

# Mini-X-OEM X-Ray Tube

## MX-50 Controller



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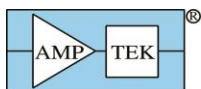
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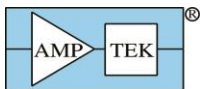
The Mini-X is based on the Newton Scientific Inc. miniature X-ray source.

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## 1 Precautions

**CAUTION:** The Mini-X-OEM is only one component of an X-ray instrument. It is the responsibility of the user, the OEM customer, or experimenter to provide a fail-safe metal enclosure to prevent escaping radiation while using this product. The final product (turn-key system) must comply with local government regulations to protect personnel from exposure to radiation. Amptek Inc. bears no responsibility for the incorrect use of this product.

### 1.1 High Voltage

The Mini-X-OEM is designed to generate voltages up to 50 kV. The high voltage system is fully shielded inside the Mini-X-OEM enclosure.

**DO NOT ATTEMPT TO ACCESS OR MODIFY THE HIGH VOLTAGE SYSTEM.**

**DO NOT UNSCREW ANY OF THE SCREWS AT THE NECK OF THE TUBE.**

**TAMPERING WITH THESE SCREWS WILL VOID WARRANTY.**



### Caution



**This device produces HIGH VOLTAGE when energized. To be operated only by qualified personnel.**

The Mini-X-OEM contains a high voltage power supply. High voltage is not exposed but the unit should be grounded as a precaution. It should be mounted to a metal fixture via the provided brackets.

The high voltage power supply has been thoroughly tested and should not ever arc to its own case. However, if at any time any high voltage arcing or popping is heard, immediately discontinue use. High voltage arcing has a distinctive sharp cracking sound. Contact sales (sales@amptek.com) if you suspect that the power supply is arcing.

### 1.2 Radiation

The Mini-X-OEM product is intended to generate X-ray radiation during normal operation. It has been designed to focus radiation in the designated output direction, but radiation can be scattered in other directions and should be addressed with shielding and/or monitoring in the final application.



### Caution



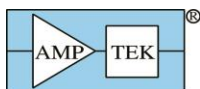
**This device produces X-RAYS when energized.  
To be operated only by qualified personnel.**

Radiation levels external to the X-ray tube housing with the brass safety plug ON do not exceed 2.5 mrem/h measured 5 cm from the surface of the housing in accordance with Requirements 5.2.2.1.1 and 5.2.2.2.2 of the NBS Handbook for Radiation Safety for X-Ray Diffraction and Fluorescence Analysis Equipment. For more information please see <http://epswww.unm.edu/xrd/nbs111.pdf>.

### 1.3 Beryllium Window

When unpacking the Mini-X-OEM pay careful attention to the Beryllium (Be) window on the front of the unit. This is a fragile window which can be damaged by impact. Beryllium (silver/gray and metallic) and beryllium oxide dust (normally a whitish powder) are harmful if inhaled or ingested.

**AVOID ALL CONTACT WITH THIS PART OF THE X-RAY TUBE.**



#### 1.4 Heat and Temperature

The ambient temperature surrounding the X-ray tube must not exceed 50 °C. Improper cooling is the single highest cause of X-ray tube failures and is not covered under the Mini-X-OEM Warranty. It is the user's responsibility to provide an adequate cooling system for the Mini-X-OEM.

#### 1.5 Prop65 Warning



## WARNING

This product contains the following chemicals, which are known to the State of California to cause cancer, birth defects or other reproductive harm if exposed to them through improper use, storage, or disposal of the product:

Prop 65 Chemical	Type of Toxicity	CAS No.	Product part containing the chemical
Beryllium	Cancer	--	Detector window

Please consult this owner's manual for proper use, storage, care and disposal of the product. For more information, go to: [www.p65warnings.ca.gov](http://www.p65warnings.ca.gov)

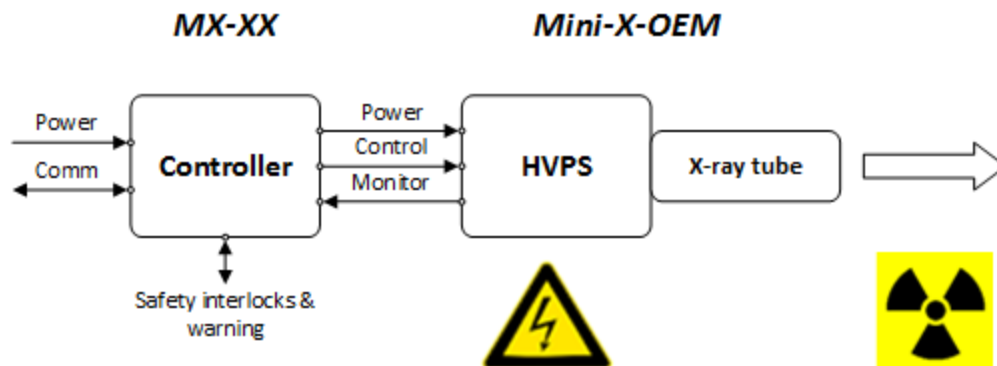
## 2 Introduction

**Important – Read the precautions in Section 1 of this manual before operating this equipment.**

#### 2.1 Description of Mini-X-OEM and MX-50 Controller

The Mini-X-OEM is a precision x-ray generator designed for applications that require small size and low power consumption. The source includes a miniature sealed x-ray tube with a transmission-type end window and a high voltage power supply encapsulated in a single radiation-shielded unit. The source is designed specifically to be used as a component of a bench-top or hand-held x-ray spectrometer for the detection of trace elements using x-ray fluorescence spectrometry.

The Mini-X-OEM differs from the Amptek Mini-X. The **Mini-X** has a USB interface to control the voltage and current through PC software and makes it easy to set up XRF experiments. The **Mini-X-OEM** version is controlled by the end user, by supplying analog voltages to control the voltage and current of the tube. This is the preferred method in table-top and hand-held OEM applications where all the functions of the instrument are controlled by a single internal computer. The **MX-50 Controller** includes the interface circuitry found in the Mini-X: it includes a USB interface to generate the necessary control voltages. A block diagram of the complete system is shown below.



The Mini-X-OEM has been designed to simplify the XRF process by providing a grounded anode, variable current and voltage controlled via USB and ease of operation. It features a 50 kV/80  $\mu$ A power supply, a gold (Au), silver (Ag), rhodium (Rh), or tungsten (W) transmission target, and a beryllium end window. A collimator and various filters are also provided.

