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REGULATORY GUIDE

OFFICE OF STANDARDS DEVELOPMENT

REGULATORY GUIDE 8.8

INFORMATION RELEVANT TO ENSURING THAT OCCUPATIONAL RADIATION EXPOSURES AT NUCLEAR POWER STATIONS WILL BE AS LOW AS IS REASONABLY ACHIEVABLE

A. INTRODUCTION

Paragraph 20.1(c) of 10 CFR Part 20, "Standards for Protection Against Radiation," states that licensees should make every reasonable effort to maintain exposures to radiation as far below the limits specified in that part as reasonably achievable. This guide provides information relevant to attaining goals and objectives for planning, designing, constructing, and operating a light-water reactor (LWR) nuclear power station to meet the criterion that exposures of station personnel[1] to radiation during routine operation of the station will be "as low as is reasonably achievable" (ALARA). Major accident situations and emergency procedures are not within the scope of this guide.

Much of the information presented in this guide also is applicable to nuclear power stations other than those cooled with light water. The applicable goals and objectives should be used for all nuclear power stations until more specific goals and objectives are available for other types of power reactors.

B. DISCUSSION

The relationship between radiation dose and biological effects is reasonably well known only for doses that are high compared with current annual dose limits and only when such doses are delivered at high dose rates.[2] An *ad hoc* committee of the National Council on Radiation Protection and Measurements (NCRP) (Ref. 1) chose in 1959 to make the cautious assumption that a proportional relationship exists between dose and biological effects and that the effect is not dependent on dose rate. Essentially, this amounts to an assumption of a non-threshold, "linear" (straight line) dose-effect relationship.

The International Commission on Radiological Protection (ICRP), the Federal Radiation Council (FRC), and committees of the National Academy of Sciences/National Research Council (NAS/NRC) have used this hypothesis to estimate conservatively the number of possible biological effects that statistically may be associated with exposures to radiation.

The NAS/NRC Biological Effects of Ionizing Radiation (BEIR) Committee (Ref. 2) reiterated that the assumption of a non-threshold linear relationship between dose and biological effects independent of the dose rate should be applied for radiation protection purposes. The radiation protection goal is to reduce doses wherever and whenever reasonably achievable, thereby reducing the risk that is assumed (for radiation protection purposes) to be proportional to the dose.

Merely controlling the maximum dose to individuals is not sufficient; the collective dose to the group (measured in man-rems) also must be kept as low as is reasonably achievable. "Reasonably achievable" is judged by considering the state of technology and the economics of improvements in relation to all of the benefits from these improvements. Under the linear non-threshold concept, restricting the doses to individuals at a fraction of the applicable limit would be inappropriate if such action would result in the exposure of more persons to radiation and would increase the total man-rem dose.

[1] "Station personnel," as used in this guide, includes all persons working at the station, whether full-time or part-time and whether employed by the licensee or by a contractor for the licensee.

[2] Throughout this guide the word "dose" will allude to "dose equivalent," the term used for radiation protection purposes, with the unit expressed in "rems."

The radiation protection[1] community has recognized for many years that it is prudent to avoid unnecessary exposure to radiation and to maintain doses ALARA. In addition to reduced biological risks, the benefits of such practices may include avoidance of costs for extra personnel to perform maintenance activities and avoidance of non-productive station shutdown time caused by restrictions on station personnel working in radiation areas.

Annual collective radiation dose equivalents received by personnel working at an LWR nuclear power station have ranged from less than 100 man-rems to over 5,000 man-rems (Refs. 3 and 4). Typically, annual collective dose equivalents range from 400 to 1,000 man-rems at LWR stations that have been in operation from 2 to 14 years and have generating capacities ranging from less than 100 MWe to 800 MWe. In view of the anticipated growth of nuclear power stations over the next few decades and the radiation exposure experience to date, additional efforts to reduce radiation doses to nuclear power station personnel are warranted.

The wide range in collective radiation doses to station personnel among the various stations appears to be primarily a function of doses received in maintenance operations in radiation areas. Some data are available to permit estimates of the distribution of doses among broad job categories and among the equipment systems or components that represent substantial sources of exposures. Doses to station personnel are influenced by many variables, including the ability of fuel elements to retain fission products, the extent of deposition of activated corrosion products throughout the primary and auxiliary coolant systems, the reliability of other specific equipment, the station layout, and radiation protection programs.

If design reviews or inspections had revealed that radiation exposures at nuclear power stations were unavoidable or that the cost of reducing the exposures would be unreasonable, the exposures might be considered ALARA by definition. However, this has not generally been the case. In many instances, poor supervisory practices or radiation protection inadequacies of one kind or another have been recognized as contributing factors to unnecessary exposures.

A major portion of the radiation exposure of station personnel is received during maintenance, radwaste handling, inservice inspection, refueling, and nonroutine operations. The decommissioning process also has a potential for substantial exposures to personnel. Effective design of facilities and selection of equipment for systems that contain, collect, store, process, or transport radioactive material in any form will contribute to the effort to maintain radiation doses to station personnel ALARA.

Products of erosion or corrosion (i.e., "crud"[4]) that become mobile and are activated constitute an important (perhaps principal) source of radiation with respect to the exposure of station personnel. (Crud is accumulated in and transported by the coolant. Some components of the crud become radioactive when passing through the reactor core. Migration of crud to other systems occurs with coolant or steam. Specific radionuclides that have been identified in crud and that can contribute substantially to the radiation source are Co-58, Co-60, Mn-54, Zn-65, and Zr-95.)

Exposures of station personnel who service equipment contaminated by crud can generally be reduced substantially by minimizing the formation of crud and by designing or modifying equipment to minimize locations where crud can deposit and accumulate. Provisions for isolating components and flushing with crud-removing fluid, such as demineralized water, can often reduce accumulations prior to activities such as maintenance or equipment replacement.

Station and equipment layout also can affect the potential for radiation exposures. Exposures at sites where multiple radiation sources exist sometimes can be reduced by additional separation of individual sources. Adequate space for ease of maintenance and other operations can permit the tasks to be completed more quickly, thereby reducing the length of exposures. Shielding by structural materials, equipment, and auxiliary or permanent shields can reduce exposures by isolating radiation sources. Where equipment components constitute a substantial radiation source that cannot be effectively reduced in-place, features that permit the removal of such components for maintenance at remote locations often can be effective in reducing exposures. The use of remote-handling features also can reduce exposures of station personnel in certain instances.

Station technical and supervisory personnel, working closely with radiation protection personnel, can reduce exposures by planning activities of personnel who must enter radiation areas, by studying the actions and procedures of individuals working in such areas, and by conducting post-operation debriefings on projects resulting in substantial exposures to iden-

[1] The term "radiation protection," as used in this guide, is considered to be synonymous with the term "applied health physics"; i.e., the development and implementation of methods and procedures necessary to evaluate radiation hazards and to provide protection to man and his environment from unwarranted exposure.

[4] "Crud" is corrosion and erosion products and other solids that are formed by chemical and physical reaction between the reactor coolant and structural materials.

tify how procedures might be modified to reduce exposures on subsequent similar tasks. Training programs for all station personnel can establish and reinforce the principles of radiation protection as applied to specific job functions. By making personnel aware of the methods and the special equipment and protective equipment available to them, potential radiation doses can be reduced.

