

Safe operation of the rotating anode x-ray generator in room 1128 ERB

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Important Notes

1. The rotating anode x-ray generator produces x-rays by accelerating electrons across a high voltage. With the shielding in place, there is no detectable flux of x-rays into the room. Under unusual conditions, or if the shielding fails, the generator can emit x-rays at potentially harmful intensities. **In an emergency, switch off the machine's power using the disconnect switch located behind and to the right of the x-ray machine – or simply leave the room and ask for help.**

If there is a problem reaching the emergency power disconnect, the power for the generator may be removed using circuit breaker 4 in panel PP-7 near the freight elevator on the 11th floor. (There are two panels; PP-7 is the nearest panel to the freight elevator. The labels for the panels are printed on the inside of the access door.)

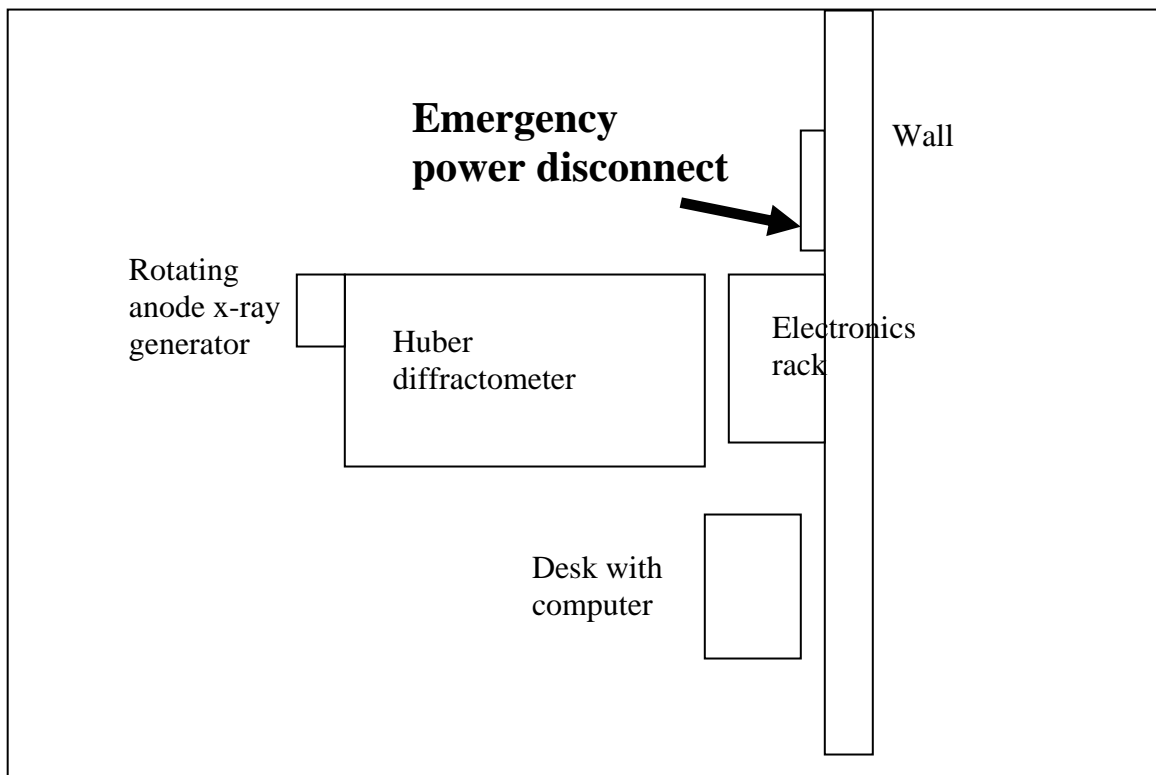


Figure 1 Location of Emergency Electrical Disconnect

2. The x-ray generator may only be used by Authorized Users. A list of authorized users can be found in the current version of this document in the red safety binder in room 1128.

