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# INSTRUCTION MANUAL

## MODEL 890

## X-RAY DOSE METER / EXPOSURE TIME METER

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# DESCRIPTION

The ECC Model 890 X-ray Dose Meter / Exposure Time Meter is used to measure the effective dose produced by diagnostic x-ray generators. The ECC Model 890 is a solid-state, digital instrument designed specifically for service personnel in assessing the performance of radiation generators and the effective dose delivered by the x-ray generator under specific test conditions. This instrument measures the amount of x-ray radiation delivered to a specific area and measures the length of an exposure. The Model 890 can be used for dental x-ray units, radiographic and fluoroscopic x-rays.

The Model 890 is a small hand held battery operated unit. Each x-ray exposure is displayed on a 2x12 digit liquid crystal display (LCD). The operator can select between English (mR) and SI (uGy) units.

Radiation is detected by a solid state detector and electronic circuit. The instrument works for half-wave, full-wave, multiphase or DC (constant potential) x-ray generators. When a measurement is being made, the Model 890 has the capability of automatically determining the type of x-ray that is being measured. It is not necessary for the user to program correction factors for different types of x-ray waveforms.

The Model 890 automatically resets at the beginning of each exposure, holding the reading until the next exposure.

The most convenient way of using the 890 is to place it under the x-ray head. With the target positioned at the point of interest. The unit can be used with an appropriate phantom or metal filter. Step back, take the exposure and then observe the reading. Refer to the section on Operation for information on how to obtain the most accurate measurements.

**It is important that the user be thoroughly familiar with the contents of this manual before performing any tests on radiation generating equipment**. **It is also imperative that the user be thoroughly qualified, and familiar with safety precautions and other practices relating to radiation generators.**

# GENERAL INSTRUCTIONS

## SWITCH SETTINGS

In order to keep operation easy and straightforward there is only one switch on the front panel of the instrument. The switch is immediately below the display. The switch serves as an ON/OFF Switch and measurement selection. The three positions are as follows:

- Left – ON, English units (measurement in mRem)
- Center – OFF
- Right – ON, SI units (measurement in uGy)

Remember to turn the instrument off when not in use to conserve the batteries. Be careful when storing the instrument in order to ensure that the switch is not accidentally switched on. We recommend ordering an optional carry case to avoid accidental switch activation.

Whenever the instrument is powered on, there will be information displayed on the LCD screen.

### DISPLAY

After a measurement, the dose value, exposure time and dose rate will be displayed. If the battery is low, a “Low Battery” message will also be shown. The display is a 2 line by 12 character display.

# OPERATION

### Dose Measurements

The user must understand that the dose measurement is a measure of the x-ray intensity for a certain length of time **over a specific area**. This instrument measures dose of the x-ray over a 1.1 cm square area. The dose equivalent of a patient in the x-ray beam includes not only the dose being measured by the Model 890, but the dose covering the entire area of the x-ray beam. Body dose or effective dose is the comprehensive dose for the organ or body. This can be roughly estimated by extrapolating the area of x-ray beam in $cm^2$ to the Model 890 measuring area of 1.1 cm x 1.1 cm (1.21 $cm^2$). This calculation assumes that the x-ray intensity is constant over the entire area.

**All dose measurements are very sensitive to the distance from the x-ray head because the x-ray intensity change is proportional to the square of the distance from the head.**

Body dose is a comprehensive concept for the organ or partial body dose equivalent and the effective dose. Body doses cannot be measured directly. Industry standard and some regulations use the concept of effective dose in which all the individual doses to the irradiated organs or parts of the body are multiplied by a factor and added together. The resulting value may not exceed the dose limit for the effective dose that a patient is allowed to receive.

### Dose Rate

To measure a dose, the beam must operate for a certain period of time. The dose rate represents the measured dose for the amount of time required to complete the dose measurement. The dose rate is equal to the measured dose mathematically scaled by exposure time and is given as mR or uGy per second.

### Exposure Time Measurements

The Model 890 measures the Exposure Time each time an x-ray exposure is made. The exposure time will be displayed in milliseconds (ms).