The concept of maintaining occupational radiation exposures ALARA does not embody a specific numerical guideline value at the present time. Rather, it is a philosophy that reflects specific objectives for radiation dose management in

(1) Establishing an ALARA program;
(2) Designing facilities and selecting equipment;
(3) Establishing a radiation control program, plans, and procedures; and
(4) Making supporting equipment, instrumentation, and facilities available.

When an adequate data base, including economic information, is available, the criteria for keeping annual collective doses to station personnel ALARA might be derived or selected in numerical terms. However, a data base of operating experience and cost information to provide quantitative guidance for establishing such criteria is not available at this time, and the criteria for meeting the provision of § 20.1(c) of 10 CFR Part 20 must therefore take the form of qualitative guidance (e.g., goals, objectives, and statements of good practice).

The NRC staff has not performed a cost-benefit analysis for each of the considerations discussed or presented in Section C of this guide. This guide presents goals and objectives that were selected to satisfy the principles of the ALARA philosophy and criteria. Attaining these goals and objectives will require good engineering judgment on a case-by-case basis. A cost-benefit analysis may be helpful in arriving at the judgment, but it should not be the decisive factor in all cases.

The nuclear steam supply system (NSSS) vendor, the designer, the architect-engineer (A/E), the constructor, and the operator of the nuclear power facility each have responsibilities related to the ALARA effort; thus, coordination and cooperation are essential to achieving the ALARA goals and objectives.

This guide is written primarily for the applicant or licensee. However, the designer, the A/E, and the constructor will find many of the guide's considerations helpful in the design and construction process to ensure that their efforts are consistent with the needs of the applicant or licensee to maintain radiation exposures ALARA.

Specific design or operational objectives for maintaining radiation exposure ALARA are suggested by the parameters that determine the magnitude of doses to station personnel, both as individuals and as a group. Doses to personnel in nuclear power stations are predominately from external exposure, i.e., from radiation sources external to the body. However, there also exists a potential for doses from internal exposures, i.e., from radioactive materials taken into the body.

Important parameters in determining doses from external exposures are (1) the length of time that the receptor remains in the radiation field and (2) the intensity of the radiation field. Some degree of exposure of station personnel cannot be avoided during the operation and maintenance of nuclear power stations. However, there are many ways by which the exposures and resultant doses can be minimized by reducing the time interval of the exposure and the intensity of the radiation field. The intensity of the radiation field is determined by (1) the quantity of radioactive material, (2) the nature (i.e., characteristics) of the emitted radiation, (3) the nature of the shielding between the radiation source and the receptor, and (4) geometry (e.g., distances and dimensions).

Parameters important in determining doses from internal exposures are (1) the quantity of radioactive material taken into the body, (2) the nature (isotopical and body deposition characteristics) of the material, and (3) the time interval over which the material is retained by the body. The principal modes by which radioactive material can be taken into the body are (1) inhalation, (2) ingestion, (3) adsorption, and (4) injection through wounds. At nuclear power stations, radioactive materials are generally confined, but some dispersion within the station is unavoidable and constitutes the source of (1) contaminated air and liquids that present the potential for intake by inhalation and adsorption and (2) contaminated surfaces that present the potential for intake by ingestion and through cuts or abrasions in the skin. Adsorption generally is not an important intake mode at nuclear power stations except for tritium, which is available for adsorption through the skin.

Consequently, the basic variables that can be controlled to limit doses from internal exposures are those that limit (1) the amount of contamination, (2) the dispersal of the contamination, and (3) the length of time that personnel must spend in contaminated areas. Protective equipment can keep the intake of the contaminant to a minimum. Physical and chemical methods can be used to hasten the elimination of radioactive material taken into the body; however, because of the risks associated with the use of these methods, they are reserved for very serious cases where the probability of experiencing biological

effects is quite substantial, e.g., large intakes such as those that might occur in serious accident situations.

ALARA objectives stated in this guide are derived by considering the parameters that affect dose, the variables that exist in the station design features, and the variables that can be provided by station administrative actions. Section C, Regulatory Position, states objectives in a manner that encourages innovation by permitting considerable flexibility on the part of the utility, the NSSS vendor, the designer, the constructor, and the architect-engineer. However, the Regulatory Position also describes a large number of specific concerns that should be addressed in meeting the goals and objectives.

C. REGULATORY POSITION

The goals of the ALARA effort are (1) to maintain the annual dose to individual station personnel as low as reasonably achievable and (2) to keep the annual integrated (collective) dose to station personnel (i.e., the sum of annual doses (expressed in man-rems) to all station personnel) as low as reasonably achievable.

The NRC staff believes that the stated objectives are attainable with current technology and with good operating practices. The costs for attaining these objectives have not been established and are expected to vary widely depending on the features of the specific power reactor facility and the method selected to accomplish the objectives. The favorable cost-benefit ratio for achieving some of these objectives may be obvious without a detailed study. For other objectives, however, a cost-benefit study might be required to determine whether the objectives are reasonably achievable. Doses to station personnel can affect station availability, and this factor should be considered in assessing the cost-benefit ratio.

Attaining the following objectives to the extent practicable, throughout the planning, designing, constructing, operating, and maintenance of an LWR station, will be considered to provide reasonable assurance that exposure levels of station personnel to radiation will be ALARA. The methods are deliberately stated such that considerable flexibility can be used in the manner by which the objectives can be achieved. Differences among stations might necessitate further innovation in methods used to achieve the objectives.

1. Program for Maintaining Station Personnel Radiation Doses ALARA

To attain the integrated effort needed to keep exposures of station personnel ALARA, each applicant and licensee should develop an ALARA Program that reflects the efforts to be taken by the utility, nuclear steam supply system vendor, and architect-engineer to maintain radiation exposure ALARA in all phases of a station's life. This ALARA Program should be in written form and should contain sections that cover the generally applicable guidance presented in this guide, as a minimum, and more specific guidance as required to address the particular LWR that is the subject of the licensing action. The ALARA Program may be combined with the station's Radiation Protection Manual, Safety Analysis Report, or other documents or submittals. It need not be an independent document.

a. Establishment of ALARA Program

(1) A management policy for, and commitment to, ensuring that the exposure of station personnel to radiation will be ALARA should be established.

(2) The policy and commitment should be reflected in written administrative procedures and instructions for operations involving potential exposures of personnel to radiation and should be reflected in station design features. Instructions to designers, constructors, vendors, and station personnel specifying or reviewing station features, systems, or equipment should reflect the ALARA goals and objectives. (Few utilities design or build their nuclear power stations; but as *customers* of designers and builders, utilities should expect the designers and builders to be responsive to their needs and instructions.)

b. Organization, Personnel, and Responsibilities

(1) In view of the need for upper-level management support, responsibility and authority for implementing the ALARA Program should be assigned to an individual with organizational freedom to ensure development and implementation. Responsibilities and authorities should include

(a) Ensuring that a corporate ALARA program that integrates management philosophy and regulatory requirements is established, with specific goals and objectives for implementation included;

(b) Ensuring that an effective measurement system is established and used to determine the degree of success achieved by station operations with regard to the ALARA goals and specific objectives;

(c) Ensuring that the measurement system results are reviewed on a periodic basis and that corrective actions are taken when attainment of the specific objectives appears to be jeopardized;

(d) Ensuring that the authority for providing procedures and practices by which the specific goals and objectives will be achieved is delegated; and

(e) Ensuring that the resources needed to achieve ALARA goals and objectives are made available.