The MX-50 family of products are controllers designed to interface with miniature X-ray tubes and HVPS modules, including Amptek's Mini-X-OEM. The MX-50 family has a USB interface to produce the voltages to control the voltage and current in the X-ray tube. Software running on the PC controls the tube. The MX-50 also includes a safety interlock circuit and controls for a warning light.

## 2.2 Options and Variations

### Anode material

The Mini-X is available with one of four anode materials: silver (Ag), gold (Au), rhodium (Rh), and tungsten (W).

### MX-50 Controllers

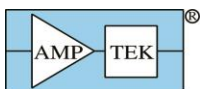
There are three different variants of the MX-50 currently available. These differ in the allowable range of control voltages for voltage, current, and power and match the specification of modules supplied by Newton Scientific. The MX-50 is suitable for the 50 kV, 4W monoblock. The MX-50.10 is suitable for the 50 kV, 10W monoblock. The MX-70 is suitable for the 70 kV, 10W monoblock unit.

The MX-50 contains hardware jumpers which indicate, to the processing software, the configuration (50 kV, 4W; 50 kV, 10W; 70 kV, 10W). It is critical that one use the correct MX-50 configuration for the tube. If one mixes these up, the tube will be operated at the incorrect voltage and current and the power may exceed the absolute maximum, thus damaging the tube.

## 3 Specifications

### 3.1 Mini-X-OEM Specification table

	Silver (Ag) Target	Gold (Au) Target	Rhodium (Rh) target	Tungsten (W) target
Target Thickness	0.75 $\mu$ m ( $\pm$ 0.1 $\mu$ m)	1 $\mu$ m ( $\pm$ 0.1 $\mu$ m)	0.75 $\mu$ m ( $\pm$ 0.1 $\mu$ m)	1 $\mu$ m ( $\pm$ 0.1 $\mu$ m)
Tube Voltage	10 kV to 50 kV			
Tube Current	5 $\mu$ A to 200 $\mu$ A max.			
Approximate Dose Rate	1 Sv/h @ 30 cm on axis, 50 kV and 80 $\mu$ A	1.3 Sv/h @ 30 cm on axis, 50 kV and 80 $\mu$ A	1 Sv/h @ 30 cm on axis, 50 kV and 80 $\mu$ A	1.3 Sv/h @ 30 cm on axis, 50 kV and 80 $\mu$ A



Approximate Flux	10 <sup>6</sup> counts per second/mm <sup>2</sup> on the axis at a distance of 30 cm (50 keV/1 $\mu$ A)	1.3x10 <sup>6</sup> counts per second/mm <sup>2</sup> on the axis at a distance of 30 cm (50 keV/1 $\mu$ A)	10 <sup>6</sup> counts per second/mm <sup>2</sup> on the axis at a distance of 30 cm (50 keV/1 $\mu$ A)	1.3x10 <sup>6</sup> counts per second/mm <sup>2</sup> on the axis at a distance of 30 cm (50 keV/1 $\mu$ A)
Continuous Power	4 W max. @ 100% duty cycle			
Window Material	Beryllium (Be); window at ground			
Window Thickness	127 $\mu$ m			
Focal Spot Size	Approximately 2 mm			
Output Cone Angle	120°			
Cooling	Air cooled			
High Voltage Stability	< 0.1%			
Leakage Radiation	<5 $\mu$ Sv/h (0.5 mrem/h) at 5 cm with safety plug installed			
Power Consumption	9 W at 50 kV and 80 $\mu$ A			
Input Voltage	6 to 12 VDC			
Setting Time	Typical < 1 s			
Weight	360 g			
Humidity	30 to 90% non-condensing			
Operating Temp	-10 °C to +50 °C			
Storage Tempe	-25 °C to +60 °C			
Warranty	One year or 2000 hours, whichever comes first			

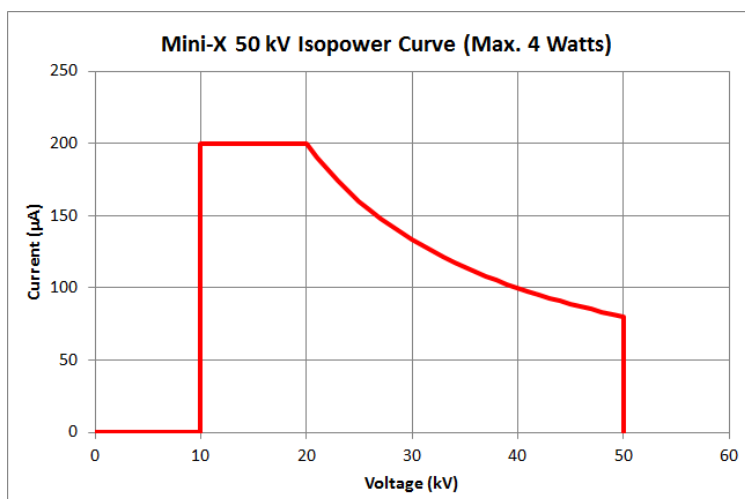


Figure 2. Mini-X Isopower. The current and voltage must be set in accordance with this curve or the Mini-X may be severely damaged. Damage of this kind is not covered under warranty. Amptek's control software limits the power to this curve. If one commands the system to a power exceeding the power limit, the software will use the commanded HV and rollback the current to meet the power limit.

### 3.2 MX-50 Specification table

Power Consumption	Up to 20 W
Input Voltage	12 VDC (AC adapter included)
Control	USB, mini-USB connector (cable included)
Setting Time	Typical < 1 s
Weight	360 g
Humidity	30 to 90% non-condensing
Operating Temperature	-10 °C to +50 °C
Storage Temperature	-25 °C to +60 °C

