SAFE OPERATING PROCEDURE GUIDELINE

INTRODUCTION

I. The purpose of this manual is to assist those using The XR200 X-ray source in developing a procedure that minimizes the possibility of overexposures and radiation accidents. The minimum goal is to keep x-ray exposure to the operator and the public below the maximum exposure allowed by the state and federal governments. Beyond that, the goal is to keep x-ray exposure as low as reasonably achievable. Exposure to radiation may lead to serious health problems up to, and including death. Any radiation dose above zero may have some biological effect.

DESCRIPTION

I. The XR200 is a portable, pulsed x-ray source. X-rays are produced by bombarding a tungsten anode with electrons. Each pulse lasts 60 nanoseconds, with a peak energy output of 150 KV, and is directed in a 40 degree beam. The XR200 can be set for 1-99 pulses. It is recommended to fire the unit no more than 200 pulses every four minutes, up to the maximum duty cycle of 3000 pulses per hour. Use beyond the duty cycle will damage the unit.

RADIATION GUIDELINES

I. We have found most states require the radiation exposure to individual members of the public in any unrestricted area not to exceed 2 mR per hour or 100 mR in any seven day period. The defined occupational dose limit for adults in these states is either 5 rems per year or not more than 1 1/4 rems in any one calendar quarter, with occupational limits for minors being no more than 10% of the annual limit for adults.

II. Most states requires radiation surveys each time a radiation producing machine is operated outside a controlled area. We have supplied comprehensive radiation surveys designed to supersede these requirements. Contact your state health department to determine if these surveys will meet their requirements.

III. In the event of an incident involving a radiation producing device, it is necessary to contact the proper regulatory agencies. Refer to your state's radiation safety program to define these instances, and ensure all personnel understand the notification process.

Contact your state board of health to receive a copy of your state's radiation protection programs.

HAZARDS OF RADIATION

I. Exposures of 600 rems or more are generally fatal. Symptoms include the early onset of nausea, vomiting, disorientation, and anxiety. Death occurs as a consequence of direct damage to the nervous system, the edema, the gastrointestinal tract, or overwhelming infection caused by severe damage to the immune system.

Individuals usually die within 14 days, but in severe cases may die within a few hours.

II. Exposures of 100 to 600 rems cause radiation sickness. Symptoms include nausea, vomiting, and repeated infections caused by the breakdown of the immune system. Long term effects can include dermatitis, cataracts, or failure of various organs. In some instances doses of 200 to 600 rem can be fatal.

III. With exposures of less than 100 rems there is the latent threat of cancer, and heritable genetic damage. Cancer could develop within five years. The International Commission on Radiological Health Protection has determined that the risk factor for death from radiation induced cancers is about one in 100 per 100 rems of accumulative radiation absorbed.

ADMINISTRATIVE PROCEDURES

I. Register the unit. Contact your state health department to obtain registration documents, and post registration and/or license in appropriate areas.

II. Draft forms to record required information and identify a secure location for keeping these records (some states make prepared forms available).
   A. Utilization log
      1. Date used
      2. Operator who signed unit out
      3. Location used
      4. Number of pulses used
      5. Other information as required by state
   B. Radiation exposure logs
      1. Name
      2. Date reading was taken
      3. Dosage measurement
      4. Other information as required by state
   C. Periodic inventory
      1. Make, model, and serial number of source
      2. Date inventory taken
      3. Quantity on hand
      4. Location of radiation sources
      5. Other information as required by state
   D. Acquisition log
      1. Date radiation source was acquired
      2. Where source was acquired
      3. Make, model, and serial number of source acquired
      4. Date radiation source was transferred
      5. Party source was transferred to
      6. Make, model, and serial number of source transferred
      7. Date unit was disposed of

8. Method of disposal
9. Make, model, and serial number of source disposed of
10. Other information as required by state

III. Assign a radiation safety officer. This person is responsible for the documentation and monitoring of radiation exposure levels to personnel.

IV. Identify the authorized operators. Verify that each proposed operator has received proper training in the operation and safety requirements of the XR200 and has met applicable state guidelines for radiographers.

V. Securely store the XR200. Identify a location for storage of the unit so that it is not accessible by unauthorized personnel. Keep the operators manual and a copy of your safe operating procedures with the unit at all times.

VI. Post sufficient quantities of safe operating procedures, state radiation guidelines, and all notices required by state law throughout your facility.

VII. Issue radiation monitoring devices. All operators of the x-ray source should receive a film badge or TLD badge to ensure that they are not being exposed to high levels of radiation. Most states also require that the operator and assistant, possess and wear a pocket dosimeter to get instant feedback on x-ray exposure.

