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# REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

## REGULATORY GUIDE 4.21

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## MINIMIZATION OF CONTAMINATION AND RADIOACTIVE WASTE GENERATION: LIFE-CYCLE PLANNING

## A. INTRODUCTION

This guide describes a method acceptable to the U.S. Nuclear Regulatory Commission (NRC) for use in the implementation of Title 10, Section 20.1406, "Minimization of Contamination," of the *Code of Federal Regulations* (10 CFR 20.1406) (Ref. 1). License, approval, and certification applicants should strive to minimize contamination and radioactive waste generation over the total life cycle of a facility, from initial facility layout and design through procedures for operation and concluding with final decontamination and dismantling at the time of decommissioning.

10 CFR 20.1406 applies to applicants for licenses (other than early site permits and renewals), design certifications, approvals of standard designs, and manufacturing licenses. The regulation requires the submittal of design information and operational procedures for (1) minimizing radioactive waste generation and contamination of the facility and the environment, and (2) facilitating decommissioning. As specifically stated in 10 CFR 20.1406:

> (a) Applicants for licenses, other than early site permits and manufacturing licenses under part 52 of this chapter and renewals, whose applications are submitted after August 20, 1997, shall describe in the application how facility design and procedures for operation

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This guide was issued after consideration of comments received from the public.

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will minimize, to the extent practicable, contamination of the facility and the environment, facilitate eventual decommissioning, and minimize, to the extent practicable, the generation of radioactive waste.

(b) Applicants for standard design certifications, standard design approvals, and manufacturing licenses under part 52 of this chapter, whose applications are submitted after August 20, 1997, shall describe in the application how facility design will minimize, to the extent practicable, contamination of the facility and the environment, facilitate eventual decommissioning, and minimize, to the extent practicable, the generation of radioactive waste.

The purpose of this regulatory guide is to present guidance that will assist applicants covered by 10 CFR 20.1406 in effectively implementing this licensing requirement. The guidance consists of specific design considerations drawn from nuclear industry experience and lessons learned from decommissioning. These have been combined to support the development of a contaminant management philosophy. The principles embodied in this philosophy are threefold: (1) prevention of unintended releases; (2) early detection, if there is unintended release of radioactive contamination; and (3) prompt assessment to support a timely and appropriate response. Applying these principles requires the use of sound design, proven engineering practices, conservative radiation protection principles, and attention to operational practices. All of this should be considered in the context of the life cycle of the facility from the early planning stages through the final plans for decommissioning and waste disposal. This guide describes some of the mechanisms that can be employed for facility life-cycle planning to meet the requirements of 10 CFR 20.1406.

This regulatory guide contains information collection requirements covered by 10 CFR Parts 20, 30, 40, 50, 61, 70 and 72 that the Office of Management and Budget (OMB) approved under OMB control numbers 3150-0014, -0017, -0020, -0011, -0135, -0009 and -0132, respectively. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

## B. DISCUSSION

### 1. Planning for Minimization of Contamination

One of the significant early lessons learned about minimizing the radiological impacts of decommissioning was the importance of early planning for decommissioning. Such planning should include consideration of decommissioning at the time of initial design and continue throughout facility operations. The strategy should also be applied to minimizing contamination of the facility and the environment. Thus, during initial facility design planning, an applicant should comprehensively consider design aspects, construction, and operation until termination of the license by the NRC. License termination includes consideration of decommissioning activities until satisfactory facility and site release is accomplished (i.e., meeting the radiological criteria in Subpart E, "Radiological Criteria for License Termination," of 10 CFR Part 20, "Standards for Protection Against Radiation." ).

### 2. Application of a Risk-Informed Approach

This guide should be implemented in a risk-informed approach that considers the magnitude of the hazard involved. License applications submitted to the NRC cover more than 100 different kinds of activities. These activities do not all reflect the same potential for contamination of a facility and the environment, or for the generation of radioactive waste. Therefore, the applicant should use judgment to determine the extent to which this guide applies to any given facility or activity. Factors that may enter into this decision include the material's form (e.g., dry solids, liquids, gases), the inventory, and the material's environmental mobility. Figure 1 shows the decision paths an applicant might take in determining the applicability of this guide. In considering the flow paths in Figure 1, note that the regulations contain no exceptions with regard to the applicability of 10 CFR 20.1406 for license, design certification, and design approval applications submitted after August 20, 1997 other than the exception for early site permits and license renewals. Even applications that do not deal with large or significant amounts of radioactive material need to address the minimization and facilitation provisions of the regulations, but they should do so using common sense and good judgment.

As seen in Figure 1, if a facility will store or handle large volumes of dispersible radioactive material, then the applicant should consider the full range of the measures found in the guide. If the facility will handle significant amounts of dispersible radioactive material (e.g., amounts that, if released, might result in extensive cleanup activities either during operation or decommissioning), the form of the material that will be released needs to be considered. A facility which primarily stores or handles liquid radioactive material, for example, should give consideration to the provisions in this guide to prevent and control inadvertent liquid releases. Similarly, for a gas, consideration should be given to the provisions to control inadvertent gaseous releases. Conceptually, this also applies to dry solid radioactive wastes, with consideration taken for obvious differences in chemical and physical forms.