### 3.3 Output X-Ray Spectra

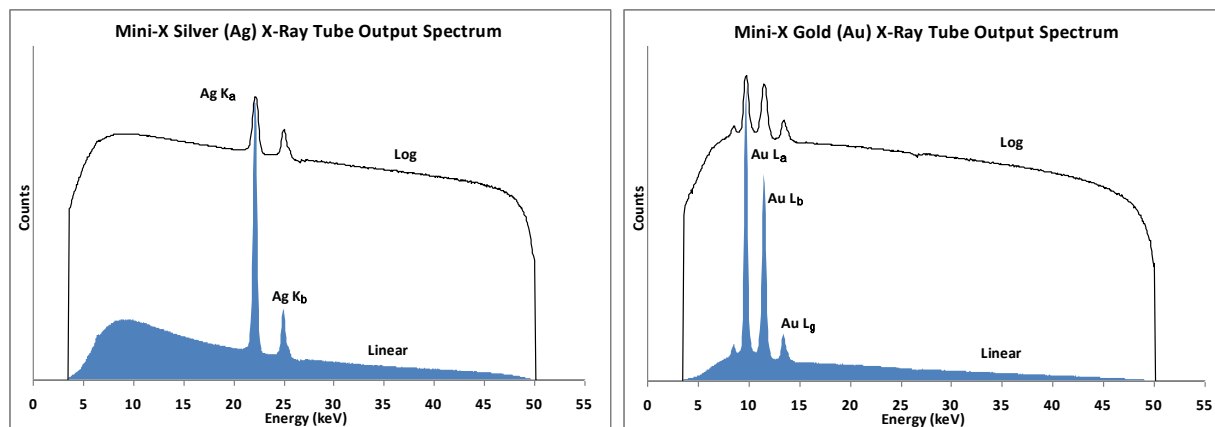


Figure 3. Output Spectrum with silver (Ag) target (left) and gold (Au) target (right). These were measured using a 1 mm thick CdTe detector located 1 meter from the Mini-X with a 1 mm pinhole collimator (made from tungsten) in front of the detector.

## 4 Mechanical Interface

### 4.1 Dimensions

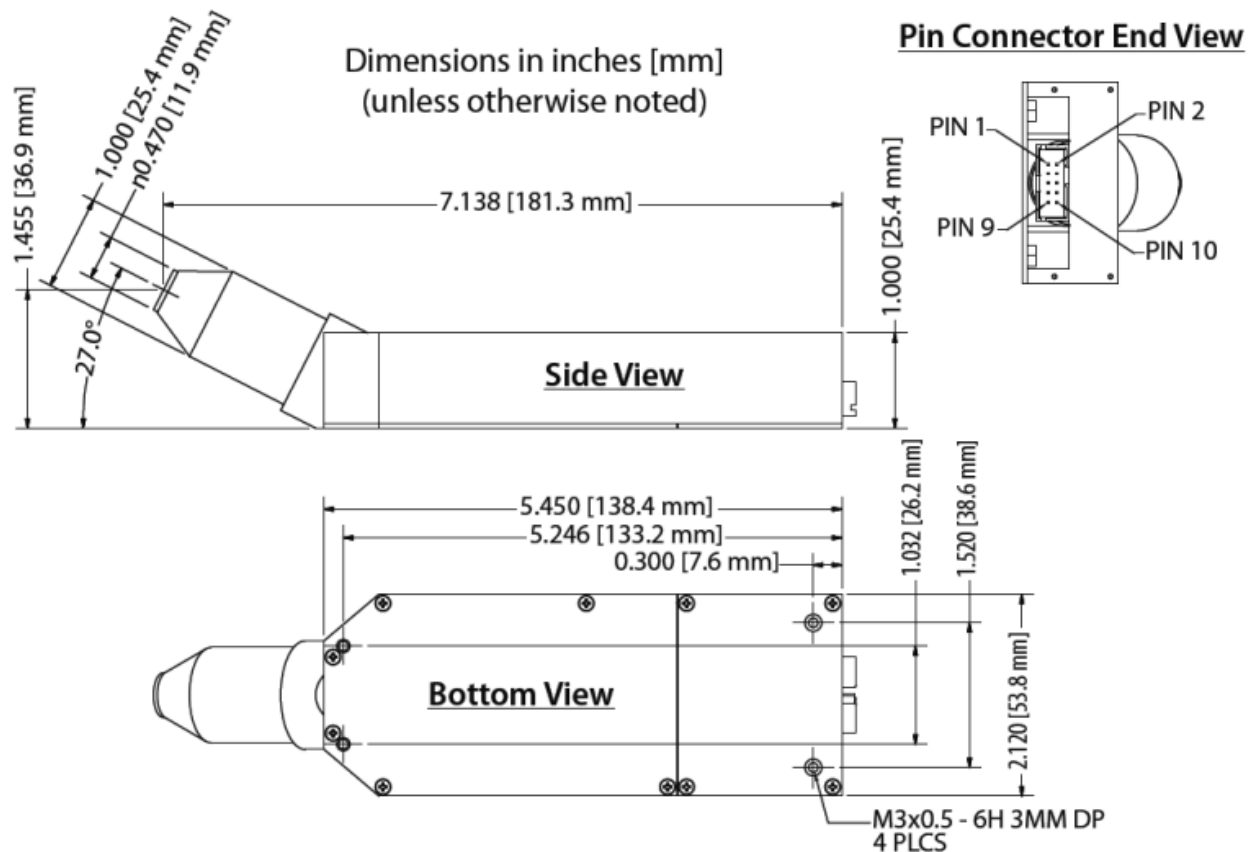


Figure 4. Mini-X-OEM mechanical dimensions in inches [mm].

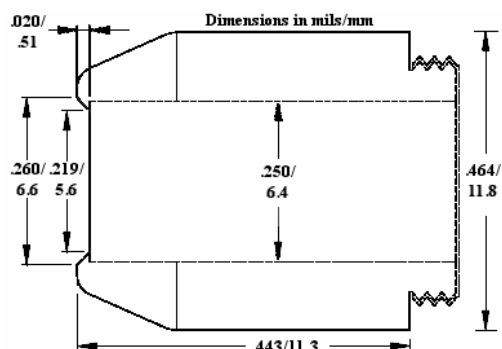


Figure 5. Brass cover dimensions (in mils/mm). This holds the safety plug or collimators and filters.

### 4.2 Mini-X-OEM Connector

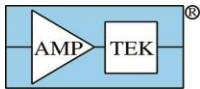
See section 4.1 for drawing and pinout.

