the Detector" to properly locate the detector. Generally, low sensitivity should be used, however if the NERO mAx does not respond to an exposure, switch to high sensitivity. Select the proper %kV for the type of generator being tested, generally ZERO or 1ØPULSE modes are needed for self-rectified generators, 75%, 80%, or 90% may be needed for three phase and medium to high frequency generators. If necessary, use a measurement delay in order to disregard any filament preheat effects at the beginning of an exposure. See "Using a Measurement Delay" and "Using %kV and Exposure Time Measurements" at the end of this section for more information about using the %kV and measurement delay functions.

To make a radiographic measurement

Make sure that the Model 8000 is turned off. Plug one end of the Model 8000's detector cable into the Model 8000 detector. Plug the other end of the detector cable into the Model 8000's detector connector. Insert the W/Al filter card into the detector and place the filter card in the correct position for the kV range to be measured. Place the Model 8000 detector on the x-ray table with the top of the detector facing the x-ray tube. Position the detector so that the detector is centered in the beam and is aligned with the x-ray tube axis. If mAs measurements are to be made, plug the mAs cable into the 8000 detector's mAs input and connect the mAs leads to the generators mAs terminals. For more information on positioning the Model 8000 detector, see section "Positioning the Detector".

WARNING

Extreme caution should be used when making connections to the mAs terminals of the X-ray generator or detector. Improper connections may result in injury, damage to the NERO mAx, and/or damage to the x-ray generator.

If results are to be printed, plug the printer cable into the printer port at the rear of the Model 8000 then plug the other end of the printer cable into the printer and turn the printer on (see Section 1.5--Printing). Plug the AC adapter into the 8000 if needed (see Section 1.4--Battery Operation and Charging) and turn the instrument on.

EXP			
CT EXP	**1Ø PULSE**		
AMSE	**ZERO**		
FLUORO	**75%**		
MAMMO	**80%**	**LOW**	
RADIO	**90%**	**HIGH**	**10 ms**
MODE	**%kV**	**SENS**	**DELAY**

Select the RADIO mode, %kV, high or low sensitivity and measurement delay, then press the ENTER key. To use a measurement delay, press the DELAY key to select and increment the delay. The delay may also be incremented or decremented by pressing the up or down keys when the delay is selected. Select the interval, as a percentage of kV peak, over which exposure time is measured, using the %kV key. ZERO selects measurement between the zero crossings on the rising and falling edges of the kV waveform. 1ØPULSE selects the single-phase pulse counting mode for exposure time measurement. The measurement delay and %kV settings are retained from one exposure to the next.

	Please wait… FILTER = 50 - 100		
RADIO	**75%**	**LOW**	**10 ms**
MODE	**%kV**	**SENS**	**DELAY**

Please wait while the Model 8000 prepares to take an exposure. Note that the selected filter kV range is displayed. The kV filter range may be changed at any time without exiting from the measurement mode. If the Model 8000 detects a fault condition such as an invalid filter card or position, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information). When the Model 8000 is ready for an exposure, it will beep and prompt for an exposure.

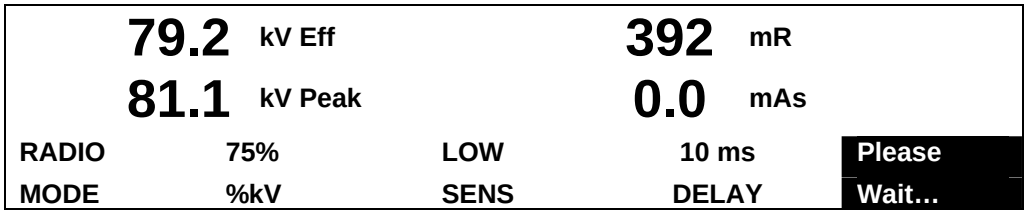
	MAKE EXPOSURE FILTER = 50 - 100		
RADIO	**75%**	**LOW**	**10 ms**
MODE	**%kV**	**SENS**	**DELAY**

Make an exposure. If nothing happens, there is insufficient x-ray intensity to make a measurement. To remedy this situation, switch to high sensitivity, switch to the next lower kVp filter range (if possible), increase mA or decrease the distance between the x-ray tube and Model 8000 detector.

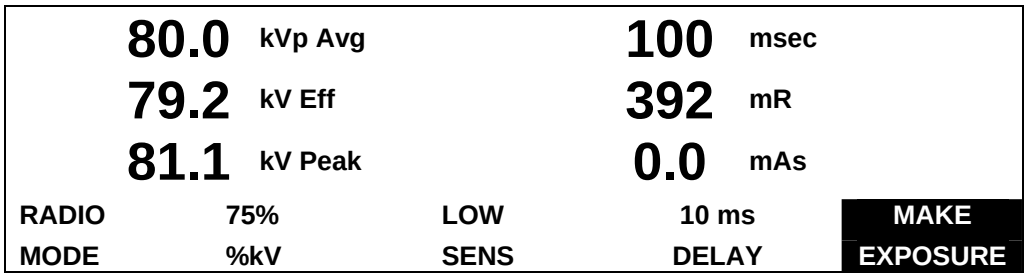
	ANALYZING DATA FILTER = 50 - 100		
RADIO	**75%**	**LOW**	**10 ms**
MODE	**%kV**	**SENS**	**DELAY**

Please wait while the NERO mAx analyzes the exposure data.

80.0	**kVp Avg**	**100**	**msec**



After data analysis is complete, kV, exposure, time and mAs are displayed. If an overrange is detected an error message is displayed. If the calculated kV is above or below the selected filter kV range, "High" or "Low" is displayed instead of kV and measured time may be "----". If the NERO mAx cannot find the selected %kV on the kV waveform, a %kV TOO LOW message is displayed (see Section 4.3--Error Messages--for more information). Please wait while the Model 8000 prepares for the next exposure. If the Model 8000 detects a fault condition such as an invalid filter card or position, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information).



The Model 8000 is now ready to take another exposure. Pressing the mode key at any time exits from this measurement mode and returns to the mode selection screen.

As a power saving feature, the Model 8000's display backlight turns off after one minute of no activity. The backlight turns back on when any button is pressed or an exposure is made. In addition, after five minutes of no activity, the 8000 exits from any measurement mode and returns to the mode selection screen.

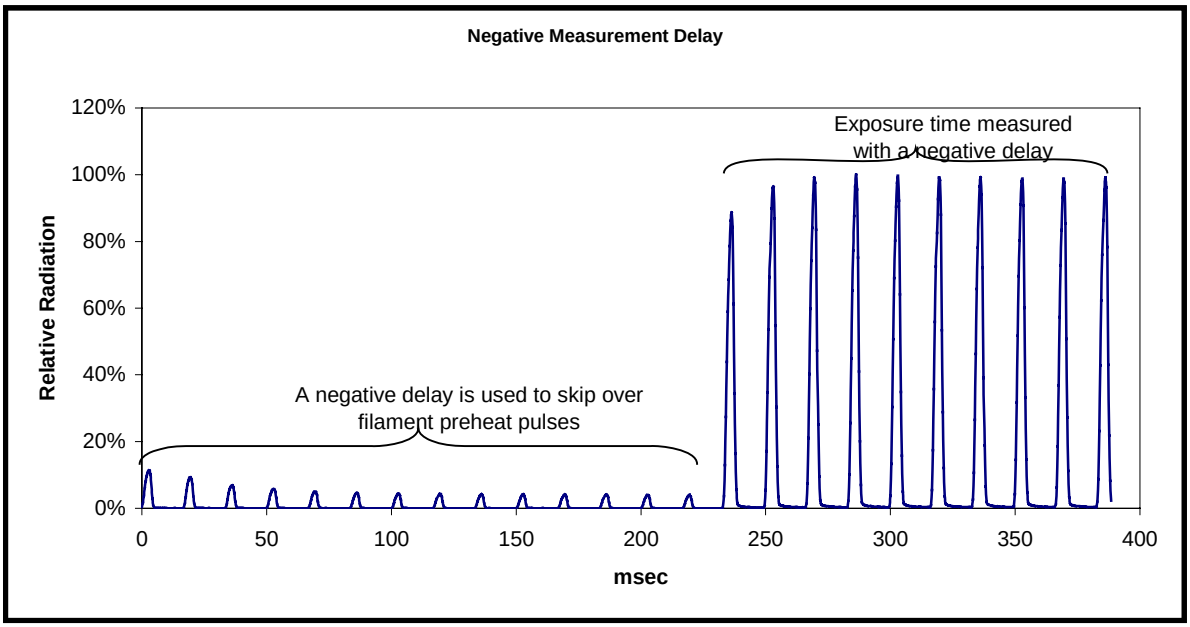
Using A Measurement Delay

A measurement delay may be used to postpone the start of data acquisition in order to skip over waveform anomalies (such as overshoots or preheat effects) that may occur at the beginning of an exposure.

When a delay is used, the NERO mAx waits for the specified delay time after its radiation threshold is exceeded before starting data acquisition. Data acquisition starts immediately after the delay time has elapsed if radiation is above the NERO mAx radiation threshold. If no radiation is detected after the delay time has elapsed, data acquisition is delayed for up to one second after the delay time has elapsed. If no radiation is detected for one second after the delay time has elapsed, the NERO mAx assumes that no exposure has occurred and displays the “DELAY TOO LONG” 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.

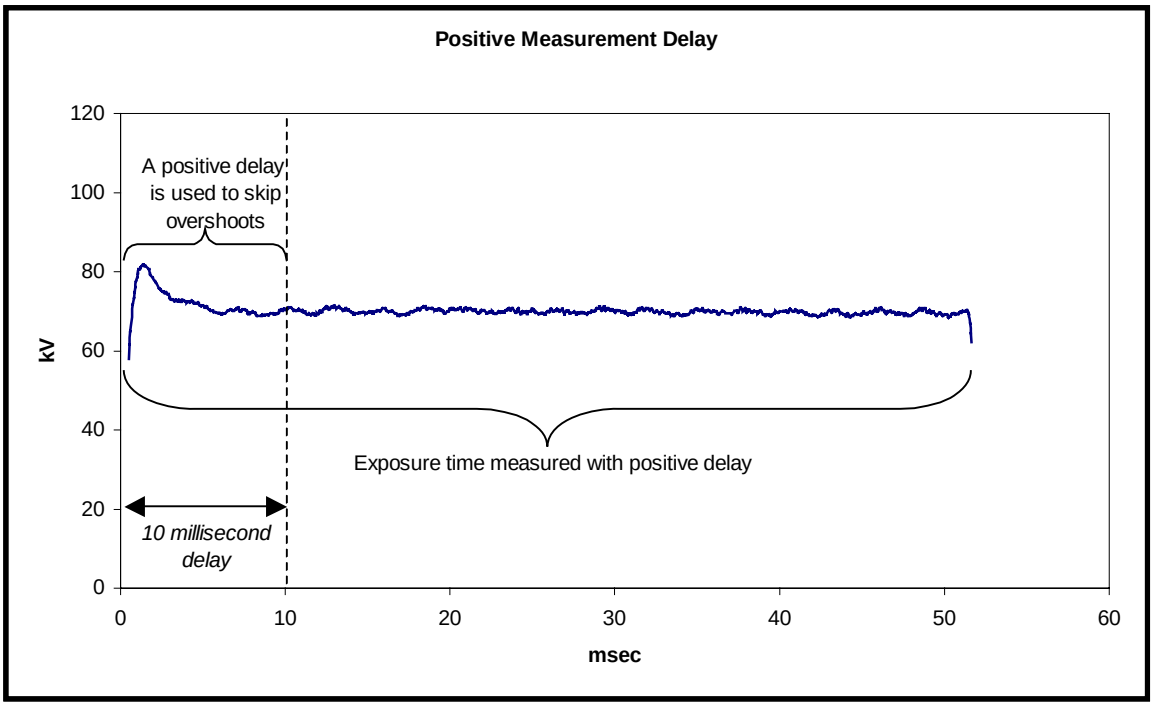
When a negative measurement delay is specified, the NERO mAx does not include the delay time in the measured exposure time. A negative measurement delay should be used in cases when x-ray generator filament preheat pulses or other waveform anomalies should be excluded from kV and exposure time measurements. In the example shown below, a 10-pulse exposure is preceded by 14 filament preheat pulses. Using a -230 millisecond delay to skip over the filament preheat pulses results in a measured



exposure time of 10 pulses.

An example showing this use of a measurement delay can also be found in troubleshooting Section 4.8--Waveforms - Dental With Filament Preheat.

When the measurement delay is positive, the NERO mAx 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. In the example shown below, an overshoot occurs in the first few milliseconds of a 50-millisecond exposure. Using a +10 millisecond delay to skip the overshoot results in a measured kVp of 72 versus 82 and an exposure time of approximately 50 milliseconds.



An example showing this use of a measurement delay can be found in troubleshooting Section 4.5--Waveforms - Overshoot.

When a positive measurement delay is used in making a measurement in the Radio or Mammo mode, the measured exposure time may be slightly longer than the exposure time between the selected %kV points on the kV waveform. This is because the Model 8000 does not store the leading edge of the x-ray output waveform when a measurement delay is used; it waits for the specified delay time before acquiring waveform data. As a result of this, the %kV point on the rising edge of the kV waveform is not stored and the time from exposure start to this point cannot be subtracted from the total time.

When exposure time is measured in pulses (1ØPULSE), use of a measurement delay may cause an error in the pulse count because no pulses are counted during the delay time. The polarity of the delay has no effect on pulse counting; for example, the number of pulses counted with a -10 millisecond delay is the same as the number counted with a +10 millisecond delay.

When using a measurement delay in pulsed and single-phase applications, care must be used in determining the correct delay period. If x-rays are detected at the end of the delay period, such as during a pulse, the NERO mAx begins timing immediately. If no x-rays are detected at the end of the delay period, such as between pulses, the NERO mAx waits up to one second for the beginning of the next pulse to begin timing. As a result of this, the delay period should terminate prior to the first x-ray pulse to be included in data analysis.

The NERO mAx Excel Add-In should be used to view radiation and kV waveforms to determine the optimum measurement delay to use. Information on using the NERO mAx Excel Add-In to view waveforms may be found in the NERO mAx Toolkit for Excel Instruction Manual. In addition, a digital storage oscilloscope may be connected to the scope output on the rear panel of the NERO mAx readout to view radiation output waveforms. Information on using the NERO mAx scope output may be found in Section 1.6 of the NERO mAx instruction manual.

Using %kV and Exposure Time Measurements

The %kV setting determines how the NERO mAx measures exposure time. When 75%, 80%, or 90% kV is selected, the NERO mAx measures exposure time between the 75%, 80%, or 90% points on the kV waveform. For best results when selecting 75%, 80%, or 90% kV, make sure that the percentage of the kV waveforms peak kV is within the selected filter range. If the %kV or the measured kV is too low, a "%kV TOO LOW" error message will be displayed.

When zero crossing (ZERO) is selected, the NERO mAx measures radiographic exposure time from the moment x-rays are detected by the NERO mAx until they are no longer detected. This corresponds to the time between first and last passage through the NERO mAx internal radiation detection threshold of the channel A radiation signal. When using zero crossing, measured exposure times may be lengthened by cable charging or by output filter capacitors used in some single phase generators to smooth the generator's output waveform.

When 1ØPULSE is selected, the NERO mAx counts the number of x-ray pulses in a pulsed or single-phase radiographic exposure. Pulses are detected by counting each passage through the NERO mAx internal radiation detection threshold of the rising and falling edges of the pulses on channel A radiation signal. This is primarily for use with single-phase full and half-wave rectified generators. Pulse counting may not function properly on single-phase generators employing output filter capacitors to smooth the generator's output because the generator's output may not drop to zero between pulses. Additionally, use of a measurement delay may cause an error in the pulse count. For more information, see "Using a Measurement Delay".

When calculating kVp average, the NERO mAx only includes peaks that are above the selected %kV in the kVp average calculation. When ZERO or 1ØPULSE are selected, the NERO mAx includes all detected peaks in the kVp average calculation.

2.5.2Mammo Mode

Mammo mode is used to make measurements on mammographic generators. Mammo mode simultaneously measures kVp, exposure time and mAs from a single mammographic exposure. Exposure time in the Mammo mode is measured between the first and last passage through the 90% points on the kV waveform. A measurement delay of up to 999 milliseconds may be used to delay the start of kV data acquisition in order to skip over waveform anomalies at the beginning of an exposure. See "Using a Measurement Delay" (at the end of this section) for more information on using a measurement delay.

To make a mammographic measurement

Make sure that the NERO mAx is turned off. Plug one end of the NERO mAx's detector cable into the NERO mAx detector. Plug the other end of the detector cable into the NERO mAx's detector connector. Insert the MAMMO filter card into the detector and place the filter card in the correct position for the x-ray tube target material. Place the NERO mAx detector on the x-ray table with the top of the detector facing the x-ray tube. Position the detector so that the detector is centered in the beam and is aligned with the x-ray tube axis. If mAs measurements are to be made, plug the mAs cable into the NERO mAx detector's mAs input and connect the mAs leads to the generators mAs terminals. For more information on positioning the NERO mAx detector, see section "Positioning the Detector".

WARNING

Extreme caution should be used when making connections to the mAs terminals of the X-ray generator or detector. Improper connections may result in injury, damage to the NERO mAx, and/or damage to the x-ray generator.

If results are to be printed, plug the printer cable into the printer port at the rear of the NERO mAx then plug the other end of the printer cable into the printer and turn the printer on (see Section 1.5--Printing). Plug the AC adapter into the NERO mAx if needed (see Section 1.4--Battery Operation and Charging) and turn the instrument on.

EXP				
CT EXP				
AMSE				
FLUORO			**Mo 30µ**	
MAMMO	**LOW**	**RHODIUM**	**Rh 25µ**	
RADIO	**HIGH**	**MOLY**	**Al 1MM**	**0 ms**
MODE	**SENS**	**TARGET**	**FILTER**	**DELAY**

Select the MAMMO mode, high or low sensitivity, target and filter and shot delay, then press the ENTER key. To use a measurement delay, press the DELAY key to select and increment the shot delay. The measurement delay may also be incremented or decremented by pressing the up or down keys when the delay is selected. The measurement delay is retained from one exposure to the next and can only be reset to zero by the user.

	Please wait… FILTER = 22 - 35			
MAMMO	**HIGH**	**MOLY**	**Mo 30µ**	**0 ms**
MODE	**SENS**	**TARGET**	**FILTER**	**DELAY**

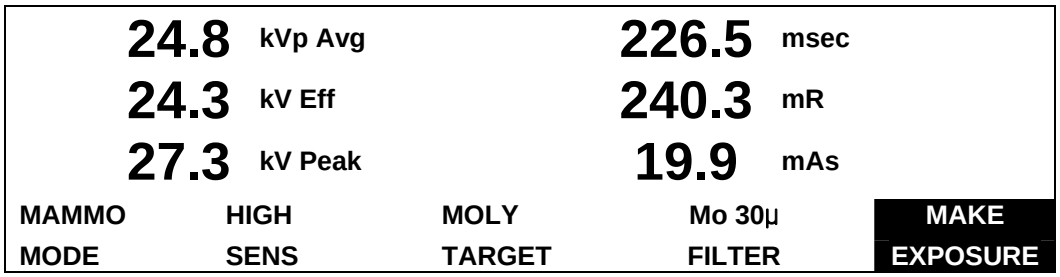
Please wait while the NERO mAx prepares to take an exposure. Note that the selected filter kV range is displayed. If the NERO mAx detects a fault condition such as an invalid filter card or position, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information). When the NERO mAx is ready to take an exposure it will beep and prompt for an exposure.

	MAKE EXPOSURE FILTER = 22 - 35			
MAMMO	**HIGH**	**MOLY**	**Mo 30µ**	**0 ms**
MODE	**SENS**	**TARGET**	**FILTER**	**DELAY**

Make an exposure. If nothing happens, there is insufficient x-ray intensity to make a measurement. To remedy this situation, switch to high sensitivity, increase mA or decrease the distance between the x-ray tube and NERO mAx detector.

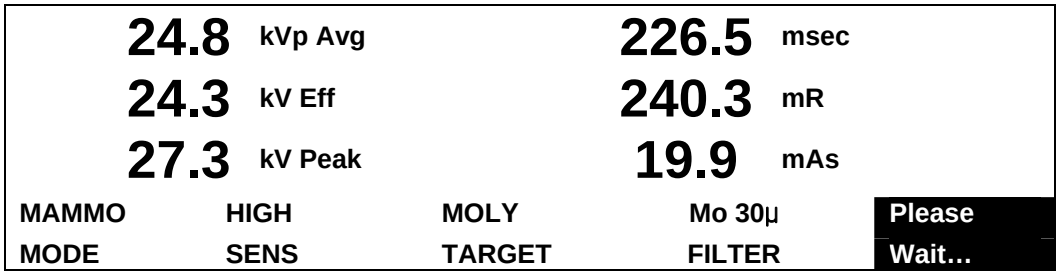
	ANALYZING DATA FILTER = 22 - 35			
MAMMO	**HIGH**	**MOLY**	**Mo 30µ**	**0 ms**
MODE	**SENS**	**TARGET**	**FILTER**	**DELAY**

Please wait while the NERO mAx analyzes the exposure data.



After data analysis is complete, kV, exposure, time and mAs are displayed. If an overrange is detected an error message is displayed. If the calculated kV is above or below the selected filter kV range, "High" or "Low" is displayed instead of kV and measured time may be "----" (see Section 4.3--Error Messages--for more information). Please wait while the NERO mAx prepares for the next exposure. If the NERO mAx detects a fault condition such as an invalid filter card or position, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information).

The NERO mAx is now ready to take another exposure. Pressing the mode key at any time exits from this measurement mode and returns to the mode selection screen.



As a power saving feature, the NERO mAx's display backlight turns off after one minute of no activity. The backlight turns back on when any button is pressed or an exposure is made. In addition, after five minutes of no activity, the NERO mAx exits from any measurement mode and returns to the mode selection screen.

Using A Measurement Delay

A measurement delay may be used to postpone the start of data acquisition in order to skip over waveform anomalies (such as overshoots) that may occur at the beginning of an exposure. 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 the measurement delay is positive, the NERO mAx 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.

When a negative measurement delay is specified, the NERO mAx 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.

More information on using a measurement delay may be found in "Using a Measurement Delay" at the end of Section 2.5.1--Radio Mode.

2.5.3Fluoro Mode

Fluoro mode is used to make measurements on fluoroscopic x-ray generators. Fluoro mode supports both continuous fluoro and pulsed fluoro measurements. In the continuous fluoro mode, the NERO mAx measures kVp, exposure rate (R/min) and mA. In the pulsed fluoro mode, the NERO mAx measures kVp, exposure rate (R/min and mR/pulse) and mAs/pulse.

To make a continuous fluoro measurement

Make sure that the NERO mAx is turned off. Plug one end of the NERO mAx's detector cable into the NERO mAx detector. Plug the other end of the detector cable into the NERO mAx's detector connector. Insert the W/Al filter card into the detector and place the filter card in the correct position for the kV range to be measured. Place the NERO mAx detector on the x-ray table with the top of the detector facing the x-ray tube. Position the detector so that the detector is centered in the beam and is aligned with the x-ray tube axis. If mA measurements are to be made, plug the mAs cable into the NERO mAx detector's mAs input and connect the mAs leads to the generators mAs terminals. For more information on positioning the NERO mAx detector, see section "Positioning the Detector". For mA limits vs. kV, refer to Appendix B.

WARNING

Extreme caution should be used when making connections to the mAs terminals of the X-ray generator or detector. Improper connections may result in injury, damage to the NERO mAx, and/or damage to the x-ray generator.