In view of the responsibilities required to implement the ALARA Program, the individual (or committee) selected for this function might also be chosen to coordinate the effort among the several corporate functional groups (such as the operations, maintenance, technical support, engineering, safety, and radiation protection groups) and to represent the corporate interests in dealing with the NSSS designer, vendor, A/E, and builder during the design and construction phases. If the expertise for performing this function is not within the corporation when the station is in the design stage, consultants who possess the required expertise should be used. The utility should obtain assurance that available data and experience obtained from similar nuclear power stations are considered and reflected in the work of the NSSS designer, vendor, A/E, and builder so as to provide features in the new station that permit an effective ALARA Program.

(2) The Plant Manager (Superintendent, or equivalent) is responsible for all aspects of station operation, including the onsite radiation protection program.

Responsibilities of the Plant Manager with respect to the ALARA Program should include

(a) Ensuring support from all station personnel;

(b) Participating in the selection of specific goals and objectives for the station;

(c) Supporting the onsite Radiation Protection Manager (RPM) in formulating and implementing the station ALARA Program; and

(d) Expediting the collection and dissemination of data and information concerning the program to the corporate management.

(3) The Radiation Protection Manager (RPM) (onsite) has a safety-related function and responsibility to both employees and management that can be best fulfilled if the individual is independent of station divisions, such as operations, maintenance, or technical support, whose prime responsibility is continuity or improvement of station operability. The RPM should have direct recourse to responsible management personnel in order to resolve questions related to the conduct of the radiation protection program.

(The specific responsibilities given here for the RPM are illustrative and not intended to be all-inclusive with respect to the ALARA Program or effort. They do not include any of the responsibilities in areas other than ALARA efforts.)

Responsibilities of the RPM with respect to the ALARA Program should include

(a) Participating in design reviews for facilities and equipment that can affect potential radiation exposures;

(b) Identifying locations, operations, and conditions that have the potential for causing significant exposures to radiation;

(c) Initiating and implementing an exposure control program;

(d) Developing plans, procedures, and methods for keeping radiation exposures of station personnel ALARA;

(e) Reviewing, commenting on, and recommending changes in job procedures to maintain exposures ALARA;

(f) Developing and participating in training programs related to work in radiation areas or involving radioactive material;

(g) Supervising the radiation surveillance program to maintain data on exposures of and doses to station personnel, by specific job functions and type of work;

(h) Supervising the collection, analysis, and evaluation of data and information attained from radiological surveys and monitoring activities;[3]

(i) Supervising, training, and qualifying the radiation protection staff of the station; and

(j) Ensuring that adequate radiation protection coverage is provided for station personnel during all working hours.

Qualifications[4] needed for the RPM job as well as those needed for other positions in organizations operating nuclear power stations, are presented in Regulatory Guide 1.8, "Personnel Selection and Training."

c. Training and Instruction

A training program in the fundamentals of radiation protection and in station exposure control

[3] Data collected during outages can indicate trends of radiation buildup in equipment that can permit estimates of probable radiation levels to be encountered during subsequent outages.

[4] Consideration has been given to peer group certification, i.e., certification of health physicists by the American Board of Health Physics (ABHP), as representing evidence of adequate qualifications for RPM candidates. While the staff believes that peer group certification is desirable, the present ABHP certification is not necessarily specifically applicable to applied health physics or radiation protection needs in nuclear power stations. However, the staff is discussing with the ABHP the prospects for a special certification program specifically directed toward the needs of radiation protection personnel at nuclear power stations.

procedures should be established. It should include instructing all personnel whose duties require (1) working with radioactive materials, (2) entering radiation areas, or (3) directing the activities of others who work with radioactive materials or enter radiation areas. The training program also should include sufficient instruction in the biological effects of exposures to radiation to permit the individuals receiving the instruction to understand and evaluate the significance of radiation doses in terms of the potential risks.

The training should be commensurate with the duties and responsibilities of those receiving the instructions, as well as with the magnitude of the potential doses and dose rates that can be anticipated. Personnel (including contractor personnel) who direct the activities of others should be familiar with the licensee's radiation control program and should have the authority to implement the licensee's commitment to ensure that radiation exposures of station personnel will be ALARA.

The training program should include instruction on (1) radiation protection rules for the station and (2) the applicable federal regulations. Copies of these rules and regulations should be made available to those receiving the instructions. The training program should be approved by the RPM and presented by competent instructors under the RPM's supervision. The information presented in the training program should be reviewed periodically and modified, where necessary, to reflect contemporary techniques and adjustments based on experience in station operations. Instruction of station personnel should stress the importance of exposure-reduction efforts by every individual and should emphasize the need for feedback of information obtained when similar tasks were performed previously.

Station personnel should receive instruction at periodic intervals to reinforce their knowledge and keep it current. Station personnel whose duties do not require entering radiation areas or working with radioactive materials should receive sufficient instruction in radiation protection and station rules and regulations to understand why they should not enter such areas.

Training programs that have as their goal an increase in craft skills provide a broader base of knowledgeable station personnel available to service equipment in radiation areas and permit the services to be performed more reliably and more efficiently. This can promote lower individual and collective dose levels.

d. Review of New or Modified Designs and Equipment Selection

(1) Since several groups within a utility (for example, maintenance, operations, radiation protection, technical support, engineering, and safety groups) are interested in station design and equipment selection, the utility should ensure that these groups are adequately represented in the review of the design of the facility and the selection of equipment. A coordinated effort by the several functional groups within the utility is required to ensure that station features will permit the goals and objectives of the ALARA Program to be achieved. Although the A/E and designers greatly influence station design features, utilities should not delegate all responsibilities for station design review and equipment selection to the NSSS designer, vendor, or A/E.

(2) Design concepts and station features should reflect consideration of the activities of station personnel (such as maintenance, refueling, inservice inspections, processing of radioactive wastes, decontamination, and decommissioning) that might be anticipated and that might lead to personnel exposure to substantial sources of radiation. Station design features should be provided to reduce the anticipated exposures of station personnel to these sources of radiation to the extent practicable.

(3) Specifications for equipment should reflect the objectives of ALARA, including considerations of reliability, serviceability, limitations of internal accumulations of radioactive material, and other features addressed in this guide. Specifications for replacement equipment also should reflect modifications based on experience gained from using the original equipment.

2. Facility and Equipment Design Features

Radiation sources within a nuclear power station differ appreciably with respect to location, intensity, and characteristics. The magnitude of the dose rates that results from these sources is dependent on many factors, including the facility and equipment design, layout, mode and length of operation, and radiation source strength and characteristics.

