

NXR-1410HR

Operator Manual



Notices

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For information, please write or call:

**Nicolet Imaging Systems
8221 Arjons Drive, Suite F
San Diego, California 92126-6319
Tel: (619) 635-8600 Fax: (619) 695-9902
Customer Service: 1-800-228-1147**

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Introduction

The Nicolet Imaging Systems NXR-1410HR X-ray systems are typically used for microfocus, real-time, nondestructive inspection of electronic components, hybrid circuitry, multilayer circuit boards, sealed components and electronic assemblies.

Remote positioning of the sample during inspection is accomplished using a joystick with the NXR-1410HR.

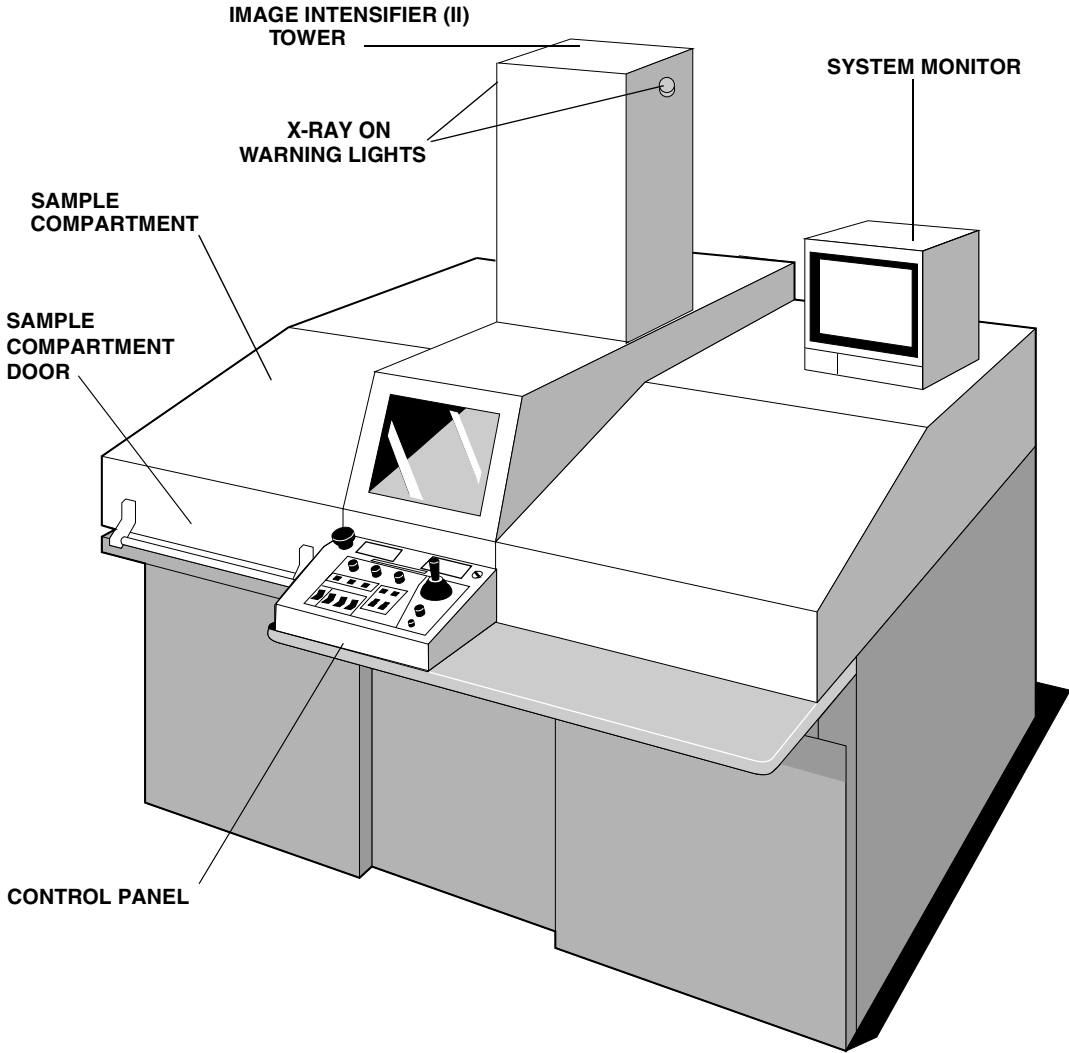
High voltage and video controls on the front control panel allow you to adjust your system for viewing the best possible image.

The basic NXR-1410HR system consists of a lead-lined cabinet that houses an x-ray source, image intensifier, CCD camera, control panel, and sample tray. A display monitor, image processor and mouse are also part of the basic system.

System Accessories

- Video hardcopy printer
- Video image processor
- Sample rotation fixture (option)
- UPS Line Conditioner (as required)
- Laser Pointer (option)
- Color Thermal Printer (option)

FIGURE 1-1 NXR-1410HR X-Ray Imaging System



User Responsibility

This Product will perform in conformity with the description thereof contained in this operating manual and accompanying labels and/or inserts when assembled, operated, maintained, and repaired in accordance with the instructions provided.

This Product must be checked periodically. A defective Product should not be used. Parts that are broken, missing, plainly worn, distorted, or contaminated should be replaced immediately. Should such repair or replacement become necessary, Nicolet Imaging Systems recommends that a telephone or written request for service advice be made to the nearest NIS Service Office.

This Product or any of its parts should not be repaired other than in accordance with written instructions provided by Nicolet Imaging Systems and NIS trained personnel.

The Product must not be altered without the prior written approval of Nicolet Imaging Systems. The user of this Product shall have the sole responsibility for any malfunction which results from improper use, faulty maintenance, improper repair, damage, or alteration by anyone other than Nicolet Imaging Systems.

You are required to register the use of this Product with the state in which the product is installed. See [Appendix A - X-ray Equipment Registration](#) at the end of this manual.

Receiving & Inspection

The NXR system is carefully inspected both mechanically and electrically before shipment and should be free from damage.

1. When the system is delivered by commercial carrier, check it for damage with the carrier. Contact the carrier's office and NIS office if any damage is found.
2. When unloading from a commercial carrier, do **not** use any hooks. If your system is shipped crated, follow the uncrating instructions attached to the shipping crate. Contact NIS if you have any questions regarding the uncrating instructions.
3. Compare the packing list with your order invoice and contact your regional NIS office if you find any discrepancies.
4. Save all packing material for the system in case it should ever have to be moved or shipped again.

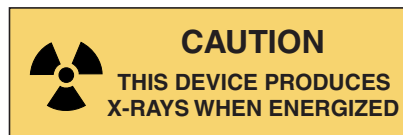
Potential, Current, and Duty Cycle Ratings

Your Nicolet Imaging Systems NXR-1410HR is designed such that:

- The x-ray source potential does not exceed 90 kv.
- The x-ray source beam current does not exceed 200 microamps.
- No combination of the x-ray source voltage and current exceeds 8 watts.
- The NXR-1410HR has a 100% duty cycle when the x-rays are on.

FIGURE 1-2

X-Ray Warning Label



Safety Precautions

Specific notations are used in this manual to call attention to conditions which could result in injury, damage to the equipment, or require special attention.

WARNING

WARNING: A Warning notation is used to describe an operating or maintenance procedure, practice, condition, or statement which, if not strictly observed, could result in injury or loss of life.

CAUTION

A Caution notation is used to describe an operating or maintenance procedure, practice, condition, or statement which, if not strictly observed, could result in damage to or destruction of equipment.

NOTE: A Note is used to describe an essential operating or maintenance procedure, condition, or statement which requires special attention.

Definitions

The terms *operation*, *maintenance*, and *service* have specific and important meanings throughout this manual. They are defined as follows:

- **Operation** means the use of the NXR system over the full range of its functions.
- **Maintenance** means the performance of those adjustments or procedures specified in this manual which are to be performed by you.
- **Service** means the performance of those adjustments or procedures which are to be performed only by individuals certified by Nicolet Imaging Systems.

About Your Manuals

The NXR system is shipped with a number of manuals depending on the options and accessories you ordered.

Read this *NXR-1410HR Operator Manual* first. It describes the basic installation, setup, and operation of the NXR-1410HR system. Then please read or refer to all other manuals before operating your NXR system.

NOTE: The installation procedures described in Chapter 2 of this manual are provided for informational purposes only. Your system must be installed by a qualified NIS Service Representative.

2





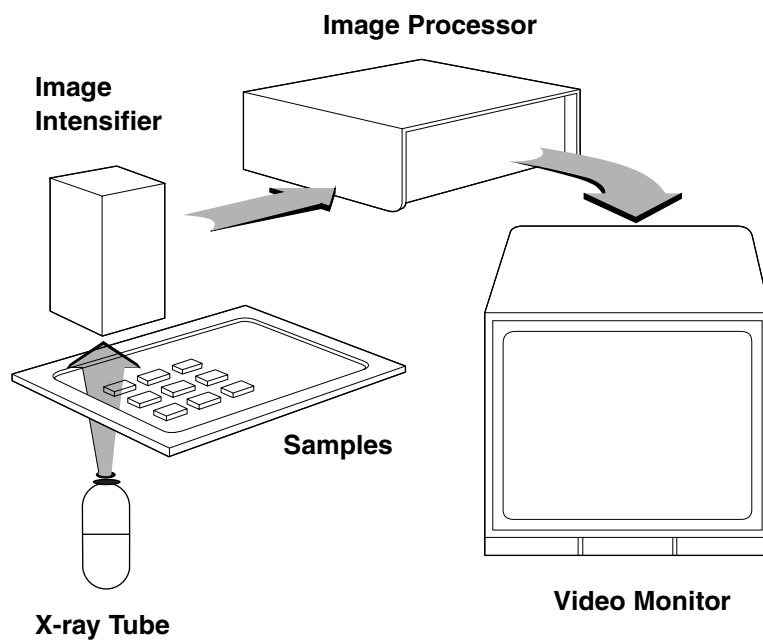
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Introduction

Figure 2-1, "Typical NXR Image Stream", shows the image stream of a typical NXR-1410HR microfocus x-ray system. The samples to be inspected are placed on the sample tray. The x-ray tube generates x-rays, some of which pass through the sample and strike the target area of the Image Intensifier (II). The image is then processed and sent to a video monitor that allows you to view the internal features of the sample in real-time.

The following pages provide a brief description of the different elements used to produce the image.

FIGURE 2-1**Typical NXR Image Stream**

X-rays

Using the highly penetrating, non-destructive properties of x-rays, the NXR creates an image on the video monitor for viewing the internal construction of an object. You can examine the image on the monitor to determine if there are hidden defects or internal irregularities in the object.

X-rays are a form of electromagnetic radiation. They exhibit properties similar to visible light rays but have shorter wavelengths.

X-rays have wavelengths less than 100 angstroms as compared to wavelengths of 10,000 angstroms in visible light. Because of their shorter wavelengths, x-rays are capable of penetrating solid objects in their path. Light rays are absorbed or reflected by the objects.

The X-ray Tube

CAUTION

Leave the system power *On* when the unit is not in use to help prolong the life of the x-ray tube. On/Off cycling of power accelerates the stress factors of any x-ray tube.

The Filament

The tube filament emits electrons when a current is passed through it. The greater the current passing through the filament, the greater the number of electrons emitted. These electrons are gated and accelerated by high voltage applied to the anode. This electron emission is called the **tube current**. X-ray output is proportional to the tube current. See *Figure 2-2, "Components of an NXR X-ray Tube"*.

Focusing Grid

The electron optics of the x-ray tube in the NXR system are designed to focus the emitted electrons down to a very small beam. This beam is then focused onto the tungsten anode.

The Anode

High voltage applied to the anode of the x-ray tube attracts the electrons emitted by the filament. X-rays are generated when the emitted electrons, which travel at high speed, either collide with the anode or abruptly change direction.

The anode is comprised of a tungsten target because of tungsten's high melting point. Large numbers of electrons strike the anode and transform to heat at the target.