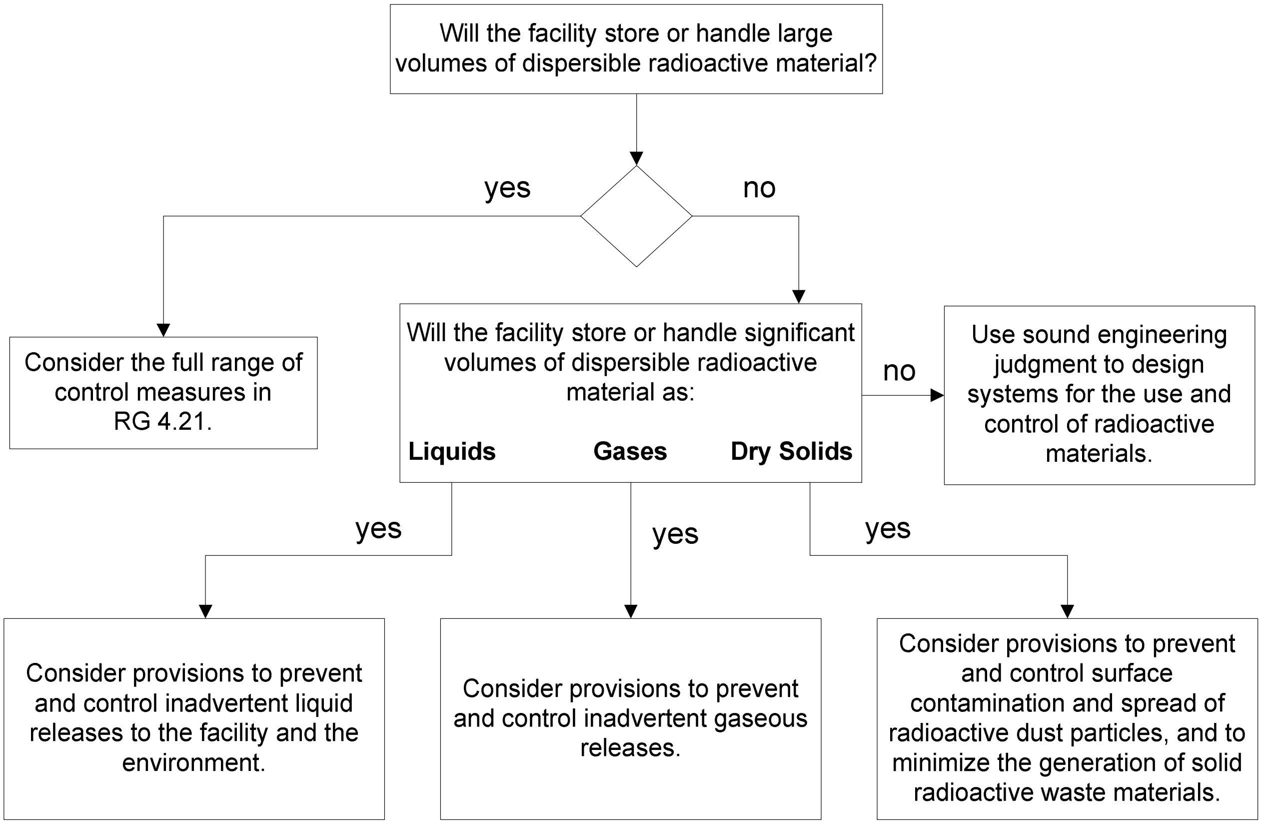


**Figure 1. Decision Paths for Determining the Applicability of Regulatory Guide 4.21**

Table 1 provides further information that may be useful in determining the applicability of the guide. This table is based on the type of facility, the physical form of the radioactive material, the material's half-life, and the facility's inventory of the material. For major, complex facilities with significant inventories of radioactive materials, such as a commercial nuclear power plant, enrichment facility, fuel fabrication facility, or a radioactive waste facility (Table 1, Groups 1 and 2), the guide should assist an applicant in meeting the requirements of 10 CFR 20.1406. For smaller facilities that do not have large inventories, especially ones in which the material has a short half-life or is in the form of a sealed source (e.g., Table 1, Group 4), an applicant would need to consider only those design measures and operational procedures that directly apply to the type of radioactive material and processes to be authorized and the potential for contamination of the facility or environment. In this case, applicants should focus on historical information and process knowledge that reflect the likelihood of contamination of the facility and environment to identify the systems that should be designed and operated consistent with 10 CFR 20.1406. Since applicability of the guidance is a facility-by-facility decision, early consultation with the appropriate regulatory agency is strongly advised.

