

tion of barriers and warning signs, stationing of attendants to keep personnel out of restricted localities, and, in extreme cases, complete closing of the areas. Safe exposure times and safe practices can be established through measurement and control, and by profiting from past experience.

Work with radiation can and should be so planned and managed that radiation exposures of employees and of the general public are kept to a minimum. No radioactive materials which can result in exposures above guide levels should be released through contaminated air or water, through loss of control over contaminated waste materials, equipment or shipments, or by employees unknowingly leaving the place of work with contamination on their persons, clothing, or shoes.

Consider the type of work involving radiation

The literature on radiation protection is an invaluable aid (see "References" at the end of this chapter). It is important to realize that any one of a wide range of operations may be under discussion, and that safety measures applying in one case may be inappropriate for another. The following examples point this out.

- Processing of feed materials for nuclear reactors and operations includes large-scale mining and processing of ores containing useful radioactive materials. Feed streams for separation and purification involve tons of materials, with a small percentage of radioactive materials which are then further processed and purified. The Atomic Energy Commission is closely associated with this.

- Certain kinds of work involve applications using radiation from radium, thorium, and other naturally occurring materials which are not controlled exclusively by the AEC. Some of these materials are used, for example, in luminous instrument dials, in gas mantles, in certain ceramic colors, and as radiation sources.

- Radiation fields occur in the operation of such devices as industrial, medical, and dental X-ray machines and X-ray diffraction machines, and cyclotrons and other particle accelerators. Relatively small amounts of

radiation are emitted in electronic tubes, television receivers, and electron microscopes (See NBS Handbooks 55, 76, 93 *Protection Against Betatron-synchrotron Radiation up to 100 mev*, *Medical X-Ray protection up to 3 Million Volts*, and *Safety Standard for Non-Medical X-Ray and Sealed Gamma-Ray Sources*).

- Industrial operations in which radioactive materials are of prime importance include fuel fabrication, shipment and transportation of radioactive materials, construction or operation of reactors, and chemical processing to recover or separate radioisotopes from spent fuel elements (See *Safety Series No. 6 Regulations for the Safe Transport of Radioactive Materials*, published by the International Atomic Energy Agency, Vienna, 1961, and also *Nuclear Energy Materials Handling Manual*, Helm's Express, Inc., P O Box 268, Pittsburgh, Pa 15230).

- Radiation is used in various operations to assist in quality control. Thickness gauges using X rays or gamma rays (Fig 44-5), or beta rays (Fig 44-6) have been used with great success to maintain tolerances on the thickness of continuous sheet strips. These devices are so mounted that the external field is a very minor source of exposure.

- Some static eliminators contain alpha emitters and are used in high-speed rolling of sheet material or in operations such as calendaring that involve the evaporation of flammable solvents.

- Radioactive tracers are used in analytical chemistry and to trace the flow of fluids in process. Parts of equipment may be irradiated to facilitate wear studies. Other material may be irradiated for purposes of sterilization or for use in chemical reactions.

Consider the sources of radiation

One must always consider the amount and kind of radiation sources which will be used in a contemplated operation. Then, suitable radiation safety operating standards can be decided upon to make sure procedures are safe. A number of examples of operations are presented in the following pages and may help to point out some basic