The University of Sheffield
Safety Services
FMD
Facilities Management Directorate

GUIDANCE IN THE USE OF X-RAY CRYSTALLOGRAPHIC EQUIPMENT

Introduction

Particular care is needed in the use of X-ray crystallographic equipment, because the very high dose rates near the target can cause injury in a very short time. A rough approximation of the dose rate to be found at a distance 'D' cms from the tungsten target of a tube running at 'V' kVp and '1' mA with 1 mm Be filtration is given by the formula:-

$$\text{Dose rate} = \frac{0.5 \times V \times I}{D^2} \text{ grays/s}$$

For other targets the expression should be multiplied by Z/74 where Z is the atomic number of the target material.

An example of this is at 10 cm from a tungsten target with the tube running at 50 kVp and 20 mA, you will have a dose rate in the beam of 5 Gy/sec.

The main principle of radiation protection is to keep all doses AS LOW AS REASONABLY ACHIEVABLE (ALARA). Although the potential hazard from this type of X-ray equipment is high, providing the following precautions are followed, together with any specific operating instructions that you may be given, there is no reason why ALARA in this case should not mean no detectable doses at all.

Precautions

1. Guards (local or total enclosures) must be provided where necessary to ensure that the fingers and other parts of the body cannot be inserted into the useful beam or areas of significant scattered radiation. These guards must be either permanently fixed or interlocked to either the shutter or X-ray generator. They should be made of a suitable material of suitable thickness (see note 1) to ensure that the dose rate outside the guards is kept below 7.5μSvh^{-l} and, where reasonably practicable, below 2.5μSvh^{-1} . In some cases it may be practicable to use an interlocked light screen or a capacitance shield as an alternative to physical barriers.

2. A beam stop of suitable material should be incorporated into an enclosure where it is possible for the primary beam to strike the wall of the enclosure in the absence of an accessory.

3. If it is necessary to move samples or other materials during irradiation, this must be done by remote control. If this is not possible and access is required to areas where the instantaneous dose rate in the beam averaged over 1 cm^2 exceeds 2.0mSvh^{-1} then a permit to work system should be instituted and followed (See your Radiation Protection Supervisor for guidance.)

4. Each port or aperture of the X-ray tube housing must be provided with an automatic beam shutter so arranged that it can only be opened when the collimating system, or other apparatus providing adequate shielding, is in place. Any unused ports should be blanked off.

5. Monitoring equipment should be available in every room where X-ray optics work is done, and monitoring should be carried out -

(a) immediately an assembly is ready for use or after any change to an accessory or enclosure;

(b) immediately before commencing operations that require a permit to work system to establish the position of any high dose rate areas; and

(c) periodically around equipment and enclosures to ensure that the shielding remains effective. (This should be done at least once per month when the set is in use.)

Records of monitoring should be kept for the monthly surveys and at other times whenever any radiation is detected which would indicate investigatory or remedial action to be taken (see note 2 for further guidance on monitoring).

6. Body monitoring badges are not required by people who only operate totally enclosed systems. All other X-ray equipment will be individually evaluated. If badges are issued these should be positioned on the body at the same height as the X-ray generators being used. If operations are being performed which require access to the open beam, then finger TLD's should be worn if thought appropriate by the Radiation Protection Supervisor or the Radiation Protection Adviser.

7. A warning sign with the legend "X-RAYS NOW ON" must be clearly displayed above the equipment, and in close proximity to it. This should he automatically switched on when the X-ray tube is energised.

8. There should he clear indication of whether a shutter is open or closed. This can be indicated by light emitting devices, coloured flag legends or pointers.

9. The mains supply to the equipment must be provided with an emergency isolation switch outside the door leading into the laboratory. This should be provided with a red indicator light and clearly labelled. It should have a warning notice by its side stating that it must be switched off in the event of a fire.

10. In the event of any accident or incident involving the use of X-ray sets, the Radiation Protection Supervisor or Safety Services should he informed immediately.

Safety Services 0114 2226198 , internal Ext 26190, or 26198, or 26203

NOTE 1

Shielding materials needed for beam stops, guards and enclosures.

