UNIVERSITY OF WASHINGTON

ENVIRONMENTAL HEALTH AND SAFETY LABORATORY SAFETY DESIGN GUIDE--

ADDITIONAL REQUIREMENTS FOR LABORATORIES WITH IRRADIATORS AND/OR RADIATION PRODUCING MACHINES

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Environmental Health and Safety
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X. ADDITIONAL REQUIREMENTS FOR LABORATORIES WITH IRRADIATORS AND/OR RADIATION-PRODUCING MACHINES

A. Introduction

Machines irradiators, and high activity non-sealed sources that produce ionizing radiation are common in research laboratories. These devices can include high-energy accelerators that require special shielding and control as well as devices that produce x-rays of such low energy and intensity that minimal shielding and controls is required. This wide variation in sources makes it difficult to write detailed guidelines for all radiation sources. It is important to involve the UW Radiation Safety Office (RSO) or a State of Washington Department of Health (Division of Radiation Protection) approved "qualified expert" in the processes related to design, installation, acceptance testing, and operations of all such sources.

The purpose of this chapter is to identify common irradiators, sources, and machines that produce external ionizing radiation at research facilities and to give general guidelines regarding the planning, installation, storage and use of these sources. For details, always refer to the UW RSO or "qualified expert".

Though these recommendations deal mostly with radiation sources found in research facilities, most campuses have medical x-ray facilities as well (e.g., hospitals, medical and dental clinics); therefore, limited comments regarding these facilities have been included. Typical sources include:

1. Machines:
    a) X-ray radiographic and/or irradiation facilities.
    b) Accelerator facilities.
    c) Analytical x-ray machines (e.g., x-ray diffraction, electron microscopes).
    d) Cabinet radiography units.
    e) Accelerators used for radioisotope production.

2. Radioactive Materials:
    a) Sealed sources.
    b) Irradiators.
    c) Moisture/density gauges.
    d) High activity non-sealed sources (i.e., sources which can produce high external radiation exposures, but do not satisfy the requirements to be considered sealed sources).

B. General Requirements/Considerations:

Early in the planning stages when an irradiator or x-ray producing device is planned for installation in a building, the RSO shall be consulted. There are numerous regulatory and design requirements that shall be addressed (e.g., registration, licensing and shielding).

1. The State of Washington Department of Health (DOH), Division of Radiation Protection, requires registration of x-ray machines. Also, when constructing or remodeling a room that will house a radiation machine, the registrant shall notify the DOH prior to the possession of the machine or commencement of the construction. This includes re-installing a machine in a previously constructed facility. All machine registrations are recorded through the UW Radiation Safety Office.

2. Sealed and unsealed sources of radioactive materials shall be licensed by the appropriate regulatory agency. Licensing is through the State of Washington DOH, as a representative of the Nuclear Regulatory Commission. The UW RSO and/or Radiation Safety Committee (RSC) approve all used of radioactive materials.

3. The shielding design shall be prepared by a "qualified expert" as defined in "National Council on Radiation Protection and Measurements Report No. 49 (NCRP 49)." The State of Washington Department of Health Division of Radiation Protection keeps a list of qualified experts approved to perform this type of work within the State. Additional requirements for shielding design and selection of qualified experts is described below in the section on facilities used for the healing arts.

4. All shielding designs, floor plans, and equipment arrangements, including final construction drawings, shall be reviewed and approved by the UW RSO and/or RSC.

C. Basis for Shielding Specifications

1. Facilities shall be designed such that the exposure limits specified in WAC 246-221 for controlled and uncontrolled areas are not exceeded when use and occupancy factors are taken into account. In addition, Washington Department of Health requires that shielding shall be designed to limit the dose equivalent in controlled areas to 10% of the regulatory limits. That is, 500 millirem/year. This requirement is in accordance with the intent of ALARA (keeping doses "As Low As Reasonably Achievable").

   Washington Administrative Code, and State of Washington DOH Division of Radiation Protection advisory documents

2. Shielding specified for uncontrolled areas must be based on the current 100 millirem/year regulatory limit. These newer, lower limits must be

adhered to in shielding calculations rather than higher values found in National Council on Radiation Protection and Measurement (NCRP) reports produced prior to 1994. In addition, some of the methodologies and assumptions (e.g., radiation attenuation data) have been updated since they were originally published. Even though there have been changes in some regulations, methodologies and assumptions, the basic information contained in these publications is sound and can serve as a basis for conservative shielding specifications if they are corrected for the current exposure limits.

