NCRP REPORT No. 59

OPERATIONAL RADIATION SAFETY PROGRAM

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Recommendations of the NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS

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Preface

This report is intended to provide, in a systematic way, the philosophy and the basic principles and requirements for an operational radiation safety program. A broad, uniform set of program recommendations and recommended practices is presented that will be helpful to management as well as to the expert in radiation protection. This report includes a range of subject material that is applicable not only to a large facility but also, in parts, to a small one. The report is not a manual nor does it contain detailed specifications and procedures; it can serve, however, as a useful guide for the preparation of working documents.

It will be apparent that each topical heading in this report could constitute the basis for an individual report. In a number of cases such reports are now available: NCRP Report No. 49, *Structural Shielding Design and Evaluation for Medical Use of X Rays and Gamma Rays of Energies Up to 10 MeV*; NCRP Report No. 50, *Environmental Radiation Measurements*; NCRP Report No. 51, *Radiation Protection Design Guidelines for 0.1-100 MeV Particle Accelerator Facilities*; and NCRP Report No. 57, *Instrumentation and Monitoring Methods for Radiation Protection*. In addition, reports on bioassay and waste disposal are in preparation. Additional reports are contemplated on subjects such as training, emergency planning, and warning and security systems. The fact that these detailed treatments are, or will be, available does not vitiate the need for the general, overall exposition of philosophy and basic principles provided in this report.

The Council has noted the adoption, by the 15th General Conference of Weights and Measures, of special names for some units of the Système International d'Unités (SI) used in the field of ionizing radiation. The gray (symbol Gy) has been adopted as the special name for the SI unit of *absorbed dose, absorbed dose index, kerma,* and *specific energy imparted.* The becquerel (symbol Bq) has been adopted as the special name for the SI unit of *activity* (of a radionuclide). One gray equals one joule per kilogram, and one becquerel is equal to one second to the power of minus one. Since the transition from the special units currently employed— rad and curie—to the new special names is expected to take some time, the Council has determined to continue, for the time being, the use of rad and curie. To convert from one set of units to the other, the following relationships pertain:

$$1 \text{ rad} = 0.01 \text{ J kg}^{-1} = 0.01 \text{ Gy}$$
$$1 \text{ curie} = 3.7 \times 10^{10} \text{ s}^{-1} = 3.7 \times 10^{10} \text{ Bq (exactly)}.$$

The present report was prepared by the Council's Scientific Committee 46 on Operational Radiation Safety. Serving on the Committee were:

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The Council wishes to express its appreciation to the members and consultants for the time and effort devoted to the preparation of this report.

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Bethesda, Maryland
March 1, 1978

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1. Introduction

For many years the National Council on Radiation Protection and Measurements (NCRP) and its predecessors have provided extensive recommendations dealing with many aspects of radiation protection (see NCRP Publications, page 55). The objective of this report is to describe the elements of an operational radiation safety program incorporating many of these recommendations. An effective radiation safety program can do much to reduce exposures to a level as low as practicable within the NCRP recommended dose limits and to minimize the potential for accidental exposures.

There is, of course, great variability in the complexity and magnitude of radiation safety problems. Clearly, the radiation safety program for a nuclear power plant must be very different from that required for a small medical group. However, the basic principles and practices of radiation safety are common to virtually all programs. This report emphasizes these common principles and practices, but leaves the development of a specific facility program to the individuals involved.

A small, independent user, such as a private physician practicing with a diagnostic x-ray machine or an individual scientist working with small amounts of radioactive materials, will find this report contains more information than he requires, but the general philosophy and some of the specific technical details will be useful. Senior management personnel will find this report useful in providing a summary of the needs and requirements of the radiation safety program. Professional health physicists may find useful information in support of their programs. Extensive bibliographies are provided at the end of each section for those who wish to pursue the topics in greater detail.

The use of shall/should for recommendations as practiced in most NCRP reports has not been followed in this document. This report is entirely advisory in nature so that the mandatory shall is not used. Should is used to denote a recommendation without regard to the importance of the radiation safety implication.

2. Organization of Radiation Safety Programs

Every organization utilizing sources of ionizing radiation should give consideration to the radiation safety measures that are necessary to protect the health and safety of its employees and the general public. The authority and responsibility for radiation safety should originate at the highest level of organizational management and should be emphasized downward through the supervisory chain. Although independent consultation may be appropriate, the responsibility for safety should be an integral part of the organization. Ultimately, the individual employee should be made aware of his own responsibility for safety.

The specific form of organization necessary to implement a radiation safety program will vary with the relative degree of hazard of the operation. In situations where the use of radiation is minimal and the hazard is small, permanent employees specializing entirely in radiation safety may be unnecessary. Periodic review by and assistance from radiation safety consultants may be useful in these cases. In larger radiation utilization programs, a qualified individual (see Section 2.1) should be designated as the Radiation Safety Officer.

Organizations utilizing complex and varied sources of radiation should appoint a radiation safety committee (see Section 2.2) with authority to review any matter affecting radiation safety and to make recommendations for senior management approval.