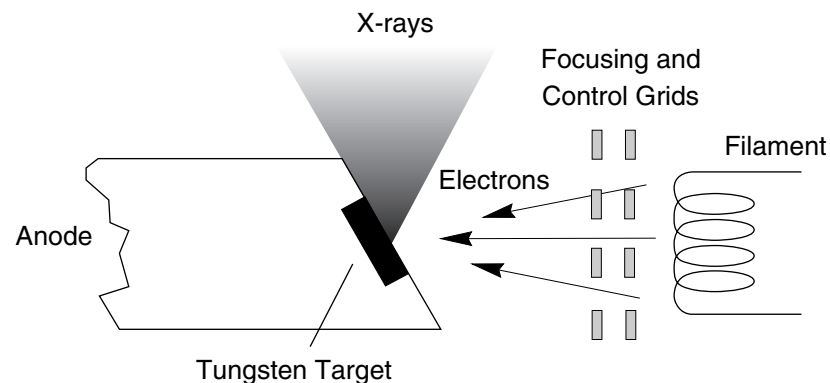
Tungsten is also an efficient material for generating x-rays because it has a high atomic number. The efficiency of a material to generate x-rays depends on its atomic number — the higher the number, the more efficient the material.

Cooling the Tube

When electrons strike the tungsten target, most of the energy is transformed into heat. This heat must be dissipated to prolong the life of the tungsten. NXR-1410HR systems circulate air through the inside of the x-ray tube enclosure to reduce the temperature to a suitable operating level.

FIGURE 2-2

Components of an NXR X-ray Tube



Shadow Formation

To understand how an x-ray image is produced, it is important to understand the principles of shadow formation.

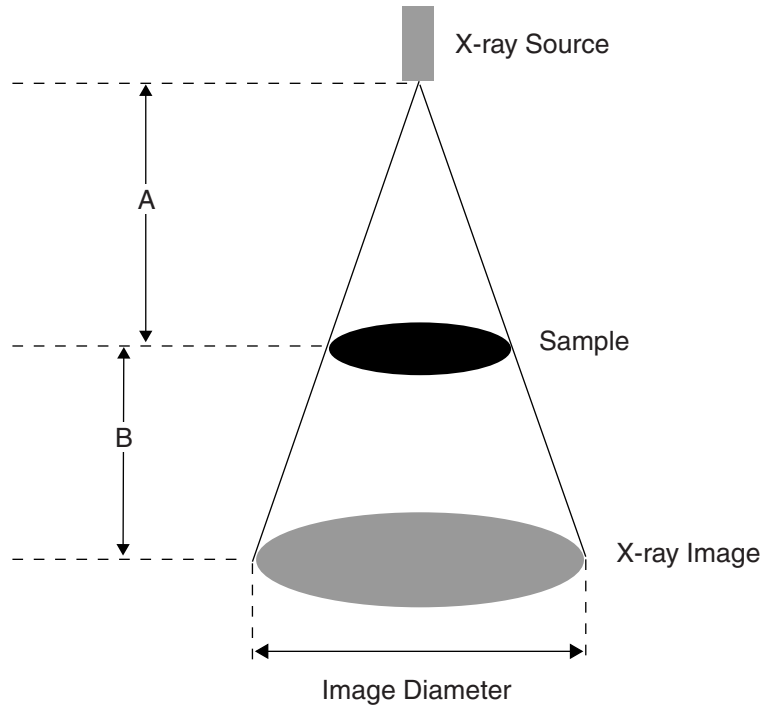
The shadow formation principles (**enlargement**, **sharpness**, and **distortion**) discussed in this chapter are explained using light rays as examples. X-rays and light rays have similar characteristics. However, x-rays have other properties, such as scattered radiation, which also affect the image. See "[Image Quality](#)" later in this chapter.

Enlargement

The displayed image can be enlarged by moving the image intensifier away from the sample and x-ray source as shown in *Figure 2-3, "Sample Magnification"*. The image diameter is calculated using the equation shown.

FIGURE 2-3

Sample Magnification



$$\text{Image Diameter} = \text{Sample Diameter} \times \text{Magnification}$$

where:

A = Distance from X-Ray Source to the Sample

B = Distance from Sample to the X-Ray Image

$$\text{Magnification} = \frac{A + B}{A}$$

Sharpness

Another characteristic of shadow formation is the sharpness of the image. As illustrated in *Figure 2-4, "Source Size"*, the size of the light source (or effective focal spot on the target) affects image sharpness. If the source is more than a single point, multiple shadows are cast that will be slightly displaced. This creates an image area, called the **penumbra**, that appears unfocused as shown in *Figure 2-5, "Images vs. Penumbra"*. The larger the effective focal spot, the greater the penumbra area.

FIGURE 2-4

Source Size

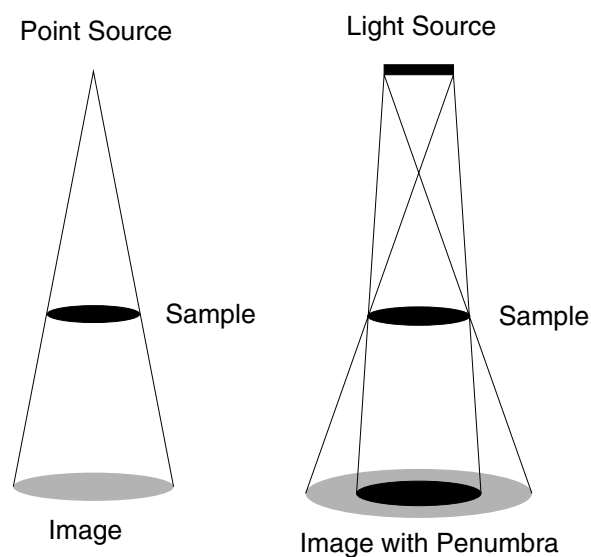


Image sharpness is also affected by the distance between the source and the object. The larger the area of the light source (or effective focal spot), the further the source must be from the object to minimize the penumbra effect as shown in *Figure 2-6, "Source to Sample"*.

Distortion

It is also important in the formation of shadow images that the object and the surface upon which the shadow is projected be as parallel as possible. The center of the light source or x-ray beam should be perpendicular to the object and collector surface. This reduces distortion and ensures that the shadow image is a true representation of the object.

FIGURE 2-5

Images vs. Penumbra

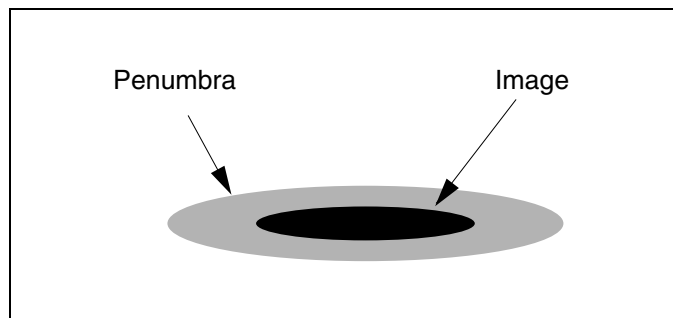


FIGURE 2-6

Source to Sample

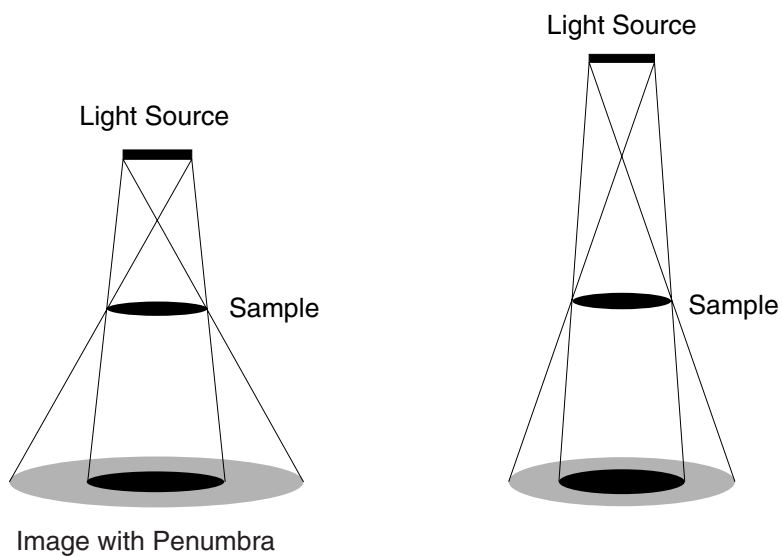


Image Quality

X-rays can penetrate solid objects because they have shorter wavelengths than visible light. Some are absorbed by the object while others pass through the object. X-rays that pass through the object are projected onto an x-ray sensitive detector that in turn produces a shadow image of the object's mass.

The quality of the image is affected by a number of factors. These include:

- x-ray intensity
- x-ray penetration
- size of the effective focal spot
- mass of the object
- properties of the detector surface.

X-ray Intensity

The amount (intensity) of radiation emitted by the x-ray tube's filament is proportional to the current flowing through the x-ray tube. Adjusting the **Power** knob on the control panel clockwise increases the intensity.

X-ray Penetration

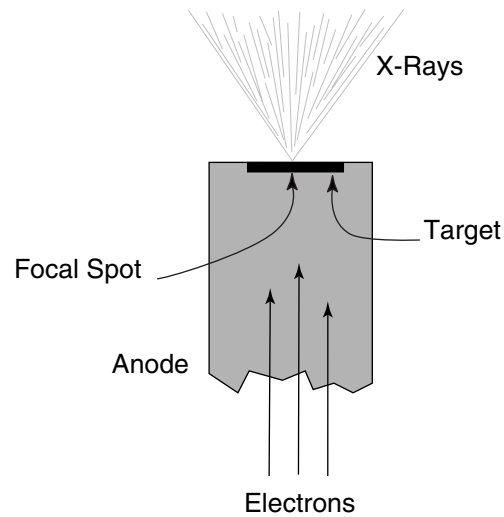
The speed of the electrons as they travel to the tungsten target is proportional to the voltage applied to the x-ray tube anode. Increasing the **Kilovolts** setting on the control panel increases the x-ray beam's penetration capabilities.

Focal Spot

NXR systems use a microfocus source (point source) x-ray tube. Microfocus refers to the size of the area onto which the electron stream is focused and the size of the effective focal spot. The target of the x-ray tube is placed under the electron beam as shown in *Figure 2-7, "Effective Focal Spot"*. This creates an effective focal spot much smaller than the actual area on the anode target.

FIGURE 2-7

Effective Focal Spot



Object Mass

The density, thickness, and atomic number of an object determine the rate at which x-rays pass through the object to illuminate the collector surface of the camera. When no or few x-rays pass through an object, the displayed image is black. The image becomes lighter and lighter as more x-rays reach the camera. If an object has mass variations, such as the object in [Figure 2-8, "Contrast at Lower Voltage"](#), the variations are displayed having different grey levels.

To adjust the contrast of the image, you need to lower or raise the voltage. For example, at lower kilovolt settings, fewer x-rays pass through the thicker side of the example in [Figure 2-8](#). In this example, the contrast ratio between the thick and thin areas of the object is 1:4.

Higher kilovolt settings add x-rays of shorter wavelengths that more readily pass through the chip. The higher voltage causes the ratio of x-rays passing through the sample to decrease. This in effect decreases the contrast between the variations on the image.

Sensitivity

When an object has minute density variations, use a lower kilovolt setting to increase the contrast between the different densities. See [Figure 2-8, "Contrast at Lower Voltage"](#).

When inspecting extremely dense objects, use a higher kilovolt setting to increase the penetration capabilities of the x-rays. See [Figure 2-9, "Contrast at Higher Voltage"](#).

Detector

The x-rays are projected onto a thin layer of fluorescent material that converts invisible x-ray photons into visible light photons to be collected by the camera. The image of the object's mass is then displayed on the monitor.

