at the end of this chapter. Many specific details, too lengthy to include here, will be found in these handbooks.

6. *Transportation by Common Carrier*

The shipment of radioisotopes by rail or air is now controlled by the Interstate Commerce Commission, which has authority to enforce its regulations by the imposition of penalties for violations. This matter was taken under their supervision in 1947 when it had become apparent that the large volume of artificial radioisotopes currently requiring shipment demanded more adequate control than had existed previously.

The problem of shipping radioisotopes is complicated by the fact that undeveloped photographic film is also shipped by common carrier and is readily damaged by very small exposures to penetrating radiation. This problem had already been encountered with shipments of radium. The solution consisted in devising a method of packing and disposition of radioactive material in transit that would reduce the level of radiation at any point occupied by photographic film below that at which practical damage could occur. All packages of radioisotopes must be labelled in a prescribed manner showing the nature of the contents and the amount of emergent radiation.

These regulations are available from the Bureau of Explosives, 30 Vesey Street, New York 7, N. Y., as Supplement No. 10 to ICC 4670. Since all shipments of radioisotopes must comply with these regulations, it is incumbent on prospective shippers to become thoroughly familiar with them. An explanatory monograph has been prepared by Robley D. Evans, Chairman of the Subcommittee on Shipment of Radioactive Substances of the Committee on Nuclear Science of the National Research Council. This monograph is obtainable from the National Research Council, 2101 Constitution Avenue N. W., Washington 25, D. C., as Publication 205.

H. PROTECTION FROM X-RAYS

1. *Special Features*

Although the problem of protecting personnel from x-radiation is similar in many respects to that of protecting them from gamma rays, actual conditions frequently are very different. Physiological effects to be expected are much the same, and tolerance doses are measured in the same unit. Where the intensities and energies of the radiations differ considerably from those usually encountered with gamma rays from radioisotopes or accelerators, the details of protective arrangements must be modified to correspond.

The source of x-rays, the x-ray tube, because of its more extensive volume and the necessity of providing electrical conductors, increases the difficulty of shielding. Such bulky sources also scatter diffuse radiation in the vicinity, an effect that is more pronounced the higher the intensities of radiation generated.

In dealing with the protection of personnel engaged in this work, the electrical hazard from high potentials also must be discussed since this is about as frequent a source of injury as exposure to radiation.

2. *Protection from Electric Shock*

For industrial applications of x-rays, this problem can be divided into two general cases depending on the two types of generating equipment commonly used. One is the portable or semiportable unit in which all parts are built into a single enclosure and shielded electrically. In the use of this unit, the operator cannot take advantage of the electrical protection offered by insulating the surface of floors and surrounding objects. Rubber shoes and gloves may reduce danger of shock to some extent, but the only sure protection from shock is a continuous grounded metal enclosure for all parts of the unit, so that it is quite impossible for the operator to touch any part that is not at ground potential. This includes high voltage and low voltage cables, control panels, and all other exterior parts. The electrical bonds between these parts not only must insure permanent electrical union of the parts, but also should be substantial mechanically. In some cases, a single heavy cable connecting some part of the grounded system to a permanently earthed point, such as a water pipe, may be sufficient. However, in some types of equipment, high frequency currents may develop that will cause sparks to ground unless several grounds are used at frequent intervals.

The second type of x-ray generating equipment, which is less common, is built into one or more rooms, requiring all work to be brought to the x-ray tube. The same general rules apply to this equipment, but greater precautions must be used where parts cannot be permanently shielded. If the high voltage is generated in a separate room, provision must be made so that it is not possible to enter the tube room with the generator in operation. Also, a cut-off switch should be provided near the tube to prevent energizing the high-voltage transformer when a workman is in the tube room. If high voltage conductors are not enclosed in grounded shields, they must be at a sufficient distance from all points where persons may normally walk that there is no possibility of injury from a spark. This distance is about $7\frac{1}{2}$ feet for voltages below 225 kilovolts and correspondingly greater for higher voltages. Suitable signal lights are recommended to indicate various conditions of the generating equipment and should be so arranged as to avoid misinterpretation. In all cases a pilot light should indicate when the main switch controlling the generator is closed.

Overload circuit breakers of a sensitive and quick-acting type should be included in the primary circuit and adjusted to throw at 20 per cent above normal load.

The control panel of all x-ray generators should be located so that the x-ray tube is completely in view of the operator. This may be accomplished by some type of indirect viewing device to screen the operator from scattered radiation;