10 Positions Header, Shrouded Connector 0.100" (2.54mm)

Sample mating connector: 3M P/N 89110-0101, 10 Position IDC Socket

Pin #	Name	Type
-------	------	------





1	V+	PWR, 6 to 12 VDC
2	V+	PWR, 6 to 12 VDC
3	GND	GND
4	GND	GND
5	TUBE I CONTROL	ANALOG IN, 0 to 4 VDC
6	TUBE HV CONTROL	ANALOG IN, 0 to 4 VDC
7	TUBE READY	DIGITAL OUT, TTL
8	TUBE ENABLE	DIGITAL IN, TTL
9	TUBE HV MONITOR	ANALOG OUT, 0 to 4 VDC
10	TUBE I MONITOR	ANALOG OUT, 0 to 4 VDC

#### 4.3 MX-50 Connectors

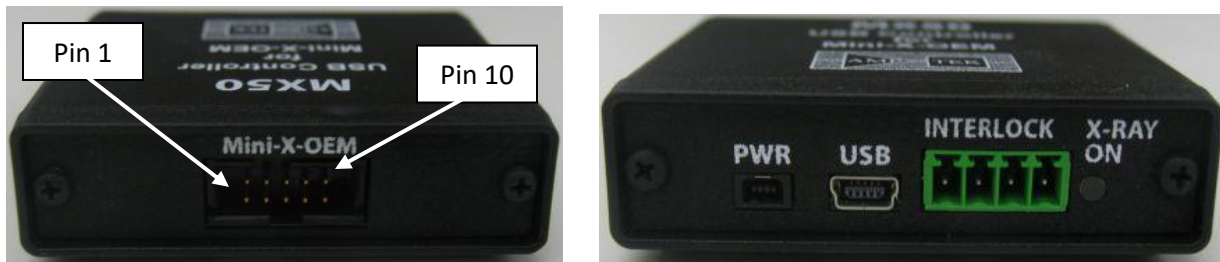
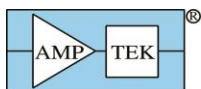


Figure 6. Front (left) and rear (right) connector panels of the MX-50.

##### Front panel Mini-X-OEM

Connector and pinout match that in section 4.2 for the Mini-X-OEM.

See section 5.1 for the voltages for the MX-50 variants.



#### Power

Power Jack on MX-50: Hirose MQ172-3PA(55).

Mating Plug: MQ172-3SA-CV

Pin #	Name
2	Do Not Connect
3	GND
1	VIN (+12 V DC)

#### Interlock

OST, EDSTLZ1550/4

Mating Plug: OST, EDZ1550/4

Pin #	Name
1	PWR to interlock
2	PWR from interlock to HVPS
3	Q1 DRAIN
4	GND

The function of the interlock is described in section 5.2.

#### USB

Standard USB 'mini-B' jack.

#### 4.4 Mounting

The Mini-X-OEM can be fastened using the mounting holes and brackets that are provided.

#### 4.5 Cooling

The Mini-X-OEM requires proper and adequate cooling for maximum life. As such, it is the user's responsibility to provide a cooling design, such that the ambient temperature of the X-ray tube does not exceed 50 °C. Air cooling via a small fan is recommended. Improper cooling is the single highest cause of X-ray tube failures. Improper cooling is not covered under the warranty.

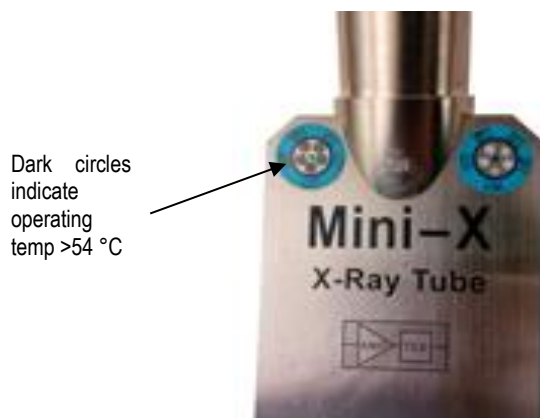
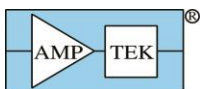


Figure 7. Temperature sensors. The maximum operating temperature of the Mini-X is 50 °C. The Temperature Sensors in this example show the Mini-X exceeded 54 °C.

**This voids warranty.**



## 5 Electrical Interface

### 5.1 Power Interface

Nominal input voltage 6 to 12 VDC

Absolute Maximum Power Supply Voltage +12.5 VDC

Absolute Minimum Power Supply Voltage + 6.0 VDC

Input power outside this range will damage Mini-X-OEM components.

### 5.2 MX-50 Voltages

PIN	NAME	MX-50	MX50.10	MX-70
1	V+	12 VDC		
2	V+	12 VDC		
3	GND	GND		
4	GND	GND		
5	TUBE I CONTROL	0.1 - 4 V → 5 - 200 $\mu$ A	0.1 - 4 V → 5 - 200 $\mu$ A	0 - 3 V → 0 - 150 $\mu$ A
6	TUBE HV CONTROL	0.4 - 4 V → 5 - 50 kV	0.4 - 4 V → 5 - 50 kV	1.8 - 3.5 V → 35 - 70 kV
7	TUBE READY	Low=Not Ready, High=Ready		
8	TUBE ENABLE	Low = Off, High = Enable		
9	TUBE HV MONITOR	0.4 - 4 V → 5 - 50 kV	0.4 - 4 V → 5 - 50 kV	1.8 - 3.5 V → 35 - 70 kV
10	TUBE I MONITOR	0.1 - 4 V → 5 - 200 $\mu$ A	0.1 - 4 V → 5 - 200 $\mu$ A	0 - 3 V → 0 - 150 $\mu$ A
	Power	4 W	10 W	10 W

### 5.3 MX-50 Interlock

The MX-50 has a hardware interlock in order to prevent accidental radiation exposure. This interlock must be shorted (enabled) in order for the Mini-X to produce X-rays. The left figure below shows the interlock disabled. The Mini-X will not produce X-rays in this configuration. The right figure shows the interlock enabled. The Mini-X will produce X-rays in this configuration. Always store with the interlock disabled when not in use.



Figure 8. Interlock disabled (left) and enabled (right).

One of the primary purposes of the interlock is so that the user can interface to external safety mechanisms. This is most commonly implemented as a shutter or cover that, when opened, disables the interlock and stops the generation of X-rays. When the tube is producing X-rays and the interlock is disabled, the tube will go into a reset mode. It is therefore necessary to restart the tube through software. Re-enabling the interlock after disabling it will not resume the production of X-rays.

The figure below is a block diagram of the MX-50 power and control interface, illustrating the use of the “Interlock” connector. This connector has two functions: it permits the user to implement a safety interlock, which turns off the X-ray tube when a switch is opened, and it permits the user to implement an external indicator to show when the tube is in use.