FIGURE 2-8

Contrast at Lower Voltage

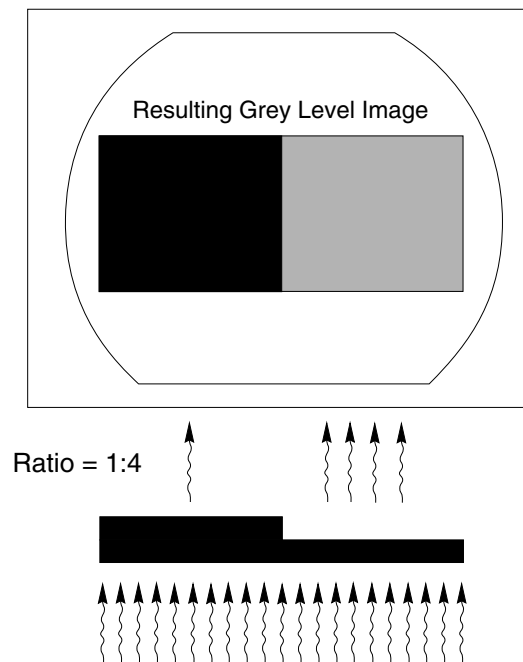
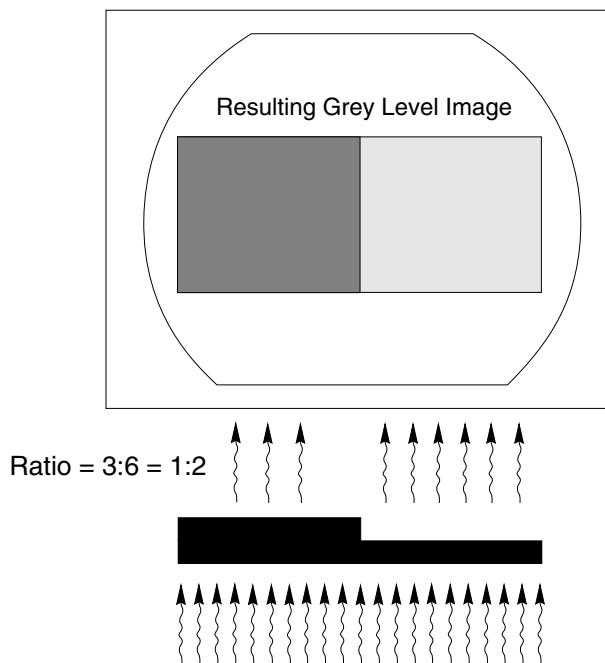


FIGURE 2-9

Contrast at Higher Voltage



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Introduction

The installation procedures described in this chapter are provided for informational purposes only. Your NXR X-ray Imaging System must be installed by a Nicolet Imaging Systems Service Representative.

System Requirements

AC Power

Your NXR system is equipped with a three-conductor power cord in accordance with NEMA recommendations. When plugged into the appropriate receptacle, the power cord is designed to ground the equipment cabinet.

NXR systems can be ordered for any of these four AC power sources:

- 110-125 VAC, 10 Amp, 50 Hz
- 110-125 VAC, 10 Amp, 60 Hz
- 210-240 VAC, 5 Amp, 50 Hz
- 210-240 VAC, 5 Amp, 60 Hz

If your power source is subject to severe fluctuations or irregularity, NIS recommends that you purchase an optional UPS line conditioner to ensure proper operation of your NXR-1410HR system.

Clearance

- Allow at least 76 cm (30 inches) in front of the cabinet for operating the system.
- Allow at least 15 cm (4 inches) between the rear of the system and wall for air circulation.
- Locate the cabinet where it can be rolled out for access to the rear panels during installation and service.

NOTE: NXR systems are caster-mounted and easy to move.

Environment

The environment for your NXR system should be free from excess dust and dirt, and the floor should not vibrate. The system is designed to tolerate the following temperature and humidity ranges:

Temperature: 0× to +35×C (32× to 95×F).

Humidity: 70% max. to 20% min. at 35×C with no condensation.

Safety

This system is designed to conform to Federal Regulation (CFR) 21, subchapter J, paragraph 1020.40, "Cabinet X-ray Systems." Various localities may have different rules and regulations that must be complied with prior to installation. Make an inquiry as to these rules and regulations with the installation facility's Safety Department and with the local Department of Health. Notify them that the installation is taking place and inquire about any special plant requirements that may apply. Requirements may involve wiring, notices, or special safety procedures unique to that particular company. Take whatever steps necessary to comply with these requirements.

See [Appendix A - X-ray Equipment Registration](#) in this manual for a listing of each state's agency with which your NXR x-ray system must be registered.

Inspection

1. Carefully inspect the NXR for any physical damage. Look for:
 - Dislodged components
 - Loose cables
 - Any other apparent damage

NOTE: Do not discard the packing material. If you find damage, the carrier may want to examine the material. Also, in the event the system needs to be returned to Nicolet, it should be shipped in the original containers.

2. Record the system serial number on the Service Installation form. The serial number appears on the back of the cabinet.
3. Compare the shipped items to those listed on the packing slip.
4. Report any discrepancies to the regional NIS Service Office.

Line Conditioner

An optional line conditioner is available if the Service Representative installing your system determines that a line conditioner is necessary.

Installing the Control Panel Shelf

Have someone help you install the shelf for the control panel.

1. Locate the eight (8) bolts provided for the shelf.
2. Position the shelf and spacer under the right front of the sample compartment.
3. Start one bolt on each end and only finger-tighten each bolt.
4. Start the remaining six bolts.
5. Securely tighten all eight bolts.

CAUTION

Do not use bolts in excess of 1-1/2 inches. Longer bolts may damage the table top.

Cabling

These instructions tell you how to route and connect all cables for the system and its components. Before you begin, locate all the cables.

Monitor

1. Set the monitor on top of the NXR.
2. Route the monitor's power cord along one side and through the cable channel.
3. Route the power plug through the hole in the top rear of the cabinet.
4. Adjust the cord so there is no excess at the rear of the monitor or where it exits the channel. The extra cord length should be inside the lower cabinet.
5. Locate the monitor's power plug by removing the right rear panel of the cabinet.
6. Plug the monitor's power cord into the utility power strip mounted on the inside right rear of the cabinet.

Electronics Chassis

1. Check that the ribbon cable connector (from the control panel to the electronics chassis) is properly seated.
2. Check all other connectors on the electronics chassis and ensure proper electrical connections.
3. Untie the AC power cord at the rear center of the cabinet.
4. Verify that the power source is correct for the system.
5. Plug the cord into the power source. The power required is specified on a label located near where the power cord enters the machine.
6. Run the ribbon cable and the other cables through the large hole in the control panel shelf.
7. Use cable ties to secure these cables to the cable anchors on the bottom of the shelf.

Control Panel

1. Connect the cables you put through the hole in the shelf to the connectors on the underside of the control panel housing.
2. Ensure that all the cables are fully seated.
3. Align the control panel housing holes with the holes in the shelf.
4. From the underside of the shelf, secure the control panel housing to the shelf with four bolts. Use the longest bolt at the left/front corner for the ground strap connection.
5. Securely tighten all bolts.

Initial Setup

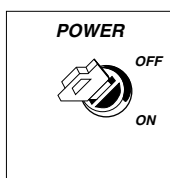
If you have not already done so, familiarize yourself with the control panel. See [Chapter 4 - Before You Begin](#), then perform the following steps **before** turning on the system.

1. Set the kilovolts to the lowest voltage by turning the **KV ADJUST** knob all the way to the left.
2. Set the x-ray milliamps power to its lowest setting by turning the **MA ADJUST** knob all the way to the left.
3. Turn on the video monitor.

4. Locate and remove the keys taped inside the sample compartment.
5. Insert the key into the **POWER** keyswitch on the control panel (*Figure 3-1, "Power Keyswitch"*).

FIGURE 3-1

Power Keyswitch



Starting the System

Start the system by turning the **POWER** keyswitch to **ON** as shown in *Figure 3-2, "Power Switch Turned On"*.

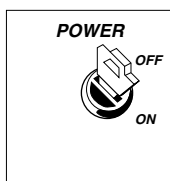
WARNING

The fans are energized when the power is turned on.

It takes approximately ten minutes for the NXR to warm up. The System Status **Ready** light appears when the system is ready to generate x-rays. While you are waiting for the system to warm up, check the indicators and joystick operation as described in the next two sections, "*Indicators*" and "*Joystick Operation*".

FIGURE 3-2

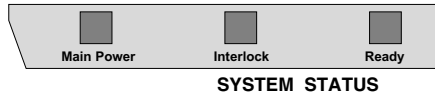
Power Switch Turned On



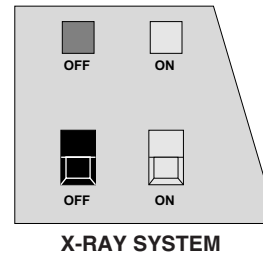
Indicators

The following indicators on the Control Panel show the status of the sytem:

- a. The **Main Power** light will come on as soon as you turn the **POWER** keyswitch on.



- b. The **Interlock** light should also come on to show that the cabinet doors are closed. This light blinks if the sample compartment door is open. If the light is blinking, close the door.
- c. When the system completes its warm-up cycle, the **Ready** light comes on to show that the system is ready for use.
- d. To begin generating x-rays, you must push the **X-RAY ON** button. The red **ON** light will come on to show that you are generating x-rays.



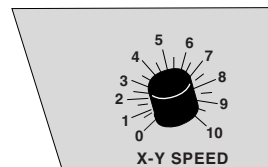
Joystick Operation

To test the joystick (*Figure 3-4, "NXR-1410HR Joystick"*):

1. Move the joystick in all directions and ensure the sample tray moves in the same direction as the joystick. Vary the speed of the tray by turning the **X-Y SPEED** control knob (*Figure 3-3*) right or left to set a quicker or slower response to the joystick.

FIGURE 3-3

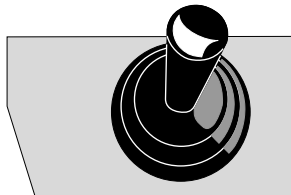
X-Y SPEED Control Knob



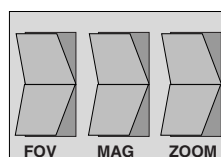
2. Use the joystick to move the tray to all extreme positions. Ensure the tray reaches its full limit of travel and stops when it contacts limit switches.

FIGURE 3-4

NXR-1410HR Joystick

**Image Control**

To check the movement of the Image Intensifier (II):



1. Press the **FOV** (Field of View) button forward and backward to ensure that the X-ray Tube changes focus as appropriate.
2. Press the **MAG** (Magnification) button forward and backward to ensure that the Image Intensifier (II) moves up and down for increasing/decreasing the magnification correctly.
3. Press the **ZOOM** button both forward and backward to ensure that the camera lens "zooms" in and out properly.

Cold Start Procedures

All System Operators Should Read This Section For Operational Information Affecting X-ray Source Life.

The life of the x-ray tube is affected by how well you adhere to specified operating procedures. All operators of your system must be informed of these procedures and the importance of following the procedures exactly. There are some general concepts regarding high voltage and high vacuum systems that must be considered.

You should not change the high voltage abruptly. An abrupt change results in a high degree of stress on all insulators within the high voltage system. These include the high voltage cables, connector dry well, high voltage power supply and components inside the vacuum tube. Abruptly switching high voltage will contribute to insulator breakdown over time resulting in failure of components.

A high vacuum system that does not have voltage applied internally can essentially lose vacuum over a period of time. Due to outgassing of the internal elements, free atoms become loose within the vacuum creating a current path for high voltage. The more free atoms, the lower the resistance. Consequently, the longer the vacuum exists without voltage applied to the internal elements of the tube, the more free atoms will exist and the greater the probability of a discharge through the now compromised vacuum.

When high voltage is once again applied to the internal elements of the tube and current flows to the anode, the free atoms tend to be attracted to the internal elements and are absorbed. The atoms are no longer free within the vacuum and cannot create a current path for high voltage. This is the rationale for the "cold start" procedure for x-ray systems that have been idle for a period of time. The longer the idle time, the longer the cold-start time required to eliminate free atoms within the tube.

