

# RP GN013 – SAFE WORKING IN X-RAY DIFFRACTOMETRY

VERSION CONTROL	
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## 1. Risk

This Guidance Note covers the use of x radiation for the purpose of analysis of molecular structures. The characteristics of the x radiation generated for this use are particular, and give rise to their own specific risk. However, it is worth remembering that one advantage of x radiation is that it is generated by an electric current; switching off the electrical supply stops the production of x rays.

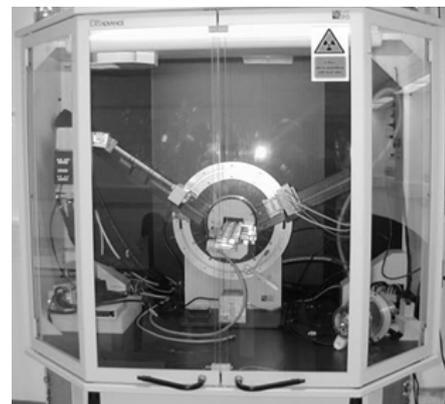
X radiation used for diffractometry exhibit the following properties relevant to radiological safety:

- very intense beams (see table overleaf for an example of x-ray output);
- very narrow beams – beams could be typically 1 mm<sup>2</sup> in area; and
- low energy – target characteristic radiation is typically in the range 6 – 22 keV.

The low energy means that the x radiation will not penetrate far into the body, and the risk of harm following exposure is to the skin and eyes. However, the high intensity means that doses can be at a deterministic level, causing skin burns and lenticular cataracts. The stochastic risk of skin cancer of course still remains. The low energy of the radiation does make it relatively easy to shield.

## 2. Safety Considerations

- The radiation should be enclosed to prevent access to the main beam. The best option is normally cabinets that provide complete enclosure of the x-ray tube sample and optics. Modern sets normally use this technique; see Fig. 1.



*Fig. 1: Cabinet Enclosure*

- The cabinet must be interlocked, so that opening the cabinet access closes the shutter on the x-ray tube, or de-energises the x-ray generator, and the x-ray shutter cannot be opened if cabinet access is available.
- It is common practice nowadays to control the generation of x radiation by microprocessor. If this is the case, it is likely that the interlocks are also controlled by the microprocessor. The reliability of the interlocks then becomes only as reliable as the software. There is a standard for the reliability of such systems (*Functional safety of electrical/electronic/ programmable electronic safety-related systems*, BS EN 61508:2010) but manufacturers rarely ensure that their software complies with it. Unless written reassurances are received from the manufacturers, it should be assumed that any controlling software does not comply with this standard, and the interlocks might be unreliable. Additional monitoring precautions are then needed, which are outlined overleaf.
- If there is a substantial reason that a local enclosure cannot be used, then the x-ray equipment needs to be either:
  - enclosed in a separate, interlocked room, or
  - each attachment locally shielded and interlocked; see Fig. 2.Neither of these is a desirable option, and the University Radiation Protection Unit must be consulted if they are being considered.
- The enclosure must be shielded. However, shielding of low energy x radiation is relatively easy, and even light material such as perspex can be utilised.
- There must be a clear indication when x radiation is being produced, and if present, when the port shutter is open.
- There must also be a sign to indicate that the device is capable of generating ionising radiation. This must be fitted in a clear position on the device or enclosure, not on the door to the laboratory. During normal use there is no need for a radiation designated area.
- Alignment of the x-ray optics with the x-ray beam on is a dangerous operation, and must be rigorously justified. If so justified, it must only be carried out by experienced and trained staff in accordance with a written protocol. This would include setting up a radiation Controlled Area, from which most people would be excluded.
- The correct function of hardwired enclosure interlocks should be tested once a month. The function of those interlocks known or thought to be wired exclusively to the programmable electronic control system should be tested at the beginning of each day that the equipment is to be used.

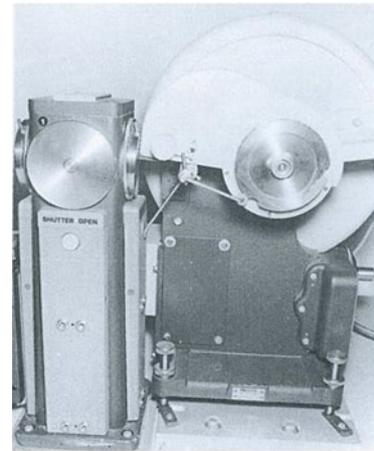


Fig. 2: Local shielding

### 3. Monitoring

- Under normal operations, monitoring around the outside of the equipment/cabinet annually by use of a thin-end-window geiger tube detector, such as the Mini Instruments type X or type E, is sufficient. The radiation levels do not need to be quantified; the survey is intended to identify any significant changes. However it is very important that monitoring is carried out immediately after any changes have been made to the equipment or shielding.
- Where the interlocks are known or thought to be microprocessor controlled, then a suitable radiation monitor fitted with an audible response must be switched on and placed in the vicinity of the x-ray tube as soon as the shielding is moved. This monitor must be left in that position until the shielding is reinstated or the x-ray generator is de-energised.
- Personal monitoring is not normally necessary. However, extremity and whole body dosimeters must be worn by those carrying out justifiable x-ray-on alignment.

#### **Approximate Output and Dose Data** (See Note 1)

Equipment settings	Location	Dose Rate (Gy/s)	Time (s) to reach		
			20 mSv dose	500 mSv dose	skin burn (See Note 2)
50 kVp, 6mA, Be filtration	10 cm from the x-ray tube port	1.0	0.02	0.5	3

#### **Transmission through various materials for specified x-ray tube targets** (See Note 3)

Material	Transmission (See Note 4)	Characteristic Spectrum Radiation Thickness (mm)			Continuous Spectrum Radiation Thickness (mm) (See Note 5)
		Cr, Fe, Co, Cu	Mo	Ag	
Lead	HVL	$3 \times 10^{-3}$	$6 \times 10^{-3}$	$9 \times 10^{-3}$	0.015
	TVL	0.01	0.02	0.03	0.05
Iron	HVL	0.02	0.02	0.04	0.07
	TVL	0.06	0.06	0.13	0.2
Perspex	HVL	0.9	10	18	33
	TVL	3.0	32	59	110

**Note 1** -The actual output varies with the type of x-ray tube, the tube voltage, current, filtration and monochromation. The values presented are reported to give the reader a guide to the levels of radiation to be expected; they must not be regarded as precise data.

**Note 2** – Skin burn occurs at a dose of around 3 Sv.

**Note 3** - The values, which must be regarded as approximate, are calculated from mass energy-absorption coefficients provided by the NIST Physical Measurement Laboratory, Hubbell, J.H. and Seltzer, S.M. (2004), *Tables of X-Ray Mass Attenuation Coefficients and Mass Energy-Absorption Coefficients* (version 1.4). Available: <http://physics.nist.gov/xaamdi>, July 2004. National Institute of Standards and Technology, Gaithersburg, MD.

**Note 4** - HVL – Half-value Layer is the thickness of a material that will reduce the dose rate to half of its original value. TVL – Tenth-value Layer is the thickness that will reduce it by a factor of ten.

**Note 5** - At 50 kVp, 6 mA, Be filtration

For advice on any of the above topics please contact the Radiation Protection Unit, [radiation@ed.ac.uk](mailto:radiation@ed.ac.uk).