To provide a basis for design, the quantity and isotopic composition of the radioactive material that can be anticipated to be contained, deposited, or accumulated in equipment during normal operation of the station should be estimated. Work on source term definition is being pursued by the ANSI N-237 working group. The method involves a mechanistic tracing of radioactive material from origin through treatment processes to release. It provides information that can be used as a starting point to estimate radiation sources within the station for normal operation.

Activation and neutron sources also should be identified and quantified. The nuclear steam system supplier can provide source data, which should be consistent with the design basis for the system (e.g.,

assuming 1% fuel cladding defects for operating conditions). Data obtained from measurements and experience in operating stations of similar design are most valuable as the basis for designing new stations. Extrapolation of data to equilibrium conditions may be needed to estimate ultimate source terms.

The magnitude of the dose is dependent on the length of time spent in the radiation field. ALARA Program objectives are presented below for each of several station features or functions. Each statement of objective is followed by a number of specific concerns or suggestions that should be addressed.

a. Access Control of Radiation Areas

To avoid unnecessary and inadvertent exposures of personnel to radiation, the magnitude of the potential dose rates at all locations within the station should be estimated during station design. Actual dose rates should be measured periodically during operation to determine current exposure potentials. Zones associated with the higher dose rates should be kept as small as reasonably achievable consistent with accessibility for accomplishing the services that must be performed in those zones, including equipment laydown requirements. Radiation zones where station personnel spend substantial time should be designed to the lowest practicable dose rates.

(It is common practice to identify "radiation zones" within a nuclear power station. The zone designations are established to reflect the design maximum dose rates that may exist in areas within the station where station personnel must have access to perform required services. Several systems for designating "radiation zones" currently exist among the utilities, and ANSI Committee 6.7 is developing a standard that should prove useful in attaining common designations and terminology in this matter. To avoid ambiguity, no reference to radiation zone numbers is used in this guide at this time.)

A system should be established to permit effective control over personnel access to the radiation areas and control over the movement of sources of radiation within the station. Where high radiation areas ($>$100 mrem/hr) exist, 10 CFR Part 20, § 20.203 requires that station design features and administrative controls provide effective ingress control, ease of egress, and appropriate warning devices and notices. Access control of radiation areas also should reflect the following considerations:

(1) Extraordinary design features are warranted to avoid any potential dose to personnel that is large enough to cause acute biological effects and that could be received in a short period of time. Positive control of ingress to such areas, permanent shielding, source removal, or combinations of these alternatives can reduce the dose potential.

(2) Administrative controls such as standard operating procedures can be effective in preventing inadvertent exposures of personnel and the spread of contamination when radioactive material or contaminated equipment must be transported from one station location to another and when the route of transport through lower radiation zones or "clean" areas cannot be avoided.

(3) Station features such as platforms or walkways, stairs, or ladders that permit prompt accessibility for servicing or inspection of components located in higher radiation zones can reduce exposure of personnel who must perform these services.

b. Radiation Shields and Geometry

Radiation shields should be designed using conservative assumptions for radioactive source quantities and geometries. Calculational methods selected to determine shield thicknesses should be known to provide reliable and accurate results. Shield design features should reflect the following ALARA considerations:

(1) Exposure of personnel servicing a specific component (such as a pump, filter, or valve) to radiation from other components containing radioactive material can be reduced by providing shielding between the individual components that constitute substantial radiation sources and the receptor.

(2) Where it is impracticable to provide permanent shielding for individual components that constitute substantial radiation sources, the exposure of personnel maintaining such components can be reduced (a) by providing as much distance as practicable between the serviceable components and the substantial radiation sources in the area and (b) by providing temporary shields around components that contribute substantially to the dose rate.

(3) Potential exposure of station personnel to radiation from certain systems containing radiation sources can be reduced by means of a station layout that permits the use of distance and shielding between the sources and work locations. These systems include (but are not limited to) the NSSS and the reactor water cleanup, offgas treatment, solid waste treatment, and storage systems, as well as systems infrequently containing radiation sources, such as the standby gas treatment and residual heat removal systems.

Radiation from an operating BWR turbine can constitute a substantial source of exposure for construction personnel or others who have access to the site for extended periods of time if insufficient shielding is provided.

(4) Streaming or scattering of radiation from locally shielded components (such as cubicles) can be reduced by providing labyrinths for access. However, such labyrinths or other design features of the cubicle should permit the components to be removed readily from the cubicle for repair or replacement. Single-scatter labyrinths may be inadequate if the cubicle contains a substantial radiation source.

(5) Streaming of radiation into accessible areas through penetrations for pipes, ducts, and other shield discontinuities can be reduced (a) by means of layouts that prevent substantial radiation sources within the shield from being aligned with the penetrations or (b) by using "shadow" shields such as shields of limited size that attenuate the direct radiation component. Streaming also can occur through roofs or floors unless adequate shielding encloses the source from all directions.

(6) The exposure of station personnel to radiation from pipes carrying radioactive material can be reduced by means of shielded chases.

(7) Design features that permit the rapid removal and reassembly of shielding, insulation, and other material from equipment that must be inspected or serviced periodically can reduce the exposure of station personnel performing these activities.

(8) Space within cubicles and other shielding to provide laydown space for special tools and ease of servicing activities can reduce potential doses by permitting the services to be accomplished expeditiously, thus reducing exposure time.

(9) The exposure of personnel who service components that constitute substantial radiation sources or are located in high radiation fields can be minimized by removing the components and transporting them to low radiation zones where shielding and special tools are available. Design features that permit the prompt removal and installation of these components can reduce the exposure time.

(10) Floor and equipment drains, piping, and sumps that are provided to collect and route any contaminated liquids that might leak or be spilled from process equipment or sampling stations can become substantial radiation sources. The drain lines can be located in concrete floors, concrete ducts, columns, or radwaste pipe chases to provide shielding. These systems can also become a source of airborne contamination because of the potential for gases to form in, and be released by, such systems (see Section C.2.d.(6)).

c. Process Instrumentation and Controls

Appropriate station layout and design features should be provided to reduce the potential doses to personnel who must operate, service, or inspect station instrumentation and controls. The following considerations should be reflected in selecting the station features.

(1) The exposure of personnel who must manually operate valves or controls can be reduced through the use of "reach rods" or remotely operated valves or controls. However, these devices can require lubrication and maintenance that can be the source of additional exposures, and these factors should be taken into consideration.

(2) The exposure of personnel who must view or operate instrumentation, monitors, and controls can be reduced by locating the readouts or control points in low radiation zones.

(3) Instrumentation must satisfy functional requirements, but the exposure of personnel can be reduced if the instruments are designed, selected, specified, and located with consideration for long service-life, ease and low frequency of maintenance and calibration, and low crud accumulation. Operating experience should be recorded, evaluated, and reflected in the selection of replacement instrumentation.

(4) The use of instrumentation that contains minimal quantities of contaminated working fluid, (for example, pressure transducers rather than bellows-type pressure gauges) can reduce the potential for exposure at the readout locations.

d. Control of Airborne Contaminants and Gaseous Radiation Sources

Station design features should be provided in all station work areas to limit the average concentrations of radioactive material in air to levels well below the values listed in Appendix B, Table I, Column I of 10 CFR Part 20. Effective design features can minimize the occurrence of occasional increases in air contamination and the concentrations and amounts of contaminants associated with any such occasional increases. Designs that permit repeated, identified releases of large amounts of radioactive materials into the air spaces occupied by personnel are contrary to an ALARA program.