X-ray Source Burn-in

A burn-in period must always be implemented when making a cold start (power up of machine after power has been removed). This burn time is proportional to the time the system has been shut off. The following table has recommended burn-in times vs. idle time:

IDLE or OFF TIME	90 KV
1 day or less	10 minutes
1 day to less than 1 week	20 minutes
1 week to less than 1 month	60 minutes
1 month to less than 2 months	90 minutes
2 months to less than 6 months	2 hours
6 months and over	3 hours

CAUTION

A lead cover should be placed between the tube and the Image Intensifier to ensure that no damage is caused during the burn-in process.

Conditioning the X-ray Tube

When you first install the NXR, or after it has been turned off or left on for a long time with no KV applied to the tube, you must condition the x-ray tube so it can withstand high voltage. To condition the tube, you must always follow the burn in procedure exactly.

1. Ensure that the green system **Ready** light is on.
2. Ensure that the sample compartment door and all panels are closed and the green **Interlock** light is on.
3. Turn the kilovolts knob (**KV ADJUST**) all the way to the left (counter-clockwise) to ensure that the voltage is set at the lowest level.
4. Turn the x-ray power control knob (**MA ADJUST**) all the way to the left (counter-clockwise) to ensure that the x-rays are set at the lowest level.
5. Press the **X-RAY ON** button. This actually starts the generation of x-rays.
6. Check for the following indicators:
 - The system beeps.
 - The high voltage power supply fan starts.
 - The green **X-RAY OFF** light goes out.
 - The red **X-RAY ON** light comes on.
 - The red **X-RAY Warning** light at the top of the tower comes on.

CAUTION

Do not increase the kilovolts at this time.

At this point, you are ready to begin conditioning the x-ray tube for high voltage usage. Nicolet advises that you use an incremental run-up procedure to safeguard and help prolong the life of the x-ray source. Increasing the target voltage in steps allows the tube to completely "out-gas" itself, and the high voltage generator to become high voltage "conditioned," which prevents destruction of components. When operating a new source or one that has been idle for more than one month, begin with the target voltage and tube current controls set at their minimum values, and take 10 to 15 minutes to process the source up to full power. At each step in the run-up schedule given below, first increase the target voltage and then the tube current, waiting at least the minimum time before proceeding to the next step.

CAUTION

When processing a source up to full power, always be alert to any arcing. If more than two arcs are observed, decrease the high voltage to the previous step. Again wait at least the minimum time, step the voltage back up and continue the procedure, **always being alert to arcing in the system** (an audible ticking sound will be produced when an arc occurs).

7. Condition the x-ray source according to the following schedule:

RUN-UP SCHEDULE			
Step	% of Max. kV	% of Max. mA	Minimum Time
1	20	0	1 minute
2	40	10	1 minute
3	60	30	2 minutes
4	80	50	2 minutes
5	90	70	3 minutes
6	100	100	3 minutes

Once the source has been fully conditioned, energizing the source with both the target voltage and tube current preset for their maximum values is acceptable. However, the following guidelines are best kept in mind when establishing your own operating routine:

- If the source is to be used throughout the working day, continuous operation within specified ratings will maintain the source at its normal operating temperature and minimize warm-up drift.
- Frequent On-Off cycling to full power, although acceptable, is stressful to the source.

Turning X-rays On

Always turn the KV control fully counter-clockwise (to the minimum setting) before turning on x-rays. *Never turn on x-rays with the KV control set at maximum.* After you press the **X-RAY ON** button, slowly rotate the KV control to increase to higher voltage.

Turning X-rays Off

Rotate the **KV ADJUST** control fully counter-clockwise at a slow rate before you turn off the x-rays (press the **X-RAY OFF** button).

Never turn off the x-rays with high kilovolts applied to the source. Doing so will result in instantaneous reduction of high voltage.

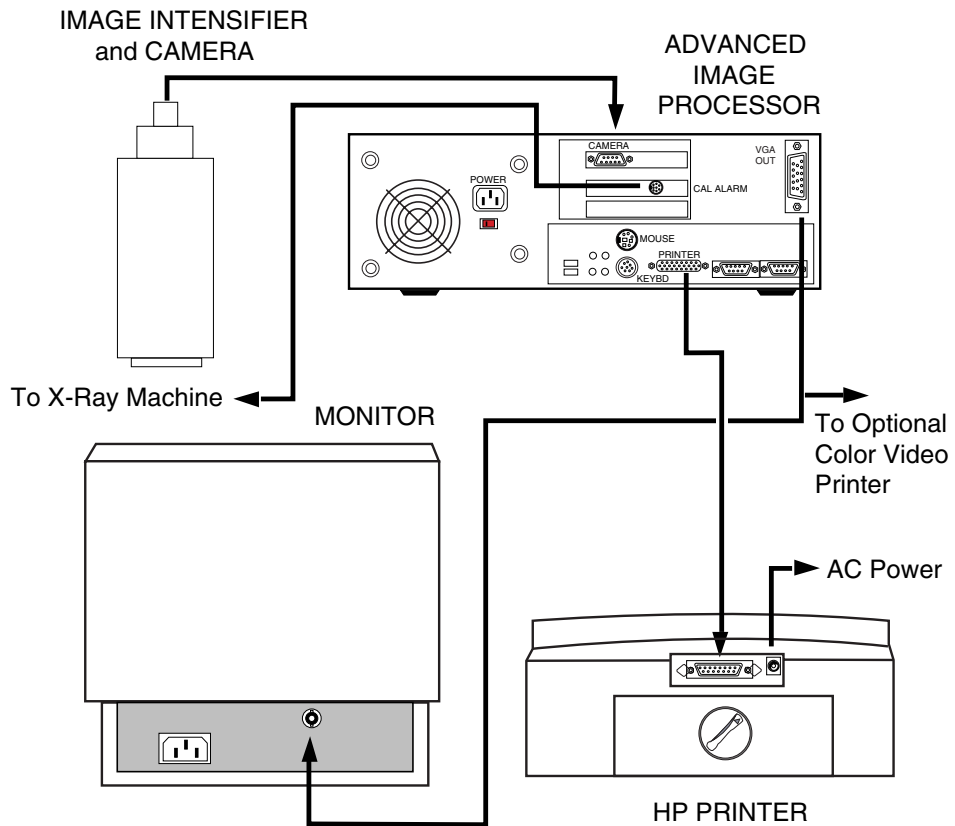
Never open the sample compartment door while the x-rays are on. Always set the **KV ADJUST** control to minimum and press the **X-RAY OFF** button before opening the sample compartment door.

Installing Accessories

Refer to your NIS Service Manual and the option or accessory's manual before installing them. *Figure 3-5, "Video Configuration with Accessories"*, illustrates the order in which to connect the accessories.

NOTE: Any other configuration may affect the signal impedance and image quality.

FIGURE 3-5 Video Configuration with Accessories



Before You Begin

4





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<i>Introduction</i>	<i>page 4-1</i>
<i>The Keys</i>	<i>page 4-3</i>
<i>Emergency Stop Button</i>	<i>page 4-3</i>
<i>Front Panel Controls</i>	<i>page 4-5</i>

Before You Begin

Introduction

Take the time to become familiar with the NXR system, its components, and any options and accessories on your system. Be aware of and pay attention to all safety precautions set by your operating site.

WARNING

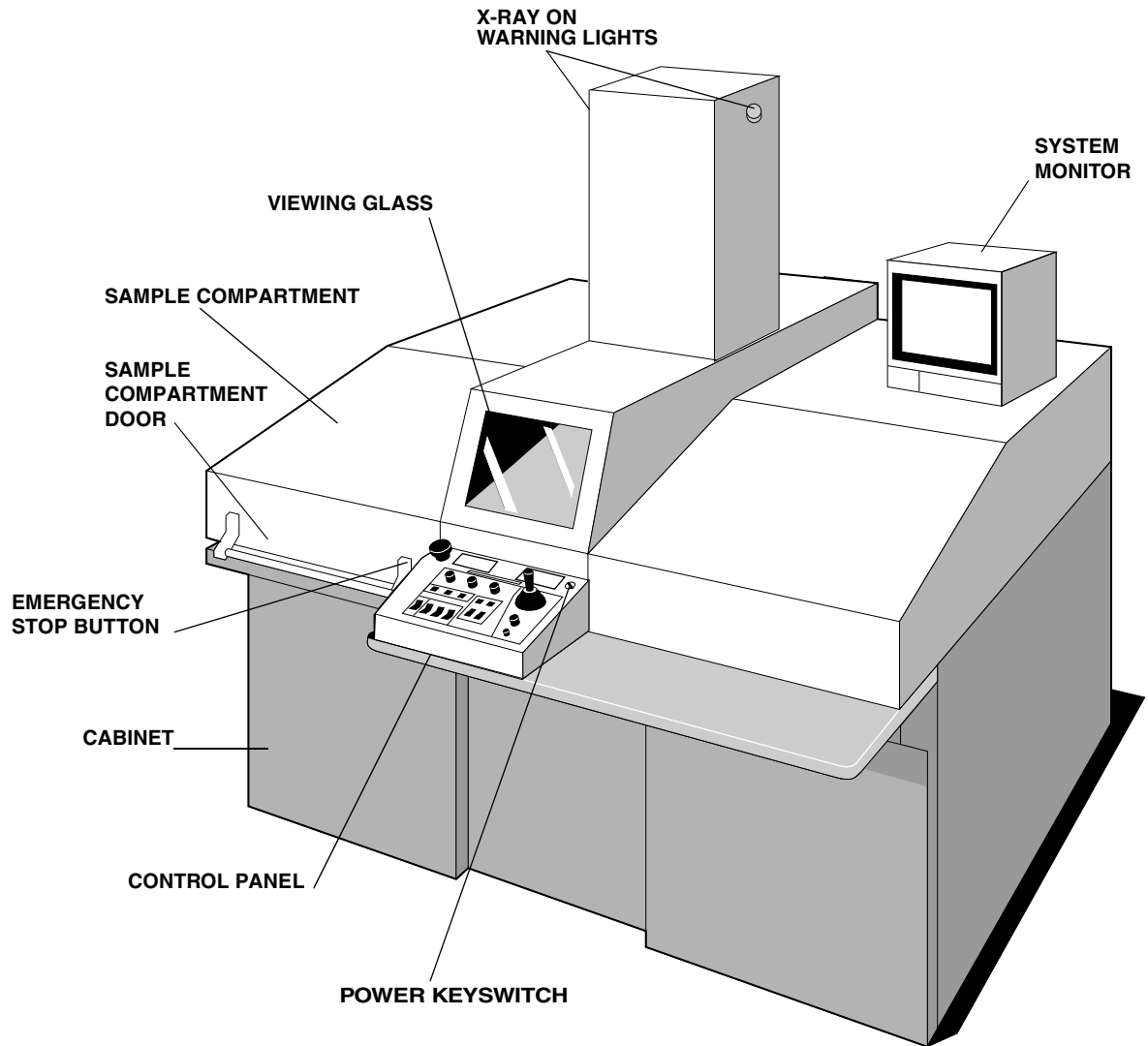
Never operate the system if either of these conditions exist: The viewing glass is cracked or broken; The lead lining is separating from the inside of the sample compartment.

WARNING

This equipment produces x-rays when energized. Follow all safety procedures set by the installation site.

FIGURE 4-1

NXR-1410HR Major Components



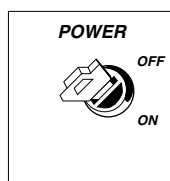
The Keys

Two identical keys were shipped with the NXR. Store one of the keys in a safe place as a master key and use the other in your day-to-day operation of the system. You can duplicate this key if necessary.

You cannot remove the key from the POWER keyswitch while the NXR is *ON*. To remove the key, turn the keyswitch to *OFF* (*Figure 4-2*).