NCRP 35, 39, 49, and 51

Washington Administrative Code, and State of Washington DOH Division of Radiation Protection advisory documents

In the following journal articles, new methodologies, assumptions and attenuation data are described for specifying shielding. It is expected that the concepts and practices proposed in these publications will be incorporated into a new NCRP publication that will eventually replace NCRP 49:

Dixon, R. L., "On the Primary Barrier in Diagnostic X-Ray Shielding", Medical Physics(Med. Phys) 21, 1785-1794 (1994)

Dixon, R. L., and Simpkin, D. J., "Primary Barriers for Diagnostic X-Ray Facilities: a New Model", Health Phys.(H. Phys) 74, 181-189 (1998)

Simpkin, D. J., "PIN A General Solution to the Shielding of Medical X and Gamma Rays by the NCRP Report 19 Methods", H. Phys. 52, 431-436 (1987)

Simpkin, D. J., "Shielding Requirements for Mammography", H. Phys. 53, 267-269 (1987)

Simpkin, D. J., "Shielding a Spectrum of Workloads in Diagnostic Radiology", H. Phys. 61, 259-261 (1991)

Simpkin, D. J. "Diagnostic X-Ray Shielding Calculations for Effective Dose Equivalent", H. Phys. 21, 893 (1994)

Simpkin, D. J., "Transmission Data for Shielding Diagnostic X-Ray Facilities", H. Phys. (1995)

Simpkin, D. J,. "Evaluation of NCRP Report 49 Assumptions on Workloads and Use Factors in Diagnostic Radiology Facilities", Med. Phys. 23(4) (1996)

Simpkin, D. J., "Scatter Radiation About Mammographic Units", H. Phys. (1996)

Simpkin, D. J., and Dixon, R. L., "Secondary Shielding Barriers for Diagnostic X-Ray Facilities; Scatter and Leakage Revisited", H. Phys. 74, 350-365 (1998)

D. Special Considerations

1. In facilities with high-energy radiation sources, walls, shielding and source components may become radioactive by the process of activation. The extent and magnitude or the activation is dependent on many factors including source "energy" and "on time". In many cases activation occurs but is not a significant concern since the radioactive materials produced have a very short half-life. The extent and magnitude of activation should be evaluated for sources with energies greater than fifteen million electron volts (MeV). When appropriate such facilities should be designed such that activation is reduced or activated materials may be removed easily.

   Good Practice

2. Exhaust ducts and collectors shall be located and/or shielded such that personnel exposures along its route of travel and at the collector are ALARA and do not exceed regulatory limits. Collectors shall be equipped with bag-in/bag-out capability and located such that there is adequate space to change out collectors without contaminating uncontrolled areas and with minimum disruption of uncontrolled operations. Since such ducting and associated collectors are often located in uncontrolled areas occupied by individuals who are unfamiliar with radiation, even small exposures may be alarming to the occupants. Therefore, it may be advisable to design shielding in order to reduce exposures far below regulatory limits or to provide additional training to the occupants regarding the effects of radiation.

   Good Practice

3. Radiation source transport systems ("rabbits") shall be routed and/or shielded such that exposure limits are not exceeded in controlled or uncontrolled areas during routine operations or emergency situations (e.g., stuck sources). To plan for emergency situations, an accident analysis shall be conducted and an emergency response plan prepared that will deal with any hazardous conditions that were identified.

4. For most single-floor facilities with energies less than 200 kVp (kilovoltage peak), shielding shall be extended from the floor to no less than seven feet high. In multi-floor/multi-level facilities, shielding walls may need to be higher than exactly seven feet. For single floor facilities with high-energy sources that can produce "skyshine," ceilings may require shielding and the shielding in walls may need to extend from floor to ceiling. In multi-level facilities, particular attention must be paid to floor shielding, since the useful radiation beam is often predominantly pointed downward.

   NCRP 49

5. Nails/screws penetrating shielding material are not required to be capped with lead in walls that require less than four pounds of lead per square foot.