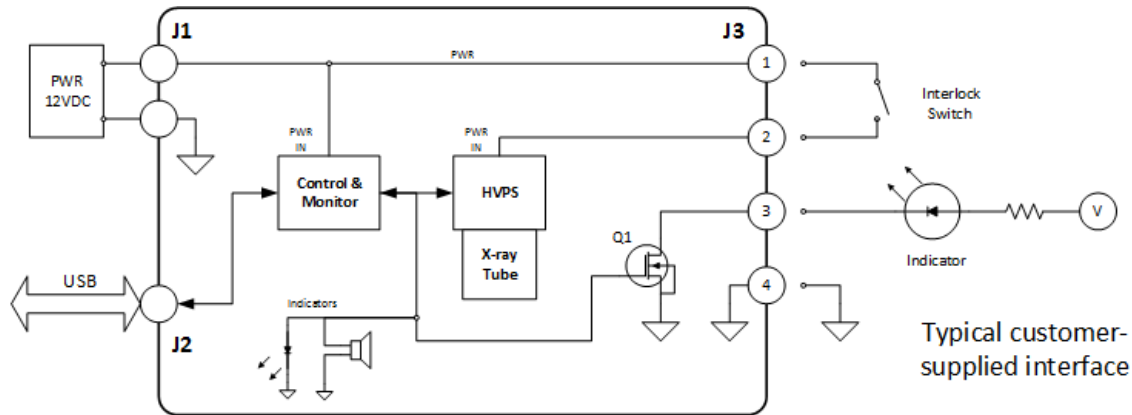


Figure 9. Block diagram of the MX-50 power and control interface.

As shown in the figure, power is supplied to the high voltage power supply (HVPS) via a connection between pins 1 and 2 of the interlock connector. If the connection between these pins is interrupted, there is no power to the HVPS and so the tube turns off. In addition, this latches a bit in the monitor circuit, which must be reset via a USB command. When a connection is restored between pins 1 and 2, although power is restored to the HVPS, the unit is not turned on until this command is received. The voltage at pins 1 and 2 is typically 12 VDC. As shown in the figure, a user could connect this to a switch, typically located on the cover of the enclosure housing the X-ray target. If a user accidentally opens the cover without first turning off the tube, this will automatically turn off the power, preventing accidental radiation exposure.

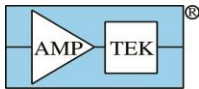
The MX-50 contains a speaker and an LED, both of which indicate that the X-ray tube is turned on. The LED is visible on the back side of the MX-50 package, but in some applications the Mini-X-OEM and MX-50 is inside an enclosure. Pins 3 and 4 can be used to drive an external indicator, such as the LED sketched above. The user must provide the circuit interfacing to pins 3 and 4. Q1 is an N-channel enhancement mode MOSFET, part number ZXM61N02FTA. Key ratings are  $V_{DS} = 20V$  (absolute max) and  $I_D = 1.7A$  (absolute max at 25 °C).

## 6 MX-50 Software Interface

### 6.1 Software Installation

#### Installing USB Drivers

If your computer is on the Internet, and your settings do not prevent updating, then the USB drivers will be automatically downloaded using Windows Update.



1. Connect the MX-50 to the PC via a Mini USB Cable. Plug the MX-50 12 VDC supply into a 110/200 VAC outlet and into the Mini-X-OEM back panel.
2. A "Found New Hardware" or "Installing Device Driver" box opens. Follow any instructions for "Automatic" installation over Windows Update (the detailed instructions will vary with the operating system).
3. If the driver has been successfully installed, it will be visible in Device Manager, as shown below.



Figure 10. The Mini-X will appear in Devices.

If your computer is not on the Internet or your Firewall or Administrative settings prevent automatic installation, then you will need to install the drivers manually. The drivers are on the installation CD and can be downloaded from Ampetek's website. Go to the "Mini-X Drivers" directory and run the appropriate "dpinst" file for your OS.

#### *Installing Application Software*

1. Locate the "Mini-X Software/Mini-X Setup" folder on the Ampetek Installation CD or download from Ampetek's website.
2. Right click the Mini-X\_Controller\_Setup.exe file and select "Run as Administrator" and follow the instructions.

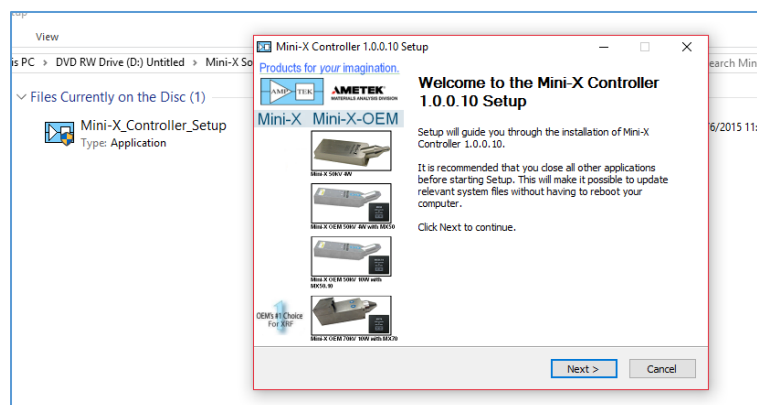
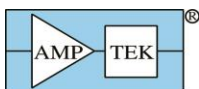


Figure 11. Mini-X setup.



## 6.2 Operating the Mini-X-OEM with MX-50

X-rays exit the Mini-X-OEM in a 120° cone. NOTE: When using the 2 mm collimator, the X-ray cone is 5°.

**SAFETY PRECAUTIONS MUST BE USED FOR EQUIPMENT THAT PRODUCE X-RAYS.**

**MINIMIZE HUMAN EXPOSURE TO X-RAYS.**

**USE A GEIGER COUNTER TO MONITOR RADIATION.**

**STOP: ONLY QUALIFIED PERSONNEL SHOULD PROCEED BEYOND THIS POINT.**

1. Install the software as described in Section 5.1.
2. Connect the Mini-X-OEM to the PC computer with the USB cable.
3. Connect the AC power adapter to the Mini-X-OEM and plug it into an appropriate 110/220 AC power outlet.
4. Remove the safety plug from the cover attached to the Mini-X-OEM. Either install the collimator into the cover or leave the cover empty. Re-attach the cover to the Mini-X-OEM.
5. Make sure that you have verified the anticipated direction of the X-ray beam as described above.
6. The MX-50 has a hardware interlock in order to prevent accidental exposure. This interlock must be shorted (enabled) to produce X-rays. Install the interlock plug to produce X-rays.
7. Open the Amptek Mini-X Controller Software. It will appear as below.