FIGURE 4-2

Position Required to Remove Key



WARNING

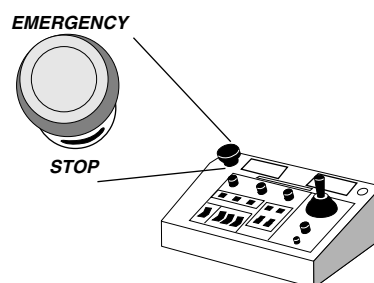
This equipment produces x-rays when energized. Follow all safety procedures set for your installation site.

Emergency Stop Button

The NXR is equipped with an **EMERGENCY STOP** button (*Figure 4-3*). Press this large, red button in case of emergency -- when you want to shut down the system **IMMEDIATELY!** This button turns off all power.

FIGURE 4-3

Emergency Stop Button



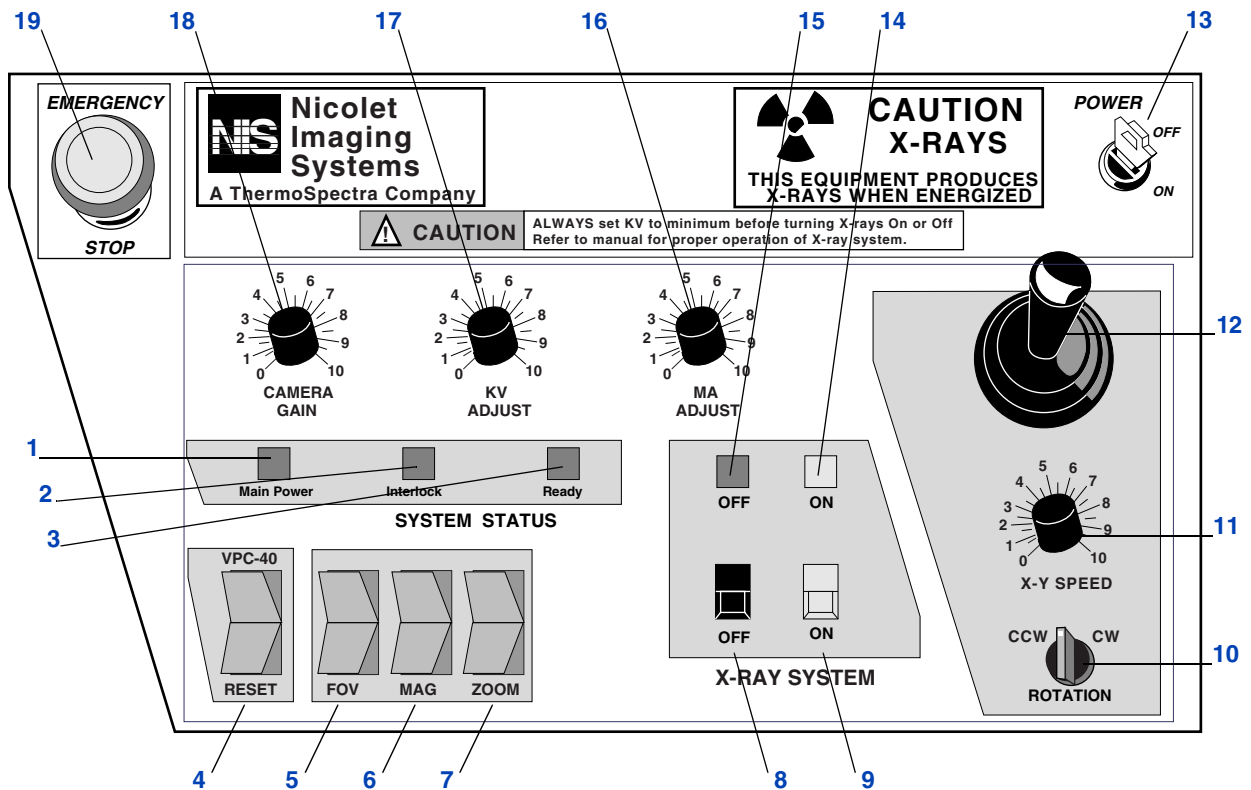
Restarting the System After Emergency Stop

To restart the system after pressing the **EMERGENCY STOP** button:

1. Set the voltage to its lowest amount by turning the **KV ADJUST** control knob all the way to the left.
2. Set the x-ray power to its lowest setting by turning the **MA ADJUST** knob all the way to the left.
3. Turn the **POWER** keyswitch to *OFF*.
4. Turn the **POWER** keyswitch back to *ON*.

The NXR needs approximately 10 minutes to warm up. When you turn on the keyswitch, the green **Main Power** light comes on. The **Interlock** light also comes on if the sample compartment door is closed. When the system is warmed up, the green **Ready** light comes on and remains on as long as the NXR is ready to generate x-rays.

FIGURE 4-4 NXR-1410HR Control Panel



Front Panel Controls

1. Main Power Light

This green LED lights when main power is on.

2. Interlock Light

This green LED lights if the sample compartment door is closed properly and no other panels are open or ajar. The Interlock light must be on for the system to generate x-rays. You cannot turn on the x-rays when either of the following conditions cause this light to blink on and off:

- X-ray tube is overheated,
or
- X-ray tube enclosure is removed.

3. Ready Light

This green LED lights when the NXR is ready to generate x-rays. The Main Power and Interlock LEDs must be showing green. You cannot turn on the x-rays until this Ready LED lights.

4. VPC-40 RESET Switch

This switch resets the optional VPC-40 system. Refer to that product's manual for further information.

5. FOV (Field of View) Switch

The switch increases or decreases the magnification and inversely, the field of view, by moving the x-ray tube up and down. Press forward (up) to increase magnification (which decreases the FOV). Press backward (down) to decrease magnification (which increases the FOV).

6. MAG (Magnification) Switch

Magnification control for the Image Intensifier (II). Press forward to raise the II, thus increasing the magnification and reducing the intensity of the displayed image. Press backward to lower the II, thus decreasing the magnification and increasing the intensity of the displayed image.

NOTE: Refer to Chapter 2, "X-ray Theory," for a detailed discussion of how the magnification factor affects x-ray imaging.

7. ZOOM Switch

Press forward on this switch to cause the camera lens the "zoom in", thus increasing the magnification of the displayed image. Press backward on this

switch to cause the camera lens the "zoom out", thus decreasing the magnification.

NOTE: Refer to Chapter 2, "X-ray Theory," for a detailed discussion of how the positioning of the Image Intensifier and Camera lens affect x-ray imaging.

8. X-RAY OFF Button

Turns off the generation of x-rays. Ensure that the KV ADJUST control is set to minimum before you press this button. When you turn off the x-rays, a short "beep" sounds, and the X-RAY ON and Warning lights turn off.

9. X-RAY ON Button

Turns on the generation of x-rays. When you press this button, the red X-RAY ON Warning light at the top of the II tower comes on, a long "beep" sounds, and the red X-RAY ON light (13) turns on.

10. ROTATION Control Knob

Rotates an object 360° around the X-axis. (The label "CCW" indicates counter-clockwise; the label "CW" indicates clockwise.) To use this control, your NXR must be equipped with the Sample Rotation accessory described in Chapter 5.

11. X-Y SPEED Control Knob

Controls the speed of response between the joystick and X-Y sample table movement. Increase the setting for a faster response, or decrease it to slow down the effect of your joystick movement.

12. Joystick

Move the joystick in the direction you want the sample tray to move. Speed of movement is controlled by the X-Y SPEED knob.

13. POWER Keyswitch

Turns the system *On* or *Off*. This is the master switch and controls the power for the entire system.

14. X-RAY ON Light

This red LED comes on when the x-rays are turned *On*.

15. X-RAY OFF Light

This green LED comes on when the x-rays are turned *Off*.

16. MA ADJUST (X-ray Milliamps) Knob

Adjust this control knob clockwise to increase the power, thus increasing the x-ray intensity.

17. KV ADJUST (Kilovolts) Knob

Kilovolt adjustment knob. Increases or decreases the voltage applied to the x-ray tube. There is a slight delay between the time you turn the control and the time the voltage is actually increased to help guard against sudden increases.

18. CAMERA GAIN Knob

Adjusts the gain of the camera which affects the contrast of the image displayed on the monitor.

19. EMERGENCY STOP Button

In case of emergency, press this button to immediately turn off the system. You then must restart the system by turning the POWER keyswitch (13) to *Off* and then back to *On*. Expect a 10 minute delay for system warm-up.

5





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<i>Generating X-rays</i>	<i>page 5-3</i>
<i>Loading the Sample</i>	<i>page 5-4</i>
<i>Inspecting the Sample</i>	<i>page 5-4</i>

Introduction

Before you can operate the NXR system, it must be installed by a qualified NIS representative. The instructions in this chapter assume the system is properly installed and operating normally. You must read this chapter completely before operating the NXR-1410HR.

CAUTION

Follow all safety rules set for the installation site. If the system has been turned off for any period, perform the "*Starting the System*" procedure in Chapter 3. To avoid damaging the Image Intensifier, remove the sample rotation's tailstock from the sample compartment before turning on the power.

Turning on the Power

Keep the NXR powered up when it is not being used for short lengths of time. Never turn the system completely off except for service or maintenance.

CAUTION

If the system has been powered down (turned *OFF*) for any reason, perform the "*Cold Start Procedures*" described in Chapter 3 of this manual. Failure to complete each step of the procedure could result in severe damage to the x-ray tube.

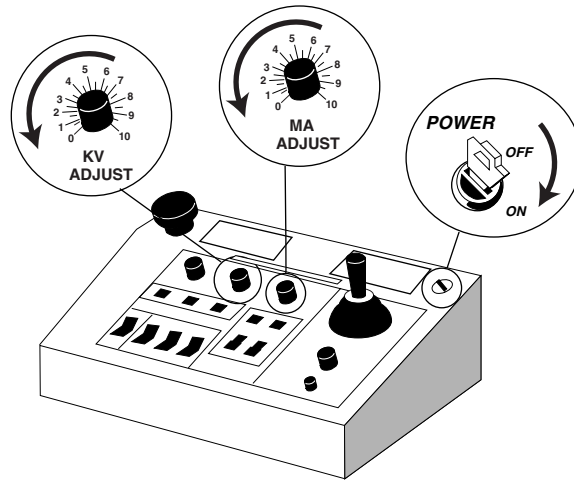
The following information tells you how to start the NXR when the power is off.

1. Set the voltage to its lowest setting by turning the **KV ADJUST** knob all the way to the left (counter-clockwise) as shown in *Figure 5-1*. It is important that you always set the kilovolts to the lowest setting (0) before turning on the system.
2. Set the amperage to its lowest setting by turning the **MA ADJUST** knob all the way to the left (counter-clockwise.) This setting is also very important for the continued proper operation of the x-ray equipment.

3. Insert the key in the **POWER keyswitch** as shown in *Figure 5-1* and turn it to the **ON** position. The light in the sample area flickers and then comes on.

FIGURE 5-1

Control Panel Start-Up Settings

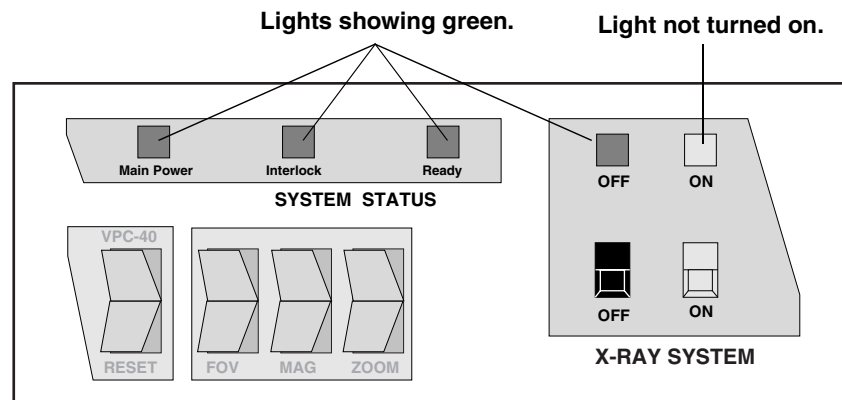


The NXR needs approximately 10 minutes to warm up. When you turn on the keyswitch, the green **Main Power** light comes on immediately. The **Interlock** light also comes on if the sample compartment door is closed.