6. For operator protection, source controls shall be located such that no first-scattered radiation reaches the control area. These controls shall also be located such that exposures from primary and secondary radiation do not exceed regulatory limits when use and occupancy factors are taken into account. The operator shall be allotted 7.5 sq. ft. or more of unobstructed floor space in control booths to allow ease of movement behind barriers. No dimension of this space shall be less than 2 ft. An extension of a straight line drawn between any point on the edge of the booth shielding and the nearest vertical edge of a cassette holder, corner of the examination table, or any part of the tube housing assembly shall not

impinge on this unobstructed space. The operator switch must be mounted so that the operator can avoid first-scattered radiation while energizing the machine. The requirement is for the switch to be permanently mounted 40 inches inside the protected control booth. A control booth-viewing window is required and shall have at least one square foot of viewing area. The viewing window must be equal or greater in lead equivalence to the shielding installed in the control booth walls.

Good Practice

WAC 246-225-030

7. Shielding required to protect people from radiation is often inadequate to protect unexposed film or emulsions stored near radiation sources. Shielding required to protect unexposed film or emulsions stored in areas near radiation sources shall be evaluated on an individual basis.

   Good Practice

8. The structure of the facility shall be designed (evaluated and updated for renovated facilities) to physically support required shielding (e.g., weight "cold flow"). It is important to recognize that some shielding materials (e.g., lead) can "cold flow" with time, particularly for tall and thick sections. It is necessary to support shielding in a way that will address this problem or to use an alternative shielding material (e.g., iron or concrete).

9. Some radiation sources and associated shielding are extremely heavy, so the structure of the facility may need to be specially designed (evaluated and updated for renovated facilities) to physically support the equipment.

10. Shielding and equipment shall be designed and installed to meet seismic restraint requirements.

    State and local building requirements

11. Hazards associated with moving heavy shields, high voltage, and high magnetic fields are often present around radiation sources. Often, special administrative and engineering controls are required to deal with these hazards safely.

12. Exhaust systems for hazardous materials (e.g., ozone, cryogens, gaseous activation products) produced or present around radiation sources need to be designed to maintain exposure levels for hazardous materials below the respective occupational exposure limits (OEL). Care shall be exercised in selecting the discharge points for these exhaust systems.

    Industrial Ventilation, a Manual of Recommended Practice, latest edition

13. Interlocks are often required on access doors to radiation sources or on required shielding components that are movable. They disable the production of radiation if doors are not closed or if shielding is not positioned as required to provide adequate protection to controlled or uncontrolled areas. Such interlocks shall be failsafe and tamper resistant.
14. Emergency "Off" (mushroom) switches are typically required in areas where exposures to individuals could exceed the limits established by the RSO and/or RSC if administrative or engineering controls should fail. Such switches shall be centrally located and in sufficient number so each potential user has convenient access.
15. Warning lights, audible signals and signs shall be in compliance with the requirements in WAC 246-225, 227, 228, and 229. Signage shall be in compliance with the requirements in WAC 246-221, 225, 227, and 228.

    Washington Administrative Code
16. Radiation area monitors are typically required when exposure rates are such that the exposure of an individual in the area could exceed institutional administrative controls specified by the UW RSO and/or the RSC.

    Washington Administrative Code

    UW Radiation Safety Committee

E. Pre-use Considerations

1. The UW RSO or State of Washington Department of Health approved "qualified expert" shall inspect shielding during construction to assure that it is installed according to specifications. Deficiencies shall be corrected prior to operation of the facility. After construction, the attenuation of shielding can sometimes be verified using a radiation source, however this is not an optimum method. Attenuation measurements can help determine the overall effectiveness of shielding, but cannot easily find small voids in the shielding.
2. A radiation survey of adjacent controlled and uncontrolled areas before use of a radiation source shall be conducted at the discretion of the UW Radiation Safety Office. The RSO usually finds it necessary to make measurements to assure that shielding is adequate to meet regulatory exposure limits and/or limits specified in the shielding design. The radiation survey should be conducted under conditions that are representative of actual operating conditions at the facility. Deficiencies shall be corrected prior to operation of the facility.

F. Facilities/Sources With Special Considerations

1. If a radiation source is totally surrounded by a shielded enclosure with "failsafe" interlocks on all access doors, no additional shielding is usually required to prevent or reduce x-ray diffraction. The RSO should be consulted for details.