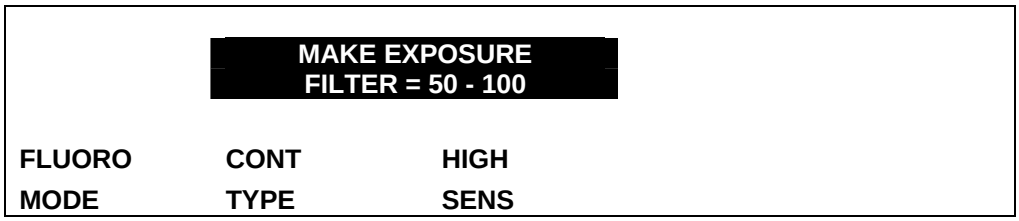
If results are to be printed, plug the printer cable into the printer port at the rear of the NERO mAx then plug the other end of the printer cable into the printer and turn the printer on (see Section 1.5--Printing). Plug the AC adapter into the NERO mAx if needed (see Section 1.4--Battery Operation and Charging) and turn the instrument on.

EXP		
CT EXP		
AMSE		
FLUORO		
MAMMO	**PULSED**	**LOW**
RADIO	**CONT**	**HIGH**
MODE	**TYPE**	**SENS**

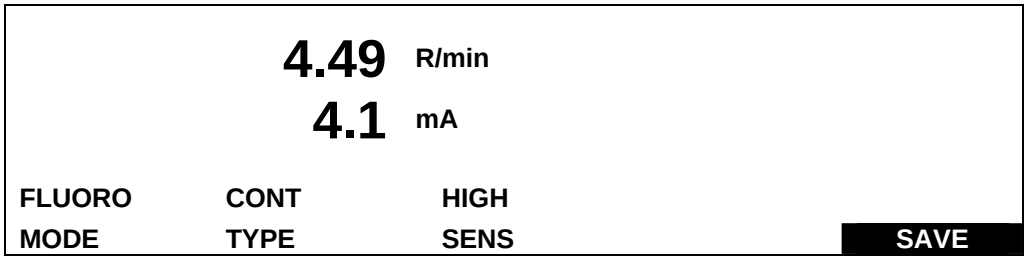
Select fluoro mode, continuous generator type and sensitivity, then press enter.

	Please wait…	
	FILTER = 50 - 100	
FLUORO	**CONT**	**HIGH**
MODE	**TYPE**	**SENS**

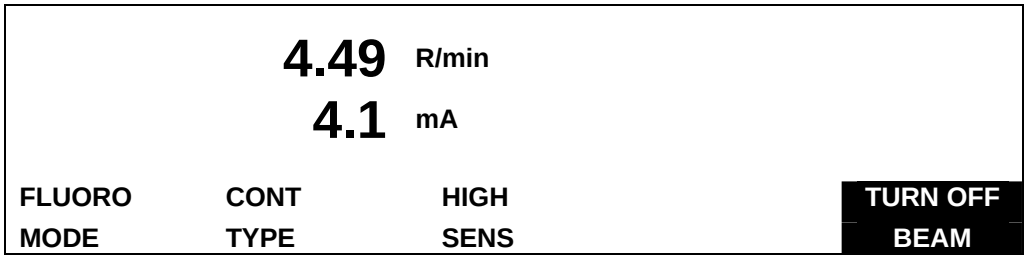
Please wait while the NERO mAx prepares to take an exposure. Note that the selected filter kV range is displayed. If the NERO mAx detects a fault condition such as an invalid filter card or position, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information). When the NERO mAx is ready to take an exposure it will beep and prompt for an exposure.



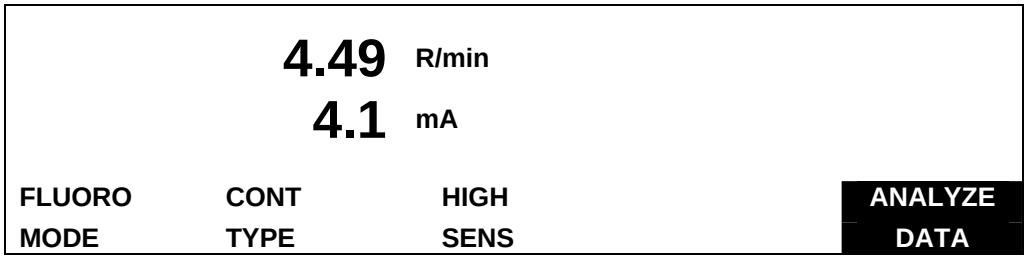
Start the fluoroscopic exposure.



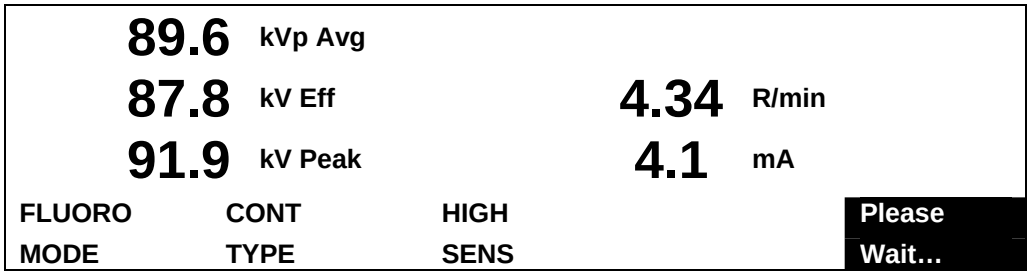
After the exposure starts, the NERO mAx displays exposure rate and mA. When the desired exposure rate and/or mA are displayed, press the SAVE key to acquire kV data.



After kV data is acquired, the NERO mAx prompts to turn off the beam.

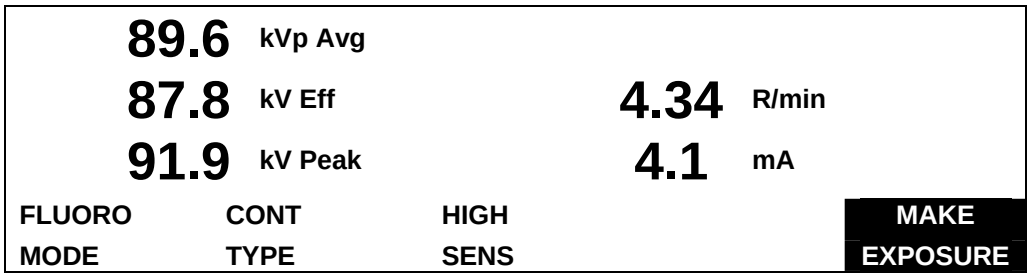


After the beam is turned off, the NERO mAx analyzes the fluoro exposure kV data.



After data analysis is complete, kV, exposure rate and mA are displayed. If an overrange is detected an error message is displayed. If the calculated kV is above or below the selected filter kV range, “High” or

"Low" is displayed instead of kV (see Section 4.3--Error Messages--for more information). After the exposure data is displayed, the NERO mAx displays a "Please wait..." message as it prepares for the next exposure.



The NERO mAx is now ready to take another exposure. Pressing the mode key at any time exits from this measurement mode and returns to the mode selection screen.

NOTE

The exposure rate displayed after the SAVE key has been pressed may be slightly different from the rate displayed before the stop key was pressed. This is because the exposure rate is calculated based upon correction factors that are based upon the measured kVp. In the fluoro mode, kVp is not measured until after the SAVE key is pressed, so a constant is used to calculate exposure and rate. The constant that is used is based upon the calibration factors corresponding to a kVp average of the mid point of the selected filter range. After the SAVE key is pressed, the NERO mAx calculates the fluoro kVp and applies an exposure correction factor based upon the calculated kVp.

As a power saving feature, the NERO mAx's display backlight turns off after one minute of no activity. The backlight turns back on when any button is pressed or an exposure is made. In addition, after five minutes of no activity, the NERO mAx exits from any measurement mode and returns to the mode selection screen.

To make a pulsed fluoro measurement

Make sure that the NERO mAx is turned off. Plug one end of the NERO mAx's detector cable into the NERO mAx detector. Plug the other end of the detector cable into the NERO mAx's detector connector. Insert the W/Al filter card into the detector and place the filter card in the correct position for the kV range to be measured. Place the NERO mAx detector on the x-ray table with the top of the detector facing the x-ray tube. Position the detector so that the detector is centered in the beam and is aligned with the x-ray tube axis. If mAs measurements are to be made, plug the mAs cable into the NERO mAx detector's mAs input and connect the mAs leads to the generators mAs terminals. For more information on positioning the NERO mAx detector, see section "Positioning the Detector". For mA limits vs. kV, refer to Appendix B.

WARNING

Extreme caution should be used when making connections to the mAs terminals of the X-ray generator or detector. Improper connections may result in injury, damage to the NERO mAx, and/or damage to the x-ray generator.

If results are to be printed, plug the printer cable into the printer port at the rear of the NERO mAx then plug the other end of the printer cable into the printer and turn the printer on (see Section 1.5--Printing). Plug the AC adapter into the NERO mAx if needed (see Section 1.4--Battery Operation and Charging) and turn the instrument on.

EXP		
CT EXP		
AMSE		
FLUORO		
MAMMO	**PULSED**	**LOW**
RADIO	**CONT**	**HIGH**
MODE	**TYPE**	**SENS**

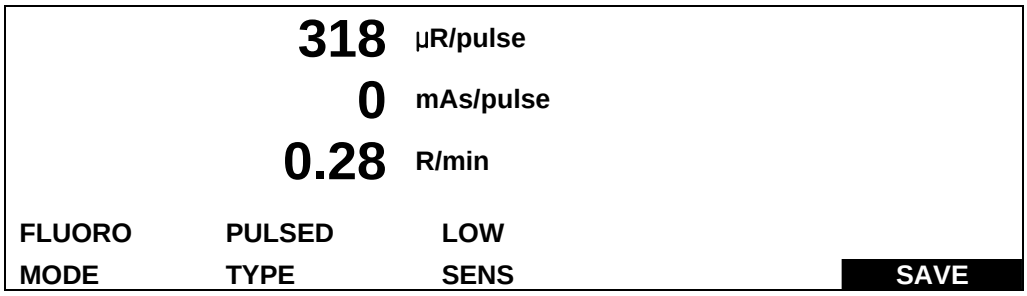
Select fluoro mode, pulsed generator type and sensitivity, then press enter.

	Please wait…	
	FILTER = 50 - 100	
FLUORO	**PULSED**	**LOW**
MODE	**TYPE**	**SENS**

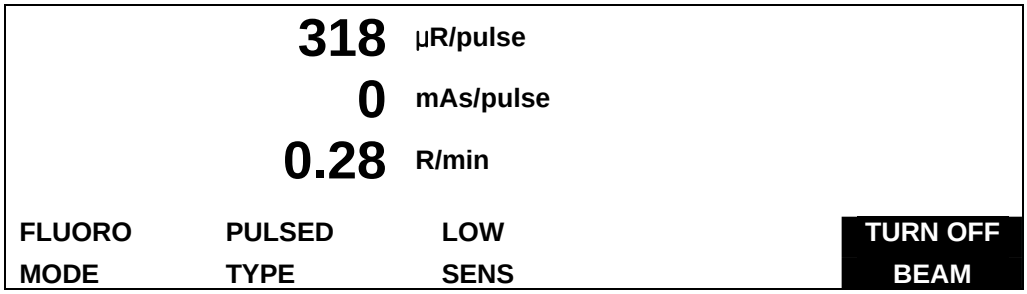
Please wait while the NERO mAx prepares to take an exposure. Note that the selected filter kV range is displayed. If the NERO mAx detects a fault condition such as an invalid filter card or position, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information). When the NERO mAx is ready to take an exposure it will beep and prompt for an exposure.

	MAKE EXPOSURE	
	FILTER = 50 - 100	
FLUORO	**PULSED**	**LOW**
MODE	**TYPE**	**SENS**

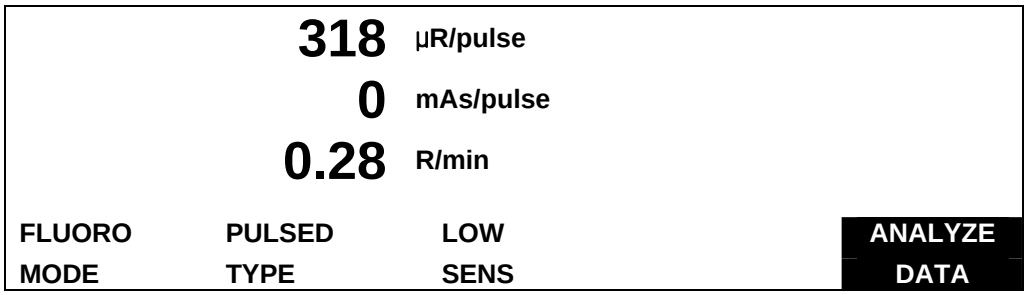
Start the fluoroscopic exposure.



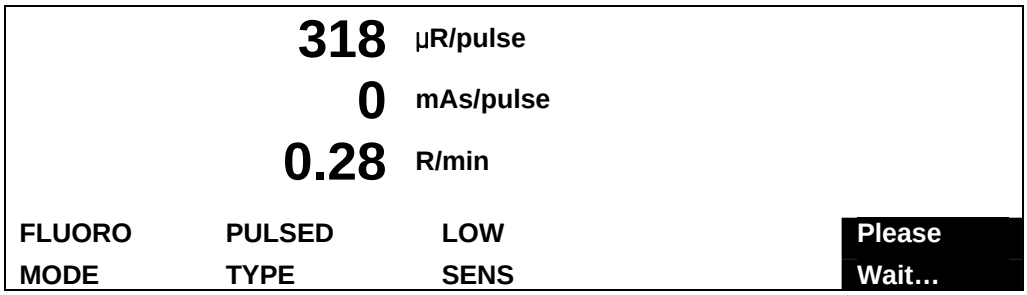
After the exposure starts, the NERO mAx displays exposure rate (R/min, mR/pulse) and mAs/pulse. When the desired exposure rate and/or mAs/pulse are displayed, press the SAVE key to acquire kV data.



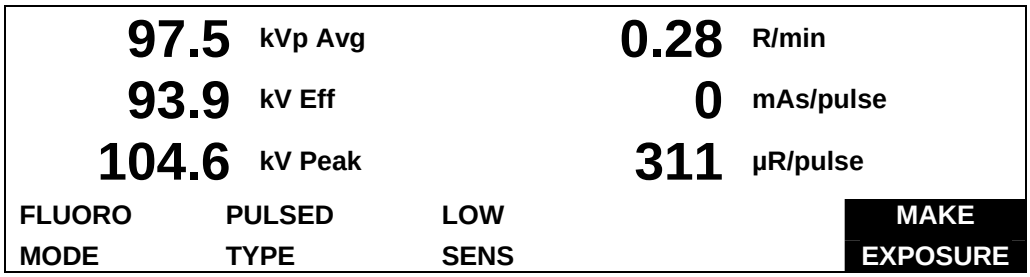
After kV data is acquired, the NERO mAx prompts to turn off the beam.



After the beam is turned off, the NERO mAx analyzes the fluoro exposure kV data.



After data analysis is complete, kV, exposure rate and mAs/pulse are displayed. If an overrange is detected an error message is displayed. If the calculated kV is above or below the selected filter kV range, “High” or “Low” is displayed instead of kV (see Section 4.3--Error Messages--for more information). After the exposure data is displayed, the NERO mAx displays a "Please wait..." message as it prepares for the next exposure.



The NERO mAx is now ready to take another exposure. Pressing the mode key at any time exits from this measurement mode and returns to the mode selection screen.

NOTE

The exposure rate displayed after the SAVE key has been pressed may be slightly different from the rate displayed before the stop key was pressed. This is because the exposure rate is calculated based upon correction factors that are based upon the measured kVp. In the fluoro mode, kVp is not measured until after the SAVE key is pressed, so a constant is used to calculate exposure and rate. The constant that is used is based upon the calibration factors corresponding to a kVp average of the mid point of the selected filter range. After the SAVE key is pressed, the NERO mAx calculates the fluoro kVp and applies an exposure correction factor based upon the calculated kVp.

As a power saving feature, the NERO mAx's display backlight turns off after one minute of no activity. The backlight turns back on when any button is pressed or an exposure is made. In addition, after five minutes of no activity, the NERO mAx exits from any measurement mode and returns to the mode selection screen.

2.5.4AMSE Mode

AMSE mode is used for **A**utomated **M**easurement of **S**equential **E**xposures. This mode is used to measure the output of CINE x-ray generators. In AMSE mode, the NERO mAx measures kVp, exposure rate (mR/frame), mAs/frame and time/frame (mS/frame).

To make an AMSE measurement

Make sure that the NERO mAx is turned off. Plug one end of the NERO mAx's detector cable into the NERO mAx detector. Plug the other end of the detector cable into the NERO mAx's detector connector. Insert the W/Al filter card into the detector and place the filter card in the correct position for the kV range to be measured. Place the NERO mAx detector on the x-ray table with the top of the detector facing the x-ray tube. Position the detector so that the detector is centered in the beam and is aligned with the x-ray tube axis. If mAs measurements are to be made, plug the mAs cable into the NERO mAx detector's mAs input and connect the mAs leads to the generators mAs terminals. For more information on positioning the NERO mAx detector, see section "Positioning the Detector". For mA limits vs. kV, refer to Appendix B.

WARNING

Extreme caution should be used when making connections to the mAs terminals of the X-ray generator or detector. Improper connections may result in injury, damage to the NERO mAx, and/or damage to the x-ray generator.

If results are to be printed, plug the printer cable into the printer port at the rear of the NERO mAx then plug the other end of the printer cable into the printer and turn the printer on (see Section1.5--Printing). Plug the AC adapter into the NERO mAx if needed (see Section 1.4--Battery Operation and Charging) and turn the instrument on.

EXP	
CT EXP	
AMSE	
FLUORO	
MAMMO	**LOW**
RADIO	**HIGH**
MODE	**SENS**

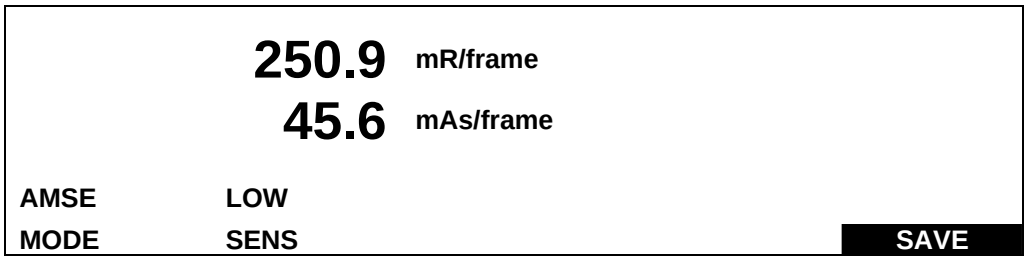
Select AMSE mode and sensitivity, then press enter.

	Please wait…
	FILTER = 50 - 100
AMSE	**LOW**
MODE	**SENS**

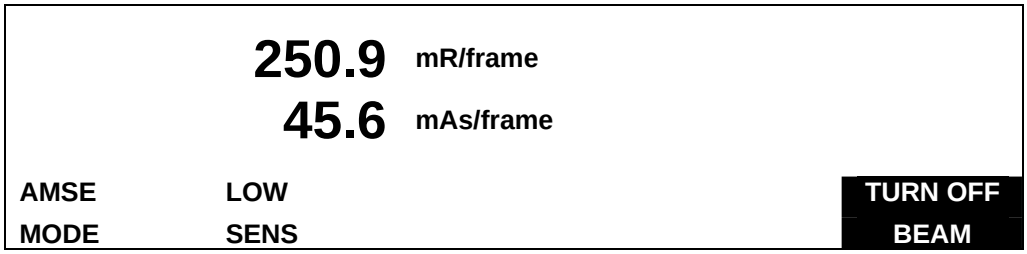
Please wait while the NERO mAx prepares to take an exposure. Note that the selected filter kV range is displayed. If the NERO mAx detects a fault condition such as an invalid filter card or position, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information). When the NERO mAx is ready to take an exposure it will beep and prompt for an exposure.

	MAKE EXPOSURE
	FILTER = 50 – 100
AMSE	**LOW**
MODE	**SENS**

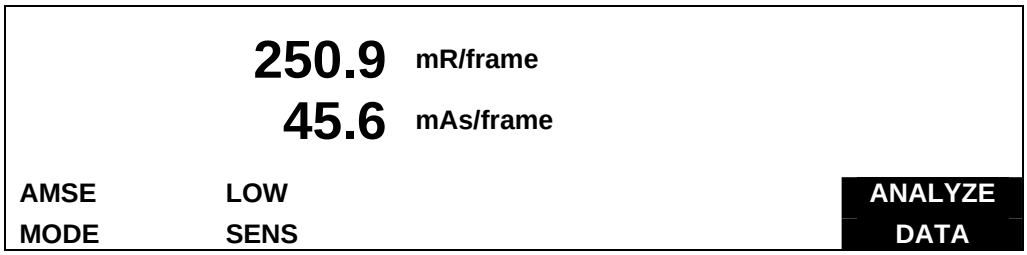
Start the exposure.



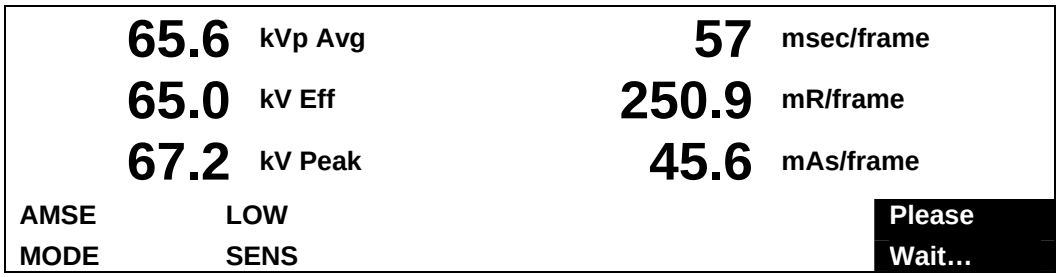
After the exposure starts, the NERO mAx displays exposure/frame and mAs/frame. When the desired exposure rate is displayed, press the SAVE key to acquire kV data.



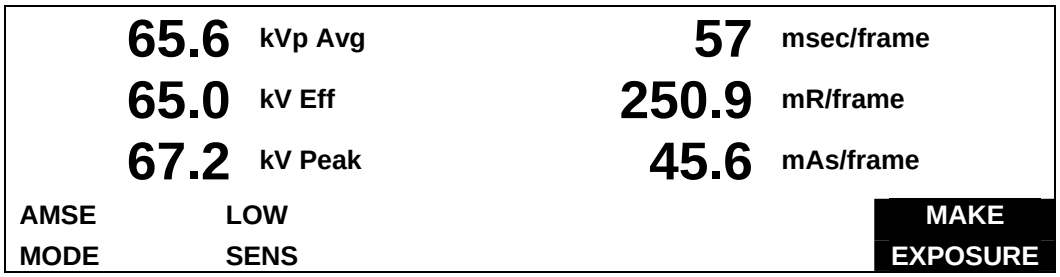
After kV data is acquired, the NERO mAx prompts to turn off the beam.



After the beam is turned off, the NERO mAx analyzes the fluoro exposure kV data.



After data analysis is complete, kV, exposure rate, mAs/frame and time/frame are displayed. If an overrange is detected an error message is displayed. If the calculated kV is above or below the selected filter kV range, “High” or “Low” is displayed instead of kV (see Section 4.3--Error Messages--for more information). After the exposure data is displayed, the NERO mAx displays a "Please wait..." message as it prepares for the next exposure.



The NERO mAx is now ready to take another exposure. Pressing the mode key at any time exits from this measurement mode and returns to the mode selection screen.

NOTE

The exposure rate displayed after the SAVE key has been pressed may be slightly different from the rate displayed before the stop key was pressed. This is because the exposure rate is calculated based upon correction factors that are based upon the measured kVp. In the AMSE mode, kVp is not measured until after the SAVE key is pressed, so a constant is used to calculate exposure and rate. The constant that is used is based upon the calibration factors corresponding to a kVp average of the mid point of the selected filter range. After the SAVE key is pressed, the NERO mAx calculates kVp and applies an exposure correction factor based upon the calculated kVp.

As a power saving feature, the NERO mAx's display backlight turns off after one minute of no activity. The backlight turns back on when any button is pressed or an exposure is made. In addition, after five minutes of no activity, the NERO mAx exits from any measurement mode and returns to the mode selection screen.