When the system is warmed up, the green **Ready** light comes on and remains on as long as the NXR is ready to generate x-rays.

FIGURE 5-2

System Ready Settings



Generating X-rays

In order to generate x-rays, the **Main Power**, **Interlock**, and **Ready** lights must be on. When the NXR is ready, you must press the **X-RAY ON** button to start the actual generation of x-rays.

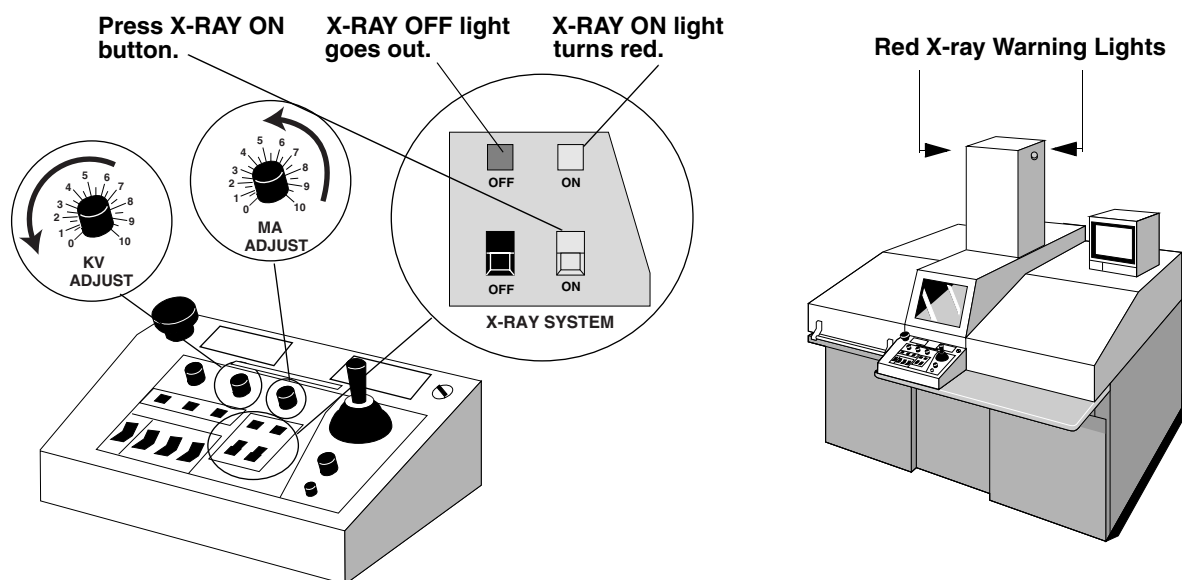
To Generate X-rays

1. Set the voltage to its lowest setting by turning the **KV ADJUST** control all the way to the left (counter-clockwise). Always set the kilovolts control to its lowest setting before enabling x-rays.
2. Set the x-ray power amperage to its mid-range setting by turning the **MA ADJUST** knob to 5.
3. Press the **X-RAY ON** button. The green **X-RAY OFF** light will go out and the red **X-RAY ON** light will come on. Also, the red X-RAY Warning light at the top of the II tower will come on and stay on as long as x-rays are being generated.

The NXR-1410HR is now generating x-rays.

FIGURE 5-3

Generating X-rays



Loading the Sample

Load the first sample while you are waiting for the system to warm up.

To Load a Sample

1. If necessary, use the joystick to move the sample tray to the front left of the sample compartment.
2. Open the sample compartment door and place the sample on the sample tray. The **Interlock** light will blink whenever the sample compartment door is open.
3. Close the compartment door. The **Interlock** light should be on but not blinking. If it is blinking, the sample compartment door is not closed securely.

NOTE: This necessary safety feature of the NXR is designed to guard against turning on the x-rays when the sample compartment door is open. The x-rays cannot be turned on until the sample compartment door is closed.

4. Press the **X-RAY ON** button to start generating x-rays. The system beeps and the X-RAY ON light and Warning lights come on.

The **X-RAY ON** light and **X-RAY ON Warning** lights stay on whenever the system is generating x-rays.

Inspecting the Sample

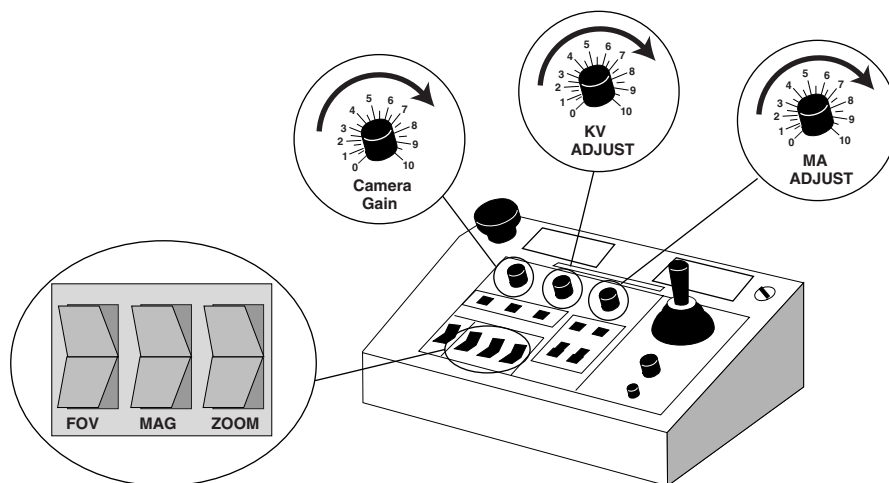
Adjusting Image Quality

1. Use the joystick to move the sample under the Image Intensifier.
2. Set both the **KV ADJUST** and the **CAMERA GAIN** to their mid-range setting, **5**.
3. Increase the voltage slowly by turning the **KV ADJUST** control clockwise. This increases the kilovolts readout and brightens the image on the monitor.
4. Turn the **CAMERA GAIN** and **KV ADJUST** controls until the displayed image is clear and distinguishable.
5. Press the **MAG** button to move the Image Intensifier (II) up and down until you have the desired image on the monitor. As you move the II toward or away from the sample, it will be necessary for you to readjust the contrast (**CAMERA GAIN**), **kV** and **mA** controls to maintain image quality. See *Figure 5-4, "Image Quality Controls"*.

6. Press the **ZOOM** button as necessary to adjust the camera lens to the optimum distance from the sample being inspected.

FIGURE 5-4

Image Quality Controls



7. Press the **FOV** button to move the x-ray tube up and down. This will change the magnification and FOV. As you move the x-ray tube up, you will decrease FOV and increase magnification.
8. If you have the optional Image Processor (for example, a VPC-40 or AIP), you can use the Frame Average function to further enhance the quality of the screen image. Refer to the Image Processor's Operator Manual for further instructions.

Options and Accessories

6





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Options and Accessories

Introduction

This chapter contains general information about accessories that do not have an accompanying manual. For options and accessories that have separate documentation provided, please refer to the appropriate manual before operating the accessory.

Contact your NIS sales representative if you are interested in upgrading or adding accessories to your system.

Sample Rotation Accessory

The Sample Rotation accessory lets you rotate samples a full 360° while they are in the x-ray beam. This helps you:

- Inspect samples such as tube ICs for bond wire height, wire sweep, molding voids, or die attach voids without manually repositioning the samples.
- View samples such as pin grid arrays and plated-through-hole boards at an angle to obtain additional information about their internal characteristics.

Installing the Sample Rotation Accessory

The Sample Rotation accessory (*Figure 6-1*) has a motor assembly that mounts on the front left swivel arm, and a tailstock (assembly) that mounts on the small rail at the back of the sample tray. To mount a sample for inspection, follow these steps:

1. Turn the **KV ADJUST** and **MA ADJUST** controls to their lowest settings.
2. Press the **X-RAY OFF** button to temporarily turn off the generation of x-rays.
3. Open the sample compartment door and locate the socket at the top left side of the compartment (*Figure 6-2, "Locating the Socket"*).

4. Plug the motor assembly's 6-pin connector into the socket. The ridges on the connector must match the grooves on the socket.

FIGURE 6-1

Sample Rotation Fixture

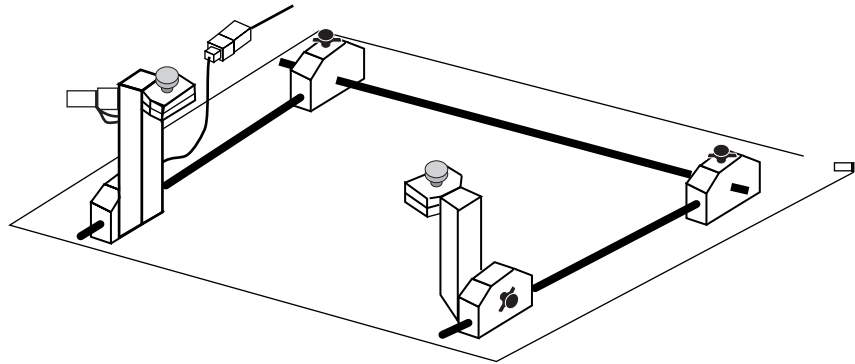


FIGURE 6-2

Locating the Socket

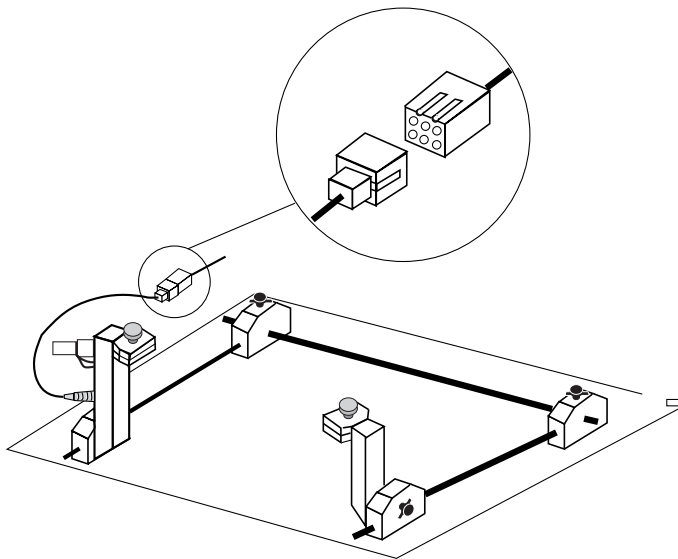
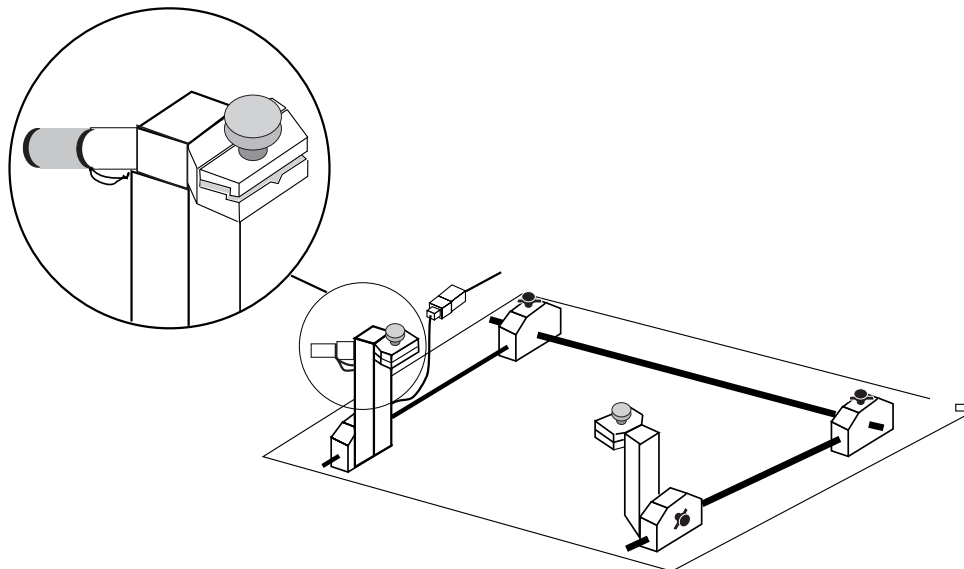


FIGURE 6-3

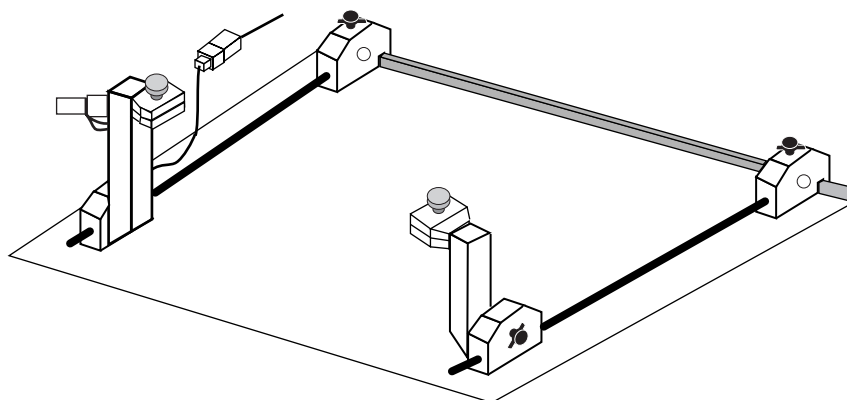
View of the Motor Assembly



5. Mount the tailstock onto the small rail at the back of the sample tray. The rail fits into the groove in the blocks at the bottom of the assembly (*Figure 6-4, "Mounting the Tailstock Assembly"*).

