PROBLEMS OF RADIATION PROTECTION IN X-RAY DIFFRACTION APPARATUS

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Analitical X-ray diffraction equipments are widely used in scientific research laboratories and in education establishments. Nowdays, these apparatus are being used also in industrial laboratories for quality and process control purposes.

The progresses in electronics and in technology have brought in the recent past to a great sophistication of X-ray diffraction equipments.

Since X-ray equipments are likely to be dangerous if mishandled, particular attention has been recently paid by the manufacturers in designing such apparatus.

While the industrial applications of X-ray diffraction, which require routine procedures, are carried out with modern equipments with high standard safety characteristics, in the research work the apparatus and their mode of operation may be different. In fact frequent modifications are required in order to obtain better performances suitable for the specific scientific work. This fact may represent a real health hazard for the operator particularly for the very high exposure rates close to the windows of the tube-shield. A certain number of accidents have been reported in the literature with consequent severe damage to the operator (1-3).

The present communication deals with an investigation on several (about 30) X-ray diffraction apparatus utilized in typical research laboratories, in order to obtain more detailed informations for a better guideline regarding some aspects of radiation safety.

The results of our analysis has allowed to locate and to weight different kinds of potential radiation sources.

Although the radiation produced in these apparatus is comparatively soft (5-50 keV) and the primary beam dimensions are rather small (because collimated with pinholes or slits), the intensity is very high.

The primary beam is particularly dangerous, since it represents the most concentrated radiation source.

A rough evaluation ($\pm$25%) of the primary beam exposure rate is given by the following empirical formula (14):

$$X = \frac{50\ ZVI}{74\ D^2}\ \text{R/sec}$$

where
$\dot{X}$ = exposure rate
Z = atomic number of the target material
V = tube voltage (kV)
I = tube current (mA)
D = distance from the focus (cm)

This formula is obeyed in the range 25-80 kV using 1 mm Be-filtration; other filters may change the exposure rate by a factor of 2.

It is to be noticed that without collimator, the primary beam diverging from the window of the tube-shield has an apex angle of 15-30° (depending on the dimension of the window hole). It follows that, close to the tube shield window, the exposure rate amounts to some thousands of R per second. A few seconds exposure to the hands of the operator exceedes the value of 60 rem, the maximum permissible annual dose, for this part of the body by causing serious somatic damages and reaching, some times, the amputation of the fingers.

Among the potential sources of radiation the direct beam is the most hazardous one.

The direct beam irradiation may be caused by:
- shutters failure;
- operator's error;
- inadequate instruction to the operator.

Other sources of potentially hazardous radiation are analyzed, even though the dose rate involved are very much smaller than those associated with the primary beam.

1. The leakage through gaps and cracks of shielding can reach values of the same order of magnitude of the primary beam. Such leakage radiation was never observed in our surveys and natural background values were measured around the shielding.

2. The faulty coupling between the tube-shield windows and cameras or collimators is observed mainly when the X-ray generator and the diffraction accessories are produced by different manifacturers. We have found such situation in several installations with an exposure rate of about hundreds mR/h. The problem is particularly serious not only for the relatively high exposure rate but also because the beams are very narrow and irregularly directed.

3. The secondary emission from the sample and other materials is uniformly distributed around the generator bench and presents a relatively low value of exposure rate (some mR/h).

4. The X-rays diffracted from the sample and other materials can reach values of the order of some R/h. The diffracted beams are particularly insidious since they exhibit small sections, irregular shape and can be oriented in whichever direction. Both secondary emission and diffracted rays constitute a real problem in the open cameras. These cameras are, therefore, the most hazardous

apparatus.

5. Exposure rate from 0 to 100 mR/h was found to be due to the nature and the number of the beam shutters and to their running mode. This hazard is typical of shutters of the old tube-shields.

Particular attention has been dedicated to the monitors used in this analysis. In order to obtain a reliable survey the monitor must have good sensitivity to low energy X-radiation (down to 10 keV and a good energy independence at very low photon energies. Moreover, because of the difficulty to locate the very narrow and irregularly directed escaping beams, a detector with a small window area is desiderable.

In our survey we have employed the following detectors:

- an IONEX 2500/3 dosimeter with a thin window Nuclear Enterprises ionization chamber 2532/3;
- a Victoreen survey meter mod. 471 with a thin window ionization chamber, used to calibrate the Eberline Geiger-Müller probe, mod. HP-190 and the Eberline NaI (Tl) scintillation counter mod. PG-2.

The experience gained in this survey tell us that the exposure rate measurement around the X-ray diffraction equipments can give rough estimates of dose rate, by employing the commercially available monitors. Therefore it is necessary to choose a suitable detector when actual measurements dose rate are required.

Moreover it is our opinion that the X-ray diffraction equipments are among the most potentially hazardous pieces of laboratory apparatus. They must be carefully overseen and handled with caution.

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