2.5.5CT Exposure Mode

CT Exposure mode is used to make CT exposure measurements using the Victoreen 6000-100 or 6000-200 CT ion chamber. A CT probe must be connected to the 8000 detector's external ion chamber input in this mode. The exposure is calculated using the user entered beam width (in mm) and the CT probe's calibration factor (Rcm/nC). This mode functions in the same manner as the Exposure Mode with the addition of beam width entry.

To make a CT exposure measurement

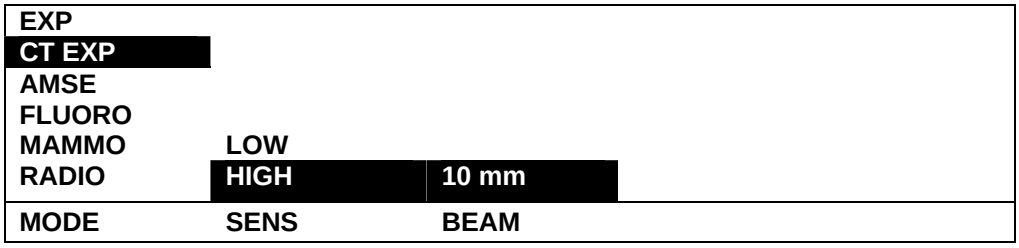
Make sure that the NERO mAx is turned off. Plug one end of the NERO mAx's detector cable into the NERO mAx detector. Plug the other end of the detector cable into the NERO mAx's detector connector. No filter card needs to be present in the detector. Plug the CT chamber's BNC connector into the ion chamber signal input at the rear of the NERO mAx detector. Plug the CT chamber's bias plug (banana jack) into the bias output at the rear of the NERO mAx detector. Position the ion chamber as needed.

If results are to be printed, plug the printer cable into the printer port at the rear of the NERO mAx then plug the other end of the printer cable into the printer and turn the printer on (see Section 1.5--Printing).

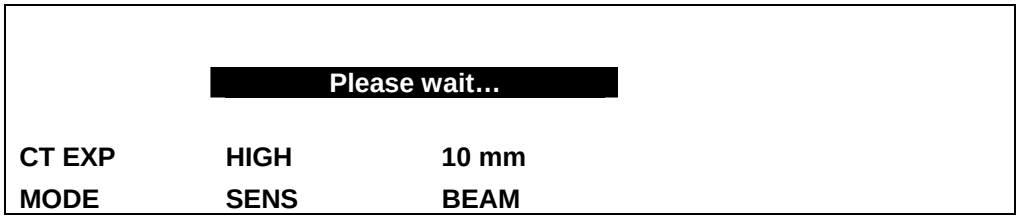
Plug the AC adapter into the NERO mAx if needed (see Section 1.4--Battery Operation and Charging) and turn the instrument on.

WARNING

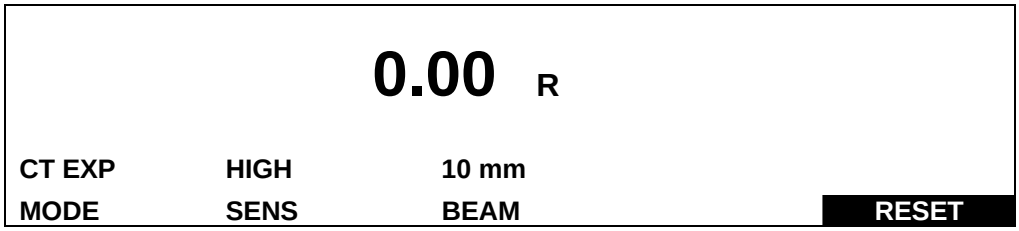
An electric shock hazard exists between the ion chamber bias connector and ground.



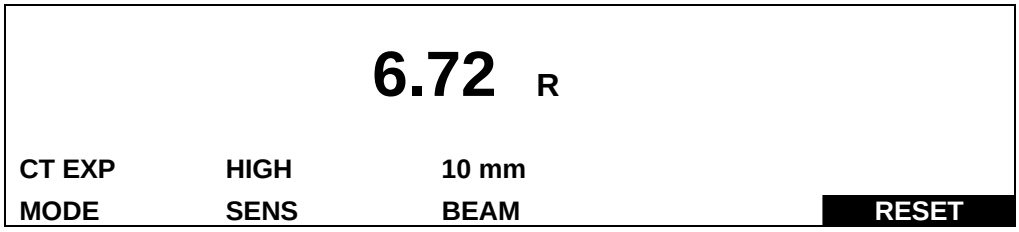
Select CT EXP mode, high or low sensitivity and beam width (1-10 mm), then press the ENTER key. Pressing the BEAM softkey (2) or the UP key increments the beam width by 1 mm, pressing the DOWN button decrements the beam width by 1 mm.



Please wait while the NERO mAx prepares to take an exposure. If the NERO mAx detects a fault condition such as a high offset, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information).



When the NERO mAx is ready to take an exposure it will beep and display zero exposure.



After the exposure ends, the measured exposure for the scan is displayed. If an overrange occurs, an error message will be displayed (see Section 4.3--Error Messages--for more information). When the exposure ends, the NERO mAx auto-resets before the next exposure while retaining the measured exposure data on screen. The NERO mAx beeps when auto reset is complete and the NERO mAx is ready for the next exposure. Press the RESET softkey (4) to zero the display or press the mode key to exit. **Do not press the RESET softkey when the beam is on. Inaccurate readings will result.**

As a power saving feature, the NERO mAx's display backlight turns off after one minute of no activity. The backlight turns back on when any button is pressed or an exposure is made. In addition, after five minutes of no activity, the NERO mAx exits from any measurement mode and returns to the mode selection screen.

2.5.6Exp Mode

Exposure mode is used to make exposure and rate measurements using the NERO mAx's internal ion chamber or an external ion chamber. The exposure is calculated using the selected ion chamber's calibration factor (along with air density correction). For more information about entry and storage of ion chamber calibration factors, see CAL mode. For more information about selecting exposure/rate units, see SETUP mode. All exposure and rate measurements are corrected for user entered air density. For more information about entering air density data, see SETUP mode.

Exposure and rate measurements made with the NERO mAx's internal ion chamber in this mode are calculated using a constant calibration factor and air density correction. In measurement modes where kV is measured, exposure and rate are calculated using calibration factors based upon the measured kV. In the exposure mode, no kV measurements are made, so a constant is used to calculate exposure and rate. The constant that is used is based upon the calibration factors corresponding to a measured kVp average of 80 kVp. A user entered calibration factor (multiplier) allows the user to adjust the calibration of the internal ion chamber. The default for this calibration factor is 1.00 E+00. For more information about entry and storage of ion chamber calibration factors, see CAL mode. For more information about entry of air density information (temperature and pressure), see SETUP mode.

Exposure and rate measurements made with the external ion chambers are calculated using the stored calibration factor (R/nC or Gy/nC) for the selected external chamber and air density correction. For more information about entry of air density information (temperature and pressure), see SETUP mode.

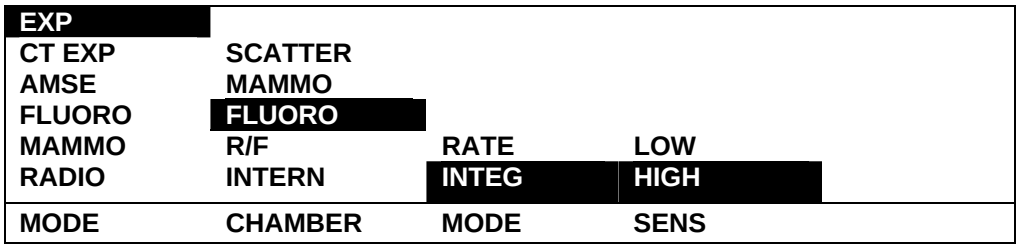
To make an exposure or rate measurement

Make sure that the NERO mAx is turned off. Plug one end of the NERO mAx's detector cable into the NERO mAx detector. Plug the other end of the detector cable into the NERO mAx's detector connector. No filter card is required for exposure or rate measurements. If using an external ion chamber, plug the ion chamber's BNC connector into the ion chamber signal input at the rear of the NERO mAx detector. Plug the chamber's bias plug (banana jack) into the bias output at the rear of the NERO mAx detector. Position the ion chamber as needed. If using the NERO mAx's internal ion chamber, position the NERO mAx detector as needed.

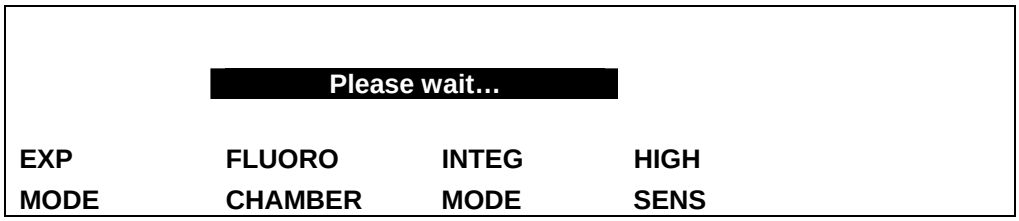
WARNING

An electric shock hazard exists between the ion chamber bias connector and ground.

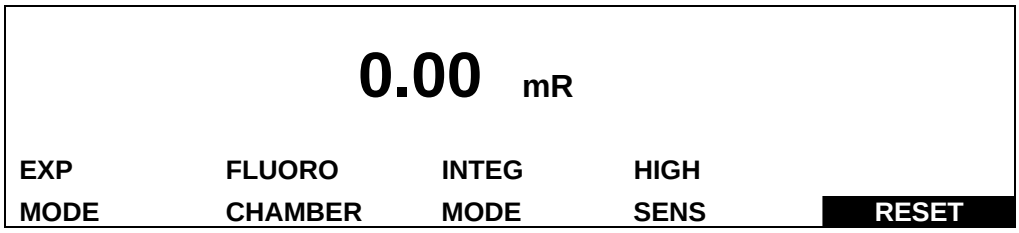
If results are to be printed, plug the printer cable into the printer port at the rear of the NERO mAx then plug the other end of the printer cable into the printer and turn the printer on (see Section 1.5--Printing). Plug the AC adapter into the NERO mAx if needed (see Section 1.4--Battery Operation and Charging) and turn the instrument on.



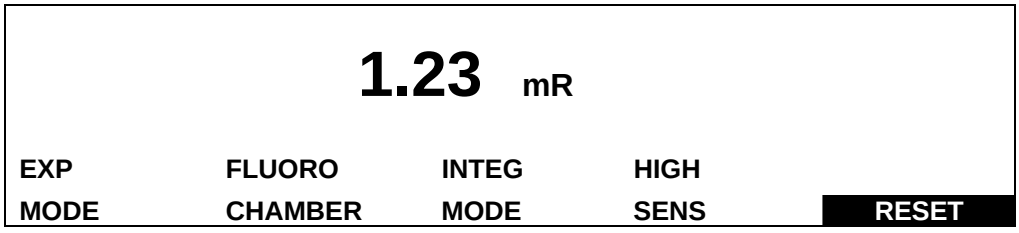
Select EXP mode, the ion chamber to be used, rate or integrate mode, high or low sensitivity, then press the ENTER key.



Please wait approximately ten seconds while the NERO mAx prepares to take an exposure. If the NERO mAx detects a fault condition such as a high offset, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information).



When the NERO mAx is ready to take an exposure it will beep and display zero exposure units.



After the exposure ends, the measured exposure is displayed. If an overrange occurs, an error message will be displayed (see Section 4.3--Error Messages--for more information). In the integrate mode, the 8000 auto-resets after an exposure while retaining the measured exposure data on screen. The NERO mAx beeps when auto reset is complete and the NERO mAx is ready for another exposure. This auto-reset feature is not present in the rate mode. Press the RESET softkey (4) to zero the display in the rate and integrate modes or press the mode key to exit. **Do not press the RESET softkey when the beam is on. Inaccurate readings will result.**

As a power saving feature, the NERO mAx's display backlight turns off after one minute of no activity. The backlight turns back on when any button is pressed or an exposure is made. In addition, after five minutes of no activity, the NERO mAx exits from any measurement mode and returns to the mode selection screen.

2.5.7HVL Mode

NOTE

In the HVL mode, the HVL report is printed only after the mode key is depressed or 10 exposures occur.

In the HVL mode, the NERO mAx calculates half value layer based upon a series of exposure or rate measurements made with varying thickness' of aluminum absorbers placed in the x-ray beam. A minimum of two measurements are required and up to ten may be used. The exposure or rate measurements may be made using the NERO mAx's internal ion chamber or an external ion chamber. Exposure and rate are calculated using the selected ion chamber's calibration factor and when using a CT chamber, beam width. For more information about entry and storage of ion chamber calibration factors, see CAL mode. For more information about selecting exposure/rate units, see SETUP mode.

The default absorber thickness is 3.30 mmAl except when the Victoreen mammo chamber has been selected. The default absorber thickness when using the mammo chamber is 0.30 mmAl. The HVL filter thickness can be incremented or decremented from the default value by pressing the up or down keys.

Exposure and rate measurements made with the NERO mAx's internal ion chamber, where kV is not measured, are calculated using the ion chamber's 80 kV calibration factors. In measurement modes where kV is measured, exposure and rate are calculated using calibration factors based upon the measured kV. In the HVL mode, no kV measurements are made, so a constant is used to calculate exposure and rate. The constant that is used is based upon the calibration factors corresponding to a measured kVp average of 80 kVp. A user entered calibration factor (multiplier) allows the user to adjust the calibration of the internal ion chamber. For more information about entry and storage of ion chamber calibration factors, see CAL mode.

HVL is calculated using a linear regression of the natural log of the normalized exposure (normalized to the first exposure) versus absorber thickness in millimeters of aluminum. In addition, the correlation coefficient ("r") of the exposure data is calculated to provide an indication of how well the data fits the linear regression. A poor fit ($r < 0.98$) is indicated by a flashing "r" value. The first exposure of the series is made with no HVL absorber in place. All subsequent exposures must be made with an aluminum absorber in the x-ray beam. The absorbers do not need to be placed in the beam in any order of thickness. Below is the formula used by the NERO mAx to calculate half value layer.

$$HVL = A * \ln(x) + B$$

Where: x = Normalized dose at Half Value Layer (0.5)

A = Slope of ln(x) vs. mmAl

B = Intercept of ln(x) vs. mmAl (Usually very close to zero)

For example, given the following table of exposure data:

Exp #	mm Al	Dose(mR)	Normalized Dose	ln Normalized Dose
1	0	556	1.000	0.000
2	4.3	273	0.491	-0.711
3	3.8	296	0.532	-0.631
4	3.3	316	0.568	-0.566
5	4.8	256	0.460	-0.777
6	5.3	238	0.428	-0.849

Linear Regression Results: A = -5.051 B = -0.000 r = -0.999

$$HVL = A * \ln(x) + B$$

= -5.051*ln(0.5) + 0

= 3.5 mm Al

Note that in the table, the added filtration is near the half value layer. Calculating HVL in this manner allows the user to improve the accuracy of the calculated HVL by making more exposures. Using this method, the closer that the *average* of the added filtration is to the calculated HVL, the more accurate the HVL calculation will be. To assist in establishing the optimum average HVL filter thickness, the NERO mAx displays either a “HIGH” or “LOW” message above the HVL if the average of the added filtration for each exposure is not within 10% of the calculated HVL. If no messages are displayed, the average added filtration is within 10% of the calculated HVL and no more exposures need to be made. As a result, the NERO mAx guides the user to the correct HVL.

The accuracy of the HVL measurement depends upon the reproducibility of the x-ray parameters, geometry errors and calculation errors caused by the approximation of the natural log of the normalized exposure data to the actual attenuation curve. This calculation error is equal to zero if the filter thickness for the second exposure reduces the exposure by exactly half.

When more than two exposures are made, the NERO mAx calculates the correlation coefficient (‘r’) of the exposure and HVL filter thickness data to test the data for goodness of fit. The closer that the correlation coefficient is to unity or one, the better the data fits the calculated approximation of the attenuation curve. If the correlation coefficient is less than 0.98, the displayed “r” value flashes to indicate a poor fit. A low correlation coefficient may be caused by poor x-ray output reproducibility, poor geometry or errors in filter thickness. In addition, the larger the variation in filter thickness from one exposure to the next, the lower the correlation coefficient.

To achieve optimal half value layer accuracy, the following are recommended:

1. The aluminum HVL filters must be placed at the collimator.
2. All exposures must be made at the same machine settings.
3. The output of the x-ray generator must be reproducible.
4. The field should be collimated to the detector or ion chamber.
5. Use HVL filter thickness’ that are near the actual HVL.

To make HVL determination using ***exposure*** measurements

Make sure that the NERO mAx is turned off. Plug one end of the NERO mAx's detector cable into the NERO mAx detector. Plug the other end of the detector cable into the NERO mAx's detector connector. No filter card is required for exposure or rate measurements. If using an external ion chamber, plug the ion chamber's BNC connector into the ion chamber signal input at the rear of the NERO mAx detector. Plug the chamber's bias plug (banana jack) into the bias output at the rear of the NERO mAx detector. Position the ion chamber as needed. If using the NERO mAx's internal ion chamber, position the NERO mAx detector as needed.

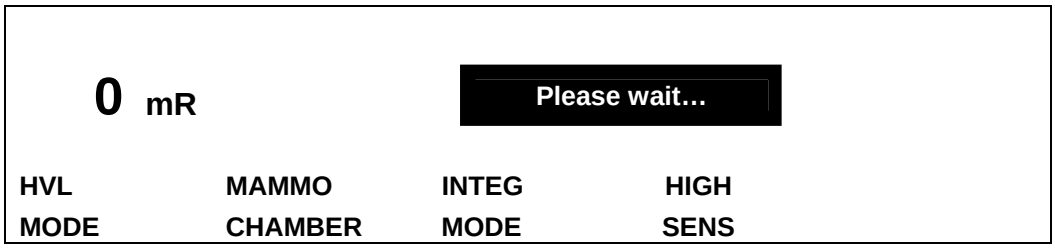
WARNING

An electric shock hazard exists between the ion chamber bias connector and ground.

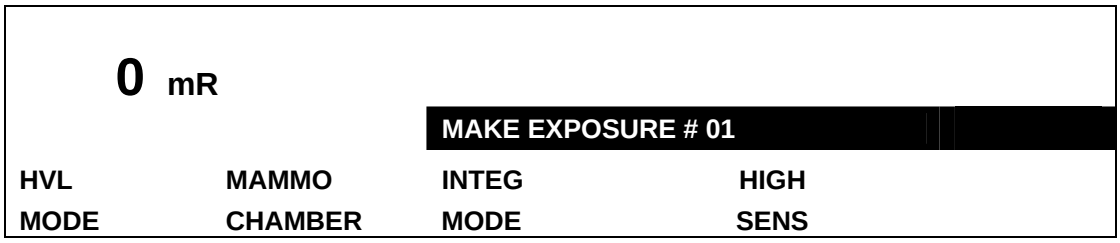
If results are to be printed, plug the printer cable into the printer port at the rear of the NERO mAx then plug the other end of the printer cable into the printer and turn the printer on (see Section 1.5--Printing). Plug the AC adapter into the NERO mAx if needed (see Section 1.4--Battery Operation and Charging) and turn the instrument on.

HVL			
EXP	**CT**		
CT EXP	**MAMMO**		
AMSE	**FLUORO**		
FLUORO	**R/F**	**RATE**	**LOW**
MAMMO	**INTERN**	**INTEG**	**HIGH**
MODE	**CHAMBER**	**MODE**	**SENS**

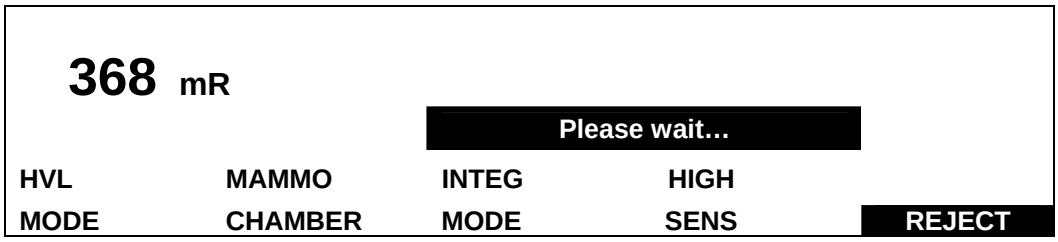
Select HVL mode, the ion chamber to be used, integrate mode, high or low sensitivity, then press the ENTER key.



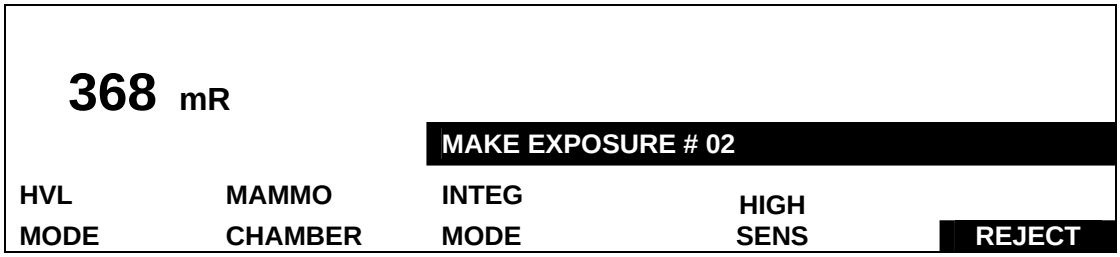
Please wait while the NERO mAx prepares to take an exposure. If the NERO mAx detects a fault condition such as a high offset, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information). When the NERO mAx is ready to take an exposure it will beep and prompt for an exposure.



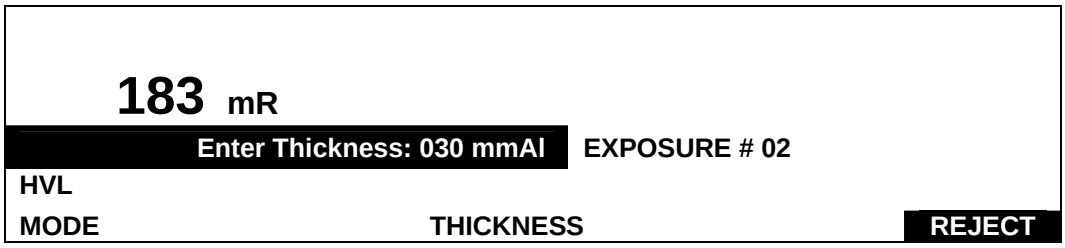
Make the first exposure **with no filtration in the beam.**



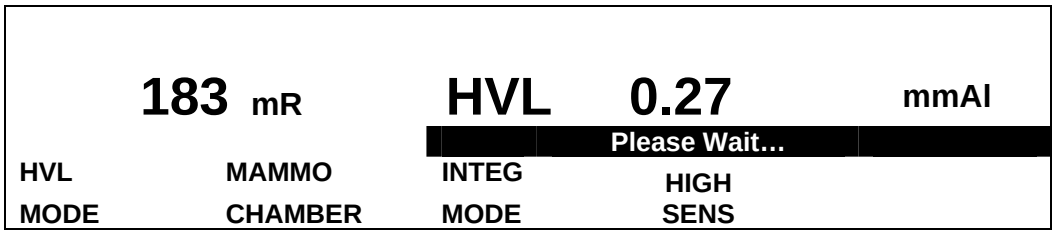
The exposure data from the first exposure is displayed and the NERO mAx prepares to take the second exposure. Please wait while the NERO mAx prepares to take the next exposure. If the NERO mAx detects a fault condition such as a high offset, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information).