3. *If you have any doubts about the safety of what you are doing, turn off the x-ray machine and seek help.*

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1. Introduction

The rotating anode x-ray generator in room 1128 of the Engineering Research Building is an extremely intense laboratory-based source of x-rays. This document describes the requirements its safe operation with respect to radiation safety, electrical safety, and mandatory procedures.

1. **Radiation Safety** The rotating anode x-ray machine in ERB 1128 is capable of producing x-ray intensities that can be harmful both immediately and after cumulative exposure. Users must understand their responsibilities with respect to radiation exposure to themselves and to others who may enter the room.
2. **Electrical Safety** The voltages and currents used to operate the rotating anode x-ray machine are potentially extremely dangerous.
3. **Procedures for Use** Users are required to follow a set of standard procedures while using the x-ray generator and diffractometer.

Safety comes first! Do not use the x-ray machine if you have any doubt about your safety or the safety of others.

2. Users and Becoming an Authorized User

The x-ray generator and x-ray diffractometer may only be used by authorized users. Visitors and others may participate in using the machine only when an authorized user is present.

To become an authorized user requires completing the following steps:

1. Attend the radiation safety training offered by the University's Safety Department.
2. Read and understand Chapter 10 of the University of Wisconsin Radiation Safety for Radiation Workers Training Manual.
3. Read and understand this entire document.
4. Demonstrate an understanding of the safety features of the generator and the locations of emergency shut-offs.
5. Complete an entry in Appendix C of this manual.

3. Radiation Safety

In normal operation users will not be exposed to radiation while using the x-ray generator in ERB 1128. There is, however, the potential for dangerous exposure in unusual circumstances. It is extremely important to act responsibly with respect to possible radiation exposure because it is possible to put others at risk without their knowledge. X-ray exposure is undetectable and can lead to chronic problems without any acute symptoms, so it is essential to act responsibly.

The background dose during normal operation falls well below the regulatory requirements and the University's safety office has not required us to wear dosimeters while using this instrument.

a. The enclosure of the generator and diffractometer

There are several features of the x-ray system that prevent accidental exposure to the direct beam from the rotating anode. Among these are:

1. A coupler between the x-ray generator and flight path that forces a mechanical x-ray shutter to close if the coupler is removed or the flight path is not present.
2. A shielded enclosure that absorbs scattered radiation and the fraction of the direct beam that is transported past the sample.

3. An electromagnetic shutter that can be opened only if the door to the x-ray enclosure is closed.
4. The rotating anode will stop and the electron beam will be switched off if the door to the enclosure is opened while the shutter is open.

Users may not bypass any of these safety features.

b. Opening the enclosure while the generator is operating

Normally, the generator will turn off if the door is opened while the generator is running. This feature can safely be bypassed by pressing the “Door Open” on the generator control panel. Doing this is completely safe. The ability to open the enclosure with the generator operating and the shutter closed is indispensable because it allows the sample, slits, etc. to be adjusted without turning off the generator.

c. Bypassing the enclosure interlock

In some special cases it may be necessary to open the door to the enclosure while electromagnetic x-ray shutter is open. This can be done using the turn key on the front panel of the x-ray generator and then pressing the “Door Open” button. Opening the enclosure with the shutter open can be extremely dangerous because it could allow you to be exposed to the direct beam. The shutter interlock should be bypassed only at the lowest generator power and for short periods of times. *Users may not under any circumstances bypass the interlock without supervision.*

4. Electrical Safety

The x-ray generator uses large currents and high voltages. The cathode can be biased at voltages up to 60 kV and can produce currents up to 300 mA. Power for the generator is provided by a three-phase 208 V AC circuit rated at 100 A. The generator can draw up to 18 kW, which presents a risk of electrocution, burns, and fire if there is an electrical problem. The water chiller and circulator is powered from a separate 250 V 30 A circuit.