The success of a radiation safety program depends on a firm management commitment to the program, clear understanding of safety responsibility, competent personnel, and adequate funding. Such support is essential for the establishment of effective programs for the safe and efficient conduct of facility operations.

2.1 Radiation Safety Officer

This individual should report to top management in a staff capacity and should have ready access to all levels of the organization. The role of the Radiation Safety Officer (RSO) is to provide specialized assistance and guidance to the operating groups in the development of the radiation safety aspects of their programs. He should also serve in an audit role to determine if established programs are being maintained and are adequate for present needs. The RSO should be provided sufficient funds to conduct an adequate program. Costs of this program should be budgeted in a manner that eliminates daily competition with other needs. The appointment of an RSO should in no way remove or reduce the responsibility of the user and his supervisor to conduct operations in a safe manner.

The minimum qualification of the RSO will depend upon the magnitude of the potential hazards and complexity of the operation. He should possess an appropriate academic background together with practical radiation safety experience germane to the operation. Specialized education in health physics at the undergraduate or college level, combined with practical experience, is preferable. The American Board of Health Physics certifies professional health physicists who meet its requirements.[1] An individual who is certified or has equivalent qualifications is therefore generally considered suitable to serve as an RSO for organizations utilizing complex and varied sources of radiation.

2.2 Radiation Safety Committee

The Radiation Safety Committee should be composed of three or more members, each possessing some background and competence in radiation utilization and radiation safety. Representatives of management, such as a comptroller, attorney, administrator, or procurement agent may be added to insure that the financial, legal, and business interests of the organization are considered. The RSO should be an ex-officio member. The committee should meet at regular intervals to review and audit the effectiveness of the radiation safety program. Special meetings should be called as requested by the RSO to review specific radiation safety questions or problems. The committee should require the submission of written radiation safety analyses of proposed programs and operations where radiation and/or contamination are involved. This submission should include standard operating procedures detailing actions to be taken in normal and emergency situations. The proposals should be prepared by, or under the authority of, the radiation user and be reviewed by the RSO prior to submission to the committee. Minutes of committee activities should be maintained.

[1] ABHP (1976). American Board of Health Physics, "Requirements for application for certification by the American Board of Health Physics," Health Phys. 31, 257.

2.3 Records Keeping

Documentation is needed as evidence to support the reliability and effectiveness of a radiation safety program. Among the records that should be considered for retention are:

(1) dose equivalent data for all personnel who have worked at the facility and for all visitors;
(2) radioactive materials inventory and disposal;
(3) radiation survey data;
(4) surface contamination survey data;
(5) airborne radioactivity data;
(6) bioassay data;
(7) training program descriptions and attendance;
(8) radioactive effluent data;
(9) environmental monitoring data;
(10) safety reviews of facility designs and operations;
(11) unusual occurrences of operational failures; and
(12) quality assurance data.

The records should be complete to the extent that they reveal the patterns of radiation exposure and working conditions at the facility. Data on typical operating and working conditions should be available for different modes of operation.

Radioactive effluent records, to the extent that the data are generated, should account for specific releases and show the amounts of radioactivity involved, the concentrations of the various radionuclides, and the time-related and dispersion aspects of the releases.

Significant information from some of the records (e.g., radiation status of plant and personnel) may have to be retained throughout the life of the facility. At the conclusion of the facility's operation, this information should be re-examined for further retention against two criteria: (1) records needed to establish personnel exposure history for medical/legal reasons; and (2) records needed to characterize the radiological status of the shut-down facility.

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3. Facility Design

Properly designed facilities allow for a much higher degree of safety than can be obtained by dependence on administrative rules and procedures in inadequate facilities. While good design can never eliminate the possibility of accidental radiation exposure or contamination, the probability and magnitude of such accidents can be greatly reduced. Proper facility design is also the most effective approach in reducing unnecessary occupational exposures. Proper attention to the radiation protection and control aspects of facility design can also minimize operating difficulties imposed as a result of radiation exposure or safety problems.

A qualified expert (defined in Appendix A) should participate in the planning and design stages of new or modified radiation facilities to ensure incorporation of proper radiation safety features. Competent review in these stages will permit the facility's operation within established safety standards and maintenance of radiation exposure at levels which are as low as practicable with minimal adverse operational effects.

3.1 Site Selection

The type and magnitude of potential radioactive material release and anticipated environmental radiation levels are the important factors in site selection. One can categorize site selection in two general ways. The first way is concerned only with external radiation, direct or scattered, such as that associated with an x-ray unit, a sealed source, or an accelerator. Within the limits established by the need to keep radiation levels as low as practicable, the most important consideration for the location of these devices is economic. The x-ray suite located in the basement is likely to need less added shielding than one above grade. The accelerator located on a large, open reservation needs less shielding to reduce exposure to the members of the public than one located on a crowded urban campus.