2. Special consideration should be given to the storage location for moisture/density gauges. Storage locations may need to be shielded or in remote locations where the exposure limits for controlled and uncontrolled areas are not exceeded. The RSO should be consulted for details. Adequate security measures for the storage area need to be provided to prevent unauthorized removal.

3. Conventional electron microscopes operating at less than 40 kVp must be registered with the UW Radiation Safety Office, but may be exempt from shielding requirements. The RSO should be consulted for details.

G. Considerations For Facilities/Sources Used For the Healing Arts

Some facilities/sources are not covered specifically by these recommendations; however, most of the "General Requirements/Considerations" apply, as do additional requirements. It is important to remember that all facilities with radioactive materials and/or machines shall be reviewed and approved by the UW Radiation Safety Officer and/or Radiation Safety Committee prior to installation/operation. Due to the many safety and regulatory aspects related to the design, installation, commissioning and operation of such facilities, early involvement of the facility RSO is advisable. Unanticipated corrective actions can result in unpleasant, unnecessary, costly delays.

1. Clinical and Veterinary facilities/sources are as follows:

    a) Diagnostic Medical: Radiographic (e.g., fixed, portable, mammography), Fluoroscopic (e.g., fixed, portable), Cine, CT, Bone density, Nuclear medicine imaging, PET imaging

    b) Diagnostic Dental: (Radiographic, Cephalometric, Panoramic, CT)

    c) Therapy: (Accelerators, Brachytherapy sources, HDR, Gamma Knife, Ortho-voltage units, Grenz rays, Intravascular brachytherapy devices)

Some important considerations for facilities/sources used for the healing arts are as follows:

2. Clinical Facilities shall include:

    a) Equipment for human use which meets FDA requirements

    b) Equipment, all of which has been checked for compliance with regulatory requirements prior to commissioning for use on patients. Equipment at JCAHO-accredited facilities shall be commissioned by

a qualified expert prior to use.

c) Facilities and/or equipment, which provide the operator with the ability to communicate with and view the patient continuously from an area protected from primary, secondary and first-scatter radiation (i.e., a controlled area) when patients are being exposed/irradiated. Exceptions to this general rule are operators of portable diagnostic x-ray equipment used at non-fixed locations, and most nuclear medicine imaging equipment. For most of these exceptions, the operator shall be at least six feet from the source of radiation and out of the primary beam.

3. Before construction, the floor plans and equipment arrangement of medical installations utilizing x-rays for diagnostic or therapeutic purposes shall be submitted to a "qualified expert" for shielding design plan review. The "qualified expert" shall be approved by the State of Washington DOH Division of Radiation Protection and shall adhere to shielding methodologies in the "National Council on Radiation Protection and Measurements Report No. 49" (NCRP 49), or equivalent. Completed shielding designs shall be submitted to the DOH for subsequent "plan review". Diagnostic veterinary, podiatric, and dental facilities are exempt from plan review by the DOH. A copy of the DOH submittal and any approval documents or other communication from/to the DOH must also be forwarded to the UW RSO.

   Washington Administrative Code 246-225

4. For dental radiographic facilities, the ordinary walls in a building (two layers of 5/8 inch drywall) often provide adequate shielding to protect surrounding areas. It should be noted that one of the common layouts for dental equipment puts the head of the dental chair adjacent to central work or patient areas. Unless modified, this common layout can result in the unacceptable practice of exposing the central work or patient areas to unshielded primary radiation. For general stationary dental intraoral equipment, the control switch shall be permanently mounted in a protected area no less than 36 inches from access to the direct scatter radiation field. Because of the many variables involved, the UW RSO or designee shall evaluate the shielding in each dental x-ray room.

   JCAHO recommendations

5. The UW RSO or designee shall evaluate the shielding (design and testing) for each veterinary radiographic facility or room.

   NOTE: Operator control booths are not always required for these facilities.

6. Provisions should be made for storage of leaded aprons in medical fluoroscopic and cine facilities.

   Good Practice

7. Medical bone density units seldom require operator control booths or additional shielding. However, the UW RSO or designee should evaluate each unit.

   Good Practice

8. Each control booth shall have at least one viewing device so the operator can view the patient during exposure, and have a full view of entries into the room when using medical diagnostic and therapeutic equipment. If electronic viewing equipment is used, an alternate viewing system shall be available as a backup in the case of electronic failure.