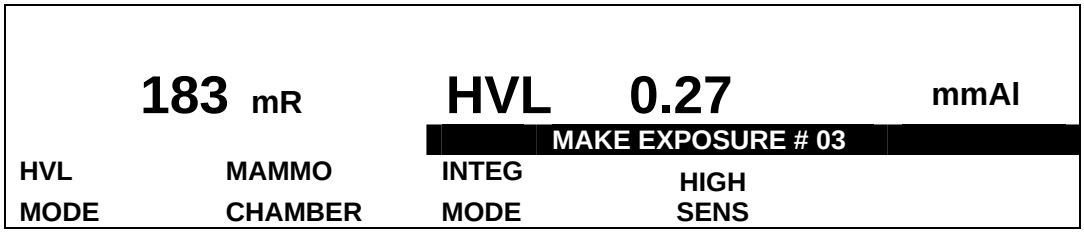
The NERO mAx is now ready to take the next exposure. Position an aluminum absorber in the beam and make the exposure. If the previously measured exposure is not acceptable, press the reject softkey to retake the exposure. If an overrange occurs, an error message is displayed and the exposure must be taken over.



The exposure data from the second exposure is now displayed and the user is prompted to enter the thickness of the aluminum filter. To enter the filter thickness, press the THICKNESS softkey to increment the filter thickness or use the UP and DOWN keys to increment and decrement the filter thickness. If a filter thickness is repeated, the NERO mAx will ask for confirmation that the latest exposure data is to be accepted. When the correct filter thickness is displayed, press the ENTER key. Pressing the enter key accepts the HVL exposure data after the absorber thickness has been entered. Pressing the reject key rejects the exposure data and the user is prompted to make the exposure over.



The HVL is calculated and displayed after the new exposure data has been entered and a “Please wait…” message is displayed while the NERO mAx prepares for the next exposure. If the NERO mAx displays “LOW” above the calculated HVL, the average of the added filtration is more than 10% less than the calculated HVL and more aluminum filtration is needed. If the NERO mAx displays “HIGH” above the calculated HVL, the added filtration is more than 10% above the calculated HVL and some of the aluminum filtration should be removed. When more than two exposures have been made, the NERO mAx checks the HVL data for goodness of fit by calculating its correlation coefficient (“r”), if the fit is poor (r< 0.98), the “r” value will flash.



The NERO mAx is now ready to take the next exposure. The NERO mAx stays in this measurement loop until ten exposures have been made or the mode key is pressed, which exits to the mode selection screen.

As a power saving feature, the NERO mAx’s display backlight turns off after one minute of no activity. The backlight turns back on when any button is pressed or an exposure is made. In addition, after five minutes of no activity, the NERO mAx exits from any measurement mode and returns to the mode selection screen.

(HVL) Exposure Rate

To make HVL determination using ***exposure rate*** measurements

Make sure that the NERO mAx is turned off. Plug one end of the NERO mAx's detector cable into the NERO mAx detector. Plug the other end of the detector cable into the NERO mAx's detector connector. No filter card is required for exposure or rate measurements. If using an external ion chamber, plug the ion chamber's BNC connector into the ion chamber signal input at the rear of the NERO mAx detector. Plug the chamber's bias plug (banana jack) into the bias output at the rear of the NERO mAx detector. Position the ion chamber as needed. If using the NERO mAx's internal ion chamber, position the NERO mAx detector as needed.

WARNING

An electric shock hazard exists between the ion chamber bias connector and ground.

If results are to be printed, plug the printer cable into the printer port at the rear of the NERO mAx then plug the other end of the printer cable into the printer and turn the printer on (see Section 1.5--Printing). Plug the AC adapter into the NERO mAx if needed (see Section 1.4--Battery Operation and Charging) and turn the instrument on.

HVL			
EXP	**CT**		
CT EXP	**MAMMO**		
AMSE	**FLUORO**		
FLUORO	**R/F**	**RATE**	**LOW**
MAMMO	**INTERN**	**INTEG**	**HIGH**
MODE	**CHAMBER**	**MODE**	**SENS**

Select HVL mode, the ion chamber to be used, rate mode, high or low sensitivity, then press the ENTER key.

0.0 **R/min**			
		Please Wait…	
HVL	**INTERN**	**RATE**	**LOW**
MODE	**CHAMBER**	**MODE**	**SENS**

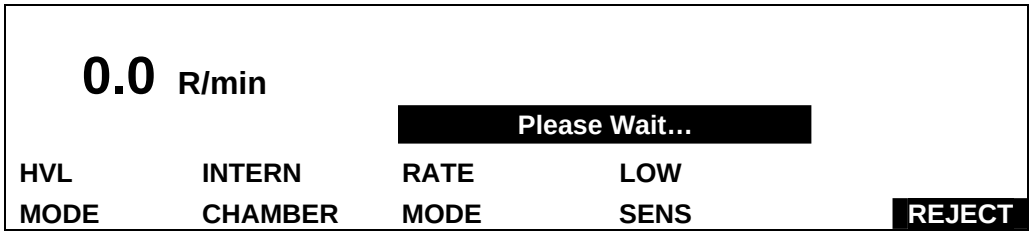
Please wait while the NERO mAx prepares to take an exposure. If the NERO mAx detects a fault condition such as a high offset, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages-- for more information). When the NERO mAx is ready to take an exposure it will beep and prompt for an exposure.

9.8 **R/min**			
		MAKE EXPOSURE # 01	
HVL	**INTERN**	**RATE**	**LOW**
MODE	**CHAMBER**	**MODE**	**SENS**

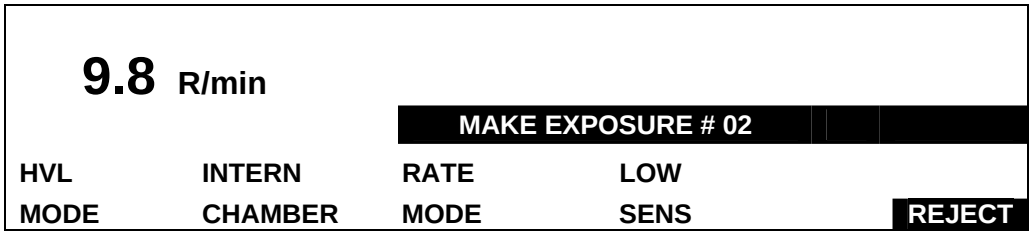
Turn the x-ray beam on **with no filtration in the beam.**

After the exposure has started, the NERO mAx displays the exposure rate. When the rate has stabilized or the desired rate has been achieved, press the SAVE softkey (softkey 4) to save the rate measurement.

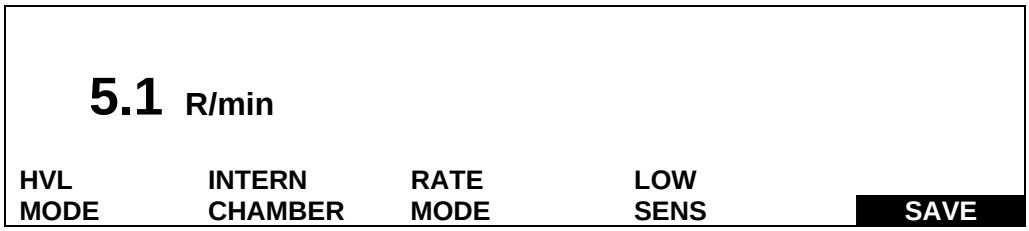
Turn off the x-ray beam. The NERO mAx has stored the measured exposure rate and will set up for the next exposure as soon as the beam turns off.



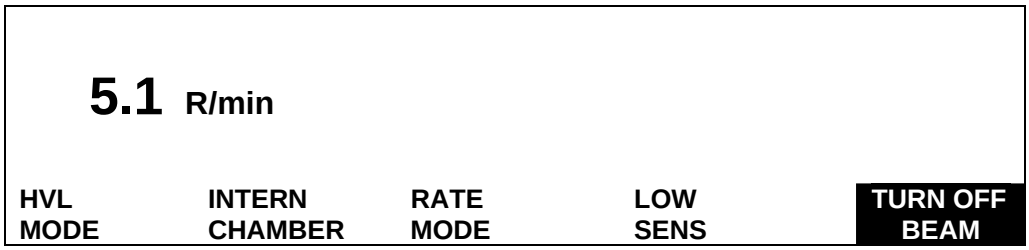
While the exposure rate from the first exposure is displayed, the NERO mAx prepares to take the second exposure. Please wait while the NERO mAx prepares to take the next exposure. If the NERO mAx detects a fault condition such as a high offset, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information).



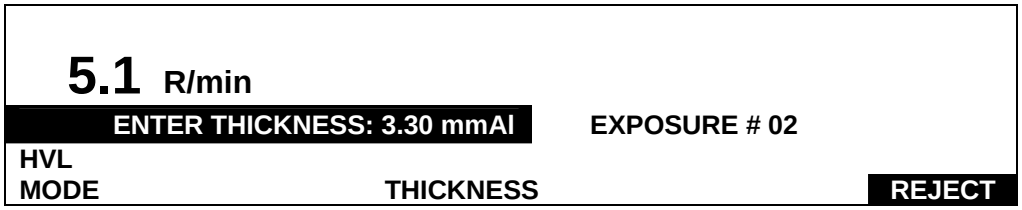
The NERO mAx is now ready to take the next exposure. Position an aluminum absorber in the beam and make the exposure. If the previously measured exposure is not acceptable, press the reject softkey to retake the exposure. If an overrange occurs, an error message is displayed and the exposure must be taken over.



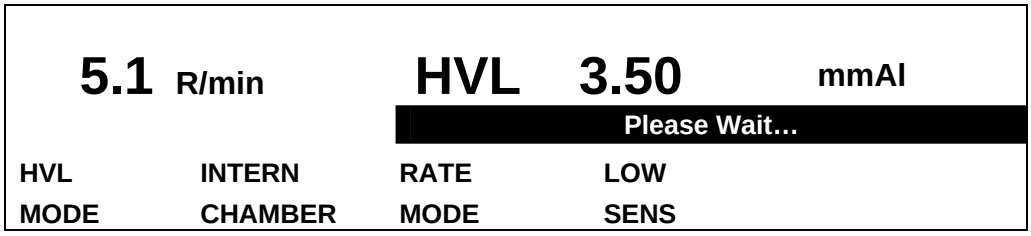
After the second exposure has started, the NERO mAx displays the exposure rate. When the rate has stabilized or the desired rate has been achieved, press the SAVE softkey (softkey 4) to save the rate measurement.



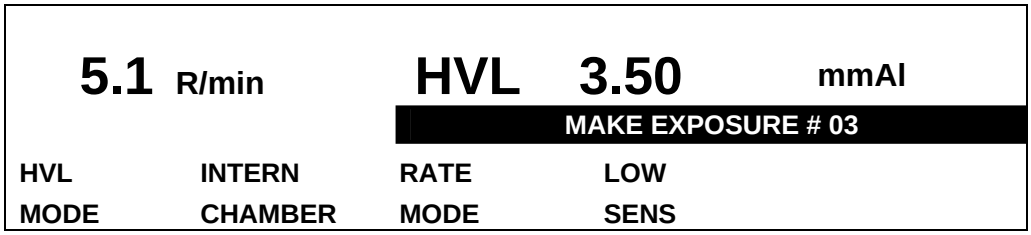
Turn off the x-ray beam. The NERO mAx has stored the measured exposure rate and will set up for the next exposure as soon as the beam turns off.



While the exposure rate from the second exposure is displayed, the user is prompted to enter the thickness of the aluminum filter. To enter the filter thickness, press the THICKNESS softkey to increment the filter thickness or use the UP and DOWN keys to increment and decrement the filter thickness. When the correct filter thickness is displayed, press the ENTER key. If a filter thickness is repeated, the NERO mAx will ask for confirmation that the latest exposure data is to be accepted. Pressing the enter key accepts the HVL exposure data after the absorber thickness has been entered. Pressing the reject key rejects the exposure data and the user is prompted to make the exposure over.



The HVL is calculated and displayed after the new exposure data has been entered and a “Please wait…” message is displayed while the NERO mAx prepares for the next exposure. If the NERO mAx displays “LOW” above the calculated HVL, the average of the added filtration is more than 10% less than the calculated HVL and more aluminum filtration is needed. If the NERO mAx displays “HIGH” above the calculated HVL, the added filtration is more than 10% above the calculated HVL and some of the aluminum filtration should be removed. When more than two exposures have been made, the NERO mAx checks the HVL data for goodness of fit by calculating its correlation coefficient (“r”), if the fit is poor ($r < 0.98$), the “r” value will flash.



The NERO mAx is now ready to take the next exposure. The NERO mAx stays in this measurement loop until ten exposures have been made or the mode key is pressed, which exits to the mode selection screen.

As a power saving feature, the NERO mAx's display backlight turns off after one minute of no activity. The backlight turns back on when any button is pressed or an exposure is made. In addition, after five minutes of no activity, the NERO mAx exits from any measurement mode and returns to the mode selection screen.

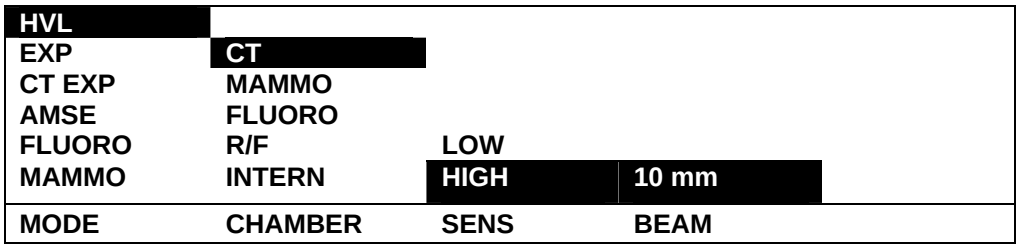
To make HVL determination using *CT exposure* measurements

Make sure that the NERO mAx is turned off. Plug one end of the NERO mAx's detector cable into the NERO mAx detector. Plug the other end of the detector cable into the NERO mAx's detector connector. No filter card is required for exposure or rate measurements. Plug the CT chamber's BNC connector into the ion chamber signal input at the rear of the NERO mAx detector. Plug the CT chamber's bias plug (banana jack) into the bias output at the rear of the NERO mAx detector. Position the CT chamber as needed.

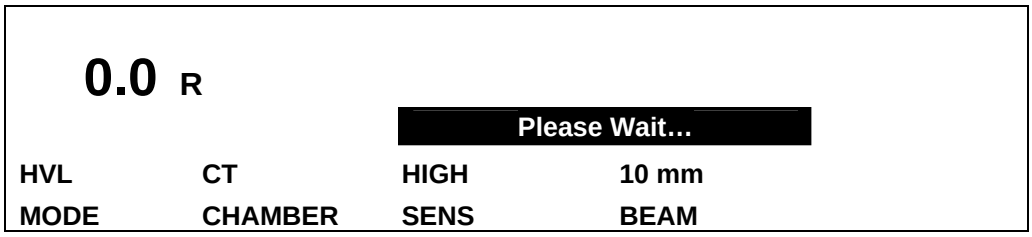
WARNING

An electric shock hazard exists between the ion chamber bias connector and ground.

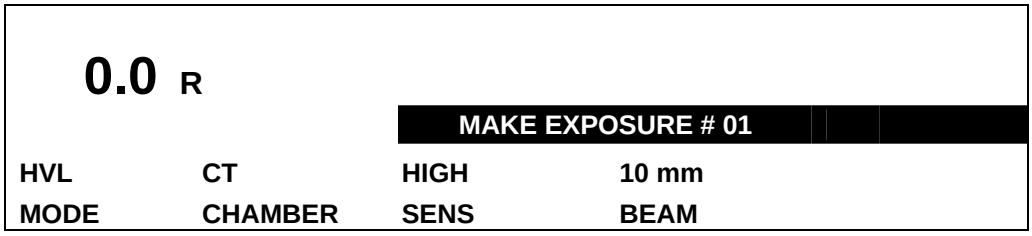
If results are to be printed, plug the printer cable into the printer port at the rear of the NERO mAx then plug the other end of the printer cable into the printer and turn the printer on (see Section 1.5--Printing). Plug the AC adapter into the NERO mAx if needed (see Section 1.4--Battery Operation and Charging) and turn the instrument on.



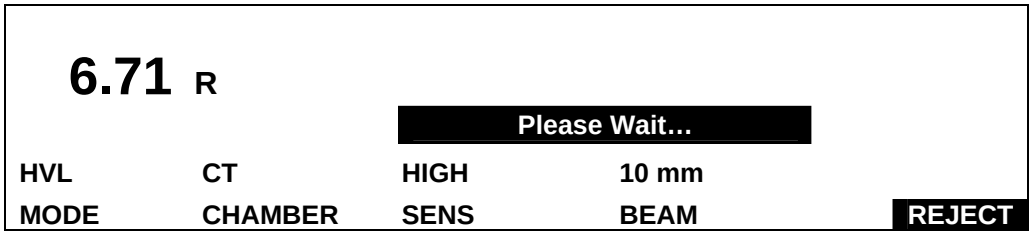
Select HVL mode, CT chamber, high or low sensitivity and, using the BEAM softkey (3), select the CT beam width, then press the ENTER key.



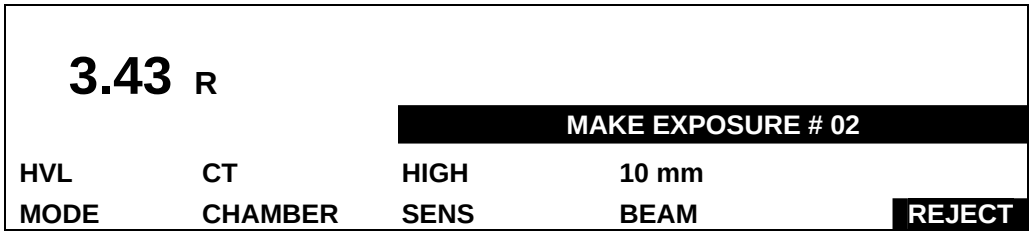
Please wait while the NERO mAx prepares to take an exposure. If the NERO mAx detects a fault condition such as a high offset, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information). When the NERO mAx is ready to take an exposure it will beep and prompt for an exposure.



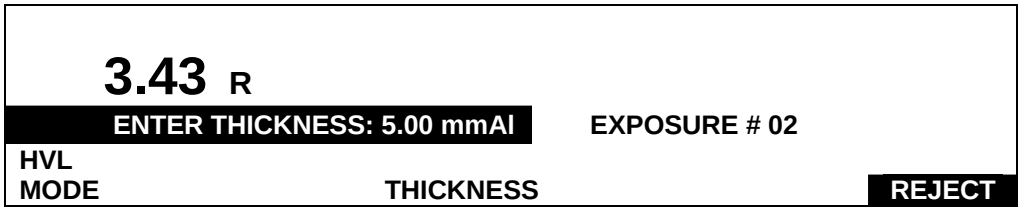
Make the x-ray exposure **with no filtration in the beam.**



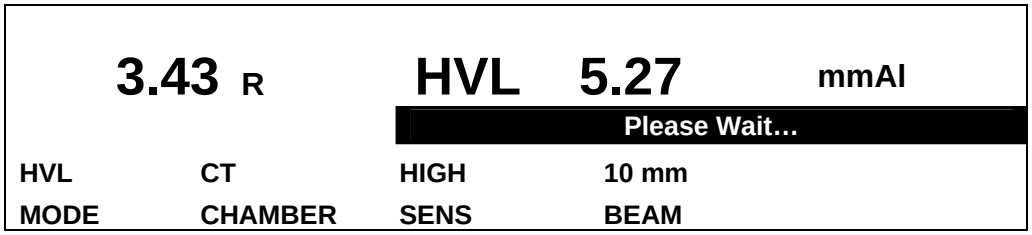
While the exposure from the first exposure is displayed, the NERO mAx prepares to take the second exposure. Please wait while the NERO mAx prepares to take the next exposure. If the NERO mAx detects a fault condition such as a high offset, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information).



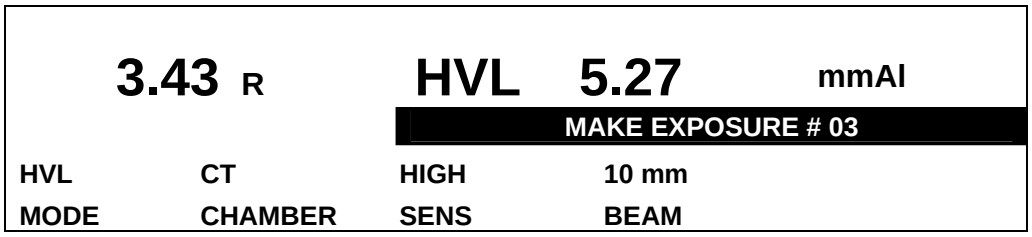
The NERO mAx is now ready to take the next exposure. Position an aluminum absorber in the beam and make the exposure. If the previously measured exposure is not acceptable, press the reject softkey to retake the exposure. If an overrange occurs, an error message is displayed and the exposure must be taken over.



While the exposure rate from the second exposure is displayed, the user is prompted to enter the thickness of the aluminum filter. To enter the filter thickness, press the THICKNESS softkey to increment the filter thickness or use the UP and DOWN keys to increment and decrement the filter thickness. When the correct filter thickness is displayed, press the ENTER key. If a filter thickness is repeated, the NERO mAx will ask for confirmation that the latest exposure data is to be accepted. Pressing the enter key accepts the HVL exposure data after the absorber thickness has been entered. Pressing the reject key rejects the exposure data and the user is prompted to make the exposure over.



The HVL is calculated and displayed after the new exposure data has been entered and a “Please wait…” message is displayed while the NERO mAx prepares for the next exposure. If the NERO mAx displays “LOW” above the calculated HVL, the average of the added filtration is more than 10% less than the calculated HVL and more aluminum filtration is needed. If the NERO mAx displays “HIGH” above the calculated HVL, the added filtration is more than 10% above the calculated HVL and some of the aluminum filtration should be removed. When more than two exposures have been made, the NERO mAx checks the HVL data for goodness of fit by calculating its correlation coefficient (“r”), if the fit is poor (r< 0.98), the “r” value will flash.



The NERO mAx is now ready to take the next exposure. The NERO mAx stays in this measurement loop until ten exposures have been made or the mode key is pressed, which exits to the mode selection screen.

As a power saving feature, the NERO mAx’s display backlight turns off after one minute of no activity. The backlight turns back on when any button is pressed or an exposure is made. In addition, after five minutes of no activity, the NERO mAx exits from any measurement mode and returns to the mode selection screen.

2.5.8Cal Mode

CAL	**CT**	**n.nn**	**E±nn**	**Rcm/nC**
HVL	**SCATTER**	**n.nn**	**E±nn**	**Gy/nC**
EXP	**MAMMO**	**n.nn**	**E±nn**	**R/nC**
CT EXP	**FLUORO**	**n.nn**	**E±nn**	**R/nC**
AMSE	**R/F**	**n.nn**	**E±nn**	**R/nC**
FLUORO	**INTERN**	**n.nn**	**E±nn**	**CF**
MODE	**CHAMBER**	**VALUE**	**EXPONENT**	**R/Gy**

The Cal mode is used to enter and store calibration factors for ion chambers used with the NERO mAx. Calibration factors are available for the NERO mAx's internal chamber and external chambers, including the Victoreen CT chamber. These calibration factors are used in all exposure and rate measurements made with the NERO mAx. Below is a list of external ion chambers that are supported by the NERO mAx.

Ion Chamber	Part Number	Nominal Volume
CT	6000-100	3.2 cc
CT	6000-200	10 cc
Scatter	6000-532B	400 cc
Mammo	6000-529	3.3 cc
Fluoro	6000-530B	105 cc
R/F	6000-528	30 cc

Calibration factors for all external chambers (except the CT chamber) may be entered in units of R/nC or Gy/nC. The calibration factor for the CT chamber must be entered as Rcm/nC. The calibration factor for the NERO mAx detector's internal ion chamber is a multiplier. All ion chamber calibration factors are stored in nonvolatile memory.

To change an ion chamber calibration factor

Using the mode key, select CAL mode. Then, using the CHAMBER softkey, select the ion chamber calibration factor to be changed (R/F, mammo, fluoro, etc.). A highlight (reverse video) will extend across the remaining 3 fields for the selected chamber. Depress the button beneath the segment of the calibration factor that is to be changed (value, exponent, R/Gy) and use the up and down arrow keys to increment and decrement the selected number. Holding down the up or down arrow keys continuously increments or decrements the selected number. The values of the calibration factors (mantissas) are limited to numbers between 1.00 and 9.99. The exponents for all ion chambers calibration factors, except for the internal chamber, are limited to ± 10. The exponent for the NERO mAx detector's internal ion chamber's correction factor is limited to ± 1. The R/Gy key toggles the calibration factor units between R/nC and Gy/nC for external ion chambers only.

