Chapter 9

X-rays and X-ray-Generators

Devices that generate X-rays, e.g., X-ray diffractometers and fluorescent X-ray analyzers (henceforth collectively referred to as “X-ray-generators”), have a risk of radiation hazards to human bodies. The “Nagaoka University of Technology Regulations for the Prevention and Control of X-Ray Hazards” has been established in accordance with the Industrial Safety and Health Act and Regulations for Prevention of Ionizing Radiation Hazards. Staff members who handle X-ray devices and need to enter the controlled area as part of their duties should apply for registration and seek permission from relevant authorities to engage in such types of work. Regulations are in place to prevent radiation hazards in the same manner as followed for RI and radiation-generating devices.

Section 1 X-rays

1 X-ray management

X-ray is an electromagnetic wave with a wavelength of 0.01–100 Å. It is harmful to the human body owing to its ionizing effect, and utmost care should be taken while handling such waves to avoid radiation exposure. In a normal X-ray tube, which generates X-rays by irradiating high-energy electron beams on the cathode metal, the generated X-rays have a superimposed spectrum of a continuous spectrum by *bremsstrahlung* with the maximum energy at the acceleration voltage (tube voltage) and an average energy of approximately 1/3 of acceleration voltage, and the energy of characteristic X-rays specific to the cathode metal. In addition, the energy diffracted X-rays are sometimes used. Since the energy of X-rays are ~100 kV at highest, the radiation shielding is relatively easy to be achieved. However, it should be carefully shielded considering the effects of leakage and scattering from gaps, since the intensity is high. Moreover, as X-rays are generated when electrons are irradiated, commercially available X-ray generators have interlock mechanisms that operate with various shielding and safety mechanisms (e.g., shielding covers) to avoid exposing radiation to users. Therefore, users should be familiar with the use of X-ray generators and their mechanisms to conduct experiments. X-ray generators are radiation managerially classified into two types; one is a type that the radiation control area is only inside devices, ant the other type is that the control area is required outside the devises. This classification depends on the structure of shielding, dose of X-rays leaking outside, and presence or absence of interlocks. The conditions for application and permission for use are different for each type. In summary, it is required to understand the mechanism and the characteristics of your using X-ray generator.

2 X-ray measurements

For X-ray detection, photographic method, fluorescence, and ionizing properties are used. Typical methods are listed in Table 9-1.

Table 9-1 X-ray measurement methods

Photographic method	X-ray films and dry plates
Counter tube method	Scintillation counters Geiger–Mueller counters and proportional counters Semiconductor detectors

The portable counter tubes (survey meters) are generally used to confirm which X-ray shielding is sufficient, although photographic methods can be used. Low-energy X-rays are difficult to detect by using ordinary radiation detectors. An effective measurement method should be selected to detect depending on the energy of X-rays.

3 Effects of X-rays on the human body

In the case of X-rays, the external exposure is dominant. The influence of X-ray is similar to dose of other radiation, and they damage the hematopoietic organs, gonads, eyes, and skin. For example, the radiation dose of X-ray that causes cataracts in the eyes is clinically estimated to be over 5 Sv.

Section 2 X-ray-Generators

The university is required to notify the Division of Industry-Academia Cooperation and Research Promotion when it intends to establish, expand, renovate, abolish, or change X-ray generators. When a room for the installation of X-ray generators is set up and is a controlled area, the X-ray facility manager is appointed, and X-ray equipment use manager is appointed for devices whose controlled area covers the inside of the device. In addition, staff members and others who use X-ray generators (here, “others” refer to students, co-users, and others who are not staff members of the university) and employees whose duties require them to enter the controlled area should register themselves in advance using the prescribed form and obtain approval from the president of the university. Employees and others who use X-ray equipment in a controlled area, or whose duties require them to enter such a controlled area, should be registered as X-ray workers, and those who use equipment in a controlled area covering the inside of the equipment should be registered as X-ray equipment users. The application will be automatically renewed until the applicants leave the university owing to retirement or graduation.