A. **For the Primary Beam -** 2-3 mm of lead or equivalent will be required.

Transmission for Lead at 50 kV

Thickness in mm	Transmission Factor
0.25	2.7×10^{-3}
0.50	9×10^{-5}
1.00	10^{-6}
2.00	10^{-11}

Lead Equivalents for Brass and Steel at 60 kV

1mm brass = 0.36 mm lead

1mm steel = 0.15 mm lead

B. **For Scattered Radiation**

Dose rates are dependent upon the scattering material, area irradiated, energy of primary beam and the scattering angle. In most cases the level of scattered radiation is low and an enclosure to prevent access to the main beam is all that is required. 6-10 mm of perspex is often the best material to use. It also affords some protection to low energy X-rays:-

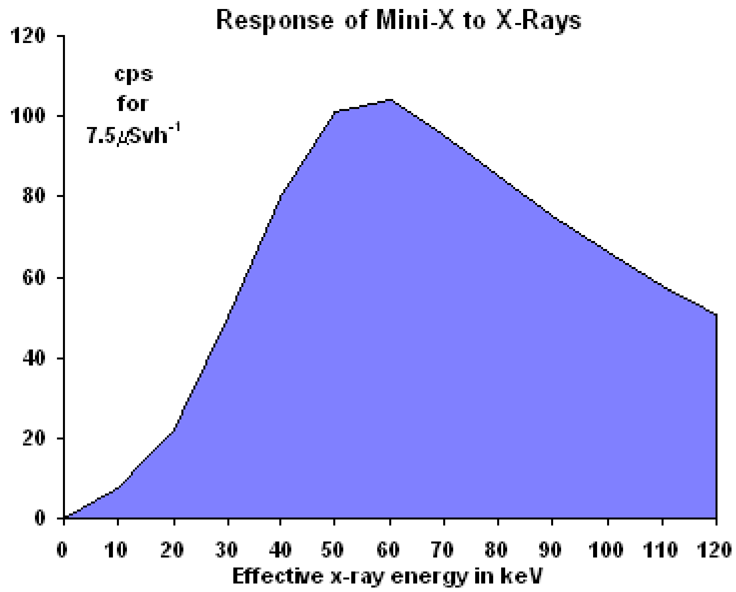
6 mm perspex has a transmission factor of	10^{-2} at 10 kV
	10^{-1} at 20 kV
10 mm perspex has a transmission factor of	10^{-3} at 10 kV
	4 $x10^{-2}$ at 20 kV

Where additional protection is required, up to 0.25 mm of lead or lead equivalent may be needed. This could take the form of aluminium or steel plate, or lead bonded in plywood or leaded perspex, e. g.: -

1 mm of aluminium has a transmission factor of	10^{-2} at 20 kV
0.3 mm of steel has a transmission factor of	10^{-3} at 30 kV
1 mm of steel has a transmission factor of	10^{-4} at 40 kV
0.254 mm of lead has a transmission factor of	3.20 x 10^{-7} at 30 kV
	1.06 x 10^{-5} at 40 kV

H7 'Premac'* 7 mm thick = 0. 3 mm of lead (* Premac - transparent leaded acrylic sheet made by Premise Engineering)

NOTE 2 - MONITORING



N.B. Above response curve for MX168 geiger tube with protective plastic cap fitted.

Radiation incident normally on window.

As can be seen in the above diagram, the response of the Mini X to X-rays increases rapidly over the region of interest (10-50 keV) from 7.5 cps for 7.5µSvh^{-l} at 10 keV up to 100 cps for the same dose rate at 50 keV. (The response of the Mini E is very similar and of the same order).

Only very rough estimates of dose rates can, therefore, be made. The safest policy is, therefore, to eliminate all X-ray leakage where possible and keep scattered radiation down to a minimum and less than 7.5 cps on a Mini X outside any enclosure.

Monitoring Records

We are required to keep records of monitoring in order to demonstrate the efficacy of the methods used to restrict exposure of personnel to ionising radiations. All routine monitoring, however, does not need to be recorded, but periodically a record should be made. It is important, the first time a new set up is used on an X-ray set, that a record is made of the radiation levels around the set to give a baseline comparison for future monitoring. The frequency of further recorded monitoring will be dependent upon work being in progress and should then ideally be on at least a monthly basis.

A record book/sheet should be kept in each laboratory where X-ray sets are used. Information should be recorded that identifies the x-ray machine, the operating conditions and any accessory used, the date of the survey and the findings (any leakage detected in cps). One sensible approach is to incorporate the monitoring record within a log of X-ray set usage.