The NERO mAx's internal ion chamber is factory calibrated to provide accurate exposure and rate measurements over the entire kVp range of the NERO mAx. These exposure and rate measurements are adjusted by applying energy dependent correction factors that are determined by comparison to applicable N.I.S.T. techniques. A calibration factor for the internal ion chamber is provided which allows the user to make adjustments in this chamber's calibration. The calibration factor for the NERO mAx's internal ion chamber is a unitless correction factor or multiplier. This calibration factor is used whenever exposure or rate measurements are made with the NERO mAx's internal ion chamber. This calibration factor does not alter the ion chamber's factory calibration but is used in conjunction with the factory calibration (along with air density correction) to calculate exposure and rate. The default for this calibration factor is 1.00 E+00. For more information about entry of air density information (temperature and pressure), see SETUP mode.

Exposure and rate measurements made with external ion chambers are calculated using the stored calibration factor (R/nC or Gy/nC) for the selected external chamber and air density correction. For more information about entry of air density information (temperature and pressure), see SETUP mode.

2.5.9Setup Mode

The Setup Mode is used to setup various features of the NERO mAx. From the setup screen the user can do the following:

- Set the instruments internal real time clock.
- Set the temperature and pressure used in air density correction of exposure measurements.
- Select exposure units of either Roentgens or Grays.
- Turn automatic printing on or off.
- Turn the clock display on or off and select normal or reverse video on screen clock display.

To Set the Time

SETUP	**CLOCK – >**	**OFF**		
CAL	**PRINT – >**	**OFF**		
HVL	**UNITS – >**	**R**		
EXP	**AIR ––– >**	**20.5 C**	**734 mmHg**	
CT EXP	**DATE ––– >**	**Oct.**	**10,**	**1996**
AMSE	**TIME –––>**	**10**	**30**	**45**
MODE	**SELECT**	**HOURS**	**MINUTES**	**SECONDS**

Using the mode key, go to the SETUP screen and use the select softkey (1) to select TIME. When time is selected, the time selection blinks and a highlight (reverse video) will extend across the other 3 display fields. The hours, minutes and seconds keys select and increment hours, minutes or seconds. Holding down any of these keys (hours, mins, secs) will continuously increment the selected unit. Once a unit of time is selected, it may also be incremented or decremented with the up or down keys. Once the desired time has been set, press the ENTER key to accept it.

The NERO mAx keeps time in a military or 24 hour format. As a result, the time must be entered in the same 24-hour format. For example 9:30 AM is entered as 9:30 but 9:30 PM must be entered as 21:30.

To Set the Date

SETUP	**CLOCK – >**	**OFF**		
CAL	**PRINT – >**	**OFF**		
HVL	**UNITS – >**	**R**		
EXP	**AIR ––– >**	**20.5 C**	**734 mmHg**	
CT EXP	**DATE ––– >**	**Oct.**	**10,**	**1996**
AMSE	**TIME –––>**	**10**	**30**	**45**
MODE	**SELECT**	**MONTH**	**DAY**	**YEAR**

From the SETUP screen, use the select softkey (1) to select DATE. When DATE is selected, the date selection blinks and a highlight (reverse video) extends across the other 3 display fields. The month, day and year keys select and increment months, days or years. Holding down any of these keys (month, day, year) will continuously increment the selected unit. Once a unit is selected, it may be incremented or decremented with the up or down keys. Once the desired date has been set, press the ENTER key to accept it.

To Set Air Density (Temperature & Pressure)

SETUP	**CLOCK – >**	**OFF**		
CAL	**PRINT – >**	**OFF**		
HVL	**UNITS – >**	**R**		
EXP	**AIR —— >**	**20.5 C**	**734 mmHg**	
CT EXP	**DATE —– >**	**Oct.**	**10,**	**1996**
AMSE	**TIME —–>**	**10**	**30**	**45**
MODE	**SELECT**	**TEMP.**	**PRESSURE**	

From the SETUP screen, use the select softkey (1) to select AIR. When AIR is selected, the air density selection blinks and a highlight (reverse video) extends across the other 2 display fields. The temperature and pressure keys select and increment temperature and pressure. Holding down either of these keys will continuously increment the selected value. Temperature and pressure may also be incremented or decremented with the up or down keys. Once the desired temperature and pressure have been set, press the ENTER key to accept them. Default values for temperature and pressure are 22° C and 760 mmHg. (Refer to Appendix A--Temperature and Pressure--for additional information.)

To Select Exposure Units (R or Gy)

SETUP	**CLOCK – >**	**OFF**		
CAL	**PRINT – >**	**OFF**		
HVL	**UNITS – >**	**R**		
EXP	**AIR —— >**	**20.5 C**	**734 mmHg**	
CT EXP	**DATE —– >**	**Oct.**	**10,**	**1996**
AMSE	**TIME —–>**	**10**	**30**	**45**
MODE	**SELECT**	**R/Gy**		

From the SETUP screen, use the select softkey (1) to select UNITS. When UNITS is selected, the units selection blinks and a highlight (reverse video) extends across the other display field. The R/Gy softkey (2) toggles the exposure units between R (Roentgens) and Gy (Grays). Exposure units may also be toggled with the up or down keys.

To Turn Automatic Printing On or Off

SETUP	**CLOCK – >**	**OFF**		
CAL	**PRINT – >**	**ON**		
HVL	**UNITS – >**	**R**		
EXP	**AIR —— >**	**20.5 C**	**734 mmHg**	
CT EXP	**DATE —– >**	**Oct.**	**10,**	**1996**
AMSE	**TIME —–>**	**10**	**30**	**45**
MODE	**SELECT**	**ON/OFF**		

From the SETUP screen, use the select softkey (1) to select PRINT. When PRINT is selected, the print selection blinks and a highlight (reverse video) extends across the other display field. The ON/OFF softkey (2) toggles automatic printing between on or off. Automatic printing print may also be turned on or off with the up or down keys.

To Setup the On Screen Clock Display

From the SETUP screen, use the select softkey (1) to select CLOCK. When CLOCK is selected, the clock selection blinks and a highlight (reverse video) extends across the other display field. The ON/OFF softkey (2) is used to select the on screen clock (time & date) display mode. The selections are normal video, reverse video or off. The clock display mode may also be toggled changed with the up or down keys.

SETUP	**CLOCK – >**	**NORMAL**		**Oct. 10, 1996**
CAL	**PRINT – >**	**ON**		**10:30:45**
HVL	**UNITS – >**	**R**		
EXP	**AIR ––– >**	**20.5 C**	**734 mmHg**	
CT EXP	**DATE ––– >**	**Oct.**	**10,**	**1996**
AMSE	**TIME –––>**	**10**	**30**	**45**
MODE	**SELECT**	**ON/OFF**		

2.5.10 Unit ID

Displays the NERO mAx's serial number, firmware part number and revision. This information is necessary when calling Fluke Biomedical at 440.248.9300 for information or assistance.

UNIT ID			**Oct. 10, 1996 12:00:00**
SETUP			
CAL	**Model 8000 S/N:**	**1234**	
HVL	**Part Number:**	**948000000**	
EXP	**Software Revision:**	**Version 1.0**	
CT EXP			

Section 3
Calibration

3.1 General

The serial numbers of the NERO mAx control console unit, detector and filter slides must be matched in order to obtain accurate results. Since the control console unit, detector and filter slides are calibrated together, they must be used together for accurate measurements.

The NERO mAx is factory calibrated for kV with reference to calibrated voltage dividers. The voltage dividers used in the calibration of the NERO mAx are calibrated on a routine basis and the calibrations are N.I.S.T. traceable.

The NERO mAx's internal ion chamber is factory calibrated to provide accurate exposure and rate measurements over the entire kVp range of the NERO mAx. These exposure and rate measurements are adjusted by applying energy dependent correction factors that are determined by comparison to applicable N.I.S.T. techniques. In addition to the factory calibration, a user entered multiplier is available for exposure and rate measurements made with the NERO mAx's internal ion chamber. The application of calibration factors to an individual measurement is the responsibility of the user and care must be exercised in interpolation or extrapolation of the calibration factors.

The NERO mAx is factory calibrated for mA with reference to a calibrated current source. Equipment used to calibrate the current source is calibrated on a routine basis and the calibrations are N.I.S.T. traceable.

A calibration report is provided with each NERO mAx. This calibration report contains the NERO mAx's calibration data as well as the recommended re-calibration date. Copies of calibration reports can be obtained by contacting Fluke Biomedical at 440.248.9300

The NERO mAx must be returned to an authorized calibration facility for re-calibration

3.2 Calibration Check

Radio mode is used to make routine kV calibration constancy checks of the NERO mAx. In this mode, the detector ratios are displayed instead of kVp. Several exposures should be made and the results averaged to eliminate variations in the readings. These detector ratios should be recorded and used for comparison to determine the constancy of the NERO mAx's calibration.

At 80 kVp, a 2% change in detector ratio corresponds to approximately a 1% change in measured kVp. Therefore, the NERO mAx can experience a change in detector ratio of up to 2% at 80 kVp and remain within its specified accuracy.

Before assuming that the NERO mAx detectors response has changed, proper generator performance should be verified. Changes in an x-ray machines output waveform can contribute to erroneous results. For this calibration check to provide valid results, it should be performed routinely on the same x-ray generator, using the same generator settings.

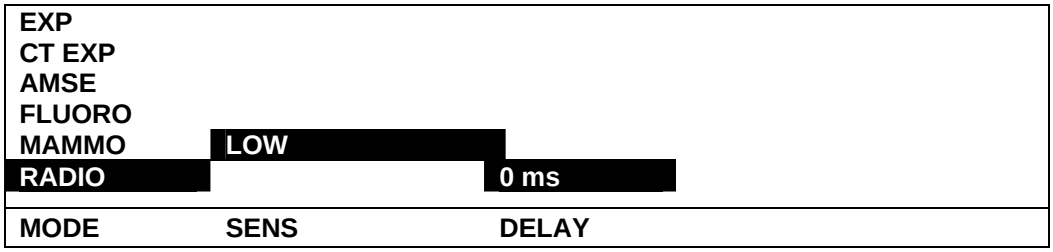
In addition, the detector must be positioned in the same manner each time that this calibration check is performed. **Failure to follow reproducible techniques will result in inaccurate measurements.**

NOTE

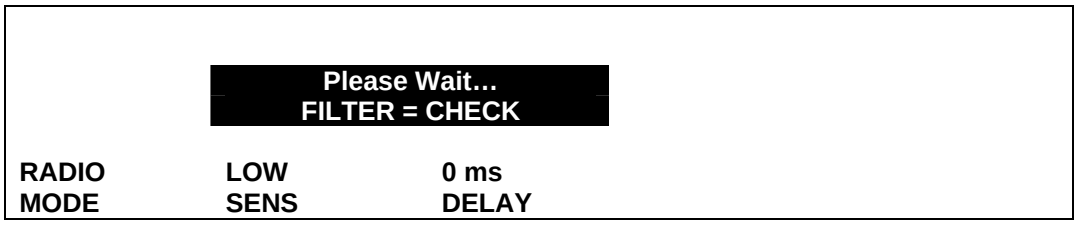
The calibration check is not intended to replace the need for periodic calibration against a reference standard.

To perform a calibration check

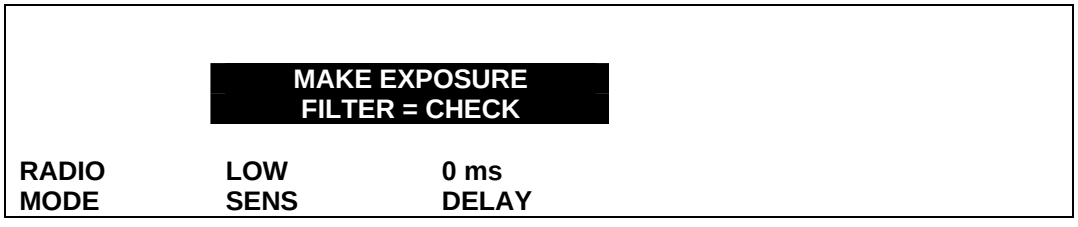
Make sure that the NERO mAx is turned off. Plug one end of the NERO mAx's detector cable into the NERO mAx detector. Plug the other end of the detector cable into the NERO mAx's detector connector. Insert the W/Al filter card into the detector and place the filter card in the CHECK position. Place the NERO mAx detector on the x-ray table with the top of the detector facing the x-ray tube. Position the detector so that the detector is centered in the beam and is aligned with the x-ray tube axis. For more information on positioning the NERO mAx detector, see Positioning the Detector. Plug the AC adapter into the NERO mAx if needed (see Section 1.4--Battery Operation and Charging) and turn the instrument on.



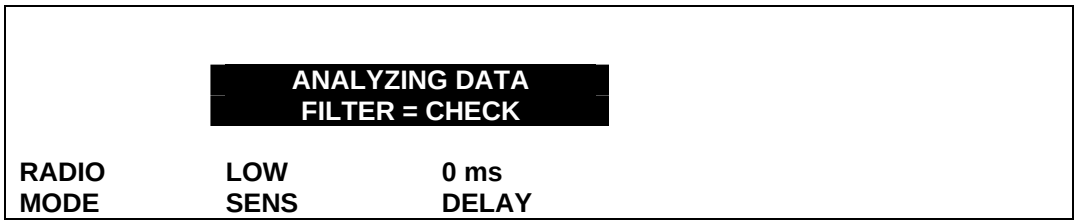
Set the x-ray machine to 60 kVp, 100 mA, 100 mS. Select the RADIO mode, low sensitivity, then press the ENTER key.



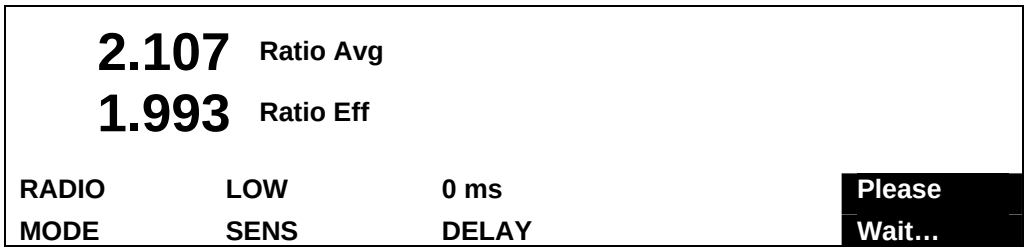
Please wait while the NERO mAx prepares to take an exposure. When the NERO mAx is ready to take an exposure it will beep and prompt for an exposure.



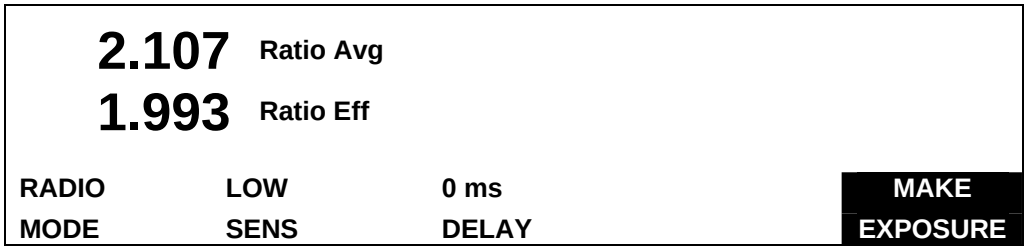
Make an exposure.



Please wait while the NERO mAx analyzes the exposure data.



After data analysis is complete, the detector ratios are displayed. The detector ratios should be near two under these conditions. If an overrange is detected an error message is displayed (see Section 4.3--Error Messages--for more information). Please wait while the NERO mAx prepares for the next exposure. If the NERO mAx detects a fault condition such as an invalid filter card or position, an error message is displayed and the user must correct the error to continue (see Section 4.3--Error Messages--for more information).



The NERO mAx is now ready to take another exposure. Pressing the mode key at any time exits from this measurement mode and returns to the mode selection screen.

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Section 4
Troubleshooting

4.1 General

For an explanation of error messages, see Section 4.3--Error Messages.

NERO mAx won't turn on

If the NERO mAx will not turn on, it may have a dead battery. If the battery is discharged below a safe operating level, but not completely discharged, the red battery low LED will illuminate and the NERO mAx will not function. When the battery is completely discharged, nothing will happen when the power switch is turned on. The solution for both these problems is to plug in the AC adapter. The NERO mAx will function properly with a discharged battery when the AC adapter is used. See Section 1.4--Battery Operation and Charging.

If the NERO mAx does not turn on with the AC adapter, the adapter may be defective or the NERO mAx is in need of repair. Please contact Fluke Biomedical at 440.248.9300.

NERO mAx battery does not appear to hold a charge

The NERO mAx rechargeable battery holds sufficient charge for up to 4 hours of operation depending upon use. The NERO mAx draws twice as much power from its from its battery when it is actively making measurements than it does when in an idle state with its backlight off.

If the battery does not appear to hold sufficient charge, verify that the battery is being charged. With the NERO mAx turned off, plug the AC adapter into the NERO mAx and plug it into a suitable power outlet. The green battery charge indicator on the front panel of the NERO mAx should illuminate when the battery is charging. If the green battery charge LED does not light, the battery is not charging and repairs are needed. Please contact Fluke Biomedical at 440.248.9300 for assistance.

For more information regarding battery operation, see Section 1.4--Battery Operation and Charging.

NERO mAx will not print

Make sure that the NERO mAx printing has been enabled by going to the Setup mode and verifying that printing has been turned on. If printing has been enabled, make sure that the printer is properly connected to the NERO mAx, is turned on and is on-line. Also make sure that the printer has sufficient paper. If the printer has a self-test mode, it may be useful to run its self-test to verify that the printer is functional. For additional assistance please contact Fluke Biomedical at 440.248.9300.

For more information about printing, see Section 1.5--Printing.

NERO mAx will not communicate with NERO mAx Excel Add-In

The NERO mAx will not communicate properly with the Excel Add-in if the Add-in is started while the NERO mAx is in a measurement mode. Under these conditions, the NERO mAx Excel Add-In ignores all data until a mode command is sent from the NERO mAx. To remedy this situation, exit from the measurement mode by pressing the MODE button then re-enter the measurement mode by pressing the ENTER key.

Make sure that the RS-232 cable is connected properly between the RS-232 connector on NERO mAx and the RS-232 connector on the computer. Also verify that the cable is a "straight" modem cable and not a null modem cable.

For more information on using NERO mAx with the Excel Add-in, please see the NERO mAx Toolkit for Excel Instruction Manual.

NERO mAx does not respond

If the NERO mAx does not respond to depression of any of its keys it may be “locked-up” (its microprocessor is no longer be executing its program properly). When this occurs, it is necessary to reset the unit by cycling its power (turning it off then on). After reset, the unit will return to its normal operating mode.

The NERO mAx may also appear to be locked up if one of its buttons is stuck in the depressed position. If the button beneath a menu function is stuck, the reverse video highlight for that function will be continuously cycling through the menu selections. If the button beneath a numeric value (time, date, etc.) is stuck, that value will continuously increment. If the button with no menu function is stuck, there is no indication on the display and the NERO mAx will not respond to any keypress. To determine if this is the problem, simply depress each key. If a key does not depress, it may be stuck down and needs to be lifted up. If a key’s function cannot be restored, repairs may be needed. Please contact Fluke Biomedical at 440248.9300 for assistance.

NERO mAx LCD goes blank or slows down during printing

When the NERO mAx is used with older, slower printers which have relatively small print buffers, the printer may slow the NERO mAx down. The NERO mAx continuously monitors the status of the printer during the printing process. When the printer’s print buffer fills and it cannot accept any more data, the NERO mAx stops sending characters and waits until the printer can accept more data before continuing. This prevents existing x-ray exposure data from being overwritten by new exposure data so that no exposure data is lost. Wait until the printer stops printing, then continue.

4.2 Modes of Operation

4.2.1Radio Mode

For an explanation of error messages, see Section 4.3--Error Messages.

The NERO mAx still says “MAKE EXPOSURE” after an exposure has been made

This happens when the x-ray beam intensity is below the NERO mAx’s detectability limit. To overcome this, switch to high sensitivity, switch to the next lower kV filter range (if the kV is still within range) or decrease the distance between the detector and the x-ray tube. See Appendix B, mA limits vs. kV, for assistance in establishing the correct sensitivity for the chosen mA and kV.

If the NERO mAx still does not respond to exposures that are within the limits in Appendix B, mA limits vs. kV, it may be in need of repair. Please call Fluke Biomedical at 440248.9300 for assistance.

Measured kV is not what is expected

If the measured kVp appears to be high, there may be an overshoot at the beginning of the exposure. To eliminate this possibility, delay the start of data acquisition by 10 milliseconds (see Radio Mode). The NERO mAx Excel Add-In may be used to extract the kV and radiation waveforms from the NERO mAx for examination. See Section 4.5--Waveforms - Overshoot.

The amount and type of filtration in the x-ray beam also effects measured kVp. The filtration that the NERO mAx is calibrated with is printed on the NERO mAx calibration report.

Incorrect kVp measurements will also result if the NERO mAx detector is not aligned properly in the x-ray beam. The NERO mAx detector should be aligned along the axis of the x-ray tube, located in the center of the beam with the top of the detector facing the tube. The x-ray beam should be collimated to the alignment marks on the top of the detector. See section "Positioning the Detector" for more information.

Inaccurate kVp measurements may occur when using high sensitivity with a filter card kV setting that is too high for the kVp being used. Under these conditions, the NERO mAx may detect enough scatter to induce it to take an exposure and calculate kVp incorrectly. To remedy this situation, switch to the next lower filter card setting.

If the NERO mAx reports “Low” kV or if the measured kV is much lower than the actual kV, one of its solid-state detectors may have failed. To easily diagnose this condition, perform the calibration check as described in Section 3.2 - Calibration Check. The ratios normally displayed after an exposure are approximately 2 and if the ratios displayed are near 1, one of the NERO mAx solid-state detectors has failed and must be replaced. Please call Fluke Biomedical at 440.248.9300 for assistance.

Inaccurate kV measurements may result when making measurements on self-rectified dental machines whose kV peaks vary by more than the selected %kV. On these generators, when the NERO mAx %kV set to 90%, 80% or 75%, kV peaks that fall below the selected %kV are ignored and are not included in the kV calculations. Setting the %kV to ZERO (exposure time measured at zero crossing) or 1ØPULSE (pulse counting mode) can eliminate this effect. See Section 4.7--Waveforms - Self Rectified--for more information.

Inaccurate kV measurements may also occur when making measurements on self-rectified dental machines that utilize a filament preheat. When making measurements on these generators, the NERO mAx typically sees the first few preheat pulses, then the intensity of the remaining preheat pulses falls below the detectability limit of the NERO mAx, causing the NERO mAx to terminate the measurement prematurely. When this occurs, the NERO mAx calculates kV based upon the first few preheat pulses instead of the pulses that occur after the filament preheat. To eliminate this effect, a measurement delay sufficient to skip over the filament preheat should be used. Additionally, the %kV should be set to ZERO or 1ØPULSE. For more information, see Section 4.8--Waveforms - Dental with Preheat.

Measured exposure time is not what is expected

The most direct method of determining the cause of a possible exposure time measurement error is to look at the radiation and/or kV waveform for the exposure in question. Two methods may be used to examine these waveforms. The first method is to use the NERO mAx Excel Add-In to extract the waveforms from the NERO mAx. Information on the installation and use of the NERO mAx Excel Add-In can be found in the NERO mAx Toolkit for Excel Instruction Manual. The second method is to capture the radiation waveform using a storage oscilloscope connected to the scope output on the back of the NERO mAx readout. Information regarding use of the NERO mAx scope output may be found in Section 1.6--Scope Output--of the NERO mAx Instruction Manual.