Station design features should provide for protection against airborne radioactive material by means of engineering controls such as process, containment, and ventilation equipment. The routine provision of respiratory protection by use of individually worn respirators rather than engineered design features is generally unacceptable. The use of respirators, however, might be appropriate in certain nonroutine or emergency operations when the application of engineering controls is not feasible or while such controls are being installed.

The approved use of respirators is subject to the requirements of 10 CFR Part 20, § 20.103, "Exposure of Individuals to Concentrations of Radioactive Materials in Air in Restricted Areas," and to regulatory guidance on acceptable use. (See Regulatory Guide 8.15, "Acceptable Programs for Respiratory Protection," and NUREG-0041, "Manual of Respiratory Protection Against Airborne Radioactive Materials" (Ref. 6).) Design features of the station ventilation system and gaseous radwaste processing systems should reflect the following considerations:

(1) The spread of airborne contamination within the station can be limited by maintaining air pressure gradients and air flows from areas of low potential airborne contamination to areas of higher potential contamination. Periodic checks would ensure that the design pressure differentials are being maintained.

(2) Effectively designed ventilation systems and gaseous radwaste treatment systems will contain radioactive material that has been deposited, collected, stored, or transported within or by the systems. Exposures of station personnel to radiation and to contamination from ventilation or gaseous radwaste treatment components occur as a result of the need to service, test, inspect, decontaminate, and replace components of the systems or perform other duties near these systems. Potential doses from these systems can be minimized by providing ready access to the systems, by providing space to permit the activities to be accomplished expeditiously, by separating filter banks and components to reduce exposures to radiation from adjacent banks and components, and by providing sufficient space to accommodate auxiliary ventilation or shielding of components.

(3) Auxiliary ventilation systems that augment the permanent system can provide local control of airborne contaminants when equipment containing potential airborne sources is opened to the atmosphere. Two types of auxiliary ventilation systems have proven to be effective. In areas where contaminated equipment must be opened frequently, dampers and fittings can be provided in ventilation ducts to permit the attachment of flexible tubing or "elephant trunks" without imbalancing the ventilation system. In areas where contaminated equipment must be opened infrequently, portable auxiliary ventilation systems featuring blowers, HEPA filters, and activated charcoal filters (where radioiodine might be anticipated) on carts can be used effectively. Portable auxiliary ventilation systems should be tested frequently to verify the efficiency of the filter elements in their mountings. When the efficiency has been verified, the system may be exhausted to the room or the ventilation exhaust duct without further treatment and thus imbalance of the permanent ventilation system can be avoided.

(4) Machining of contaminated surfaces (e.g., welding, grinding, sanding, or scaling) or "plugging" of leaking steam generator or condenser tubes can be substantial sources of airborne contamination. These sources can be controlled by using auxiliary ventilation systems.

(5) Sampling stations for primary coolant or other fluids containing high levels of radioactive material can constitute substantial sources of airborne contamination. Such sources can be controlled by using auxiliary ventilation systems.

(6) Wet transfer or storage of potentially contaminated components will minimize air contamination. This can be accomplished by keeping contaminated surfaces wet, by spraying, or, preferably, by keeping such surfaces under water.

e. Crud Control

Design features of the primary coolant system, the selection of construction materials that will be in contact with the primary coolant, and features of equipment that treat primary coolant should reflect considerations that will reduce the production and accumulation of crud in stations where it can cause high exposure levels. The following items should be considered in the crud control effort.

(1) Production of Co-58 and Co-60, which constitute substantial radiation sources in crud, can be reduced by specifying, to the extent practicable, low nickel and low cobalt bearing materials for primary coolant pipe, tubing, vessel internal surfaces, heat exchangers, wear materials, and other components that are in contact with primary coolant. Colmonoys and Hastelloys can frequently be substituted for stellite for hard facings of wear material, and Alloy-800 can frequently be substituted for Alloy-600 in heat exchangers.

(2) Loss of material by erosion of load-bearing hard facings can be reduced by using favorable geometrics and lubricants, where practicable, and by using controlled leakage purge across journal sleeves to avoid entry of particles into the primary coolant.

(3) Loss of material by corrosion can be reduced by continuously monitoring and adjusting oxygen concentration and pH in primary coolant above 250°F and by using bright hydrogen-annealed tubing

and piping in the primary coolant and feedwater systems.

(4) Crud can be removed from primary coolant by high-temperature filtration (graphite or magnetic filters), by reactor water cleanup systems, by isolation and chemical decontamination of major serviceable components of the system, and by draining and flushing of the system.

(5) Leakage of contaminated coolant from the primary system can be reduced by using live-loaded valve packings and bellow seals.

(6) Deposition of crud within the primary coolant system can be reduced by providing laminar flow and smooth surfaces for coolant and by minimizing crud traps in the system to the extent practicable.

f. Isolation and Decontamination

Potential doses to station personnel who must service equipment containing radioactive sources can be reduced by removing such sources from the equipment (decontamination), to the extent practicable, prior to servicing. Serviceable systems and components that constitute a substantial radiation source should be designed, to the extent practicable, with features that permit isolation and decontamination. Station design features should consider, to the extent practicable, the ultimate decommissioning of the facility and the following concerns:

(1) The necessity for decontamination can be reduced by limiting, to the extent practicable, the deposition of radioactive material within the processing equipment—particularly in the "dead spaces" or "traps" in components where substantial accumulations can occur. The deposition of radioactive material in piping can be reduced and decontamination efforts enhanced by avoiding stagnant legs, by locating connections above the pipe centerline, by using sloping rather than horizontal runs, and by providing drains at low points in the system.

(2) The need to decontaminate equipment and station areas can be reduced by taking measures that will reduce the probability of release, reduce the amount released, and reduce the spread of the contaminant from the source (e.g., from systems or components that must be opened for service or replacement). Such measures can include auxiliary ventilation systems (see C.4.b), treatment of the exhaust from vents and overflows (see C.2.h.(8)), drainage control such as curbing and floors sloping to local drains, or sumps to limit the spread of contamination from leakage of liquid systems.

(3) Accumulations of crud or other radioactive material that cannot be avoided within components or systems can be reduced by providing features that will permit the recirculation or flushing of fluids with the capacity to remove the radioactive material through chemical or physical action. The fluids containing the contaminants will require treatment, and this source should be considered in sizing station radwaste treatment systems.

(4) Continuity in the functioning of processing or ventilation systems that are important for controlling potential doses to station personnel can be provided during servicing of the systems if redundant components or systems are available so that the component (with associated piping) being serviced can be isolated.

(5) The potential for contamination of "clean services" (such as station service air, nitrogen, or water supply) from leakage from adjacent systems containing contaminants can be reduced by separating piping for these services from piping that contains radioactive sources. Piping that carries radioactive sources can be designed for the lifetime of the station, thus avoiding the necessity for replacement (and attendant exposures) and lessening the potential for contamination of clean services if it is impracticable to provide isolation through separate chases.