The second way is concerned with release of radioactive materials to the environment during normal and abnormal operations. The design should preclude or minimize the release of radioactive contaminants. Meteorological and hydrological parameters must be evaluated if radioactive materials will be released. Such analyses are particularly necessary for complex facilities such as reactors, high-energy accelerators, and fuel reprocessing facilities.

3.2 Facility Layout

Facility layout is an important aspect of design and an inherent aspect in the implementation of the as low as practicable philosophy. Functional portions of the facility need to be located properly, relative to each other, for efficient operations, for ease of movement of supplies, components, and equipment into and out of the processing areas, and for maintenance. The layout must also consider the movement of personnel into and out of the facility, as well as source storage and radioactive waste disposal. Facility layout is a major determinant in the prevention and control of accidents and in the control of occupational exposure.

A facility for handling significant quantities of unsealed radioactive materials is best designed with various zones of contamination control determined by the amount or type of radioactive material used and the potential for contamination. These zones should range from clean office and lunchroom areas to radioactive materials processing and containment areas.

Facilities in which high radiation areas will be present should be designed to reduce exposure to as low as practicable and to facilitate access control. The isolation of areas by increasing radiation levels may be important in attaining these goals.

Traffic patterns within the facility should be designed to keep work areas for significant quantities of radioactive material isolated from other personnel activities not related to these functions. A personnel monitoring area and a protective clothing change room should be established adjacent to the entrance to areas used for the handling of radioactive materials. In addition, facilities to decontaminate components, equipment, areas, and workers may be necessary.

Facilities and equipment for the collection, isolation, handling, processing, and disposal of radioactive solid, liquid, and gaseous waste should be provided at a convenient location near the place of generation or use of these materials.

3.3 Equipment and System Design

In addition to designing the facility layout to maximize radiation protection and operational efficiency, it is important to consider specific equipment and system items. Some equipment may become highly radioactive or contaminated. Such equipment should be designed for accessibility, ease of maintenance, ease of removal and reinstallation, ease of decontamination, and other features to reduce the time needed in the vicinity of the equipment. Selection of materials should be considered so that induced activity and contamination levels can be minimized and decontamination efforts and service life are optimized.

3.4 Shielding

Appropriate shielding is necessary to reduce exposures to workers and the public to levels that are below dose limits consistent with the as low as practicable philosophy. The use factor of the radiation producing equipment, occupancy times, work load, and estimates of potential increases in these parameters should be taken into consideration. It is generally unwise to design shielding for radiation exposures at or near the allowable dose equivalent limits. Personnel may be irradiated additionally from work inside the shield or from sources of radiation other than the one being shielded.

Various materials are used for shielding, depending on the type of radiation, the source term, and the desired final dose-equivalent rate. Although shielding should be an integral part of the initial layout of the facility, there are situations where the need for flexibility may be overriding, e.g., experimental facilities. In these situations, other items such as floor loading must be considered to assure that future additions can be accommodated. In some situations, changes in shielding are frequently difficult to accomplish and often cannot bring about the desired dose-equivalent rates without considerable effort, additional cost, and loss of planned work space. For these reasons, it is wise to design shielding to accommodate all known future increases in workload.

3.5 Ventilation

Proper ventilation is necessary to control the movement of airborne radioactivity in order to prevent or minimize irradiation from internally-deposited radionuclides and the spread of contamination within the facility.

Operations that routinely produce airborne contamination should utilize engineered containment and ventilation systems to prevent airborne releases. Appropriate respirators may be used in accordance with the requirements specified in Section 6, but only when effective engineering controls are not feasible.

The design of the ventilation system should provide for proper air flow under all conditions including open and closed positions of doors and windows and changes in setup. The flow should always be from clean areas to contaminated areas. Recirculation of air should be avoided unless the system has been specifically designed for such use. Exhaust air filters or traps should be considered to assure that releases are as low as practicable. Filter systems should be designed for easy access, removal, contamination control, and in-place testing. Exhaust vents and stacks should be carefully engineered and located to avoid recirculation of exhaust air via intakes to the ventilation system. The design should also include provision for modifying the ventilation during an accident, e.g., containment, use of a redundant system, use of a by-pass system, and change in flow rates. Controls for the ventilation system should be located in an area that will be readily accessible in the event of an accident. Ventilation systems should be reviewed for fire protection requirements.

3.6 Radioactive Sources and Waste: Clean-up, Disposal, and Storage

In order to assure ease of clean-up, surface materials which are easy to decontaminate should be used. Sinks and drains for radioactive liquid waste should be provided for clean-up in radioactive work areas. Holding and sampling tanks, as well as processing or radioactivity removal systems, may be required for contaminated waste drains and sinks to assure that radioactive effluents do not exceed permissible levels.

To reduce unnecessary exposure, storage areas for radioactive materials should be provided in areas separate from work places. Ventilation should be provided for storage areas for radioactive material when airborne releases are possible. Access to these areas should be restricted to authorized personnel.

3.7 Facility Design Bibliographies

3.7.1 *Facility Design Bibliography*

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