When using the NERO mAx with single phase x-ray machines, the measured exposure time may be shorter than the actual exposure time when an inappropriate %kV has been selected, such as 75%, 80%, or 90%. This is because the definition of exposure time for single-phase x-ray machines is not the same as that for three phase, medium and high frequency machines. For single-phase generators, exposure time is defined as the number of radiation pulses that occur during the exposure multiplied by the pulse period. This is equivalent to the time between the first and last passage through 0% of kVp average (zero crossing). When making measurements with the NERO mAx on single-phase x-ray machines, %kV should be set to ZERO (for time between zero crossings) or 1ØPULSE (pulse counting mode) to accurately assess timer performance. Additionally, when measuring exposure time between zero crossings, the NERO mAx measures the time from when x-ray are detected until they are no longer detected. This measured time will usually be slightly shorter than the time calculated by multiplying the number of pulses by the pulse period. This is because the NERO mAx does not "see" the rising and falling edges of the kV waveform that fall below the bottom of the selected filter range.

If the measured exposure time appears to be short and the %kV is set at 90%, there may be an overshoot at the beginning of the exposure. If the peak kV of an overshoot is more than 10% higher than the kV of the rest of the exposure, the NERO mAx will detect the overshoot as a single peak and will find no other peaks. When this happens, the exposure time will be very short (a few milliseconds) and the kVp average and kV peak will be the same. This happens when the %kV is set at 90% because the NERO mAx measures exposure time between the first and last passage through 90% of the peak kV and will only calculate the time of the overshoot. To eliminate the effect of the overshoot, delay the start of

data acquisition by 10 milliseconds or select a lower %kV. For more information see Section 4.5--Waveforms - Overshoot.

Short measured exposure times may also result when the NERO mAx only “sees” only part of an x-ray exposure. This can happen when exposures are made near the NERO mAx’s minimum detectability and only a portion of the exposure is above the instrument’s threshold. This also results in low exposure measurements. To remedy this situation, switch to high sensitivity, switch to the next lower kV filter range (if the kV is still within range) or decrease the distance between the detector and the x-ray tube. See Section 4.6--Waveforms - Partial kV Waveforms.

Short exposure times will also be calculated if the x-ray exposure stops for more than 20 milliseconds. When this occurs, the NERO mAx assumes that the exposure is complete after 20 milliseconds and proceeds with data analysis.

Errors may occur in the measured exposure time when making measurements on self-rectified dental machines with the NERO mAx %kV set to 90%, 80% or 75%. On self-rectified generators whose kV peaks vary by more than the selected %kV, kV peaks that fall below the selected %kV are ignored. If the peaks that fall below the selected %kV occur at the beginning or end of the kV waveform, they are not included in the exposure time calculation. Setting the %kV to ZERO (exposure time measured at zero crossing) or 1ØPULSE (pulse counting mode) can eliminate this effect. See Section 4.7--Waveforms - Self Rectified--for more information.

Exposure time errors can also occur when making measurements on self-rectified dental machines that utilize a filament preheat. When making measurements on these generators, the NERO mAx typically sees the first few preheat pulses, then the intensity of the remaining preheat pulses falls below the detectability limit of the NERO mAx, causing the NERO mAx to terminate the measurement prematurely. When this occurs, the NERO mAx measures the exposure time of the first few preheat pulses that is usually much shorter than the set exposure time. To eliminate this effect, a measurement delay sufficient to skip over the filament preheat should be used. Additionally, the %kV should be set to ZERO or 1ØPULSE. For more information, see Section 4.8--Waveforms - Dental with Preheat.

Generator loading may also effect the exposure time measured by the NERO mAx. The NERO mAx may indicate longer exposure times for exposures made under light generator loading (low mA, e.g. 25 mA) than for exposures made under heavy generator loading at the same time and kV settings. This is because more time is required at the end of the exposure for the tube potential (kV) to discharge when a generator is lightly loaded.

Measured exposure is not what is expected

The measured exposure may appear to be low when the NERO mAx only “sees” only part of an x-ray exposure. This happens when exposures are made near the NERO mAx’s minimum detectability and only a portion of the exposure is above the instrument’s threshold. This also results in short measured exposure times. To remedy this situation, switch to high sensitivity, switch to the next lower kV filter range (if the kV is still within range) or decrease the distance between the detector and the x-ray tube. See Section 4.6--Waveforms - Partial kV Waveforms.

The measured exposure will also be low if the x-ray exposure stops for more than 20 milliseconds. When this occurs, the NERO mAx assumes that the exposure is complete after 20 milliseconds and proceeds with data analysis.

The measured exposure is also affected by the user entered ion chamber correction factor and air density correction factors. Make sure that the internal ion chamber’s correction factor has not been changed by accident (default is 1.00, see Cal Mode) and make sure that temperature and atmospheric pressure have been correctly entered (defaults are 22°C, 760 mmHg., see Setup Mode). For more information regarding NERO mAx calibration see Section 3--Calibration.

Measured mAs is not what is expected

The measured mAs may appear to be low when the NERO mAx only “sees” only part of an x-ray exposure. This happens when exposures are made near the NERO mAx’s minimum detectability and only a portion of the exposure is above the instrument’s threshold. This also results in short measured exposure times. To remedy this situation, switch to high sensitivity, switch to the next lower kV filter range (if the kV is still within range) or decrease the distance between the detector and the x-ray tube. See Section 4.6--Waveforms - Partial kV Waveforms.

The measured mAs will also be low if the x-ray exposure stops for more than 20 milliseconds. When this occurs, the NERO mAx assumes that the exposure is complete after 20 milliseconds and proceeds with data analysis.

4.2.2Mammo Mode

For an explanation of error messages, see Section 4.3--Error Messages.

All of the explanations of perceived anomalies that may occur in the radio mode also apply to the mammo mode. Please refer to those listed for the radio mode in addition to those listed for this mode.

Measured kV is not what is expected

In the mammo mode, improper menu selection of target or filter will result in inaccurate kVp measurements. The amount and type of filtration in the x-ray beam greatly effects measured kVp in the mammo mode. The filtration that the NERO mAx is calibrated with is printed on the NERO mAx calibration report.

Measured exposure is not what is expected

Incorrect menu selection of target or filter may result in inaccurate exposure measurements. This is because exposure measurements made in the mammo mode are corrected based upon calculated kV and if the calculated kV is incorrect, the calculated exposure may also be incorrect.

4.2.3Fluoro Mode

For an explanation of error messages, see Section 4.3--Error Messages.

The NERO mAx says “MAKE EXPOSURE” even after the stop key has been pressed

This can occur when the x-ray beam intensity is below the NERO mAx’s detectability limit. To overcome this, switch to high sensitivity, switch to the next lower kV filter range (if the kV is still within range) or decrease the distance between the detector and the x-ray tube.

This also occurs in the pulsed fluoro mode when pulse rates are less than 1 pulse per second. When this happens, the displayed exposure per pulse may occasionally drop to zero also. To correct this problem, increase the pulse rate above one pulse per second.

Measured kV is not what is expected

Inaccurate kVp measurements will result if the NERO mAx detector is not aligned properly in the x-ray beam. The NERO mAx detector should be aligned along the axis of the x-ray tube, located in the center of the beam. Also, the top of the detector must face the x-ray tube. For fluoroscopic use (under table x-ray tubes), this usually means that the detector must be turned upside down. The beam should be collimated to the detector. See section "Positioning the Detector" for more information.

The amount and type of filtration in the x-ray beam also effects measured kVp. The inherent filtration that the NERO mAx is calibrated with is printed on the NERO mAx calibration report.

Inaccurate kVp measurements may occur when using high sensitivity with a filter card kV setting that is too high for the kVp being used. Under these conditions, the NERO mAx may detect enough scatter to induce it to take an exposure and calculate kVp incorrectly. To remedy this situation, switch to the next lower filter card setting.

If the NERO mAx reports “Low” kV or if the measured kV is much lower than the actual kV, one of its solid-state detectors may have failed. To easily diagnose this condition, perform the calibration check as described in Section 3.2 - Calibration Check. The ratios normally displayed after an exposure are approximately 2 and if the ratios displayed are near 1, one of the NERO mAx solid-state detectors has failed and must be replaced. Please call Fluke Biomedical at 440.248.9300 for assistance.

In the pulsed fluoro mode, overshoots can occur on the leading edges of the pulses. This is usually indicated by a significant difference between the peak or average kVp and the effective kV. To determine if this is the case, use the NERO mAx Excel Add-In to extract the kV waveform from the NERO mAx for examination.

Blank screen after exposure starts in Pulsed Fluoro mode

This happens when pulsed fluoro mode is incorrectly used on a continuous fluoro generator. In the pulsed fluoro mode, the NERO mAx calculates exposure and mAs per pulse; if no pulses are detected, exposure and mAs per pulse cannot be calculated. This may also happen in high sensitivity if the x-ray intensity is excessive and drives the detector into saturation. To cure this, switch to low sensitivity.

4.2.4AMSE Mode

For an explanation of error messages, see Section 4.3--Error Messages.

All of the explanations of perceived anomalies that may occur in the Fluoro mode also apply to the AMSE mode. Please refer to those listed for the Fluoro mode for assistance.

4.2.5Exposure Mode & CT Exposure Mode

The measured exposure is affected by the user entered ion chamber calibration factor and air density correction factors. Make sure that the selected ion chamber is the same as the chamber that is in use. Also make sure that the ion chamber’s correction factor has been entered accurately and has not been changed by accident (see Cal Mode). In addition, verify that temperature and pressure have been correctly entered (defaults are 22°C, 760 mmHg., see Setup Mode). For more information regarding NERO mAx calibration see Section 3--Calibration.

4.2.6HVL Mode

The reproducibility of the x-ray machine can directly affect the accuracy of HVL measurements made with the NERO mAx. If an x-ray machine has poor reproducibility of time, mA or kV, the calculated HVL may be in error.

Another possible source of error in HVL measurements may be incorrect absorber thickness. Make sure that the aluminum absorber thickness is accurate and that the thickness is entered correctly into the NERO mAx.

The NERO mAx calculates HVL via linear regression of the natural log of the normalized exposure (normalized to the first exposure) versus absorber thickness in millimeters of aluminum. To provide an indication of how well the exposure data fits the natural log of the normalized exposure the NERO mAx calculates the correlation coefficient (“r”) of the data whenever it calculates HVL. A poor fit ($r < 0.98$) is indicated by a flashing “r” value. Poor reproducibility in the x-ray exposures or errors in absorber thickness will result in a low correlation coefficient.

Also, the closer that the added filtration is to the calculated HVL, the more accurate the HVL calculation will be. To assist in establishing the optimum average HVL filter thickness, the NERO mAx displays either a “HIGH” or “LOW” message above the HVL if the average of the added filtration for each exposure is not within 10% of the calculated HVL. If no messages are displayed, the average added filtration is within 10% of the calculated HVL and no more exposures need to be made.

If the calculated HVL is displayed as a negative number, the second exposure is greater than the first exposure. Remove all HVL plates and start over, making sure that no HVL filters are in place for the first HVL exposure. **The first HVL exposure must be made with no absorbers in the x-ray beam.**

4.3 Error Messages

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The measured quantity (time and/or exposure) cannot be calculated. This typically occurs along with the High or Low kVp error messages. If the kVp is more than 10% above or below the selected kV filter range, the NERO mAx cannot accurately calculate kVp. When this happens, the NERO mAx cannot measure exposure time between the selected %kV points on the kV waveform and cannot correct the measured exposure based upon kV. To remedy this situation switch to the next higher or lower filter range based upon the High or Low kVp messages. This error is automatically cleared when an exposure is made that is within the selected kVp range.

%kV TOO LOW

If the NERO mAx cannot find the selected %kV on the kV waveform, a %kV TOO LOW message is displayed. This occurs when the kVp of an exposure is so low that the kV at the selected %kV is less than 80% of the minimum kV of the selected kV filter range. For instance, if an exposure is made at 51 kVp using the 50 - 100 kVp filter with the %kV set at 75%, the NERO mAx cannot calculate exposure time because 38.25 kV (75% of 51 kVp) is below 40 kV (80% of the minimum kV of the 50 - 100 kV filter). To resolve this situation, select a higher %kV or switch to the next lower filter range.

BATTERY LOW

The battery charge is getting low. This message comes on when there is approximately 20 minutes of battery life remaining. This error message is cleared a few minutes after the AC adapter is plugged into the NERO mAx. If this message is ignored and the batteries are allowed to discharge below a safe operating level, the NERO mAx will become inoperable and the Low Battery indicator on the front panel will illuminate. (See Section 1.4--Battery Operation and Charging.)

Blinking HIGH or LOW

The measured kVp is above or below the selected kV filter range but still within 10% of the filter's kV range. To remedy this situation switch to the next higher or lower filter range based upon the High or Low kVp messages. This warning is automatically cleared when an exposure is made that is within the selected kVp range.

CALIBRATION CHECKSUM ERROR

An error has been detected in the calibration coefficients that have been stored in the NERO mAx. The NERO mAx is not usable in this state and must be returned to Fluke Biomedical for repair. Please contact Fluke Biomedical at 440.248.9300 for assistance.

DELAY TOO LONG

The programmed measurement delay is longer than the x-ray exposure that has just been made. Verify that the set exposure time is longer than the programmed measurement delay. This error is cleared when an exposure is made that exceeds the programmed delay.

This error may occur when the NERO mAx only "sees" part of an x-ray exposure. This can happen when exposures are made near the NERO mAx's limit of detectability and only a portion of the exposure is above the instrument's threshold. To remedy this situation, switch to high sensitivity, switch to the next lower kV filter range (if the kV is still within range) or decrease the distance between the detector and the x-ray tube.

This can also be caused by an x-ray exposure that stops prematurely for more than 20 milliseconds. When this occurs, the NERO mAx assumes that the exposure is complete after 20 milliseconds.

EXPOSURE TOO LONG

This error message is displayed if the exposure time, including any measurement delay, is longer than 60 seconds. The fluoro mode may be used for kV measurements when exposure time exceeds 60 seconds. To measure exposure when exposure time exceeds 60 seconds, the exposure mode should be used.

FILTER CARD IS NOT INSTALLED

The filter card is not installed. This error message is cleared when a filter card is inserted. If this message persists after the filter card has been installed, verify that the detector cable is connected at both ends and that the connectors are fully seated.

FILTER CARD IS NOT SEATED

The filter card is not in a valid position. This error message is cleared when the filter card is seated in a valid position. If this message persists after the filter card has been installed, verify that the detector cable is connected at both ends and that the connectors are fully seated.

Flashing 'r' value in HVL mode

A flashing 'r' value in the HVL mode indicates a poor correlation coefficient ($r < 0.98$) for the data used in the HVL calculation. The NERO mAx calculates HVL via linear regression of the natural log of the normalized exposure (normalized to the first exposure) versus absorber thickness in millimeters of aluminum. To provide an indication of how well the exposure data fits the natural log of the normalized exposure the NERO mAx calculates the correlation coefficient ('r') of the data whenever it calculates HVL. Poor x-ray exposure reproducibility or errors in absorber thickness will result in a low correlation coefficient.

HIGH HVL

This message indicates that the average thickness of the HVL absorbers is more than 10% higher than the calculated HVL. If only two exposures have been made, the added filtration of the second exposure is more than 10% higher than the calculated HVL. When this message appears, decrease the filtration used for subsequent exposures until the message disappears. This message is provided to assist in establishing the optimum HVL filter thickness for a given x-ray beam.

HIGH kVp

The measured kVp (average, effective, or maximum) is more than 10% above the filter's kV range and the kV cannot be calculated. To remedy this situation, switch to the next higher filter range. This error message is automatically cleared when an exposure is made that is within the selected kVp range.

ILLEGAL FILTER SELECTION

The filter card is in the wrong position for the selected measurement mode. This error occurs in the fluoro or AMSE modes when the filter card is in the CHECK position. This error occurs in the MAMMO mode when the filter card is in the Moly Target position and the Rhodium target measurement mode has been selected or when the filter card is in the Rhodium Target position and the Moly target measurement mode has been selected. This error message is cleared when the filter card is in the correct position for the selected measurement mode. Verify that the detector cable is connected at both ends and that the connectors are fully seated.

LOW HVL

This message indicates that the average thickness of the HVL absorbers is less than 90% of the calculated HVL. If only two exposures have been made, the added filtration of the second exposure is less than 90% of the calculated HVL. When this message appears, increase the filtration used for subsequent exposures until the message disappears. This message is provided to assist in establishing the optimum HVL filter thickness for a given x-ray beam.

LOW kVp

The measured kVp (average, effective, or maximum) is more than 10% below the filter's kV range and the kV cannot be calculated. To remedy this situation, switch to the next lower filter range. This error message is automatically cleared when an exposure is made that is within the selected kVp range.

OFFSET ERROR…# nnnn

A high offset has been measured while preparing for an exposure. The offset error message is followed by a number that identifies the offset error. Offset errors are listed below:

Offset Error # 0010 - High Ion Chamber Offset

Offset Error # 0020 - High mAs Offset

Offset Error # 0080 - High Channel A Offset

Offset Error # 0100 - High Channel A Offset

Offset Error # 0200 - High Channel B Offset

These offset error messages may be combined to provide multiple offset error messages. For example, offset error #0030 indicates that excessive offsets exist from both the ion chamber and mAs inputs.

Offset errors will result if the x-ray beam is on while the NERO mAx is preparing to take an exposure. Make sure that the beam is off when the NERO mAx is preparing to take an exposure.

Offset errors may also occur when the NERO mAx detector is not fully connected to the NERO mAx readout unit. Verify that the detector cable is connected at both ends and that the connectors are fully seated.

In the Radio, Mammo, Fluoro and AMSE modes mAs offset errors may be caused by current flowing in the NERO mAx mAs measurement circuit when no exposure is being made. This occurs when a voltage exists between the mAs terminals and ground. This may be caused by a ground loop between the mAs terminals of the generator and another line powered device connected to the NERO mAx such as a computer, printer or oscilloscope. To remedy this situation, disconnect any line-powered devices from the NERO mAx or unplug the line-powered devices.

In the exposure, CT exposure and HVL modes, offset error #0010 may be caused by defective external ion chambers which may be connected to the NERO mAx. If the offset error message goes away when the external chamber is disconnected from the NERO mAx, the chamber is defective and should be repaired.

If an offset error message persists, contact Fluke Biomedical at 440248.9300 for assistance.

OVERRANGE ERROR…# nnnn

The NERO mAx has received a signal from its detector that is above its measurement range and therefore cannot be accurately measured. The overrange error message is followed by a number that identifies the overrange error. Overrange errors are listed below:

Overrange Error # 0001 - Ion Chamber Overrange

Overrange Error # 0004 - mAs Overrange

Overrange Error # 0010 - Channel A Overrange

Overrange Error # 0020 - Channel B Overrange

These overrange error messages may be combined to provide multiple overrange error messages. For example, overrange error #0005 indicates that both the ion chamber and mAs inputs experienced an overrange.

Radio, Mammo, Fluoro and AMSE modes

If an overrange occurs on channels A or B when using high sensitivity, switch to low sensitivity. If using low sensitivity, switch to the next higher filter range (if the kV is within that range), decrease mA or increase the distance between the detector and the x-ray tube.

If an ion chamber overrange occurs, decrease mA or increase the distance between the detector and the x-ray tube.

If an mA or mAs overrange occurs, the tube current is above the measurement limit of the NERO mAx. This overrange may also be caused by excessive voltage between the generator's mAs terminals and ground. This may be caused by a ground loop between the mAs terminals of the generator and another line powered device connected to the NERO mAx such as a computer, printer or oscilloscope. To remedy this situation, disconnect any line-powered devices from the NERO mAx or unplug the line-powered devices. Verify that the mAs leads are properly connected in the ground return of the high voltage transformer and that the set mA is within the measurement limits of the NERO mAx (1000 mA).

Exposure, CT Exposure and HVL modes

If an ion chamber overrange occurs when using high sensitivity, switch to low sensitivity. If using low sensitivity, the exposure rate is too high, decrease mA or increase the distance between the ion chamber and the x-ray tube.

PRINTER ERROR

The printer may be out of paper, off line or not connected. If printing is to be used, verify that the printer is connected to the NERO mAx, that it is turned on and is on line and that it is not out of paper then press any key to continue. If a printer is not in use, turn printing off by going to the setup mode and turning print off.

RAD TOO LOW

This error occurs when most of an exposure is below the NERO mAx's detectability limit. Under these conditions, there may be a few data points above the NERO mAx's detectability limit but there is insufficient data to accurately calculate the average, effective or maximum kV. Increasing the x-ray intensity at the detector by increasing mA or decreasing the source to detector distance will alleviate this error condition.

RS232 TIMED OUT

This error occurs when a device connected to the NERO mAx RS-232 port is not accepting data. This may happen when a computer connected to the RS-232 port is off or is powering up when the NERO mAx is preparing to take an exposure. This may also happen when using the NERO mAx Excel Add-In with slower computers. To continue making measurements, press any key.

TABLE CHECKSUM ERROR

An error has been detected in the kV calibration coefficients that have been stored in the NERO mAx for the filter that is presently in use. The NERO mAx cannot be used for measurements with this filter and must be returned to Fluke Biomedical for repair. Please contact Fluke Biomedical at 440.248.9300 for assistance.

WRONG FILTER CARD FOR THIS MODE

The incorrect filter card for the selected measurement mode has been inserted in the detector. This error is caused by attempting to use the W/Al filter card for mammo measurements or attempting to use the MAMMO filter card for radio, fluoro or AMSE measurements. This error message is cleared when the correct filter card is inserted for the selected measurement mode. If this message persists after the correct filter card has been installed, verify that the detector cable is connected at both ends and that the connectors are fully seated.

4.4 Power Up Diagnostic Messages

The following power up diagnostic tests and messages are incorporated in the NERO mAx and are listed below to aid the user.

Ram Test ……. PASSED

The NERO mAx has successfully tested its memory.

Ram Test Failed nnnn:nnnn

The NERO mAx has tested its memory and unreliable memory has been detected at memory location nnnn:nnnn. Cycle power to clear this error. If this error reoccurs, record the error message and call Fluke Biomedical at 440.248.9300 for assistance.

UART test failed

The NERO mAx has tested its RS-232 port and the port is not functioning properly. Press any key to clear this error and continue. Under these conditions, the NERO mAx will not communicate properly with a computer but remains functional. Call Fluke Biomedical at 440.248.9300 for assistance.

POWER SUPPLY test failed

The NERO mAx has tested its power supplies and one or more of the NERO mAx power supplies has been found to be greater than 10% above or below its nominal voltage. Cycle the instrument power off then on again, if this error message persists, call Fluke Biomedical at 440.248.9300 for assistance.