### Detection

The Model 890 uses a semiconductor diode detector. The semiconductor diode detector has advantages over other detection methods. There are less statistical fluctuations than detectors that depend on gas ionization, which yields more accuracy and repeatability than moderately priced scintillation detectors. Radiation creates electron-hole pairs which are the carriers that are detected by the semiconductor diode. The use of semiconductor materials results in a large number of carriers. The electron-hole pair is similar to the ion pair created in gas filled detectors. The electron-hole motion generates small electrical currents that can be measured by sensitive amplifiers. Semiconductor detectors are more physically durable that scintillation detectors, making the Model 890 a more reliable and durable instrument.

**Detector Location**
In this instrument, the detector is located directly below the target image on the top label. The detector is 15 mm below the target image.

# REMOTE SENSOR CONNECTION

The remote sensor, Model 890RS, allows to take measurements up to 6 feet away from an x-ray generator. Its small size enables use with phantoms. It can be utilized by simply plugging in the remote sensor's cable into the side connector of the Dose Meter, Model 890.

# STATUS MESSAGES

The alphanumeric display on the Model 890 is capable of displaying messages along with the output readings that give the user additional information. Each message is described below:

Ready - Unit is ready for a reading.

Over Range - The x-ray output is too high. Use a lower mA or kV setting.

Over Scale - The dose value exceeds the measurable range of the Model 890.

Low Battery - Battery is low. The unit may still be operated for several hours, but accuracy may suffer. Replace the batteries as soon as possible.

**Momentary Messages**
When the unit is first turned on, there are two momentary messages that are displayed for about 1 second each.

Software revision level - The first momentary message is the name and revision level of the internal software. In normal operation, this information will not be needed by the user. However, when contacting the factory about a possible problem, you may be asked for this information. Please write down this information before calling the factory.

Battery Voltage – The second momentary message is the actual battery voltage. This voltage is a good guide to battery life. The unit uses a 9 Volt battery. The battery low message will be displayed when battery voltage is below 5.8 Volts.

# BATTERY REPLACEMENT

The Model 890 is supplied with one 9V battery. Replace the battery when the "Low Battery" indication shows on the display. Any standard 9V battery can be used in the 890. We recommend the Duracell MN1604 9 Volt Alkaline Battery. This battery has the longest life and is the most reliable battery we have found. Long life Lithium batteries are also very good.

To prolong battery life, turn the instrument off when not in use. If the instrument is to be stored for an extended period of time or shipped, remove the battery.

To replace the battery, open the battery compartment on the bottom of the case by applying finger pressure and slide toward bottom of case. Remove the old battery, and install the new battery.

# WARRANTY

Electronic Control Concepts warrants the Model 890 Dose Meter / Exposure Time Meter from defects in materials and workmanship for a period of 2 years. There is no warranty on the battery. ECC will replace or repair any Model 890 during the first year after shipment that does not show obvious signs of abuse. Contact the factory as described below.

# SERVICE INFORMATION

If a unit should need calibration or service, please contact the factory by phone or fax to obtain a Return Materials Repair authorization.

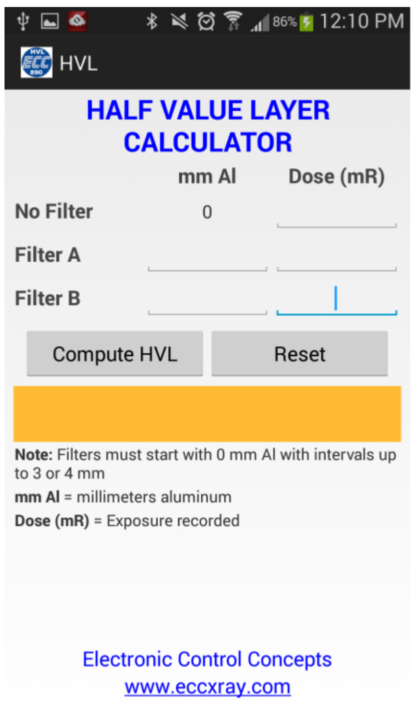
(800)VIP-XRAY or (800)847-9729 Phone
(845)247-9028 Fax