The registration of X-ray workers will be approved by the president based on the discussion among the Radiation Safety Committee according the results of medical examination, education, and training. After

registration, the individuals must undergo radiation dosimetry and medical examinations once every 6 months. Education and training after registration shall be conducted when there are changes in the trends of occupational accidents, socioeconomic conditions, and environments in the university. However, students should attend training after registration and when continuing their studies.

The registration of X-ray equipment users will be approved by the president based on the discussion among the Radiation Safety Committee according the results of education and training. After registration, the individuals must undergo radiation dosimetry and medical examinations once every 6 months. Education and training after registration shall be conducted when there are changes in the trends of occupational accidents, socioeconomic conditions, and environments in the university. However, students should attend training after registration and when continuing their studies.

X-ray facility manager and X-ray equipment use manager should receive education and training every year. The education and training should be used to reduce the radiation exposure of the personnel working in the facility or the personnel using the equipment.

The following precautions should be taken while using X-ray generators:

1 Precautions when using X-ray-generators

While using an X-ray generator whose installation room is a controlled area, or the controlled area needs to be accessed frequently, radiation exposure should be checked by the person in charge using a glass badge, a pocket dosimeter, or other radiation measuring devices. The user must be familiar with the functions and mechanisms of the device and must carefully handle it to minimize exposure to radiation. Utmost care should be taken while removing or modifying individual components. Any changes observed in the device must be notified in advance. The user should carefully adjust the device to avoid exposing fingers, arms, and other parts of the body to radiation. Ring-shaped dosimeters, which can be worn on the fingers, can be additionally used to check the exposure to radiation.

The X-ray generators, in which only the inside of the device is set as a controlled area, includes safety components, e.g., interlocks, installed on each part of the device to prevent X-ray exposure. Therefore, there is very little risk of X-ray exposure during normal use. However, the user must be familiar with the mechanism in advance and must carefully handle the device. Certainly, each component must not be inadvertently removed or altered. The device should be carefully adjusted as it is easy to expose fingers and arms to radiation. Ring-shaped dosimeters, which can be worn on the fingers, can be additionally used to check the exposure to radiation.

X-ray generators must be inspected annually to ensure safety.

While using X-ray generators, please refer to the university's Regulations on the Prevention and Control of X-Ray Hazards for details. Moreover, it is recommended to refer to the Regulations for the Prevention of Ionizing Radiation Hazards at https://elaws.e-gov.go.jp/document?lawid=347M50002000041. In

addition, one can apply for the X-ray work chief license, which can be obtained by passing an examination. With this license, one can become the X-ray work chief. Students who are conducting research using X-rays are encouraged to take the examination, as it may be a useful qualification in the future.

Article 50 of the Ordinance on Prevention of Ionizing Radiation Hazards states that the examination to obtain the X-ray work chief license should be conducted based on the following subjects:

1 Knowledge on X-ray management

2 Knowledge of X-ray measurement

3 Knowledge of the effects of X-rays on the human body

4 Knowledge of relevant laws and regulations

A person who holds a Type 1 Radiation Protection Supervisor License is also eligible to become the X-ray work chief. A Type 1 Radiation Protection Supervisor License can be obtained by passing an examination and then undergoing training. The cost of the training is relatively high; however, there is no time limit between passing the exam and receiving the training; thus, it is possible to receive the training after employment and take the exam. If you can secure funding, taking the exam to obtain the Type 1 Radiation Protection Supervisor License is recommended.

2 Other precautions

The high-voltage power supply applied to an X-ray tube is a DC power supply with an output of 50–60 kV and 30–40 mA. This voltage is extremely dangerous for those who come in contact. The replacement of the X-ray tube and maintenance and inspection of the equipment should be performed after the power is turned off and the high-voltage charge is fully discharged.