VIII. Identify an employee contact within the appropriate radiation regulatory agency.

OPERATIONAL PROCEDURES

I. Ensure all personnel are wearing personal monitoring devices.

II. Record pocket dosimeter readings or zero dosimeters prior to x-ray use.

III. Clear the radiation area. In operating the XR200 X-ray source it is necessary to carefully evaluate the area of intended use. Not only the area in front of the unit, but also behind, above, and below the unit needs careful examination to determine what level of shielding the surrounding structures will provide. It is possible for a person one floor removed from the operation of the x-ray unit to receive a dose of higher than .002 R per hour.
   A. In all operating scenarios, move the operator at least 10’ behind the unit.
   B. When x-raying a single item, using no more than 99 pulses:
      1. In the absence of shielding:
         a. Clear the area in a 50’ radius from the source of all personnel, and designate it a radiation area.
      2. In a wood structure:
         a. Clear one floor above and below the unit.
         b. When one wall provides shielding, clear a 25’ radius, and designate it a radiation area.

3. When the unit is used within concrete walls at least 3 1/4” thick:
    a. All personnel should move behind the concrete walls, at least 10’ from the unit.
    b. Designate the area within the concrete wall a radiation area.
    c. The area behind the concrete wall within 10’ from the unit should be designated a radiation area.
4. When the unit is contained within a box covered in at least 1/8” of lead:
    a. Clear all personnel from within a radius of at least 5’ from the unit.
    b. Designate the lead lined box a radiation area.

C. When x-raying items, using up to 3000 pulses per hour:
1. In the absence of shielding:
    a. Clear the area in a 100’ radius from the source of all personnel, and designated it a radiation area.
2. In a wood structure:
    a. Clear two floors above and below the unit.
    b. When one wall provides shielding, clear a 75’ radius, and designate it a radiation area.
3. When the unit is used within concrete walls at least 3 1/4” thick:
    a. All personnel should move behind concrete walls, at least 10’ from the unit.
    b. Designate the area within the concrete wall a radiation area.
    c. The area behind the concrete wall within 10’ from the unit should be designated a radiation area.
4. When the unit is contained within a box covered in at least 1/8” of lead:
    a. Clear all personnel from a radius of at least 5’ from the unit.
    b. Designate the lead lined box a radiation area.

IV. Follow The XR200’s operator instructions to produce a radiograph.

V. Chart the area of use.
A. Detail surrounding structures and the radiation area cleared.
B. Keep these records on file with radiation survey measurements.

VI. Complete the utilization log.

VII. Take pocket dosimeter readings.
A. If the dosimeter is discharged beyond its range, immediately have film badge processed.
B. Record results from dosimeter to each operator's log.
1. State policies vary, but it is common for states to require these records to be kept at least ten years after employment termination.

VIII. Return the x-ray source to its secured storage location.

RADIATION SURVEY

I. The following data gives the operator a basis for the determination of potential radiation dose measurements. The operator can approximate radiation dose measurements for any number of pulses in the XR200's duty cycle.

II. This information is also designed to meet state requirements for the performance of on site radiation surveys. Combined with a detailed representation of the area in which the X-ray was used, these surveys will meet the requirements of most states.

II. Using a Victoreen model 660 control with a Victoreen 660-5 radiation probe, tests were conducted to measure the transmission of x-rays from XR200 through air, lead, concrete, wood floors, and walls covered with gypsum board.

A. In charts 1-4, maximum allowable radiation doses beyond 12 inches from the source, were obtained using the inverse square law (figures rounded to the nearest thousandth).

CHART 1, UNSHIELDED MEASUREMENTS IN BEAM CENTER

DISTANCE FROM SOURCE	PULSES	RADIATION MEASURED	DISTANCE FROM SOURCE	PULSES	RADIATION MEASURED
12"	1	4mR	60"	1	.16mR
12"	10	40mR	60"	10	1.6mR
12"	99	396mR	60"	99	15.84mR
12"	3000	12000mR	60"	3000	480mR
24"	1	1mR	90"	1	.071mR
24"	10	10mR	90"	10	.711mR
24"	99	99mR	90"	99	7.04mR
24"	3000	3000mR	90"	3000	213mR
30"	1	.64mR	120"	1	.04mR
30"	10	6.4mR	120"	10	.4mR
30"	99	63.36mR	120"	99	3.96mR
30"	3000	1920mR	120"	3000	120mR

CHART 2, UNSHIELDED MEASUREMENTS IN BEAM CENTER

DISTANCE FROM SOURCE	PULSES	RADIATION MEASURED	DISTANCE FROM SOURCE	PULSES	RADIATION MEASURED
180"	1	.018mR	480"	1	.003mR
180"	10	.178mR	480"	10	.025mR
180"	99	1.76mR	480"	99	.248mR
180"	3000	53.3mR	480"	3000	7.5mR
240"	1	.01mR	600"	1	0.002mR
240"	10	.1mR	600"	10	.016mR
240"	99	.99mR	600"	99	.158mR
240"	3000	30mR	600"	3000	4.8mR
360"	1	.004mR	1200”	1	<.001mR
360"	10	.044mR	1200”	10	.004mR
360"	99	.44mR	1200”	99	.040mR
360"	3000	13.3mR	1200”	3000	1.2mR

I. These results indicate that it would be possible for individuals within 77.5’ of the unit, to receive a dose of higher than 0.002 R per hour.