(6) Surfaces can be decontaminated more expeditiously if they are smooth, nonporous, and free of cracks, crevices, and sharp corners. These desirable features can be realized by specifying appropriate design instructions, by giving attention to finishing work during construction or manufacture, and by using sealers (such as special paints) on surfaces where contamination can be anticipated. (ANSI N-101.2 provides helpful guidance on this matter (Ref. 7).)

(7) Where successful decontamination of important systems could be prevented by an anticipated failure of a critical component or feature, additional features that permit alternative decontamination actions can be provided.

(8) Contaminated water and deposited residues in spent fuel storage pools contribute to the exposure at accessible locations in the area. Treatment systems that remove contaminants from the water can perform more efficiently (a) if intake and discharge points for the treatment systems are located to provide enhanced mixing and to avoid stagnation areas in the pool and (b) if pool water overflows and skimmer tanks are provided. Fluid jet or vacuum cleaner type agitators can help reduce the settling of crud on surfaces of the pool system.

g. Radiation Monitoring Systems

Central or "built-in" monitoring systems that give information on the dose rate and concentration

of airborne radioactive material in selected station areas can reduce the exposure of station personnel who would be required to enter the areas to obtain the data if such systems were not provided. These systems also can provide timely information regarding changes in the dose rate or concentrations of airborne radioactive material in the areas. (The installation of a central monitoring system is easier and less expensive if it is a part of the original station design.) The selection or design and installation of a central monitoring system should include consideration of the following desirable features:

(1) Readout capability at the main radiation protection access control point;
(2) Placement of detectors for optimum coverage of areas;
(3) Circuitry that indicates component failure;
(4) Local alarm and readout;
(5) Clear and unambiguous readout;
(6) Ranges adequate to ensure readout of the highest anticipated radiation levels and to ensure positive readout at the lowest anticipated levels; and
(7) Capability to record the readout of all systems.

h. Resin and Sludge Treatment Systems

Systems used to transport, store, or process resins or slurries of filter sludge present a special hazard because of the concentrated nature of the radioactive material. Design features for resin and sludge-handling systems should reflect this concern and the following specific considerations:

(1) The accumulation of radioactive material in components of systems used to process resin and sludges can be reduced by

(a) Reducing the length of piping runs;
(b) Using larger diameter piping;
(c) Reducing the number of pipe fittings;
(d) Avoiding low points and dead legs in piping;
(e) Using gravitational flow to the extent practicable; and
(f) Minimizing flow restrictions of processed material.

(2) The need for maintenance and the presence of intense local radiation sources can be reduced by

(a) Using full ported valves constructed such that the slurry will not interfere with the opening or closing of the valve and
(b) Avoiding cavities in valves.

(3) The deposition of resin and sludge that would occur if elbow fittings were used can be reduced by using pipe bends of at least five pipe diameters in radius. Where pipe bends cannot be used, long radius elbows are preferred.

(4) Smoother interior pipe surfaces at connections (with attendant reductions in friction losses, deposition of material, and tendencies to "plug") can be achieved by using butt welds rather than socket welds and by using consumable inserts rather than backing rings.

(5) Where the use of tees cannot be avoided, line losses can be reduced if the flow is through the run (straight section) of the tee, and accumulations of material in the branch of the tee can be reduced by orienting the branch horizontally or (preferably) above the run.

(6) Slurry piping is subject to plugging that may require backflushing from the tank and equipment isolation valves and pressurizing with water, nitrogen, or air to "blow out" plugged lines. However, the use of pressurized gas for blowing out lines can present a potential contamination source and may not be effective in relieving plugged lines.

(7) Water, air, or nitrogen for sparging can be used to fluidize resins or sludges in storage tanks. The use of gases, however, presents a potential source of airborne contamination and tank rupture from overpressures.

(8) The spread of contamination by the loss of resin or sludge through overflows and vents can be reduced by using screens, filters, or other features that will collect and retain solids. However, such features generally require cleaning by remote flushing, by rapid replacement, or by other means to reduce exposures during servicing.

i. Other Features

Station layout and station tasks should be reviewed to identify and provide special features that complement the ALARA Program. Station design should reflect consideration of the following concerns:

(1) The selection of radiation-damage-resistant materials for use in high radiation areas can reduce the need for frequent replacement and can reduce the probability of contamination from leakage.

(2) The use of stainless steel for constructing or lining components, where it is compatible with the process, can reduce corrosion and can provide options for decontamination methods.

(3) Field-run piping that carries radioactive material can cause unnecessary exposures unless due consideration is given to the routing. Such unnecessary exposures can be avoided if the routing is accomplished under the cognizance of an engineer

familiar with the principles of radiation protection or if a detailed piping layout is provided, i.e., if the piping is not field-run.

(4) Where filters or other serviceable components can constitute substantial radiation sources, exposures can be reduced by providing features that permit operators to avoid the direct radiation beam and that provide remote removal, installation, or servicing. Standardization of filters should be considered.

(5) The servicing of valves can be a substantial source of doses to station personnel. These doses can be reduced by providing adequate working space for easy accessibility and by locating the valves in areas that are not in high radiation fields.

(6) Potential doses from servicing valves and from leakage can be reduced by specifying and installing the "best available" valves for the required service, by using radiation-damage-resistant seals and gaskets, and by using valve back seats. The use of straight-through valve configurations can avoid the buildup of accumulations in internal crevices and the discontinuities that exist in valves of other configurations. In most cases, valves can be installed in the "stem-up" orientation to facilitate maintenance and to minimize crud traps.

(7) Leaks from pumps can be reduced by using canned pumps where they are compatible with the service needs. If mechanical seals are used on a pump in a slurry service, features that permit the use of flush water to clean pump seals can reduce the accumulation of radioactive material in the seals. Drains on pump housings can reduce the radiation field from this source during servicing. Provision for the collection of such leakage or disposal to a drain sump is appropriate.

(8) The sources of radiation such as sedimentation that occurs in tanks used to process liquids containing radioactive material and residual liquids can be reduced when servicing by draining the tanks. The design can include sloping the tank bottoms toward outlets leading to other reprocessing equipment and, where practicable, providing built-in spray or surge features.

(9) Spare connections on tanks or other components located in higher radiation zones may be desirable to provide flexibility in operations. Exposures of personnel can be avoided if these connections are provided as a part of the original equipment rather than by subsequent modification of the equipment in the presence of radiation.

(10) Inspections to satisfy the ASME Code (Ref. 8) and regulatory requirements can result in exposures of station personnel to radiation. Many of the objectives presented above will aid in reducing potential exposures to personnel who perform the required inspections. Station features and design should, to the extent practicable, permit inspections to be accomplished expeditiously and with minimal exposure of personnel. The ALARA effort can also be aided by prompt accessibility, shielding and insulation that can be quickly removed and reinstalled, and special tools and instruments that reduce exposure time or permit remote inspection of components or equipment containing potential radiation sources.

(11) Components can be removed from processing systems more expeditiously if adequate space is provided in the layout of the system and if the interconnections permit prompt disconnects.

(12) Station features that provide a favorable working environment, such as adequate lighting, ventilation, working space, and accessibility (via such means as working platforms, cat walks, and fixed ladders), can promote work efficiency.