Users should immediately shut off the generator or chiller if they expect an electrical problem. The procedures for doing this are given in part d of section 5, below.

5. Procedures for Use

a. Mandatory use of the log book

All use of the rotating anode x-ray machine must be reported in the log book in 1128. Anything unusual must be noted in the book. Doing this is a safety issue because safe operation depends on proper shielding and electrical and water safety.

b. Turning the generator on and off

Electrical arcs can be produced by operating the rotating anode generator improperly. These are usually harmless, but have the potential to damage the generator. These problems can be avoided by operating the generator using the following procedures.

i. Turning the generator on

The rotating anode x-ray generator is almost always left in a state where the turbomolecular pump is operating but the anode is not biased and not rotating. From this state, the generator can be turned on with the following procedure.

1. Verify that the valves supplying water to the Haskris chiller are open
2. Turn on the Haskris chiller using the switch on its front panel.
3. Push the “Power on” button on the front panel of the x-ray generator.
4. Once the water is on, the message on the front panel of the generator will switch from “Power on now.” to “Ready now.”
5. Be sure that the generator says “Ready now.” Then push the “X-ray on” button on the generator. The anode will begin to rotate and an electron beam with a bias of 20 kV and current of 10 mA will be started. This is the lowest power under which the generator can be operated.
6. The generator is operated at much higher power than it initially reaches. The maximum power depends on the choice of cathode and filament. At present, the maximum power is 5.4 kW. The generator can be safely raised to this power by increasing the power in two to three steps over a total of 10 to 15 minutes.

ii. Turning the generator off

1. Decrease the generator power from the high power used in experiments to the minimum power 20 kV, 10 mA in several steps taking a total of 5 to 10 minutes.
2. Push the “x-ray off” button on the front panel of the generator.
3. Push the “power off” button on the front panel of the generator.
4. Switch off the Haskris chiller.
5. The generator can be left in this state indefinitely.

c. Extended unattended use (including overnight)

When necessary, the rotating anode generator can be operated unattended or remotely for extended periods of time. This can be useful in acquiring diffraction data at a large number of points in reciprocal space, for example. Any of the authorized users of the machine may do this at their discretion, provided the following rules are followed:

1. The “In-Use” card must be completed and posted on the door to room 1128. This card can be found in Appendix B.
2. Users leaving the x-ray machine running unattended must provide a phone number where they can be reached.

These rules must be observed in order to protect the other occupants of the building and for the safety of maintenance people who respond to water leaks, fires, and other problems.

d. Shutting off the generator or chiller in case of a fire, electrical problem, or water leak

i. X-ray generator

In some cases an electrical or radiation safety problem may require the generator to be switched off immediately. There are three ways to do this.

1. Push the “Power Off” button on the generator. This will switch off the bias voltage and electron current, but it will not remove power from the rest of the generator electronics. This

will remove the radiation hazard immediately, but will not completely remove an electrical hazard.

2. Switch off the power to the generator using the emergency disconnect on the supply panel on the wall behind the x-ray machine. The location of this disconnect is shown in

Figure 1 on page 1. This will completely remove power from the generator, including the vacuum pumps, and control electronics. Do this if you suspect a fire in the generator's electronics.

3. The power can also be removed from the system by switching off the main circuit breaker supplying the generator. The power to the generator is supplied by circuit breaker 4 in panel PP-7 near the freight elevator on the 11th floor. (There are two panels; PP-7 is the nearest panel to the freight elevator. The labels for the panels are printed on the inside of the access door.) The location of the circuit breaker is shown in Figure 2.

Note: The diffractometer and other equipment are powered separately from the generator and will not be switched off if steps 2 or 3 are followed.