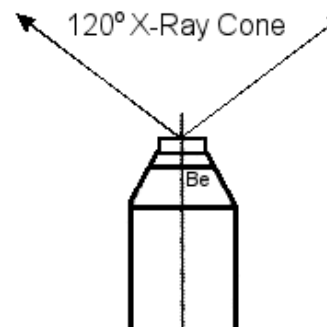


Figure 12.

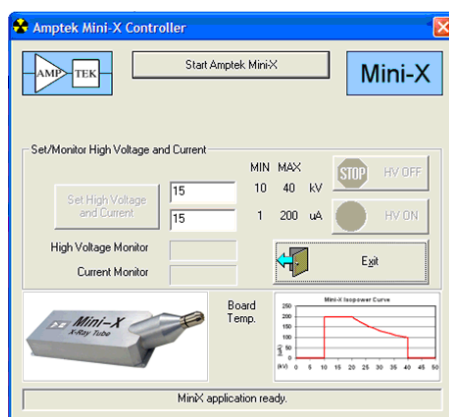


Figure 13.

8. Click the Start Amptek Mini-X button. The software will display the serial number of the MX-50.

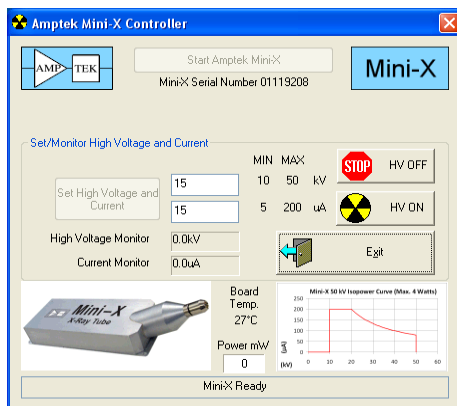
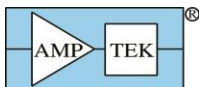


Figure 14.

9. The software defaults to a setting of 15 kV and 15  $\mu$ A. To change the values click into the appropriate text box and type in the desired number.

**IMPORTANT:** Do not enter a voltage higher than is rated for your unit. In addition, the total power is governed by the Isopower curve. Do not enter a current that exceeds the indicated value for that voltage. If a requested current is too high, the software will automatically adjust it to the maximum allowed value.

10. Click the HV ON button to turn on the tube. The software will ask you to confirm. Click Yes.



**THE MINI-X IS NOW PRODUCING X-RAYS**



11. The Mini-X-OEM will start to beep and the red LED on the end panel of the unit will flash. In addition the yellow and black “Radiation Symbol” will blink in the Mini-X Software and the words “X-Ray ON” will appear.

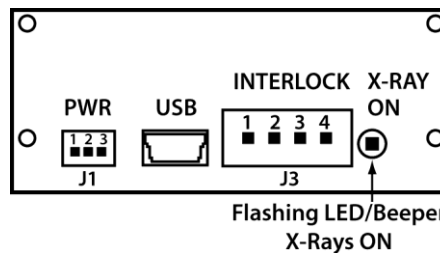
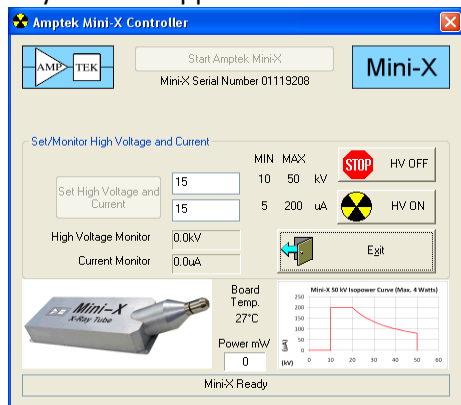
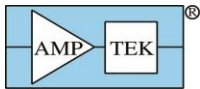


Figure 15.

12. The Voltage and Current monitors now show the actual X-ray tube condition. Although the values for Voltage and Current might be slightly different from the requested values, these are the actual values of the tube.
13. To change the high voltage and current, click into the appropriate text box and enter the number. Then click the Set High Voltage and Current button.



14. To turn off the Mini-X-OEM click the HV OFF button, then click the Exit button to exit the software. Always unplug the Mini-X-OEM, install the safety plug, and disable the interlock when not in use.

## 7 Mini-X-OEM Design

### 7.1 X-ray tube

The heart of the Mini-X-OEM is a compact X-ray tube which uses a transmission target. The high voltage power supply (HVPS) produces a bias voltage between the target (which is grounded) and the filament. This voltage accelerates electrons produced at the filament into the target. When these electrons decelerate in the target material, they produce bremsstrahlung radiation, X-rays with a continuous energy spectrum. They also produce X-rays at the characteristic energy of the target material. Many of these X-rays are directed towards the window, made of Be (beryllium), where they can be collimated into the sample. The X-ray tube contains shielding which stops X-rays outside of the 120° cone.

### 7.2 High Voltage Power Supply

The HVPS takes the 12 VDC input and steps it up to the commanded bias (10V to 50V). It is a switch mode regulator with a conventional Cockcroft-Walton multiplier, operating between 40 and 100 kHz.

There are three inputs to the HVPS: an analog voltage which sets the HV, an analog voltage which sets the current, and an ON/OFF logic signal. The HV and current signals have a range of 0 to 4V, which correspond to the HPVS settings: a 2V input to the HV results in a half-scale output of 25 kV.

There are three outputs from the HVPS: an analog voltage reading the HV, an analog voltage reading the current, and a STATUS logic signal. These have the same scale factors as the inputs.

### 7.3 MX-50 Control and Interface Module

The control module takes the control values commanded via USB and uses these to set the proper control voltages and to send the ON/OFF command. It also reads the outputs. There are a few key details to the control and interface module:

- The interlock circuit is very important, both for radiation safety and for successful operation of the Mini-X-OEM. Please refer to sections 4.2 and 8.2 for details.
- The software compares the commanded values for HV and current to the outputs. If the inputs and outputs differ (outside of tolerance limits and sustained for a certain time), the HVPS is disabled.