(13) The exposure of station personnel who must replace lamps in high radiation areas can be reduced by using extended service lamps and by providing design features that permit the servicing of the lamps from lower radiation areas.

(14) An adequate emergency lighting system can reduce potential exposures of station personnel by permitting prompt egress from high radiation areas if the station lighting system fails.

3. Radiation Protection Program

A substantial portion of the radiation dose to station personnel is received while they are performing services such as maintenance, refueling, and inspection in high radiation areas. The objectives that were presented in Section C.2 can provide station design features conducive to an effective ALARA Program. However, an effective ALARA Program also requires station operational considerations in terms of procedures, job planning, record keeping, special equipment, operating philosophy, and other support. This section deals with the manner in which the station administrative efforts can influence the variables of (1) the number of persons who must enter high radiation areas or contaminated areas, (2) the period of time the persons must remain in these areas, and (3) the magnitude of the potential dose.

a. Preparation and Planning

Before entering radiation areas where significant doses could be received, station personnel should have the benefit of preparations and plans that can ensure that exposures are ALARA while the personnel are performing the services. Preparations and plans should reflect the following considerations:

(1) A staff member who is a specialist in radiation protection can be assigned the responsibility for contributing to and coordinating ALARA efforts in support of operations that could result in substantial individual and collective dose levels.

(2) To provide the bases for planning the activity, surveys can be performed to ascertain information with respect to radiation, contamination, airborne radioactive material, and mechanical difficulties that might be encountered while performing services.

(3) Radiation surveys provided in conjunction with inspections or other activities can define the nature of the radiation fields and identify favorable locations where personnel may take advantage of available shielding, distance, geometry, and other factors that affect the magnitude of the dose rate or the portions of the body exposed to the radiation.

(4) Photographs of "as installed" equipment or components can be valuable for planning purposes and can be augmented by additional photos taken during the surveys. The use of portable TV cameras with taping features has considerable merit as both an operational aid and a teaching aid.

(5) The existing radiation levels frequently can be reduced by draining, flushing, or other decontamination methods or by removing and transporting the component to a lower radiation zone. An estimate of the potential doses to station personnel expected to result from these procedures is germane in selecting among alternative actions.

(6) A pre-operational briefing for personnel who will perform services in a high radiation area can ensure that service personnel understand the tasks about to be performed, the information to be disseminated, and the special instructions to be presented.

(7) A program can be implemented to provide access control and to limit exposures to those persons needed to perform the required services in the radiation areas. Such a program would address conditions that require a special work permit or other special procedures.

(8) A work permit form with an appropriate format can be useful for recording pertinent information concerning tasks to be performed in high radiation areas so that the information is amenable to cross-referencing and statistical analysis. Information of interest would include the following items:

(a) Designation of services to be performed on specific components, equipment, or systems;

(b) Number and identification of personnel working on the tasks;

(c) Anticipated radiation, airborne radioactive material, and contamination levels, based on current surveys of the work areas, and date of survey;

(d) Monitoring requirements, such as continuous air monitoring or sampling equipment;

(e) Estimated exposure time required to complete the tasks and the estimated doses anticipated from the exposure;

(f) Special instructions and equipment to minimize the exposures of personnel to radiation and contamination;

(g) Protective clothing and equipment requirements;

(h) Personnel dosimetry requirements;

(i) Authorization to perform the tasks; and

(j) Actual exposure time, doses, and other information obtained during the operation.

(9) Consideration of potential accident situations or unusual occurrences (such as gross contamination leakage, pressure surges, fires, cuts, punctures, or wounds) and contingency planning can reduce the potential for such occurrences and enhance the capability for coping with the situations expeditiously if they occur.

(10) Portable or temporary shielding can reduce dose rate levels near "hot spots" and in the general area where the work is to be performed.

(11) Portable or temporary ventilation systems or contamination enclosures and expendable floor coverings can control the spread of contamination and limit the intake by workers through inhalation.

(12) "Dry runs" on mock-up equipment can be useful for training personnel, identifying problems that can be encountered in the actual task situation, and selecting and qualifying special tools and procedures to reduce potential exposures of station personnel.

(13) Adequate auxiliary lighting and a comfortable environment (for example, vortex tube coolers for supplied air suits) can increase the efficiency of the work and thus reduce the time spent in the higher radiation zones.

(14) Radiation monitoring instruments selected and made available in adequate quantities can permit accurate measurements and rapid evaluations of the radiation and contamination levels and changes in levels when they occur. Routine calibration of instruments with appropriate sources and testing can ensure operability and accuracy of measurements.

(15) Performing work on some components inside disposable tents or, for less complicated jobs, inside commercially available disposable clear plastic glove bags can limit the spread of contamination. Such measures can also avoid unnecessary doses

resulting from the need to decontaminate areas to permit personnel access or to allow for entry with less restrictive protective clothing and equipment requirements.

(16) Careful scheduling of inspections and other tasks in high radiation areas can reduce exposures by permitting decay of radiation sources during the reactor shutdown period and by eliminating some repetitive surveys. Data from surveys and experience attained in previous operations and current survey data can be factored into the scheduling of specific tasks.

b. Operations

During operations in radiation areas, adequate supervision and radiation protection surveillance should be provided to ensure that the appropriate procedures are followed, that planned precautions are observed, and that all potential radiation hazards that might develop or that might be recognized during the operation are addressed in a timely and appropriate manner.

(1) Assigning a health physics (i.e., radiation safety or radiation protection) technician the responsibility for providing radiation protection surveillance for each shift operating crew can help ensure adequate radiation protection surveillance.

(2) Personnel monitoring equipment such as direct-reading dosimeters, alarming dosimeters, and personal dose rate meters can be used to provide early evaluation of doses to individuals and the assignment of those doses to specific operations (see Regulatory Guides 1.16, "Reporting of Operating Information—Appendix A Technical Specifications," and 8.4, "Direct-Reading and Indirect-Reading Pocket Dosimeters").

(3) Communication systems between personnel in high radiation zones and personnel who are monitoring the operation in other locations can permit timely exchanges of information and avoid unnecessary exposures to monitoring personnel.

c. Postoperations

Observations, experience, and data obtained during nonroutine operations in high radiation zones should be ascertained, recorded, and analyzed to identify deficiencies in the program and to provide the bases for revising procedures, modifying features, or making other adjustments that may reduce exposures during subsequent similar operations.

(1) Formal or informal postoperation debriefings of station personnel performing the services can provide valuable information concerning shortcomings in pre-operational briefings, planning, procedures, special tools, and other factors that contributed to the cause of doses received during the operation.

(2) Dose data obtained during or subsequent to an operation can be recorded in a preselected manner as part of a "Radiation Work Permit" or similar program [see C.3.a(8)] so that the data are amenable to statistical analyses.

(3) Information concerning the cause of component failures that resulted in the need for servicing in high radiation areas can provide a basis for revising specifications on replacement equipment or for other modifications that can improve the component reliability. Such improvements can reduce the frequency of servicing and thus reduce attendant exposures.

(4) Information gained in operations can provide a basis for modifying equipment selection and design features of new facilities.

(5) Summaries of doses received by each category of maintenance activity can be reviewed periodically by upper management to compare the incremental reduction of doses with the cost of station modifications that could be made.

