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Hazards of Operating Machine Sources of X-Rays

I. Hazards of Operating Machine Sources of X-Rays

The radiation from x-ray machines can be very dangerous, and such danger should not be minimized. On the other hand, there is no reason to be afraid to operate these machines after receiving proper training and instructions. The operator of an analytical x-ray machine should never become complacent or overconfident about the potential danger from an x-ray beam.

Numerous safety devices may be provided, but the user should not depend too heavily on these safety devices lest he become overconfident. If a safety device should fail unnoticed, serious injury may result. Adequate safeguards must be provided, but these can never replace constant vigilance and alertness to possible danger. Proper training in the operation of these machines should teach the nature of the hazards so that the user can be properly alert and vigilant.

The wavelengths of the x-rays used most commonly in x-ray diffraction and fluorescent x-ray spectroscopy fall in the range from approximately 0.5 to 10A. These are so-called "soft" x-rays which are readily absorbed in matter. A thickness of only a few mm or less of Al, Fe, or Pb is required to reduce the intensity of the transmitted beam to 1/10 that of the initial intensity even for x-rays with a wavelength of 0.5A. The 1.54A wavelength corresponds to CuKa radiation, and 1.93A is the wavelength of FeKa radiation. These are commonly used sources in x-ray diffraction work.

It is apparent that only relatively thin layers of shielding are required to protect against this radiation, but it is this same property that makes these x-rays very dangerous. They are highly absorbed in soft tissue, and severe burns can result from exposure of the hands, arms, skin or eyes to the direct or diffracted beams. The maximum permissible dose of radiation for various parts of the body are shown in Table I. For comparison, x-ray intensities that may be obtained with high-power tubes and strongly diffracting crystals are also shown in Table I. It is apparent that a dose of 100 to 500 times the permissible yearly dose may be obtained from a 1-second exposure to the most intense direct beam. Even a strong diffracted beam can deliver the maximum permissible yearly dose to the eye in less than 10 minutes.

II. Biological Effects of Intense X-Ray Beams

It is possible to provide a general classification of the kind of changes that ionization radiation can produce in skin. It is useful to categorize these effects into three areas.

A. Reversible changes.
B. Conditional reversible changes.
C. Irreversible changes

A. Reversible Changes

The most common and earliest reversible change is the production of reddening of the skin or erythema. If the dose and energy is low enough that most of the radiation is absorbed in the superficial layers of the skin, reddening occurs, then disappears apparently with no future effects. Another reversible change is the loss of hair or epilation. It is possible to give a dose of radiation that will stop cell division in the epithelial cells so that hair ceases to grow temporarily and falls out. With a low dosage, the hair will begin to grow after a period of time, with no apparent permanent ill effects. A third system that shows reversible effects are the sebaceous glands (oil-producing glands in the skin) which are temporarily affected to produce less sebum (oil secretion of these glands in the skin).

B. Conditional Reversible Changes

Pigmentation of the skin is not a totally reversible change. If a large area of skin is irradiated, erythema and pigmentation will occur with the pigmentation eventually fading. It has been shown that the resulting skin is not normal and has some "memory of the injury." Future doses of the same area do not produce the same skin response.

C. Irreversible Changes

If enough radiation of the proper energy is absorbed in the skin this will result in permanent destruction of either hair or sweat glands, or whole skin, with a resulting scar. The irreversible changes are categorized in the heading of:

1. Radiation Dermatitis
2. Chronic radiation dermatitis
3. Radiation cancer

A summary of the various effects to be expected after given acute dose to low energy x-rays and the time of exposure to receive the dose in the beam are given in Table II on page 75.

Sources of Exposure

1. The primary beam.
2. Leakage of primary beam through cracks in shielding.
3. Penetration of primary beam through shutters, cameras, beam stops, etc.
4. Secondary emission (fluorescence) from a sample or shielding material.
5. Diffracted rays from crystal.
6. Radiation generated by rectifiers in the high voltage power supply.

TABLE 1

NRC OCCUPATIONAL EXPOSURE LIMITS*
YEARLY LIMIT (mrem)

WHOLE BODY 5000
SKIN OF THE WHOLE BODY 50000
EXTREMITY 50000
LENS OF EYE 15000
MINORS (PERSONS UNDER THE AGE OF 18) 500
FETAL EXPOSURE 500/Nine months

*Note: State of Connecticut exposure limits vary slightly. For more information contact Radiation Safety.