## 8 Mini-X-OEM Accessories

### 8.1 Collimator

The Mini-X is provided with two collimators to facilitate its use in XRF applications. They consist of brass collimators with aluminum (Al) inserts and a cover that screws into the Mini-X-OEM. The collimators have 1 and 2 mm diameter holes. A brass safety plug is also provided which, when installed, reduces the flux from an operating tube to less than 25  $\mu\text{Sv/h}$  (2.5 mrem/hr) at 5 cm away in accordance with Requirements 5.2.2.1.1 and 5.2.2.2.2 of the NS Handbook for Radiation Safety for X-Ray Diffraction and Fluorescence Analysis Equipment. Insert the collimator into the cover and then carefully screw the assembly onto the Mini-X-OEM. The collimator has a 2 mm diameter hole.





Figure 16. Left photo shows the Mini-X-OEM collimators, safety plug, and cover. The middle photo shows the safety plug installed in the cover and attached to the Mini-X-OEM. This configuration meets the radiation requirements discussed above. The Mini-X-OEM ships from the factory in this configuration. The right photo shows the collimator installed in the cover.

## 8.2 Brass Safety Plug

When the brass safety plug is installed in the cover (figure 16, middle) and screwed onto the Mini-X-OEM it meets the radiation safety requirements of Section 1.2. For personal protection always install the safety plug into the cover and attach to the Mini-X-OEM when not in use. The Mini-X-OEM ships from the factory in this configuration.

## 8.3 Filters

The Mini-X-OEM is shipped with a set of filters to modify the output spectrum of the tube to better suit a particular application. The use of any filter will reduce the flux, so the current may have to be increased to obtain an appropriate flux. Install the filter at the Mini-X screw base. Then screw on the cover with the collimator. Make sure that the cover screws all the way down, otherwise radiation will leak through the gap. All filter thicknesses will fit except for the 40 mil Al. This filter must be installed on the outside output aperture of the collimator and held in place with the black cap provided.

Filters are very important for obtaining high quality results in XRF analysis. Please refer to Amptek's application note, "X-ray Tube Filters FAQ", for more information.

Material	Thickness μm/mils	# Included
Al	1016 / 40	5
Al	254 / 10	5
Cu	25.4 / 1	3
Mo	25.4 / 1	2
Ag	25.4 / 1	1
W	25.4 / 1	1

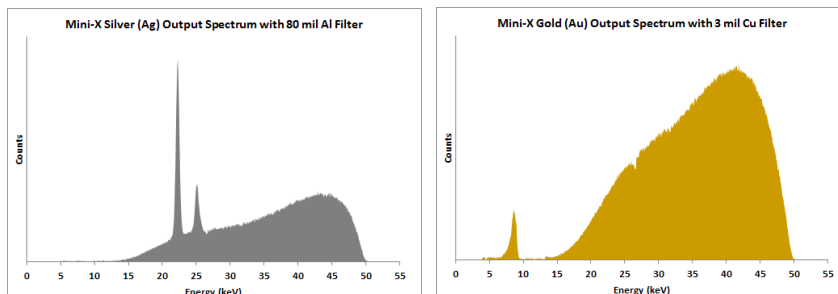
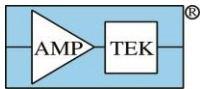


Figure 17. Filtered output spectra.



## 9 Radiation Levels and Example Shielding

Radiation levels external to the X-ray tube housing with the brass safety plug ON do not exceed 25  $\mu\text{Sv/h}$  (2.5 mrem/h) measured 5 cm from the surface of the housing in accordance with Requirements 5.2.2.1.1 and 5.2.2.2.2 of the National Bureau of Standards (NBS) Handbook for Radiation Safety for X-Ray Diffraction and Fluorescence Analysis Equipment. For more information please see the NBS Handbook.

### Examples of Shielding (that comply with the above standard)

- 1 mm (0.040 inch) of Pb will result in radiation levels of 0.5 mrem/h.
- 6.35 mm (0.250 inch) of Fe will result in radiation levels of 0.5 mrem/h.
- 3.18 mm (0.125 inch) of Brass will result in radiation levels of 2.5 mrem/h.

The inside of the housing can also be lined with 3.18 mm (0.125 inch) of aluminum (Al) in order to absorb the XRF from the shielding material.

**CAUTION:** The Mini-X-OEM is only one component of an X-ray instrument. It is the responsibility of the user, the OEM customer, or experimenter to provide a fail-safe metal enclosure to prevent escaping radiation while using this product. The final product (turn-key system) must comply with local government regulations to protect personnel from exposure to radiation. Amptek Inc. bears no responsibility for the incorrect use of this product.

## 10 Understanding the Interlock and Alarm

Safety is an important consideration with the Mini-X-OEM X-ray tube. Two key elements in the safety system include the interlock and the alarm (the light and the beeper).

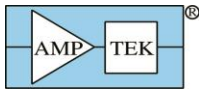
The Mini-X includes three main components: (a) the X-ray tube, (b) a High Voltage power supply (HVPS) and (c) the control and monitor circuit. The interface between the high voltage power supply and the control circuit is critical to understanding the interlock system. Shown below is a schematic which shows the connection between the control/monitor circuit and the HVPS, the interlock, and the alarm.

J4 connects the control/monitor circuit and the HVPS. Pins 1 and 2 carry the power (12 VDC) to the HVPS. Pins 3 and 4 are ground. Pins 5 and 6 are analog signals, inputs to the HVPS which set the current and HV bias respectively. They are produced by DACs in the control and monitor circuit. Pins 7 and 8 are logic signals; pin 7 is an output from the HVPS indicating that it is functioning properly while pin 8 is an enable to the HVPS. Pins 9 and 10 are analog signals, output from the HVPS indicating the HV bias and current respectively.

For the HVPS to turn on there must be power on the power pins, valid voltages on the analog control lines, and the logic enabled. The HVPS then produces three outputs read by the monitor circuit. Key issues for the safety interlock are the following:

- 1) The interlock is the connection between pins 1 and 2 of J3. This connection carries the 12 VDC power supply current to the HV supply. If the interlock is opened, the HV supply is powered off so cannot operate. This is important because it guarantees that the HVPS will turn off when the interlock is opened: there is no other path to supply power to the HVPS.

Note that the interlock carries the full supply current, so long wires are not recommended. If the interlock will be operated from a remote switch, we recommend having the switch operate a relay located close to the Mini-X.