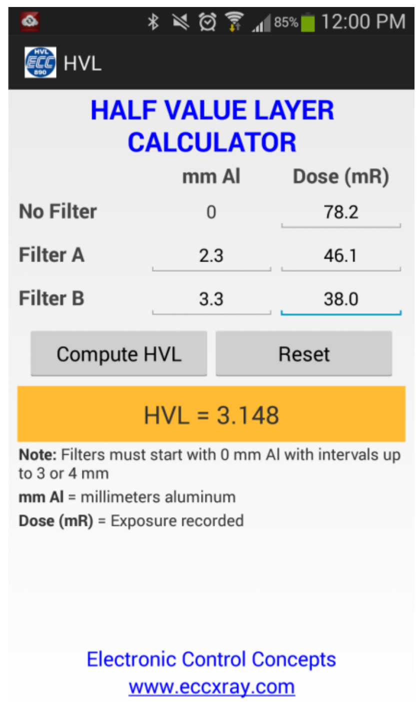
After obtaining an RMR number, ship the unit to:
Electronic Control Concepts
160 Partition Street
Saugerties, NY 12477

# MEASURING HALF VALUE LAYER

It is important to know the Half Value Layer (HVL) for diagnostic x-rays. Many states require this measurement as an integral part of periodic x-ray tests. The HVL test verifies that there is sufficient filtration in the x-ray beam to remove low level radiation. Low level radiation does not contribute to the x-ray image, but could be harmful to patients. By measuring the dose with different thicknesses of high purity aluminum (Al) the HVL can be determined.

The best way to calculate HVL is by using a smart phone application. We offer an inexpensive App for Android smart phones and tablets at this time. Our App allows you to quickly and easily calculate a value of HVL with only 3 dose readings. It is listed in the Google Store as “HVL Calculator”. Here is what the App looks like:




Place the Model 890 Dose Meter at a distance from the x-ray head that is normally used for procedures. Take an x-ray and record the dose measurement. Place the first sheet of aluminum (Al) in the x-ray beam, midway between instrument and x-ray head. Again, take an x-ray and record the dose measurement and the thickness of Al filter. Add one more sheet of Al or use a thicker sheet, and record dose value and Al thickness in this case. By simply entering the recorded data in the App and pressing “Compute HVL” button, it will display the computed HVL such as shown above.

# TECHNICAL INFORMATION

**Radiation Exposure and Dose**
The concepts of radiation exposure and dose are important, for the patient as well as x-ray personnel.

**Dose Definition**
When an x-ray is taken, radiation in the form of x-ray beams, are released. Using these beams, the x-ray technician can make images of whatever is being examined. This radiation penetrates objects and human bodies, passes through them, and is weakened in the process.

In simple terms, this weakening is equivalent to a reduction in the number of individual radioactive particles. A measurement of the amount of radiation measured at a site over a specific period of time, produces the concept of "dose". Not all the radiation particles generated during the x-ray are used to produce the resulting images, and because radiation can cause damage to the human body, medical personnel try to get the best possible image with the smallest possible dose of radiation. The concept of "dose" can mean different things according to the where and how the measurement is made, particularly with respect to the site where the dose is measured.

**Incident Dose**
The incident dose is the dose measured in the middle of the radiation field on the surface of a body or phantom. However, it is only measured at this point if there is no body in the path of the x-ray beam. There is no scatter radiation from the body or phantom during this measurement. Whenever radiation strikes a substance, there is always some scattering of radioactive particles.

**Absorbed Dose**
Different materials when subjected to the same x-ray exposure will absorb different amounts of energy. Changes to physical properties and induced chemical reactions are expected as the amount of radiation is absorbed in human tissue or the human body. The energy absorbed from radiation is defined as the absorbed dose. The traditional unit of absorbed dose has been the rad, defined as 100 ergs/gram. The metric or SI equivalent, the gray (Gy) is defined as 1 joule/kilogram. The two units are related by the following formula:

$$1 \text{ Gy} = 100 \text{ rad}$$

The absorbed dose is a reasonable measure of the chemical and physical effects by a specific radiation exposure in an absorbing material. When the effects of radiation on living organisms are evaluated, the absorption of equal amounts energy per unit mass will not have the same effects. The biological effects of radiation is traceable to the chemical alteration of the biological molecules that are influenced by the ionization or excitation caused by the radiation. The severity and permanence of these changes are directly related to the local rate of energy or dose. There are many papers and texts that describe the relation of dose, absorbed dose and dose equivalent. For fast electron radiation such as x-rays, the dose equivalent is basically the same as absorbed dose, or the dose reading from this instrument. This is not true for radiation from charged particles such as radioactive sources.