4. Radiation Protection Facilities, Instrumentation, and Equipment

A radiation protection staff with facilities, instrumentation, and protective equipment adequate to permit the staff to function efficiently is an important element in achieving an effective ALARA program. The selection of instrumentation and other equipment and the quantities of such equipment provided for normal station operations should be adequate to meet the anticipated needs of the station during normal operations and during major outages that may require supplemental workers and extensive work in high radiation areas. (Accident situations are not considered in this guide.) Station design features and provisions should reflect the following considerations.

a. Counting Room

A low-radiation background counting room is needed to perform routine analyses on station samples containing radioactive material collected from air, water, surfaces, and other sources. An adequately equipped counting room would include

(1) Multichannel gamma pulse height analyzer (Regulatory Guide 5.9, "Specifications for Ge(Li) Spectroscopy Systems for Material Protection Measurements—Part 1: Data Acquisition Systems," provides guidance for selecting Ge(Li) spectroscopy systems);

(2) Low-background alpha-beta radiation proportional counter(s) or scintillation counter(s);

(3) End-window Geiger-Muller (G-M) counter(s); and

(4) A liquid scintillation counter for tritium analyses. Analyses of bioassay and environmental samples and whole body counting (see Regulatory Guide 8.9, "Acceptable Concepts, Models, Equations, and Assumptions for a Bioassay Program") call for additional equipment and laboratory space if the analyses are performed by station personnel rather than by other specialists through contractual arrangements.

b. Portable Instruments

Portable instruments needed for measuring dose rates and radiation characteristics would include

(1) Low-range (nominally 0 to 5 R per hour) ion chambers or G-M rate meters;
(2) High-range (0.1 to at least 500 R per hour) ion chambers;[7]
(3) Alpha scintillation or proportional count rate meters;
(4) Neutron dose equivalent rate meters;
(5) Air samplers for short-term use with particulate filters and iodine collection devices (such as activated charcoal cartridges); and
(6) Air monitors with continuous readout features.[7]

c. Personnel Monitoring Instrumentation

Personnel monitoring instrumentation selection should include consideration of

(1) G-M "Friskers" for detecting low levels of radioactive material;
(2) Direct-reading low-range (0 to 200 mR) and intermediate-range (0 to 1000 mR) pocket dosimeters (see Regulatory Guide 8.4);
(3) Alarm dosimeters;
(4) Film badges and/or thermoluminescent dosimeters (TLD);
(5) Hand and foot monitors; and
(6) Portal monitors.

d. Protective Equipment

Utility-supplied protective equipment selection should include consideration of

(1) Anti-contamination clothing and equipment that meet the requirements of ANSI Z-88.2, 1969, for use in atmospheres containing radioactive materials, or the National Institute of Occupational Safety and Health's (NIOSH) "Certified Personal Protective Equipment List," July 1974, and current supplements from DHEW/PHS (Refs. 9 and 10).

(2) Respiratory protective equipment including a respirator fitting program that satisfies the guidance of Regulatory Guide 8.15 and NUREG-0041 (Ref. 6).

e. Support Facilities

Design features of radiation protection support facilities should include consideration of

(1) A portable-instrument calibration area designed and located such that radiation in the calibration area will not interfere with low level monitoring or counting systems;

(2) Personnel decontamination area (this facility should be located and designed to expedite rapid cleanup of personnel and should not be used as a multiple-purpose area or share ventilation with food-handling areas) with showers, basins, and installed "frisker" equipment;

(3) Facilities and equipment to clean, repair, and decontaminate personnel protective equipment, monitoring instruments, hand tools, electromechanical parts, or other material (highly contaminated tools or other equipment should not be decontaminated in the area used to clean respiratory equipment);

(4) Change rooms that (preferably) connect with the personnel decontamination area and a control station area equipped with sufficient lockers to accommodate permanent and contract maintenance workers who may be required during major outages;

(5) Control stations for entrance or exit of personnel into radiation and contamination controlled access areas of the station, such as the personnel entrance to the containment buildings and the main entrance to the radwaste processing areas; these control stations also may be used as the control point for radioactive material movements throughout the station and for the storage of portable radiation survey equipment, signs, ropes, and respiratory protective equipment;

(6) Equipment to facilitate communication between all areas throughout the stations; and

(7) Sufficient office space to accommodate the temporary and permanent radiation protection staff, permanent records, and technical literature.

[7] Variable alarm set point features on these instruments can be valuable in providing a warning when unexpected substantial changes in dose rate or air concentration occur.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

This guide reflects current NRC staff practice in license application reviews. Therefore, except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the methods described herein are being and will continue to be used in the evaluation of submittals for construction permits and operating license applications until this guide is revised as a result of suggestions from the public or additional staff review.

At the operating license review stage, the radiation protection design presented in the applicant's final safety analysis report will be reviewed against Section C.2 of this guide and differences from the recommendations of the guide will be identified (particularly for plants designed before Regulatory Guide 8.8 was issued). However, no substantive design changes will be required at the operating license stage unless the design change can prevent substantial man-rem exposures which cannot be prevented by procedural measures and the design change is consistent with the cost-effectiveness principle of the ALARA philosophy.

Methods other than those set forth in this guide may be substituted for those stated herein, provided they satisfy the criterion "as low as is reasonably achievable" of 10 CFR Part 20, §20.1(c).

REFERENCES

1. Ad Hoc Committee of the National Council on Radiation Protection and Measurements, "Somatic Radiation Dose for the General Population," Science 131, 482 (1960).

2. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," National Academy of Sciences/National Research Council, DHEW Contract PH-43-64-44, November 1972.

3. C. A. Pelletier et al., "Compilation and Analysis of Data on Occupational Radiation Exposure Experienced at Operating Nuclear Power Plants," Atomic Industrial Forum, 1974.

4. T. D. Murphy, N. J. Dayem, J. Stewart Bland, and W. J. Pasciak, "Occupational Radiation Exposure at Light-Water-Cooled Power Reactors, 1969-1975," NUREG-0109, U.S. Nuclear Regulatory Commission, August 1976. Copies may be obtained from the National Technical Information Service, Springfield, Va. 22161.

5. Proceedings, Public Meeting on Revision of Regulatory Guide 8.8, "Information Relevant to Assuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable," April 25, 1975, p. 171, available in the NRC Public Document Room.

6. Copies of NUREG-0041 may be obtained from the National Technical Information Service, Springfield, Va. 22161.

7. ANSI N-101.2, "Protective Coatings (Paints) for Light Water Nuclear Reactor Containment Facilities." Copies may be obtained from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

8. Section XI, ASME Boiler and Pressure Vessel Code and Addenda. Copies may be obtained from the American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.

9. ANSI Z-88.2, "Practices for Respiratory Protection." Copies may be obtained from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

10. NIOSH, "Certified Personal Protective Equipment List," July 1974, and supplements by DHEW/PHS. Published by U.S. Department of Health, Education and Welfare, Public Health Service, Center of Disease Control, National Institute of Occupational Safety and Health. Copies are available from the Office of Technical Publications, National Institute of Occupational Safety and Health, Post Office Building, Cincinnati, Ohio 45202.