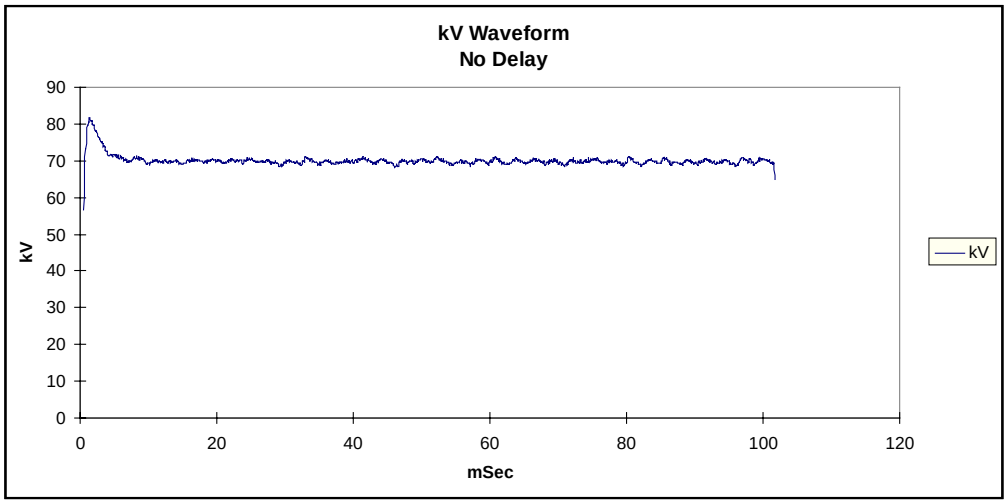
EPROM checksum test failed

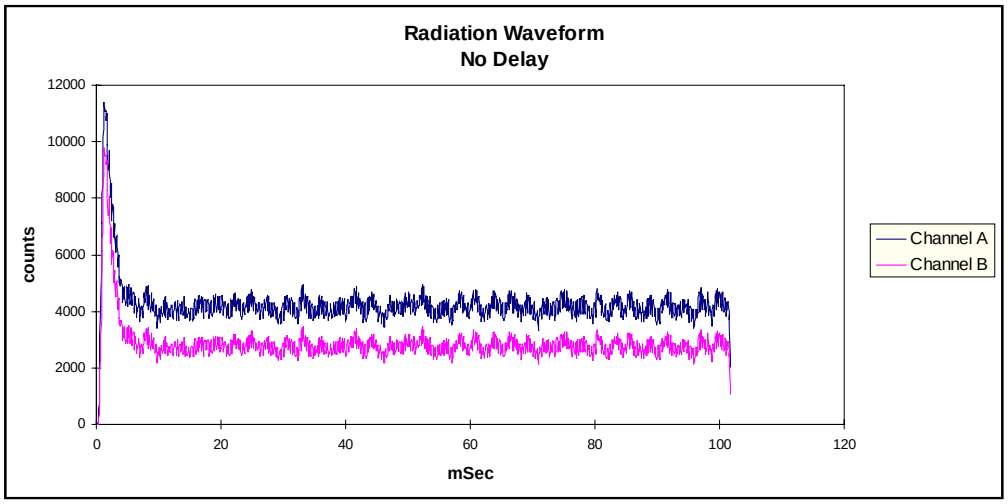
A CRC test of the NERO mAx program (EPROM) memory has detected an error. Cycle power to clear this error. If this error reoccurs, please contact Fluke Biomedical at 440.248.9300 for assistance.

4.5 Waveforms - Overshoot

An overshoot during the start of a radiographic exposure can cause the NERO mAx to calculate kV and/or exposure time incorrectly when a high %kV, such as 90%, is selected. This may also occur in the mammographic mode, where the %kV is fixed at 90% of kVp. Note that the calculated exposure time for the 100-millisecond exposure shown below is only 12.6 milliseconds and that the average and peak kV's are the same. This is caused by the 15% kV overshoot at the beginning of the exposure. The overshoot causes the NERO mAx to find only one peak (the overshoot) and measure exposure time of that peak. This is because the NERO mAx finds peaks and calculates exposure time only between 90% of kVp on the kV waveform. Since this peak is 80.5 kV, any peaks below 72.5 kV (90% of the peak kV) will be ignored. Two methods may be used to eliminate this effect. One method is to reduce the %kV, the other method is to use a measurement delay when making the measurement. When a reduced %kV is selected, the kV overshoot is included in kV calculations. When a measurement delay is used, the kV overshoot is skipped and is not included in kV calculations.

Exposure Results, No Delay				
kVp Avg	kV Eff	kV Peak	mSec	mR
80.5	70.3	80.5	***12.6***	220

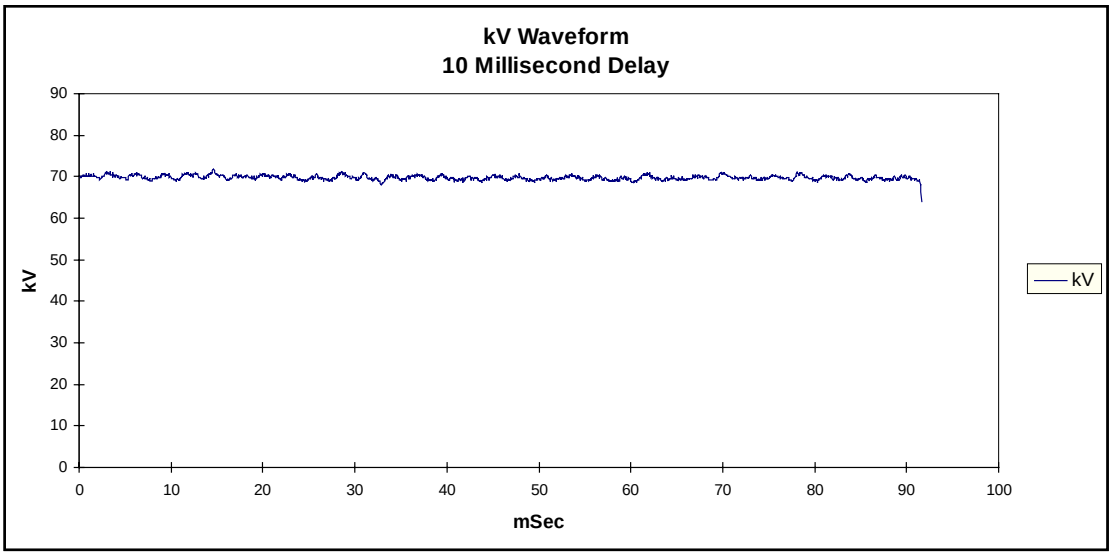


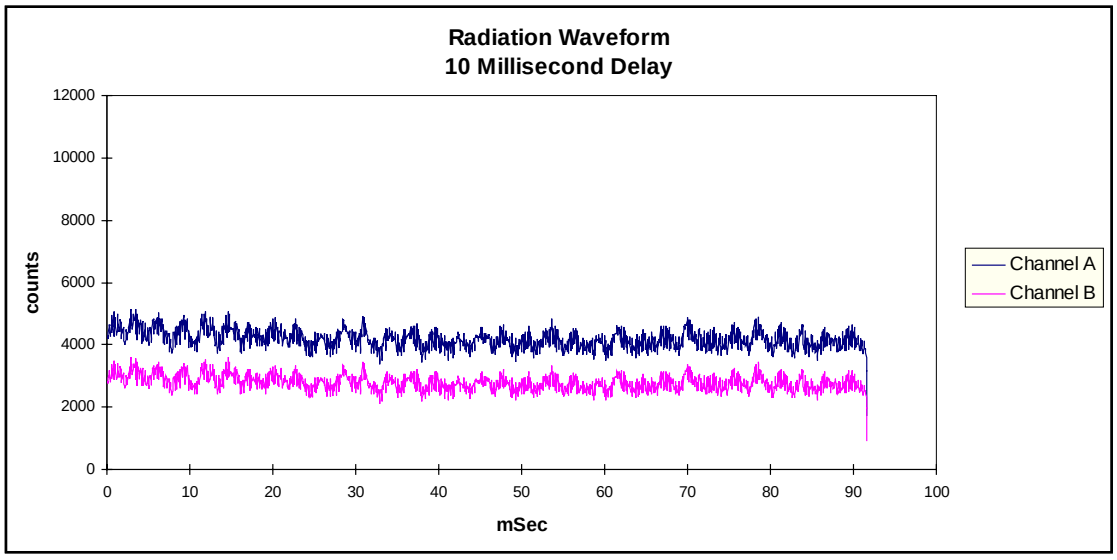


NOTE

The calculated exposure time for this 100 millisecond exposure, taken with a ten millisecond delay, is now correct and the overshoot at the beginning of the exposure has been skipped. The waveform is now only 90 milliseconds in length because the NERO mAx delayed data acquisition for ten milliseconds.

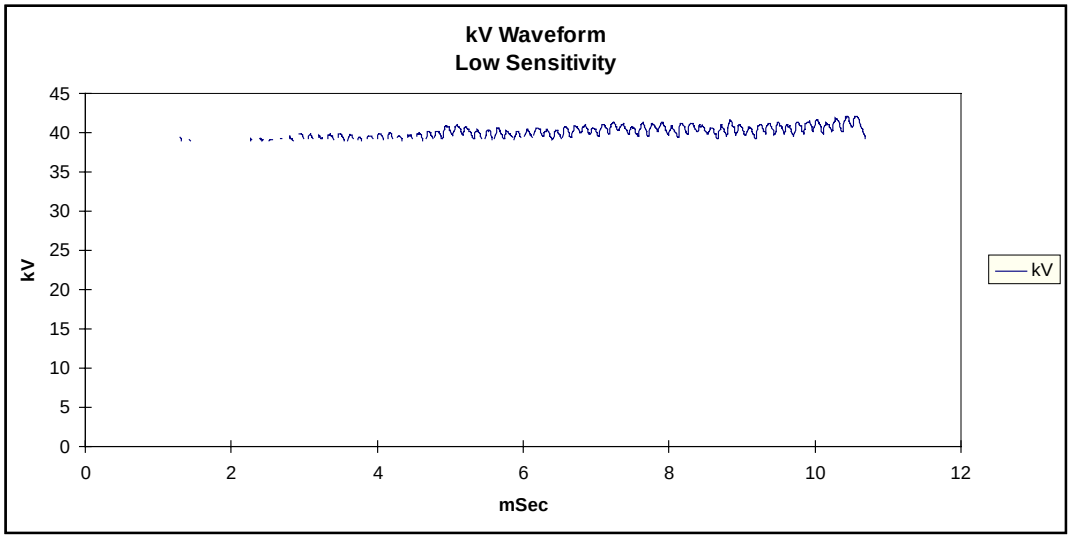
Exposure Results with 10 Millisecond Delay				
kVp Avg	kV Eff	kV Peak	mSec	mR
70.3	69.8	71.8	***101.5***	227





4.6 Waveforms - Partial kV Waveforms

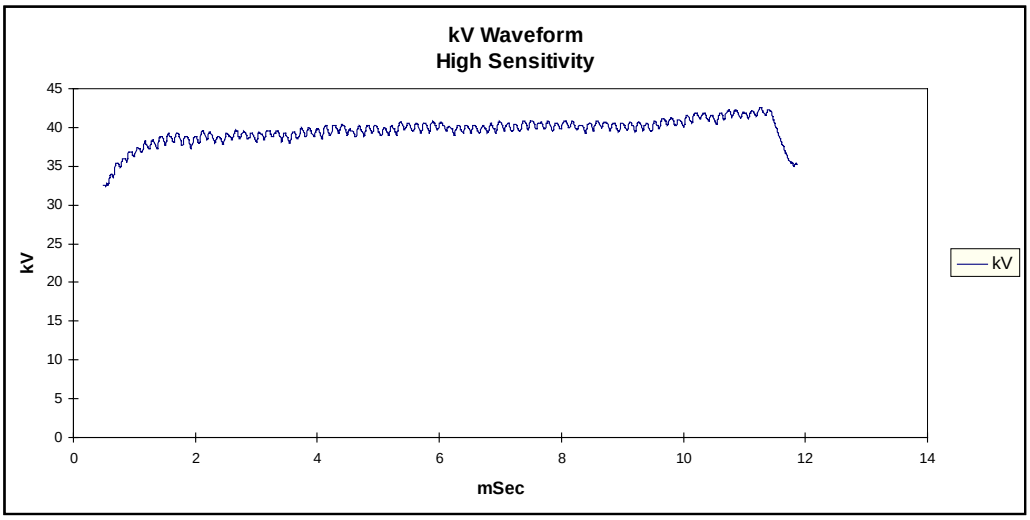
Exposure Results, Low Sensitivity				
kVp Avg	kV Eff	kV Peak	mSec	mR
40.5	39.7	42	10.6	2



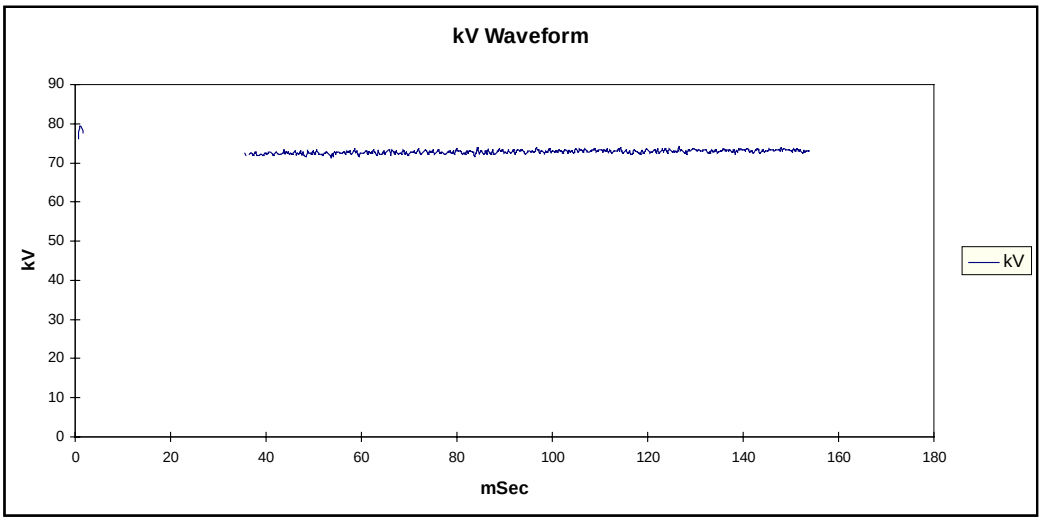
NOTE

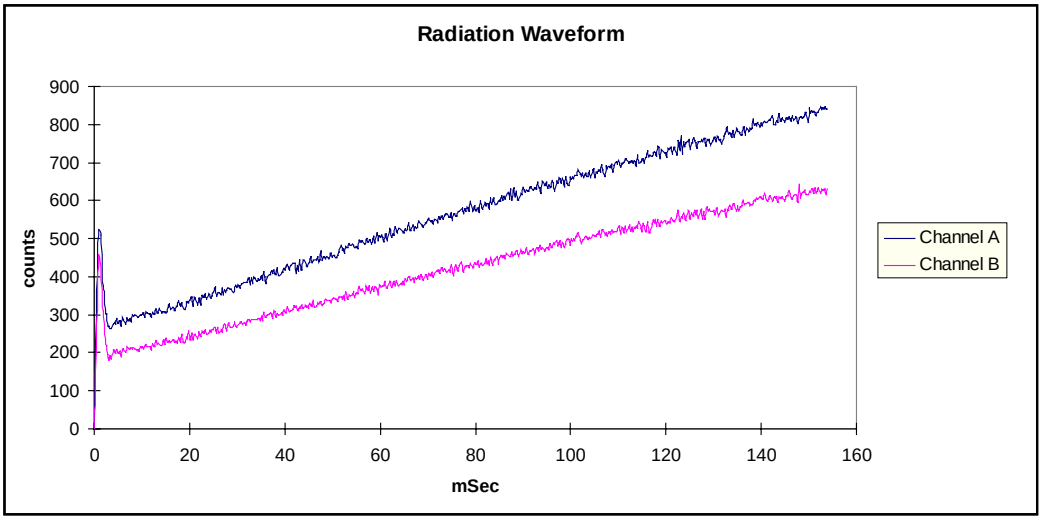
In the above kV waveform, no data is plotted below approximately 39 kV. This is because there is insufficient data available to fully construct the kV waveform. This occurs when exposures are made near the detectability limit of the NERO mAx. To remedy this situation, switch to high sensitivity or to the next lower filter range. Below is the kV waveform from the same exposure made using high sensitivity.

Exposure Results, High Sensitivity				
kVp Avg	kV Eff	kV Peak	mSec	mR



In the exposure below, part of the kV waveform appears to disappear after an initial peak. This is because after the initial peak, the radiation output drops below the level at which the NERO mAx can accurately reproduce the kV waveform. This level is approximately 400 counts on the channel A radiation waveform.



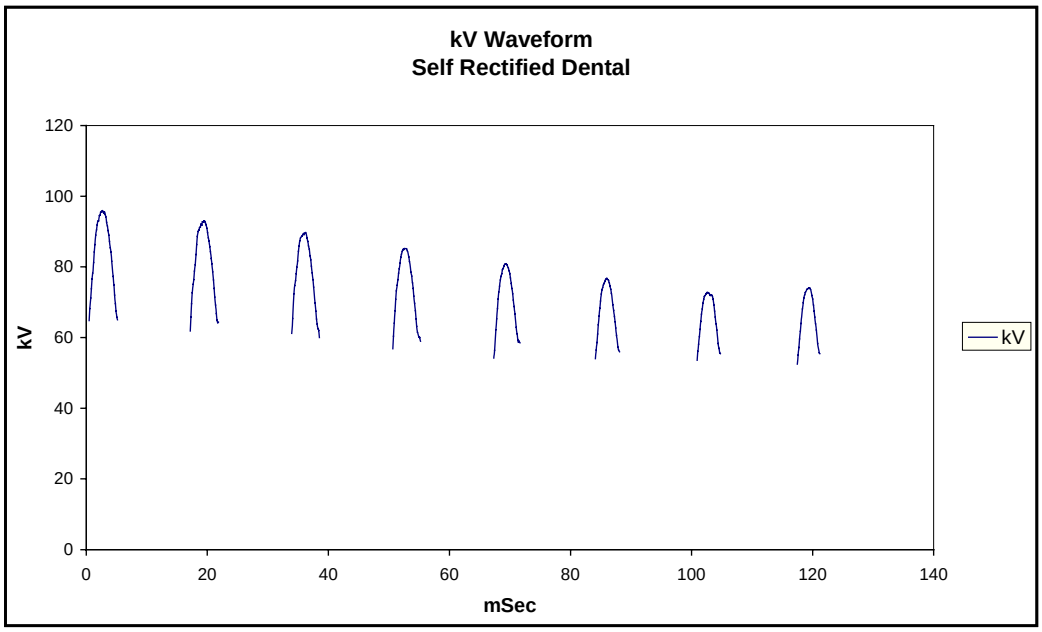


4.7 Waveforms - Self-Rectified

This example shows the effects of using an incorrect %kV setting when making measurements on a single-phase, self-rectified dental x-ray machine. The x-ray machine was set for 70kVp, 15mA and 8 pulses (133 milliseconds). The NERO mAx %kV was set to 90% and no measurement delay was used. Note that the measured exposure time is less than the actual exposure time. This is because the NERO mAx finds peaks and calculates exposure time only between 90% of kVp on the kV waveform. Since the first peak is 96.4 kV, any peaks below 86.8 kV (90% of the peak kV) will be ignored. Consequently, the NERO mAx only bases its calculations on the first 4 peaks of the waveform. In this case, setting the %kV to 1ØPULSE (pulse counting mode) is advisable since the generator's exposure time is set in pulses. If the exposure time is set in milliseconds, setting the %kV to a lower percentage or ZERO (zero crossing) will also yield more accurate results. Generally, a %kV setting of ZERO or 1ØPULSE should be used for single-phase, self-rectified x-ray machines.

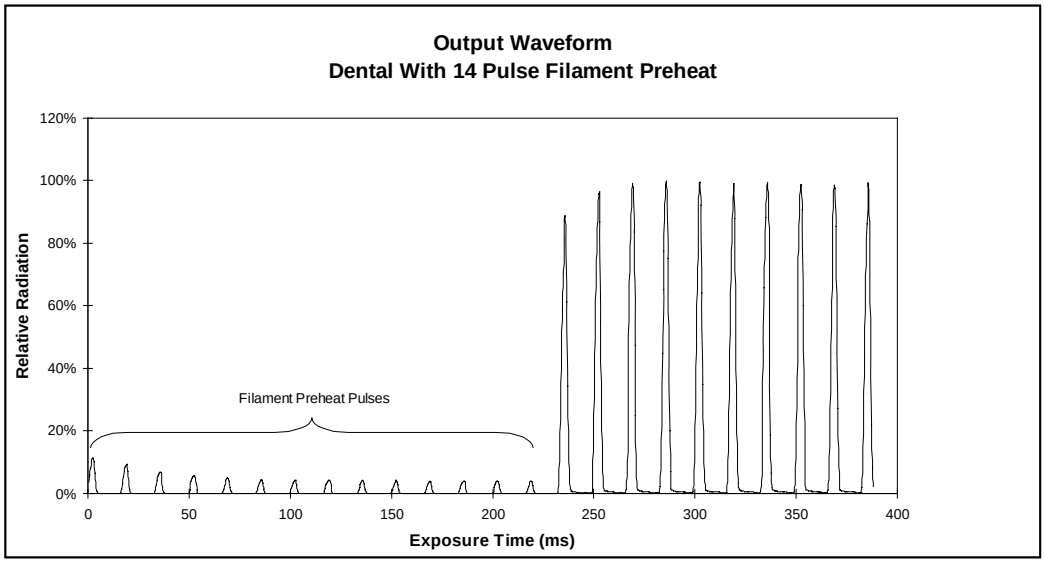
The NERO mAx Excel Add-In should be used to view kV waveforms to determine the best %kV setting to use. Information on using the NERO mAx Excel Add-In to view waveforms may be found in the NERO mAx Toolkit for Excel Instruction Manual.

Exposure Results, High Sensitivity				
kVp Avg	kV Eff	kV Peak	mSec	mR
40.4	39.9	42.2	10.9	2

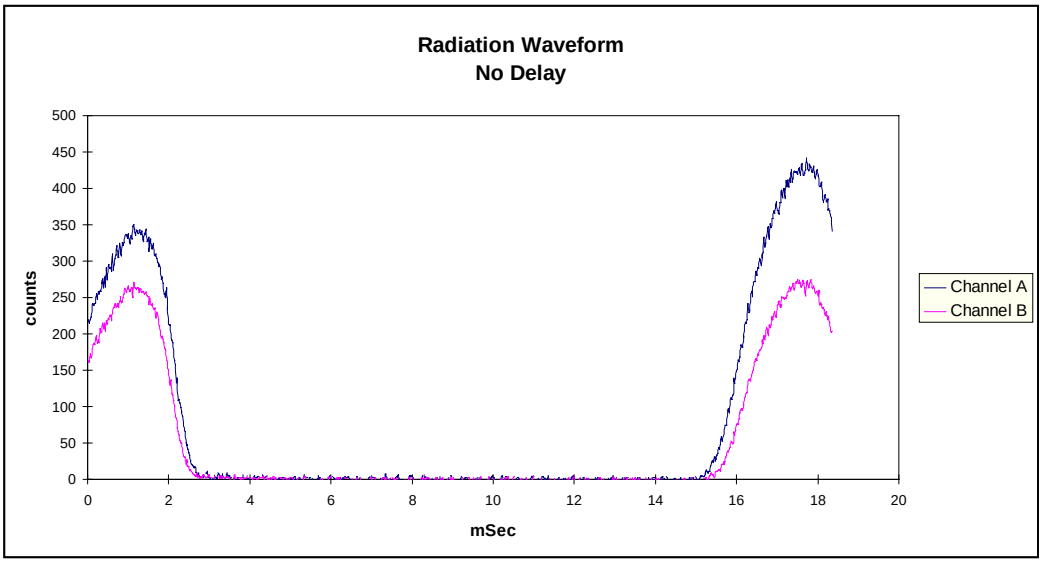


4.8 Waveforms - Dental with Filament Preheat

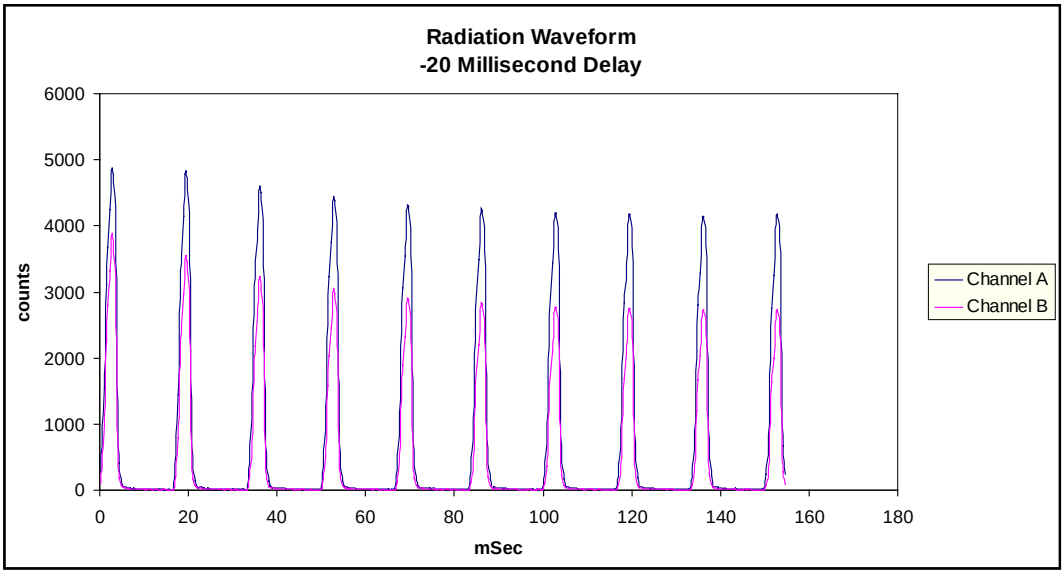
The radiation waveform below is from a single-phase dental x-ray machine that utilizes a 14 pulse filament preheat. The exposure time on this generator is set in pulses (instead of milliseconds) but does not include the filament preheat pulses. For instance, when the exposure time control is set for 10 pulses, the generator actually outputs 24 pulses, 14 of which are filament preheat pulses.