CHART 3, UNSHEILDED MEASUREMENTS ADJACENT TO UNIT

DISTANCE FROM SOURCE	PULSES	RADIATION MEASURED	DISTANCE FROM SOURCE	PULSES	RADIATION MEASURED
6"	1	.008mR	30"	1	<.001mR
6"	10	.08mR	30"	10	.003mR
6"	99	.792mR	30"	99	.032mR
6"	3000	24mR	30"	3000	.96mR
12"	1	0.002mR	60"	1	<.001mR
12"	10	.02mR	60"	10	<.001mR
12"	99	.198mR	60"	99	.008mR
12"	3000	6mR	60"	3000	.24mR
24"	1	<.001mR	120"	1	<.001mR
24"	10	0.005mR	120"	10	<.001mR
24"	99	.0495mR	120"	99	0.002mR
24"	3000	1.5mR	120"	3000	.06mR

II. Chart 3 indicates the maximum radiation doses generated by the XR200 adjacent to the unit.
   A. Reflected radiation may cause actual radiation doses to be higher in this area.

CHART 4, UNSHIELDED MEASUREMENTS BEHIND UNIT

DISTANCE FROM SOURCE	PULSES	RADIATION MEASURED	DISTANCE FROM SOURCE	PULSES	RADIATION MEASURED
12"	1	.015mR	120"	1	<.001mR
12"	10	.152mR	120"	10	0.002mR
12"	99	1.501mR	120"	99	.015mR
12"	3000	45.6mR	120"	3000	.45mR
24"	1	.004mR	180"	1	<.001mR
24"	10	.038mR	180"	10	<.001mR
24"	99	.371mR	180"	99	.007mR
24"	3000	11.25mR	180"	3000	.200mR
60"	1	<.001mR	240"	1	<.001mR
60"	10	.006mR	240"	10	<.001mR
60"	99	.059mR	240"	99	.004mR
60"	3000	1.8mR	240"	3000	.113mR

III. Chart 4 indicates the maximum radiation doses generated by the XR200 behind the unit.
   A. These findings indicate that the area within 5’ behind the source could present a radiation hazard. The risk an operator takes by standing 4.75’ behind the unit is comparable to the risk of an individual 77.5’ in front of the unit given there is no shielding present.
   B. Reflected radiation may cause actual radiation doses to be higher in this area.

CHART 5, LEAD ATTENUATION

LEAD THICKNESS	PULSES	DISTANCE TO SOURCE	RADIATION MEASURED
.062"	1	24"	.001mR
.062"	10	24"	.009mR
.062"	99	24"	.089mR
.062"	3000	24"	2.7mR
.125"	1	24"	<.001mR
.125"	10	24"	<.001mR
.125"	99	24"	0.005mR
.125"	3000	24"	.152mR

IV. In chart 5, the test results indicate radiation measurements obtained through different thickness' of lead shielding.
   A. Through .125 inches of lead at a distance of 24 inches from the source, it would take 39,600 pulses to generate a dose of 0.002 Roentgens, and 99,000 pulses to produce 0.005 Roentgens.
   B. Through .062 inches of lead at 24 inches, it would take 2222 pulses to produce 0.002 R, and 5555 pulses to produce 0.005 R.
   C. Considering these findings, using 1/8" lead shielding measured at 24" from the XR200, the measurable radiation dose is reduced to levels within state parameters for individual members of the public. This would hold true for any number of pulses in the XR200's duty cycle of 3000 pulses per hour.

CHART 6, CONCRETE ATTENUATION

CONCRETE THICKNESS	PULSES	DISTANCE TO SOURCE	RADIATION MEASURED
3.25"	1	12"	.018mR
3.25"	10	12"	.180mR
3.25"	99	12"	1.782mR
3.25"	3000	12"	54mR
4.88"	1	12"	.004mR
4.88"	10	12"	.036mR
4.88"	99	12"	.356mR
4.88"	3000	12"	10.8mR
6.50"	1	12"	.001mR
6.50"	10	12"	.008mR
6.50"	99	12"	.079mR
6.50"	3000	12"	2.4mR

V. In chart 6, the test results indicate radiation measurements obtained through different thickness' of concrete.
   A. Through 6.5 inches of concrete, measured at a distance of 12 inches from the source, it would take 2500 pulses to generate a dose of 0.002 Roentgens, and 6250 pulses to produce 0.005 Roentgens.
   B. Through 3.25 inches of concrete measured at 12 inches, it would take 111 pulses to produce 0.002 R, and 277 pulses to produce 0.005 R.