FIGURE 6-4

Mounting the Tailstock Assembly



CAUTION

When the Sample Rotation fixture is in the sample compartment, be extremely careful when you move the sample tray. Avoid striking the Image Intensifier with the motor assembly or tailstock.

Adjusting the Swivel Arms

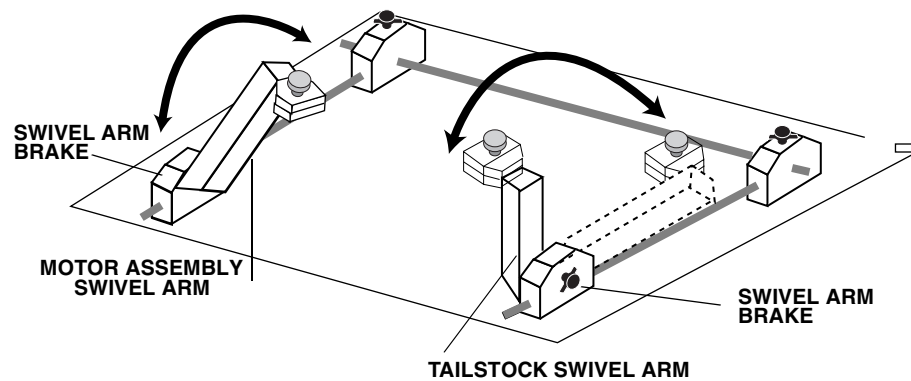
Before using the Sample Rotation feature, raise or lower the swivel arms on the Sample Rotation fixture so the sample just clears the sample tray. When the swivel arms are in their lowest positions, there is approximately 0.5-inch clearance between the rotation shaft and the sample tray. When the arms are in the highest position, there is approximately 5.5 inches of clearance. You can position the arms at any height between these two extremes.

Adjust the swivel arms so the sample is as close as possible to the sample tray, but far enough away so it does not strike the tray when it rotates.

1. Loosen the swivel brake at the bottom of the left swivel arm (*Figure 6-5, "Adjusting the Swivel Arms"*).

FIGURE 6-5

Adjusting the Swivel Arms

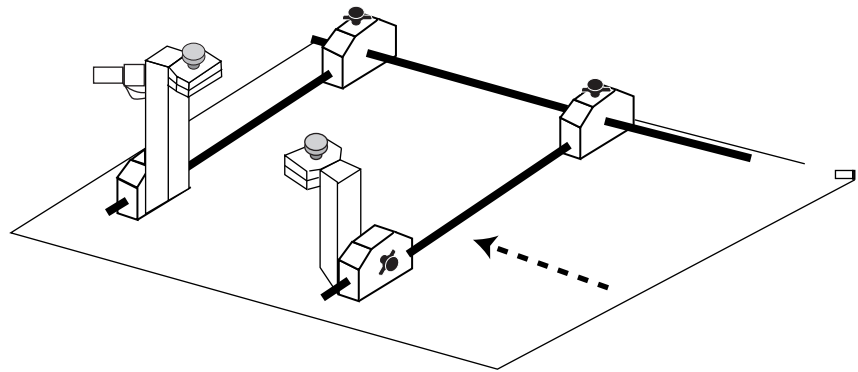


2. Rotate the arm toward the front of the sample compartment until there is sufficient clearance for the sample to rotate freely. Always keep the distance between the sample and the tray to a minimum to take advantage of the denser x-ray field.
3. Tighten the swivel brake to lock the arm in position.

4. If you are using the tailstock, adjust its swivel arm (the front, right arm) to the same height as the swivel arm on the motor assembly. If necessary, slide the right tailstock arm inward to accommodate a narrower sample (*Figure 6-6, "Adjusting the Tailstock"*).
5. Test to ensure that the sample rotates freely by turning the **Rotation** knob. The rotating sample must not touch the tray or Image Intensifier.

FIGURE 6-6

Adjusting the Tailstock

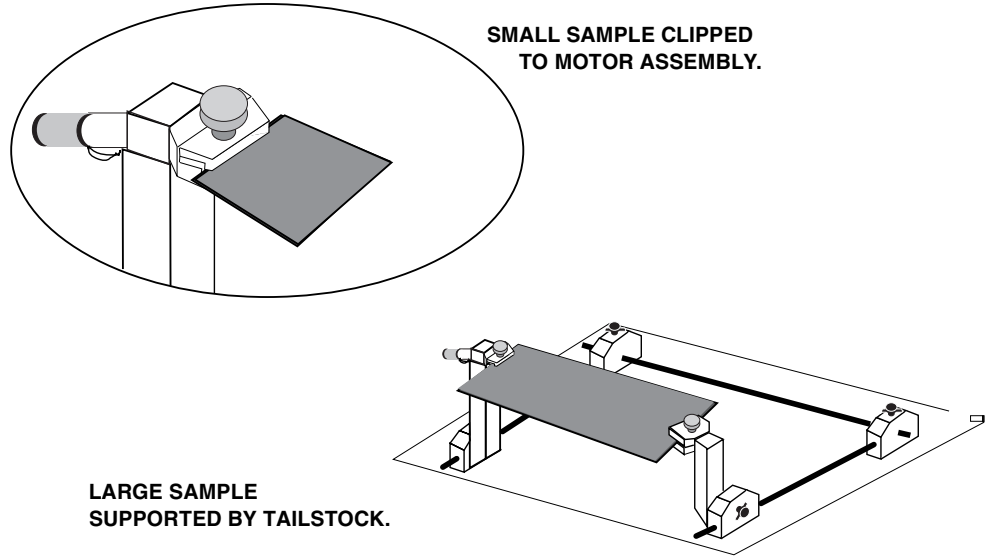


Using the Sample Rotation Accessory

1. When you are inspecting small samples, simply clip them to the motor assembly. Use the tailstock to support large samples (*Figure 6-7, "Mounting Samples"*).

FIGURE 6-7

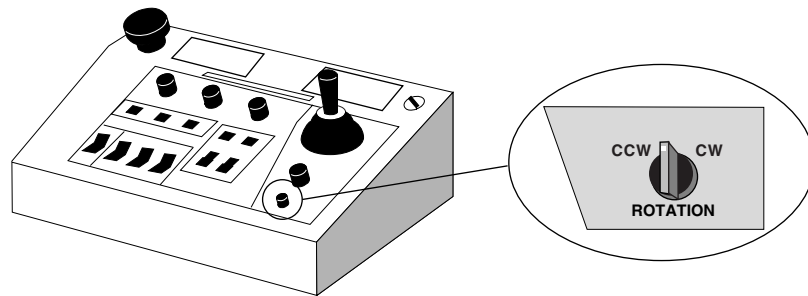
Mounting Samples



-
2. Turn the **ROTATION** knob (*Figure 6-8, "Rotation Knob"*) on the control panel to rotate the sample. Turning the knob all the way to the right (clockwise) rotates the sample slightly more than 360°.
-

FIGURE 6-8

Rotation Knob



Maintenance and Troubleshooting

7





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Maintenance	<i>page 7-1</i>
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Maintenance and Troubleshooting

Introduction

This chapter contains basic maintenance procedures you should follow to keep your NXR performing at its optimum capabilities. It also includes how to obtain service information, and a list of problems and their solutions.

If you have questions, please call NIS Customer Service (CS).

CS: 800-228-1147

FAX: 619-693-0815

LOCAL: 619-635-8696

Maintenance

Cleaning - General

To avoid damage and unnecessary cleaning, protect the equipment from dust, dirt, and any other environmental hazards that damage surfaces or impair operation.

Do not use rough, abrasive cloths to clean equipment, or solvents such as acetone, carbon tetrachloride, or trichloroethylene. These solvents may damage painted surfaces.

- Clean controls and other machine surfaces with a no-rinse liquid cleaner.
- Clean acrylic plastic surfaces with an acrylic plastic cleaner and a soft cloth.
- Clean glass surfaces with a glass cleaner and a soft cloth

CAUTION

Use only glass cleaner and a soft cloth to clean the viewing glass. The leaded glass is especially designed for protection against x-ray radiation exposure. Abrasives may damage its protective capabilities.

WARNING

Do NOT operate the system if the viewing glass is damaged in any way. Immediately contact NIS Customer Service for repairs.

Cleaning - Sample Tray and Sample Table

To keep the sample tray moving smoothly and the displayed images distinct, regularly clean the tray and table. Remove the sample tray by unscrewing the four screws along the right edge. Thoroughly clean the table top and the bottom of the tray.

Inspection

As with any equipment or system, periodically inspect the NXR for signs of wear and damage.

- Examine the interior of the sample compartment and make certain that the lead lining is intact.
- Examine the viewing glass for any cracks, chips, or scratches.

Shipping Kit

The shipping kit packaged with your system contains additional lamps and fuses. Keep this kit in a safe place. If you suspect that a lamp or fuse has burned out, please contact Nicolet Imaging Systems' Customer Service (see "Service" below.) Depending on its location, an NIS service representative may need to replace the lamp or fuse.

Service

If you have questions, please call NIS Customer Service. If you need service, please call your regional office. Phone numbers appear on page 1 of this chapter.

Troubleshooting

This section describes solutions to common problems you may encounter as you use the NXR system.

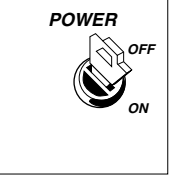
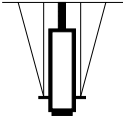
Check your system for any indicators that may be listed and see that the same conditions exist before trying the solution.

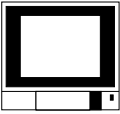
Before Calling Help


In order to help us better serve you and determine whether a service call is necessary, please complete the following steps before you call:


1. Determine the general problem.
2. Follow the appropriate troubleshooting procedure described in this section.
3. If the problem cannot be solved with a troubleshooting procedure, turn off the power. Let the system cool down, and then turn on the power again. Determine if the problem still exists.
4. Make a visual inspection of all controls and cables. Note any unusual conditions, or correct improper settings and connections.
5. Make a note of any other control panel indicators and all abnormal conditions you observe.