**Dose Area Product**

The dose-area product is a measurement of the amount of radiation that the patient absorbs. It is measured on the side of the patient where the radiation enters the body, by passing the x-ray beam through the measuring device. The dose-area product is independent of the distance between the X-ray tube and the measuring device because the further away from the X-ray tube this measurement is taken, the more the size of the device increases, and the dose itself decreases. The dose to the patient can be calculated from the dose-area product, the size of the measuring device, and the distance to the X-ray tube and the patient. The Model 890 dose detector covers an area of 1.1 cm by 1.1 cm (1.21 $cm^2$). Mathematically, dose area product is equal to the measured dose times 1.21 $cm^2$. Please note that the Model 890 cannot be left in the x-ray beam when an actual x-ray image is desired.

**Body Dose and Effective Dose**

Body dose cannot be measured directly. Body dose is a comprehensive concept for the body or partial body dose equivalent and the effective dose. In the practical application of radiation, local and individual doses are measured and extrapolated over the affected body surface area. Radiation protection regulations use the concept of effective dose, which includes all of the individual doses to the irradiated parts of the body multiplied by a factor and then added together. The resulting value must be less than the dose limit for the effective dose that a patient can receive.

References:

Glenn F. Knoll, *Radiation Detection and Measurement*, $2^{nd}$ edition. John Wiley & Sons, 1989

Nicholas Tsoulfanidis, Sheldon Landsberger, *Measurement and Detection of Radiation*, CRC Press, 2011

Gad Shani, *Radiation Dosimetry Instrumentation and Methods*, CRC Press, 1991

For further information, with a good explanation of different types of dose, please refer to:
http://www.e-radiography.net/radtech/d/Dose_ge/dose.htm

# MEASURING X-RAY QUALITY

## X-ray mAs Reproducibility

Measuring dose allows a user to test x-ray generator consistency with respect to kV, mA and mAs without using a kVp meter or an mA / mAs meter. The dose measurement is proportional to the x-ray intensity and time. The x-ray intensity is proportional to kV output and x-ray tube current . For any mA and exposure time setting there is a corresponding mAs value:

mAs = mA x time

An important test is to see how accurate the x-ray generator is at one selected mAs, which is created based on several different mA and or time settings. An actual set of data looks like this:

| kV set | mA set | mS set | mAs calc | Dose in mR |
|---|---|---|---|---|
| 80 | 50 | 200 | 10 | 107.8 |
| 80 | 100 | 100 | 10 | 106.5 |
| 80 | 200 | 50 | 10 | 108.8 |
| 80 | 400 | 25 | 10 | 107.5 |

For more accuracy, three readings could be taken at each setting, then average the three readings. For instruction purposes we show one reading for each setting. Note that all the x-rays were taken at 10 mAs, and this column of data was calculated based on the mA and exposure time settings. When setting up for this test, the height of the x-ray head above the Model 890 is not important since this test is based on the change of dose at different mA and mAs settings. Select a height that gives a reasonably large value of dose. The test can also be done using metric units (uGy).

The reproducibility as a percentage can be calculated as follows:

Reproducibility = (Maximum Dose – Minimum Dose) / (Maximum Dose + Minimum Dose)

Multiply by 100 to get the percent. For the data above, the calculation becomes:

Reproducibility = (108.8 – 106.5) / (108.8 + 106.5) x 100 = 1.07%

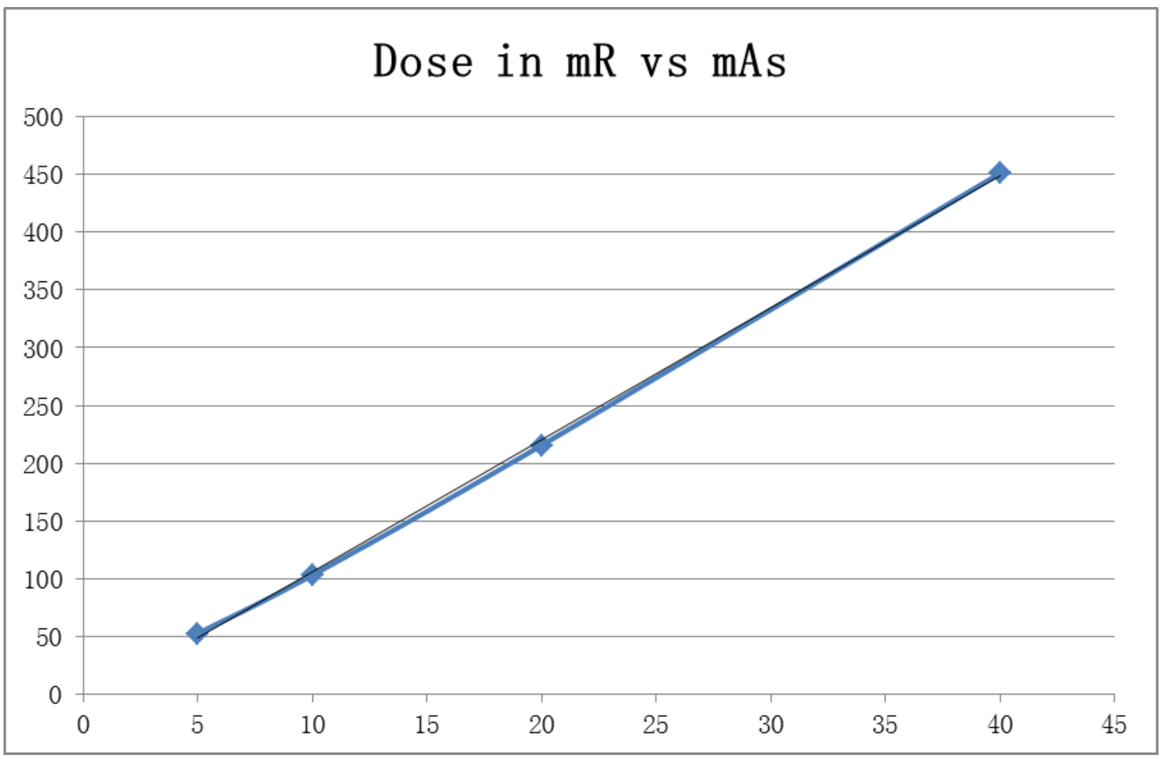
For most quality assurance tests, the reproducibility should be lower than 10%. This is also a requirement of several states. In addition to testing the linearity of mA and mAs, these tests verify that the kV output remains constant at different current and mA settings.

**X-ray mA and mAs Linarity**

For a particular mAs, doubling the time or mA will double the mAs. If there is a problem at different mA or time settings, the change will not be linear.
As an example, the following test data was recorded at an actual x-ray facility:

| kV set | mA set | set | mAs calc | dose in mR |
|---|---|---|---|---|
| 80 | 50 | 100 | 5 | 52.7 |
| 80 | 100 | 100 | 10 | 103.4 |
| 80 | 200 | 100 | 20 | 215.7 |
| 80 | 400 | 100 | 40 | 450.9 |

Rather than do a complicated mathematical analysis of the data, enter the data in a spreadsheet such as Excel. Plot the last two columns (mAs and Dose) using the Scatter Plot function. Then right click on the plot line and select “add trend line”, and select “linear”. The spreadsheet graph will show a perfectly linear trend line and your data plot. It is easy to see if there is a substantial deviation from linear. The chart below shows excellent correlation between the data (with squares) and the trend line generated by the spreadsheet.



## SPECIFICATIONS

DOSE RANGE
1 mR to 2000 mR
0.01mGy to 20 mGy
10uGy to 20000

DOSE ACCURACY
5% +/- 1 mR

EXPOSURE TIME ACCURACY
1% +/- 1 millisecond - 20 to 5000 mS

DISPLAY
Liquid Crystal
0.21" (5.5mm) Character Height
2 line by 12 Character Alphanumeric

CONTROLS
ON/OFF - UNITS Switch

OUTPUTS
2x12 Character Liquid Crystal Display

POWER
9 Volt Battery
Accessible from bottom of case
Duracell MN1604 or equivalent

BATTERY LIFE
120 hours continuous
Typically one year of normal use

PHYSICAL SIZE
80 X 147 X 40 mm
3.15 X 5.8 X 1.6 inches

WEIGHT
0.35 kg, (0.81 lb)

ENVIRONMENTAL
Temperature
Operating +10$^{o}$C to 40$^{o}$C
Storage 0$^{o}$C to 50$^{o}$C
Humidity
Up to 75% relative humidity

CONNECTIONS
None – without Remote Sensor
Remote Sensor plugs into rear

OPTIONAL ACCESSORIES
Remote Sensor
Hard Carrying Case 870HC