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10.2. Protection from ionizing radiation

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10.2.1. General

Because of the diversity of apparatus for the generation of ionizing radiations and the significant differences that exist between laboratories within and between countries, it is not possible to give other than general guidelines as to the preventative measures to be taken.

It will be assumed here that the most likely sources of exposure will be X-ray generators and radioisotopes used in the manufacture of specimens for Mössbauer and NMRON use, for example. The basis for this assumption is the belief that establishments maintaining neutron and particle accelerator sources will have local regulations more stringent than those of the country in which they exist – certainly more stringent than those suggested in ICRP-26. They will also have a radiation protection officer who will discharge a list of duties similar to those stated in Subsection 10.1.3.2.

10.2.2. Sealed sources and radiation-producing apparatus

The types of source and apparatus covered in this section include: (1) sealed sources, such as those used for radiography, and for X-ray scattering experiments; (2) apparatus that produces ionizing radiations, such as X-ray generators and particle accelerators; (3) apparatus that produces ionizing radiation incidentally, such as electron microscopes, cathode-ray oscilloscopes, and high-voltage electronic rectifiers.

10.2.2.1. *Enclosed installations*

Most modern equipment is produced in such a form as to meet the prevailing radiation-protection regulations of the country in which it is sold, and care must be taken that safety circuits provided by the manufacturer are not defeated by staff members undertaking setting-up procedures. Such safety devices might cause visual or audible signals to be given and turn off power to the irradiating device.

Many early X-ray generators, electron microscopes, *etc*. have by modern standards inadequate radiation-protection facilities. Where practicable, therefore, special enclosures should be fabricated to house the apparatus producing the ionizing radiation. These should be designed such that:

(i) no person should have access to the interior during irradiation;

(ii) access should be prevented during irradiation by the provision of fail-safe interlocks that turn off the irradiating source;

(iii) no person should be able to remain in an enclosure during irradiation;

(iv) a means of rapid exit should be available to an individual should by chance he (she) be within a enclosure when irradiation commences;

(v) the source can be turned off from within the enclosure;

(vi) during operation the dose equivalent at any accessible surface outside the enclosure shall not exceed 25 mSv (2.5 rem) per hour;

(vii) when not in use, sealed sources should be capable of being housed, by remote control, within suitable shielding inside the enclosure;

(viii) all interlocks should be fail-safe enabling isolation of the source in the event of the loss of electrical power.

10.2.2.2. *Open installations*

An open installation because of operational requirements cannot have many of the safeguards suggested in Subsection 10.2.2.1. It is essential that extreme caution be exerted by the operators of such installations. They should bear in mind the following facts:

(i) almost all radiation injuries in X-ray diffraction laboratories are to the fingers of the operators and occur when setting up monochromators close to the radiation source. Necrosis of the skin occurs within seconds under these circumstances.

(ii) The beams scattered from single crystals are highly directional and very intense. Finding and monitoring these beams is usually difficult, and normal radiation monitors tend to underestimate the dose.

10.2.2.3. *Sealed sources*

Sealed sources ought to be manipulated only by remote means such as forceps and long tongs. Shielding should be close to the source to minimize the risk of scattered radiation reaching other workers.

Sealed sources should be registered by the RSO according to nature and activity. He (or she) is also responsible for their physical integrity and for regular examinations to detect corrosion or other damage.

Note that high-activity neutron sources can activate their immediate housings and give rise to additional radiation hazards.

10.2.2.4. *X-ray diffraction and X-ray analysis apparatus*

X-ray-generating devices such as sealed tubes and rotating-anode generators produce intense beams of small cross section and are capable of giving severe radiation burns within a second or so of exposure. Great care is necessary when working close to the exit port of these devices.

Apertures in the housing enclosing the X-ray source should be covered by a shutter when the source is not being used. Interlocking devices should exist to prevent the emission of X-rays when:

(i) the shutter is open without the analysing components and the beam stops being in place;

(ii) the analysing device is not properly in its position in relation to the housing.

Housings, shutters, shielded enclosures, and beam stops should be constructed such that the dose equivalent at any accessible point 0.05 m from their surface does not exceed 25 mSv for all practical operating conditions of the source.

Warning lights and illuminated signs should be fitted, interlocked such that they are lit when a shutter is open.

10.2.2.5. *Particle accelerators*

The codification of rules for the safe operation of high-energy particle accelerators is not simple because the various ionizing radiations produced by them require different protective procedures.

Particle accelerators ought to be operated in an enclosure from a remote control room in which the dose equivalent rate does not exceed 25 mSv h^{-1}. A lower dose rate (2.5 mSv h^{-1}) is required in adjacent areas used by non-radiation workers.

The probability of mixed radiations (*e.g.* X-rays and neutrons) co-existing makes servicing hazardous and all maintenance should be performed under the supervision of the RSO.

10.2.3. Ionizing-radiation protection – unsealed radioactive materials

The most common controlled situation in which unsealed radioactive materials is used is in the construction of samples for use in Mössbauer experiments, NMRON experiments, and radioactive tracer experiments. Uncontrolled situations can occur, for example, whenever maintenance is being carried out on particle accelerators and neutron generators where radioactivity might be induced in the materials being handled by the particle beams. Great care should be taken to avoid the radioactive material being taken into the body by inhalation, ingestion or absorption through the skin or a wound.

Factors that influence the manner in which unsealed radioactive materials are handled include: its radiotoxicity, its volatility, the external radiation level, the nature of the work, and the design of the equipment and ultimately the design of the laboratory.

The decision concerning the manner of handling unsealed radioactive materials is the responsibility of the RSO and the safe implementaion is that of the worker.

A great many rules exist concerning the handling of this material, but in the final analysis the worker should:

(i) think the problem through, rehearsing his actions where possible;

(ii) use his common sense by minimizing the risk of breathing, eating or absorbing on his skin the radioactive material. In particular, eating, drinking or smoking in radioactive environments is to be avoided;

(iii) exercise caution and wear the appropriate protective clothing at all times;

(iv) be fully cognisant of the rules and regulations pertinent to the laboratory in which he is working. It is the duty of the RSO to ensure that this is so;

(v) ensure that he carries the appropriate radiation monitor and the RSO records his levels of exposure regularly;

(vi) have ready access to handbooks and textbooks on radiation safety, *e.g.* Brodsky (1982) and Stott (1983).

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International Commission on Radiation Units and Measurements, 7910 Woodmont Avenue, Suite 1016, Washington, DC 20013, USA.

International Atomic Energy Agency, Wagramerstrasse 5, PO Box 100, A-1400 Vienna, Austria.

World Health Organization, CH-1211 Genève 27, Switzerland.

National Health and Medical Research Council of Australia, PO Box 100, Woden, ACT 2606, Australia.

International Labour Organization, 4 route des Morillons, CH-1211 Genève 22, Switzerland.

OECD Nuclear Energy Agency, 38 Bd Suchet, F-75016 Paris, France.

National Committee on Radiation Protection and Measurement, C/- National Institute of Standards and Technology, Gaithersburg, MD 20899, USA.

Her Majesty's Stationery Office, PO Box 598, London SE1 9NH, England.

National Radiological Protection Board, Chilton, Didcot, Oxford OX11 0RQ, England.

Food and Drug Administration, 5600 Fishers Lane, Rockville, MD 20857, USA.

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