Below is an example of what the NERO mAx "sees" when making a measurement without a measurement delay on this type of generator. Note that the NERO mAx only acquires the two pulses during the filament preheat period. This is because the intensity of the remaining filament preheat pulses fall below the detectability limit of the NERO mAx. This causes the NERO mAx to stop acquiring data, ending the measurement after the first two pulses resulting in a measured exposure time of 18.36 milliseconds. For this exposure, the x-ray generator was set for 10 pulses, which should result in a waveform containing 24 pulses (including 14 filament preheat pulses).



To accurately assess this generator's performance, a measurement delay should be used to skip over the filament preheat pulses. The radiation waveform shown below illustrates the effect of using a -20 millisecond delay. Again, the x-ray generator was set for 10 pulses but the measurement delay caused the NERO mAx to skip the first 2 preheat pulses, wait for the exposure to resume and only record the desired portion of the generator's output. For this x-ray machine, a delay from 20 milliseconds up to approximately 230 milliseconds would yield the same measurement results. This is because the NERO mAx waits for up to one second after the delay time has elapsed for its radiation detection threshold to be exceeded, initiating data acquisition and measurement.



The NERO mAx Excel Add-In may be used to view kV and radiation waveforms to determine the optimum measurement delay to use. Information on using the NERO mAx Excel Add-In to view waveforms may be found in the NERO mAx Toolkit for Excel Instruction Manual. In addition, a digital storage oscilloscope may be connected to the scope output on the rear panel of the NERO mAx readout to view radiation output waveforms. Information on using the NERO mAx scope output may be found in Section 1.6 of the NERO mAx instruction manual.

Section 5
Maintenance

5.1 Fuse Replacement

CAUTION

Replacement fuses must be of the same type and rating.

1. Make sure that the NERO mAx has been disconnected from its AC adapter and is turned off.
2. Turn the NERO mAx upside down and remove the four recessed phillips head screws located in the four corners of the case.
3. Holding the case top and bottom together, turn the NERO mAx over so that it is in its upright position.
4. Carefully lift the case top and place the case top to the right side of the case bottom.
5. Unplug the red positive battery lead.
6. Locate the fuse holder in the positive (red) battery lead and open it by unscrewing the two fuse holder halves.
7. Remove the fuse and replace it with a fuse of the same type and rating. See Appendix F--Replacement Parts--for part numbers.
8. Reconnect the positive battery lead and reassemble the NERO mAx in the reverse order of disassembly.
9. Turn the NERO mAx on and verify that the NERO mAx powers up successfully. If the NERO mAx does not power up properly, please call Fluke Biomedical at 440.248.9300.

5.2 Battery Replacement

CAUTION

This instrument contains a rechargeable sealed lead acid battery. Proper precautions must be used in handling and/or disposal of this battery. Replacement battery must be of the same type and rating.

1. Make sure that the NERO mAx has been disconnected from its AC adapter and is turned off.
2. Turn the NERO mAx upside down and remove the four recessed phillips head screws located in the four corners of the case.
3. Holding the case top and bottom together, turn the NERO mAx over so that it is in its upright position.
4. Carefully lift the case top and place the case top to the right side of the case bottom.

5. Disconnect both battery leads (red and black) from the battery.
6. Cut the two tie wraps that retain the battery.
7. With a flat bladed screwdriver, pry the battery up from its mounting plate and remove the battery.

NOTE

The battery is held to the mounting plate with double-sided tape.

8. Replace the battery, in its original position at the rear of the battery mounting plate with its positive lead to the right. Use the double-sided tape from the old battery to hold the new battery in place and secure the battery to the mounting plate with two new tie wraps. See Appendix F--Replacement Parts--for part numbers.

9. Reconnect the battery leads and reassemble the NERO mAx in the reverse order of disassembly.

10. Turn the NERO mAx on and verify that the NERO mAx powers up successfully. If the NERO mAx does not power up properly, please call Fluke Biomedical at 440.248.9300.

5.3 Routine Cleaning

CAUTION

Do not immerse the Model 8000. The unit is not waterproof. Liquid could damage the circuits. The unit should be kept clean and free from dirt and contamination. The unit may be cleaned by wiping with a damp cloth or using any commercially available cleaning or decontaminating agent.

Appendix A
Temperature and Pressure

A.1 Temperature and Pressure

Any ionization chamber consists of a defined volume of air in which ions produced by radiation passing through the chamber can be collected and measured. A potential difference (voltage) is placed across the plates of the ion chamber. When ionizing radiation passes through the chamber, ion pairs are produced, each pair consists of one positive and one negative ion. Under the influence of the electric field produced by the potential on the plates, the ions move toward their opposite charged plate. The net effect of this is to cause a current to flow through the electronics in the NERO mAx connected to the plates, the magnitude of which is proportional to the rate of the exposure of radiation.

The sensitivity of any ion chamber depends upon the number of air molecules in the chamber. These quantities are directly proportional. The number of air molecules is a function of volume, temperature, and pressure. The volume of air in the internal and external ion chambers attached to the NERO mAx are fixed, although at different quantities. The difference in sensitivity between different size ion chambers are addressed in the CAL mode. Since all of these chambers communicate with the atmosphere, temperature and pressure will vary with ambient conditions.

In the NERO mAx the ambient temperature and pressure are manually entered. These values are used to calculate the correction factor that is automatically applied to the output of both internal and external ion chambers. These ion chambers provide rate and exposure measurements, and the corrections are applied in all modes as appropriate. Temperature and pressure does not affect other readings such as kV, time, or mAs. The correction factor is computed as follows:

$$cf = \frac{P_0}{P} \times \frac{T + 273.16}{T_0 + 273.16}$$

Where T is the temperature in degrees Celsius and P is the pressure in mm of Hg. T_0 and P_0 is the temperature and pressure, respectively, at which the chamber was calibrated.

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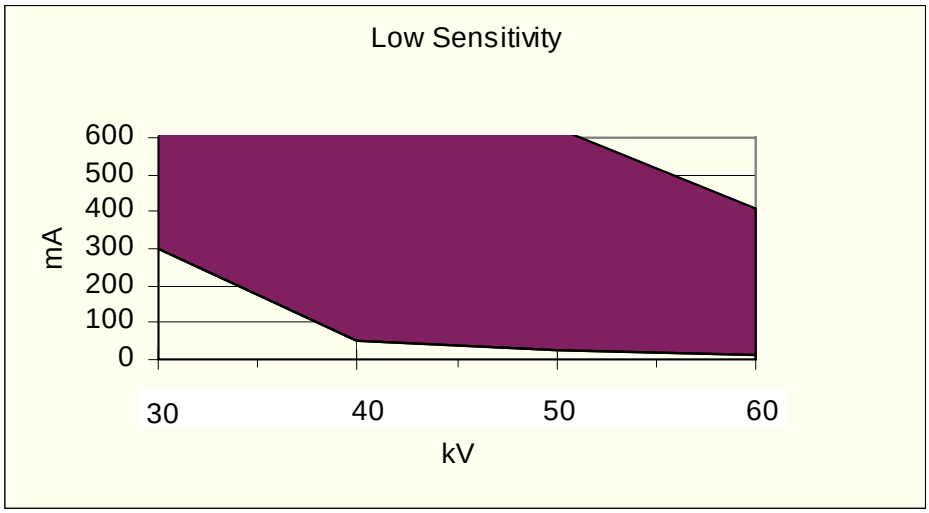
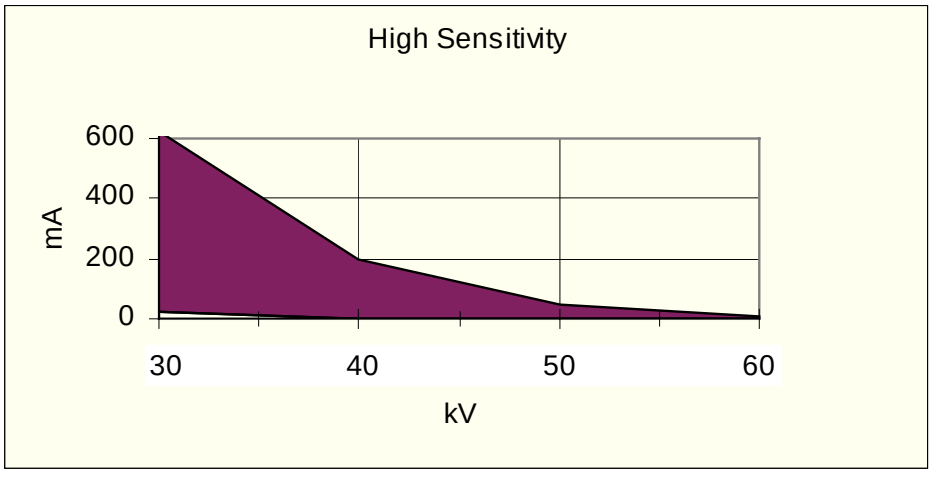
Appendix B
mA Limits vs. kV

B.1 mA Limits vs. kV

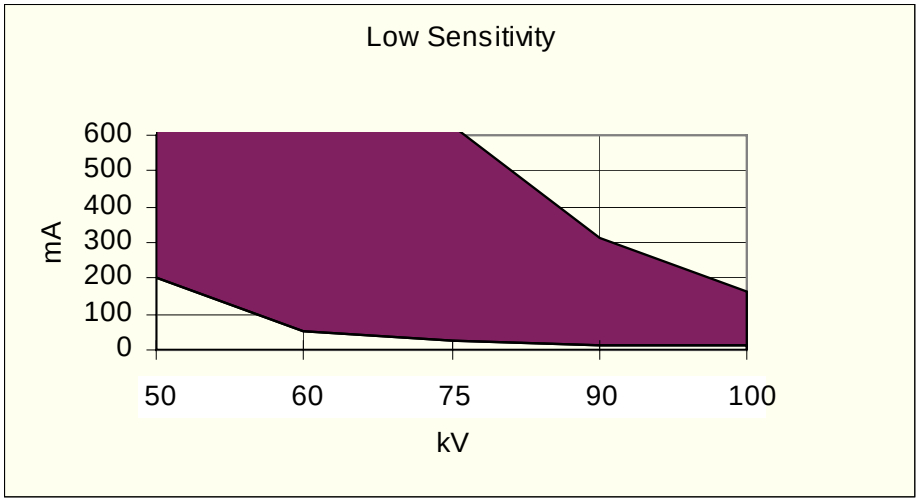
mA Limits vs. kV at 26" SDD, 1.2 mm Al Inherent Filtration - Low Sensitivity: W/Al, 30 - 60 kV Filter



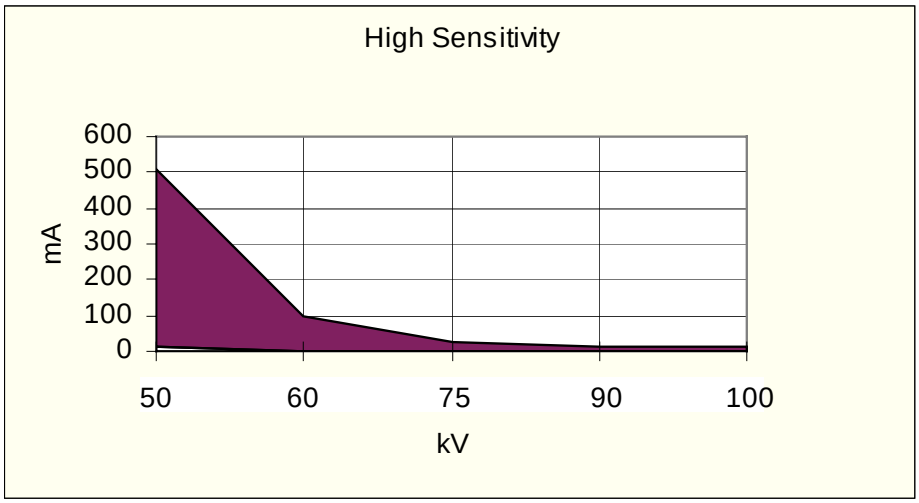
mA Limits vs. kV at 26" SDD, 1.2mm Al Inherent Filtration - High Sensitivity: W/Al, 30 - 60 kV Filter



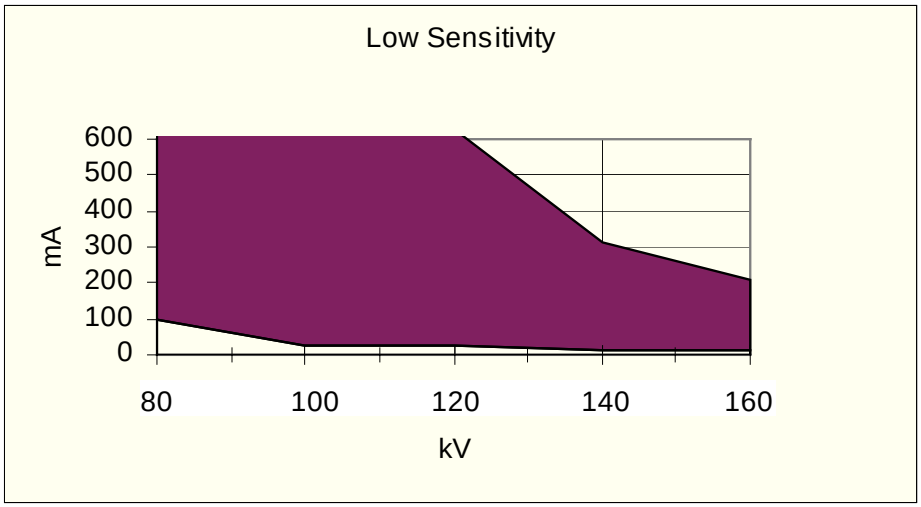
mA Limits vs. kV at 26" SDD, 1.2mm Al Inherent Filtration - Low Sensitivity: W/Al, 50 - 100 kV Filter



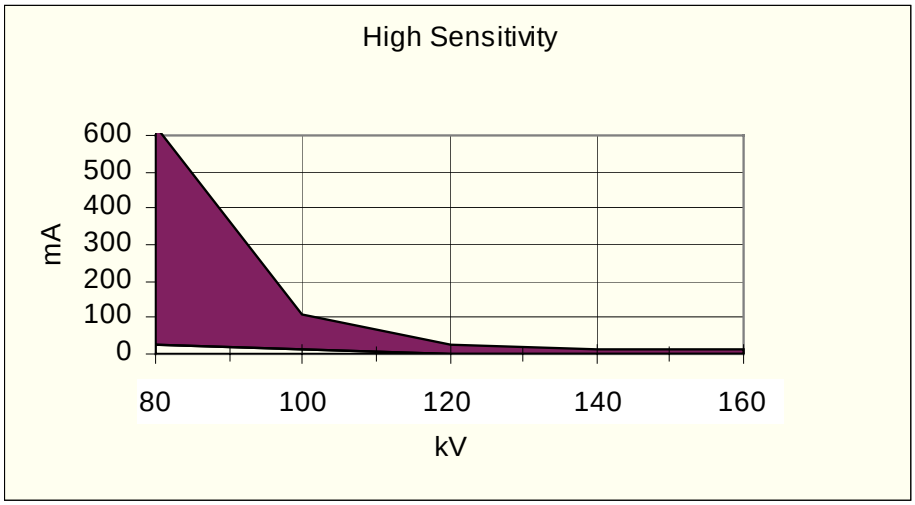
mA Limits vs. kV at 26" SDD, 1.2mm Al Inherent Filtration - High Sensitivity: W/Al, 50 - 100 kV Filter



mA Limits vs. kV at 26" SDD, 1.2mm Al Inherent Filtration - Low Sensitivity: W/Al, 80 - 160 kV Filter



mA Limits vs. kV at 26" SDD, 1.2mm Al Inherent Filtration - High Sensitivity: W/Al, 80 - 160 kV Filter



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Appendix C
Exposure and Rate Resolution and Limits

C.1 Exposure and Rate Resolution and Limits

Exposure and Rate Resolution, Standard Units (R)

Ion Chamber	Low Sensitivity		High Sensitivity	
	Exposure	Rate	Exposure	Rate
Mammo	.01 R	1 R/min	1 mR	.1 R/min
Fluoro	.1 mR	.01 R/min	.01 mR	1 mR/min
R/F	1 mR	.1 R/min	.1 mR	.01 R/min
Scatter	.1 mR	.01 R/min	.01 mR	1 mR/min
Internal	1 mR	.1 R/min	.1 mR	.01 R/min

Rate Limits, Standard Units (R)

Ion Chamber	Low Sensitivity	High Sensitivity
Mammo	10 kR/min	1000 R/min
Fluoro	250 R/min	25 R/min
R/F	1000 R/min	100 R/min
Scatter	100 R/min	10 R/min
Internal	1000 R/min	100 R/min

Exposure and Rate Resolution, SI Units (Gy)

Ion Chamber	Low Sensitivity		High Sensitivity	
	Exposure	Rate	Exposure	Rate
Mammo	.1 mGy	.01 Gy/min	.01 mGy	1 mGy/min
Fluoro	1 uGy	.1 mGy/min	.1 uGy	.01 mGy/min
R/F	.01 mGy	1 mGy/min	1 uGy	.1 mGy/min
Scatter	1 uGy	.1 mGy/min	.1 uGy	.01 mGy/min
Internal	.01 mGy	1 mGy/min	1 uGy	.1 mGy/min

Rate Limits, SI Units (Gy)

Ion Chamber	Low Sensitivity	High Sensitivity
Mammo	100 Gy/min	10 Gy/min
Fluoro	2 Gy/min	200 mGy/min
R/F	10 Gy/min	1 Gy/min
Scatter	1 Gy/min	100 mGy/min
Internal	10 Gy/min	1 Gy/min

Appendix D
CT Exposure Resolution

D.1 CT Exposure Resolution

CT Exposure Resolution vs Beam Width, Standard Units (R)

Beam Width (mm)	Low Sensitivity	High Sensitivity
1	1 R	.1 R
2	1 R	.1 R
3	1 R	.1 R
4	1 R	.1 R
5	1 R	.1 R
6	1 R	.1 R
7	.1 R	.01 R
8	.1 R	.01 R
9	.1 R	.01 R
10	.1 R	.01 R

CT Exposure Resolution vs Beam Width, SI Units (Gy)

Beam Width (mm)	Low Sensitivity	High Sensitivity
1	.01 Gy	1 mGy
2	.01 Gy	1 mGy
3	.01 Gy	1 mGy
4	.01 Gy	1 mGy
5	1 mGy	.1 mGy
6	1 mGy	.1 mGy
7	1 mGy	.1 mGy
8	1 mGy	.1 mGy
9	1 mGy	.1 mGy
10	1 mGy	.1 mGy

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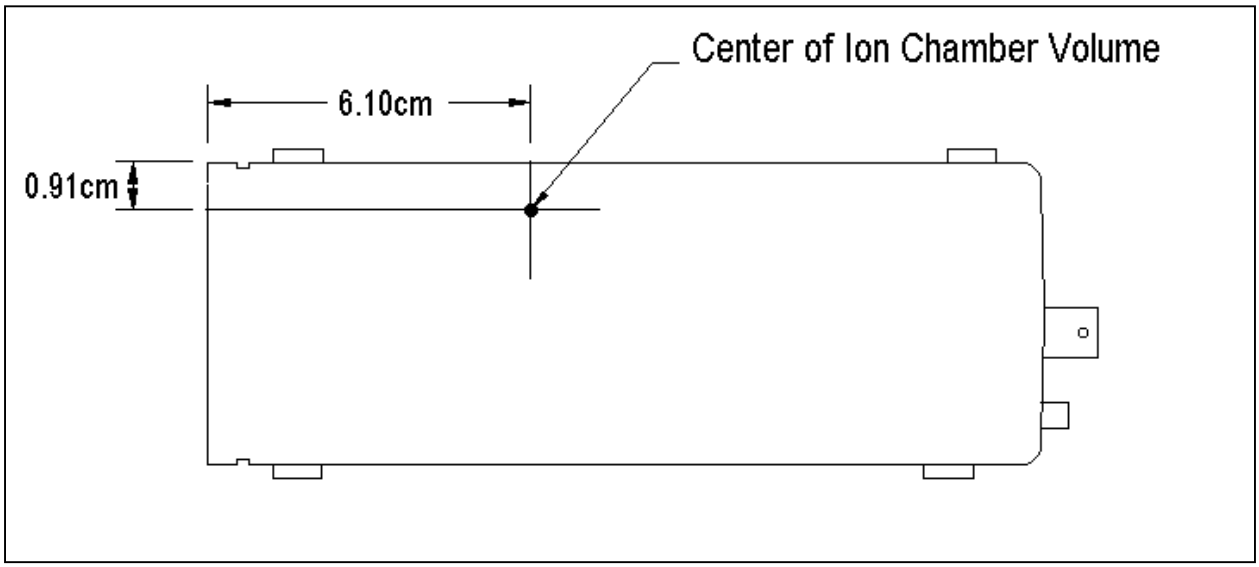
Appendix E
Ion Chamber of Sensitive Volume

E.1 Ion Chamber of Sensitive Volume

The center of the NERO mAx internal ion chamber is located along the center line of the detector, 6.10 centimeters from the front edge of the detector. The dotted black crosshairs on the top of the detector indicate the approximate center of the chamber. The center of the chamber on the vertical axis lies 0.91 centimeters below the top surface of the detector.



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Appendix F
Replacement Parts

F.1 Replacement Parts

Item	Part Number
AC Adapter (United States, Canada) Input: 120 VAC, 60 HZ, 22 W Output: 12 VDC, 1 A	14-328
AC Adapter (Europe) Input: 230 VAC, 50 HZ Output: 12 VDC, 1 A	14-401
AC Adapter (United Kingdom) Input: 240 VAC, 50 HZ, 21.2 VA Output: 12 VDC, 1 A	14-414
AC Adapter (Australia) 220/240 VAC	14-414 + 14-416
Battery, 12 V, 2.2 Ah	16-47
Carrying Case	8000-69
Detector Cable	105-252
HVL Plate, 2.3 mm	141049
HVL Plate, 1.0 mm	150113
HVL Plate, 0.3 mm	150470
Manual	8000-100-1
mAs Leads	105-253
mAs Extension Leads	105-254
NERO mAx Toolkit for Excel	8000MAX
Rubber Feet, Detector Top	978028
Rubber Feet, Readout Unit	978014
Fuse, .75 A, 250 V, 3 AG, Fast Acting	19-29

F.2 Accessories

Item	Part Number
Computer, Laptop	Call Customer Service
Ion Chamber, CT dose	14-401
Ion Chamber, Fluoro, 150 cc	14-414
Ion Chamber, Mammo, 3.3 cc	14-414 + 14-416
Ion Chamber, R/F dose, 30 cc	16-47
Ion Chamber, Scatter, 400 cc	8000-69
HVL Plates, Set of 11	105-252
HVL Plates, High Purity for Mammo HVL, Set of 5	141049
Phantom, CT Body Dose	150113
Phantom, CT Head Dose	150470
Carrying Case, CT Phantoms	8000-100-1
RS-232 Cable, 6 ft	105-253

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