Note also that these pins can provide the power to the HVPS and to the monitor/control circuits. For customers who do not want to use the AC/DC supply provided by Amptek, these pins on J3 may be used as an alternate power supply connection. Note that the input power is 12 VDC and must go to both pins 1 and 2 (pin 2 supplies the HVPS while pin 1 supplies the control circuits).

Note also that the user is then responsible for the interlock circuitry.

- 2) If the interlock is opened, U3 is held low, generating the /RESET signal. This signal resets the two DACs used to control the HV and current. These DACs, P/N AD5623, go to zero volts when reset and latch the zero voltage. The Mini-X requires a command be sent over the USB interface to set these to a non-zero voltage.

This is important because this prevents the HVPS from turning back on as soon as power is restored. When the interlock is restored, power is restored to the HV supply but the control inputs are still at zero volts. A command must be sent after the interlock is restored to produce X-rays. This ensures a redundant sequence for turning on X-rays: a hardware switch must be closed and a software command must be issued.

The schematic also shows the how the alarm functions. When the controller brings the control line high, it activates the two 555 timers. One produces a 1.6 Hz signal, the other a 5 kHz signal. These signals control the speaker and the LED on the Mini-X: the LED flashes at 1.6 Hz, and the speaker produces a 5 kHz tone, modulated at 1.6 Hz. Please note that there is no heat-sinking on the FET so it cannot dissipate significant continuous current.

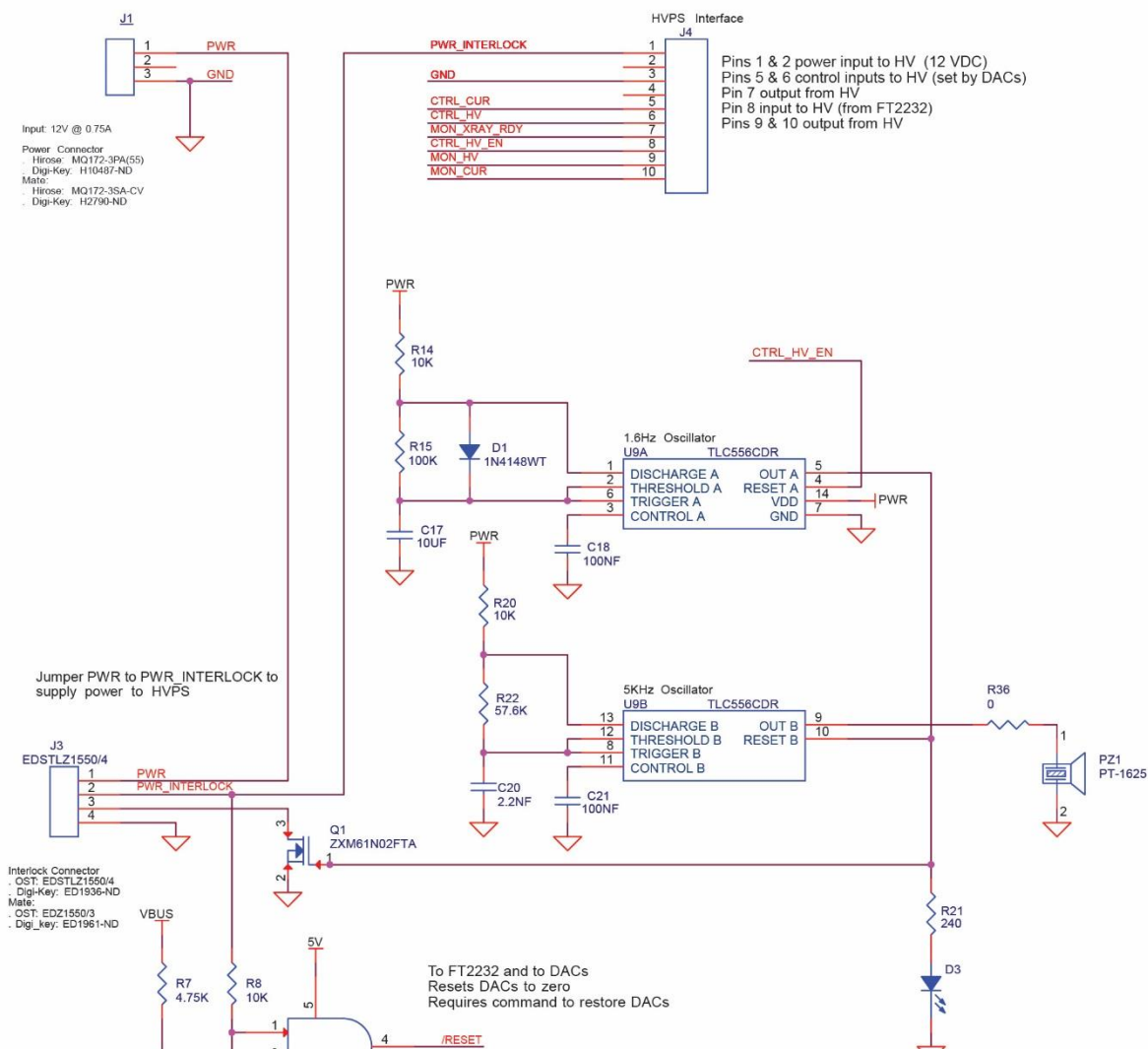
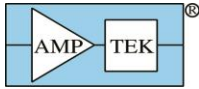


Figure 18. Schematic of the interlock and alarm portion of the Mini-X Control and Monitor circuitry.



## 11 Warranty

### WARRANTY

AMPTEK, INC. warrants to the original purchaser this instrument to be free from defects in materials and workmanship for a period of one year from shipment or 2000 hours, whichever comes first. AMPTEK, INC. will, without charge, repair or replace (at its option) a defective instrument upon return to the factory. This warranty does not apply in the event of misuse or abuse of the instrument or unauthorized alterations or repair. AMPTEK, INC. shall not be liable for any consequential damages, including without limitation, damages resulting from the loss of use due to failure of this instrument. All products returned under the warranty must be shipped prepaid to the factory with documentation describing the problem and the circumstances under which it was observed. The factory MUST be notified prior to return shipment. The instrument will be evaluated, repaired or replaced, and promptly returned if the warranty claims are substantiated. A nominal fee will be charged for unsubstantiated claims. Please include the model and serial number in all correspondence with the factory.

## 12 Technical Questions

For all technical questions, please contact the factory via:

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FAX: +1 781 275 3470

Email: [Amptek.sales@ametek.com](mailto:Amptek.sales@ametek.com)

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