Troubleshooting Procedures

<p>POWER</p> 	<p>Problem: The POWER keyswitch is set <i>On</i> but the system is not on.</p> <p>Indicator: Main Power LED is out.</p> <p>Solution: Ensure that the system is plugged into an active AC power source and the fuse has not been blown. Also, someone may have pressed the EMERGENCY STOP button but did not restart the system. To restart the system, make sure the EMERGENCY STOP button is in the normal position (pulled out). Then, turn the POWER keyswitch to <i>Off</i> and back to <i>On</i>.</p>
<p>X-RAYS</p>	<p>Problem: The power is on but you cannot turn on the x-rays.</p> <p>Indicators: Main Power LED is lit. Ready LED is out.</p> <p>Solution: The system probably needs to warm up. The NXR needs approximately ten minutes to warm up after you turn on the power. The Ready LED comes on when the system is ready to generate x-rays.</p>
	<p>Problem: The power is on but you cannot turn on the x-rays.</p> <p>Indicator: Interlock LED is blinking.</p> <p>Solution: Ensure that the sample compartment door is closed securely.</p>
<p>Image Intensifier</p> 	<p>Problem: The Image Intensifier (II) does not move up when you press forward on the MAG button.</p> <p>Indicators: POWER keyswitch is <i>On</i>. Main Power LED is lit.</p> <p>Solution: The II is already at its maximum height. You can only lower the II by pressing backward on the MAG button.</p>

	<p>Problem: The II does not move down when you press backward on the MAG button.</p> <p>Indicators: POWER keyswitch is <i>On</i>. Main Power LED is lit.</p> <p>Solution: The II may be impacting the sample or already at its lowest position. Raise the II by pressing forward on the MAG button.</p>
<p>MONITOR</p> 	<p>Problem: No image appears in the monitor.</p> <p>Indicators: X-RAY ON LED and X-RAY ON Warning light are lit. Sample is below Image Intensifier. Coaxial cable is connected to the back of the monitor. Monitor is <i>On</i>.</p> <p>Solution: Try adjusting the following controls on the control panel: KV ADJUST CAMERA GAIN MA ADJUST FOV MAG ZOOM</p> <p>If an image still does not appear, try adjusting the Brightness and Contrast controls on the monitor. Pressing the RESET button on the color monitor's front panel resets all variable control settings on the monitor to their mid-range settings. Also ensure the camera power is <i>On</i> and the high voltage supply is <i>On</i>. Bypass all other options/accessories between the NXR and monitor. For example, if the image processor accessory is being used, disconnect it from the string and connect the monitor directly to the NXR.</p>

<p>PRINTER</p>  <p>Refer to the printer's manual for additional troubleshooting and service information.</p>	<p>Problem: Printer does not respond when you press the Print button.</p> <p>Solution: Press the POWER switch on the front of the printer to turn on the printer's power. If that does not work, ensure that the cable is properly connected between the monitor and printer, and that there is paper in the printer. The Alarm lamp on the front of the printer lights when the printer is out of paper.</p>
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	<p>Problem: You cannot preview the printer’s output on your color monitor.</p> <p>Solution: Press either the Line A or Line B button on the front of the color monitor. You must turn on the line to which the printer’s Mon Out cable is connected in order to preview the printer’s output.</p>
<p>SAMPLE ROTATION</p> 	<p>Problem: The sample hits the tray when you try to rotate it.</p> <p>Solution: Adjust the swivel arms on the Sample Rotation fixture. See Chapter 6 - Options and Accessories.</p>
	<p>Problem: The sample does not rotate or slips when you turn the ROTATION knob.</p> <p>Solution: The weight of the sample may be causing the clips to slip. Try using the tailstock to help support the sample. If that does not work, please contact your NIS representative for an application-specific solution.</p>

Appendix

X-ray Equipment Registration

A





X-ray Equipment Registration

Introduction

This appendix contains additional information pertaining to your NXR-1410HR X-ray System.

Registration of X-ray Equipment

Each state requires you to register your NXR Real-Time X-ray Imaging System. Below is a list of agencies for each of the states in which your x-ray equipment is located.

Alabama (AL) Director of X-ray Compliance, Division of Radiological Health, State Department of Public Health, State Office Bldg, Montgomery, AL 36130
Tel. (205) 261-5315

Alaska (AK) Radiological Health Program, Department of Health & Social Services, Box H, Juneau, Alaska 99811-0613 Tel. (907) 465-3019

Arizona (AZ) X-ray Compliance, Arizona Radiation Regulatory Agency, 4814 South 40th St., Phoenix, Arizona 85040 Tel. (602) 255-4845

Arkansas (AR) Division of Radiation Control and Emergency Management, Department of Health, 4815 West Markham Street, Little Rock, Arkansas 72205-3867 Tel. (501) 661-2301

California (CA) Radiological Health Branch, State Department of Health Service, 714 P Street, Office Bldg #18, Sacramento, California 95814 Tel. (916) 322-2040

Colorado (CO) Radiation Control Division, Department of Health, 4210 East 11th Avenue, Denver, Colorado 80220 Tel. (303) 331-8480

Connecticut (CT) Radiation Control Unit, Dept. of Environmental Protection, 165 Capitol Avenue, Hartford, Connecticut 06106 Tel. (203) 566-5668

Delaware (DE) Office of Radiation Control, Division of Public Health, Robbins Bldg., Silver Lake Plaza, Box 637, Dover, Delaware 19903 Tel. (302) 736-4731

District of Columbia (D.C.) Department of Consumer and Regulatory Affairs, Service Facility Regulation Administration, 614 H Street, N.W., Room 1014, Washington, D.C. 20001 Tel. (202) 727-7190

Florida (FL) Office of Radiation Control, Department of Health and Rehabilitative Services, 1317 Winewood Boulevard, Tallahassee, Florida 32399-0700 Tel. (904) 487-1004

Georgia (GA) Radiological Health Section, Department of Human Resources, 878 Peachtree Street, Room 600, Atlanta, Georgia 30309 Tel. (404) 894-5795

Hawaii (HI) Noise and Radiation Branch, Environmental Protection and Health Services Division, Dept. of Health, 591 Ala Moana Blvd., Honolulu, Hawaii 96813 Tel. (808) 548-4383

Idaho (ID) Bureau of Hazardous Materials, Division of Environmental Quality, 450 West State Street, Boise, Idaho 83720 Tel. (208) 334-5879

Illinois (IL) Department of Nuclear Safety, 1035 Outer Park Drive, Springfield, Illinois 62704 Tel. (217) 785-9868

Indiana (IN) Radiological Health Section, State Board of Health, 1330 West Michigan Street, Box 1964, Indianapolis, Indiana 46206 Tel. (317) 633-0152

Iowa (IA) Bureau of Environmental Health, Iowa Department of Public Health, Lucas State Office Building, Des Moines, Iowa 50319 Tel. (515) 281-4928

Kansas (KS) Bureau of Air Quality and Radiation Control, Department of Health and Environment, Forbes Field, Bldg. 321, Topeka, Kansas 66620 Tel. (913) 296-1542

Kentucky (KY) Radiation Control Branch, Cabinet for Human Resources, 275 East Main Street, Frankfort, Kentucky 40621 Tel. (502) 564-3700

Louisiana (LA) Department of Environmental Quality, Box 44066, Baton Rouge, Louisiana 70804 Tel. (504) 342-9103

Maine (ME) Division of Health Engineering, 157 Capitol Street, State House, Station 10, Augusta, Maine 04333 Tel. (207) 289-3826

Maryland (MD) Center for Radiological Health, Environmental Science and Health, Maryland Dept. of the Environment, 201 W. Preston St., Baltimore, Maryland 21201 Tel. (301) 333-3130

Massachusetts (MA) Radiation Control Program, Department of Health, 150 Tremont Street, Second Floor, Boston, Massachusetts 02111 Tel. (617) 727-6214

Michigan (MI) Div. of Radiological Health, Bureau of Environmental & Occupational Health, Dept. of Public Health, 3500 N. Logan St., Box 30035, Lansing, MI 48909 Tel. (517) 335-8200

Minnesota (MN) Section of Radiation Control, Minnesota Dept. of Health, 717 Delaware St, S.E., Box 9441, Minneapolis, Minnesota 55440 Tel. (612) 623-5351

Mississippi (MS) Division of Radiological Health, State Department of Health, 3150 Lawson Street, Box 1700, Jackson, Mississippi 39215-1700 Tel. (601) 354-6657

Missouri (MO) Bureau of Radiological Health, 1730 East Elm Street, Box 570, Jefferson City, Missouri 65102 Tel. (314)-751-6083

Montana (MT) Environmental Sciences Division, Department of Health and Environmental Sciences, Cogswell Building, Helena, Montana 59620 Tel. (406) 444-3948

Nebraska (NE) Division of Radiological Health, Department of Health, 301 Centennial Mall South, Box 95007, Lincoln, Nebraska 68509 Tel. (402) 471-2168

Nevada (NV) Radiological Health Section, Health Division, Department of Human Resources, 505 East King Street, Carson City, Nevada 89710 Tel. (702) 885-5394

New Hampshire (NH) Radiological Health Program, Box 148, Concord, New Hampshire 03302 Tel. (603) 271-4588

New Jersey (NJ) Division of Environmental Quality, Department of Environmental Protection, 380 Scotch Road, CN411, Trenton, New Jersey 08625 Tel. (609) 530-4002

New Mexico (NM) Radiation Protection Bureau, Environmental Improvement Division, Dept. of Health and Environment, Box 968, Santa Fe, New Mexico 87504-0968 Tel. (505) 827-2959

New York (NY) Bureau of Environmental Radiation Protection, New York State Health Department, Two University Place, Albany, New York 12203 Tel. (518) 458-6461

North Carolina (NC) Radiation Protection Section, Division of Facility Services, Department of Human Resources, 701 Barbour Drive, Raleigh, North Carolina 27603 Tel. (919) 733-4283

North Dakota (ND) Division of Environmental Engineering, Department of Health, 1200 Missouri Avenue, Box 5520, Bismark, North Dakota 58502-5520 Tel. (701) 224-2348

Ohio (OH) Radiological Health Program, Department of Health, 122 Kinnear Road, Columbus, Ohio 43212 Tel. (614) 481-5800

Oklahoma (OK) Radiation and Special Hazards Service, State Department of Health, Box 53551, Oklahoma City, Oklahoma 73152 Tel. (405) 271-5221

Oregon (OR) Radiation Control Section, State Health Division, Department of Human Resources, 1400 Southwest Fifth Avenue, Portland, Oregon 97201 Tel. (503) 229-5797

Pennsylvania (PA) Bureau of Radiation Protection, Department of Environmental Resources, Fulton Bldg., 16th floor, Third and Locust St., Harrisburg, Pennsylvania 17120 Tel. (717) 787-2480

Puerto Rico (PR) Radiological Health Division, G.P.O., Call Box 70184, Rio Piedras, Puerto Rico 00936 Tel. (809) 767-3563

Rhode Island (RI) Division of Occupational Health and Radiation Control, Department of Health, Cannon Bldg, Davis Street, Providence, Rhode Island 02908 Tel. (401) 277-2438

South Carolina (SC) Bureau of Radiological Health, South Carolina Department of Health and Environmental Control, 2600 Bull Street, Columbia, South Carolina 29201 Tel. (803) 734-4700

South Dakota (SD) Licensure and Certification Program, State Dept. of Health, Joe Foss Office Building, 523 East Capital, Pierre, South Dakota 57501 Tel. (605) 773-3364

Tennessee (TN) Division of Radiological Health, TERRA Building, 150 9th Avenue North, Nashville, Tennessee 37219-5404 Tel. (615) 741-7812

Texas (TX) Bureau of Radiation Control, Texas Department of Health, 1100 West 49th Street, Austin, Texas 78756-3189 Tel. (512) 834-6688

Utah (UT) Bureau of Radiation Control, State Department of Health, 288 North 1460 West, Box 16690, Salt Lake City, Utah 84116-0690 Tel. (801) 538-6734

Vermont (VT) Division of Occupational and Radiological Health, Dept. of Health, Administration Bldg., 10 Baldwin St, Montpelier, Vermont 05602 Tel. (802) 828-2886

Virginia (VA) Bureau of Radiological Health, Division of Health Hazards Control, Department of Health, 109 Governor Street, Richmond, Virginia 23219 Tel. (804) 786-5932