Figure 2 Circuit breaker supplying the rotating anode x-ray generator.

ii. Chiller

The chiller can draw up to 30 A from a 250 V circuit, so it can also be a significant electrical or fire hazard. There are two ways to shut off the chiller:

1. The chiller can be shut off at any time using the switch on its front panel. If the x-ray generator is running it will immediately shut off because as the water flow and water pressure fall.
2. The chiller may be shut off at its circuit breaker (breakers 13,15, and 17, labeled “Chiller 1128” in panel RPDF 11 in the hall outside 1128.) The location of the circuit breaker is shown in Figure 3.



Figure 3 Location of the water chiller circuit breaker.

iii. Water supply

The chiller is cooled by water drawn from the city water supply. This water supply can be shut off at any time by closing the shut off valve shown in Figure 4. If the chiller and x-ray generator are running, doing this will cause the chiller to overheat and shut down within a few minutes.



Figure 4 Water shut off valve.

Appendix A: Resources

1. Radiation protection resources

a. University of Wisconsin Radiation Safety for Radiation Workers Training Manual

This manual describes the University's guidelines for working with radiation sources based on radioactive isotopes, x-ray generators, and lasers. The section on analytical x-ray machines is Chapter 10. The requirements for shielding x-ray generators are given on page 161:

"The leakage radiation from the x-ray tube housing, with all shutters closed, must not exceed 2.5 mR/hr at 5 cm from the surface. The x-ray generator must have a protective cabinet which limits leakage radiation at 5 cm from the surface to 0.25 mR/hr or less. This helps to insure that the background radiation within the room or immediate vicinity of the generator is low."

The manual also includes a very nice discussion of the basic components of analytical x-ray systems and strategies for mitigating doses. There is a copy of this manual in the cabinet in 1128 ERB it is also available at <http://www2.fpm.wisc.edu/safety/Radiation/trainman.htm> .

b. Radiation safety training

The University of Wisconsin offers a weekly radiation safety training course. More information is available at <http://www2.fpm.wisc.edu/safety/Radiation/schedu.html>.

c. Wisconsin Radiation Safety Regulations

The state of Wisconsin has regulations that require safety training for people who work with radiation. The regulations can be found at <http://www2.fpm.wisc.edu/safety/Radiation/docs/regs.pdf>. Our requirements for authorized users are based on the following rule on page 18:

"7. Persons only working with machine produced radiation (e.g., x-ray diffraction) should review Chapter 10, Radiation Safety for Radiation Workers and be briefed on the basic safety measures for the particular source they will be using."

d. University of Wisconsin Safety Department FAQs

The University of Wisconsin Safety Department has answers to frequently asked questions at <http://www2.fpm.wisc.edu/safety/Radiation/FAQ.htm>. The most relevant question for the rotating anode x-ray machine in 1128 ERB is:

"X-ray / Laser

Q: What about X-ray machines, analytical devices (e.g., x-ray diffraction, electron microscope) or lasers?

A: Call Radiation Safety, 262-9748, to receive an x-ray survey, training, check on your x-ray / laser system and insure the state licensing paperwork is completed and forwarded."

e. Guide to Beamline Radiation Shielding Design at the Advanced Photon Source

There's a discussion of shielding strategies and requirements in the original design documents for the Advanced Photon Source. They have very different requirements for shielding because the spectrum and divergence of radiation from undulators, but the goals of

shielding are similar. The document is at:

http://www.aps.anl.gov/Science/Publications/techbulletins/tb7/TB-7_toc.html

2. Equipment manuals

The manual for the Rigaku x-ray generator is available on paper in the cabinet in room 1128 and at <http://xray.engr.wisc.edu/equipment.shtml>.

Appendix B: "In-Use" Card

Caution
X-ray Generator in Unattended Use

User:

Email:

Home Phone:

Work Phone:

Date and Time this Form was Completed:

Date and Time User Will Return:

Please contact the user or Paul Evans (evans@engr.wisc.edu, work (608) 265-6773, home (608) 233-3746) with any problems.

Appendix C: List of Authorized Users

Name	Email address	Date	Signature	Signature of Trainer
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