**Table 1. Applicability of Regulatory Guide 4.21 Relative to Type of Facility, Physical Form of Radioactive Material, Half-Life, and Inventory**

| Type of Facility or Use of Radioactive Material | Physical Form of Radioactive Material Involved | | |
|---|---|---|---|
| | Liquid | Gas | Dry Solid |
| **Group 1 — High Inventory, Long Half-Life - Power Plants and Fuel Cycle Facilities** | | | |
| Commercial nuclear power plant | high | high | high |
| Fuel fabrication plant | high | high | high |
| Enrichment plant | high | high | high |
| Reprocessing facility | high | high | high |
| **Group 2 — High Inventory, Long Half-Life - Waste Facilities** | | | |
| High-level waste disposal facility | high | moderate | moderate |
| Low-level waste disposal facility | moderate | low | high |
| Radioactive waste processors | moderate | low | moderate |
| **Group 3 — Intermediate to Low Inventory, Long Half-Life** | | | |
| Uranium mills | moderate | moderate | moderate |
| Research and test reactors | moderate | moderate | high |
| Laboratory, research facility, and academic and broad-scope facility | moderate | moderate | moderate |
| **Group 4 — Low Inventory, Half-Life Generally Not Long** | | | |
| Medical use of radioactive material | low* | low | low* |
| Industrial use of radioactive material | low | low | low, dependent on material* |
| Medical or industrial use of sealed sources | low | low | low |

<u>Legend:</u>

high - highest likelihood of using the measures in this guide
moderate - moderate likelihood of using the measures in this guide
low - low likelihood of using the measures in this guide
* - emphasis on inventory control

# C. REGULATORY POSITION

## 1. Minimizing Facility Contamination

### 1.1 General Statement

In general, an applicant should minimize radioactive contamination of the facility by using structure, system, and component (SSC) designs and operational procedures that limit leakage and/or control the spread of contamination. The design and operational procedures should provide for the early detection of leaks thus allowing prompt assessment to support a timely and appropriate response. Applicants should note that 10 CFR 20.1406 requires that contamination be minimized "…to the extent practicable..." This implies that other competing concerns such as the implication to safety systems and the overall cost should be considered. Thus the minimization of facility contamination must be considered in the context of overall facility safety.

### 1.2 Minimization of Leaks and Spills and Provision of Containment

Through design, worker practices, preventive maintenance, and effective operating procedures, applicants covered by 10 CFR 20.1406 should strive to minimize leaks and spills, provide containment in areas where such events might occur, and provide for detection that supports timely assessment and appropriate response. This approach should be applied in a risk-informed and performance-based manner considering the nature of the hazard. Radiologically significant leaks and spills[1] need to be addressed, and containment should be considered where practical and cost effective. Areas where licensed materials are used and stored should be designed to facilitate maintenance and operations (including cleanup). Radiological work should be restricted to a localized section of the facility in order to minimize the potential area requiring decontamination.

### 1.3 Prompt Detection of Leakage

The facility should be designed such that any SSC that has the potential for leakage is provided with adequate leak detection capability to the extent practical. In addition to design considerations to control and, if possible, prevent radioactive system leakage, it is important during operations to be able to promptly detect leakage as close as possible to the leakage source to allow timely intervention and to prevent the potential for widespread contamination. Thus, monitoring and routine surveillance programs are an important part of minimizing potential contamination. This approach should include the placement of instruments to detect leakage at readily accessible locations and the use of operational practices that will enable early detection of contamination. Because leakage detection is only the first step in minimizing contamination, the applicant also should be prepared to provide a timely assessment and response based on the location and characteristics of the leak or spill.

### 1.4 Avoidance of the Release of Contamination from Undetected Leaks

Past experience has shown that leaks of radioactive material from SSCs containing radiation can go undetected over long periods of time if these SSCs are not readily accessible for surveillance or when the amount of leaking material is below the sensitivity of the survey instrument. Under these conditions,

[1] Unless already defined in an application or licensing basis document, radiologically significant generally refers to the presence of radioactive materials at levels which could result in radiation exposures and doses in excess of the 10 CFR Part 20 requirements for radiation workers and members of the public, or in excess of liquid and airborne effluent concentration limits and releases to sewers under Appendix B to Part 20.

contamination from undetected leaks can accumulate as subsurface residual radioactivity that may require remediation prior to license termination. This contamination generally occurs as minor leaks over an extended period of time. SSCs that are buried, embedded in concrete, or in contact with soil (such as spent fuel pools, underground tanks, and buried pipes) are particularly susceptible to undetected leakage. Facilities undergoing decommissioning commonly discover previously undetected contamination in the subsurface environment. These releases were generally minor leaks that occurred over an extended period of time. Many of the leaks occurred in areas where it was difficult or impossible to conduct regular inspections. This likely contributed to the failure to identify the leaks at the time of occurrence. Monitoring of some SSCs was not sufficiently sensitive to identify small leaks and leakage rates. Such situations and conditions should be avoided during facility design. Leak detection systems should be included within the facility design that are capable, to the extent practical, of detecting minor leaks that otherwise, over time, could potentially cause significant environmental contamination.

### 1.5 Measures for Reducing the Need To Decontaminate Equipment and Structures

Leakage from components containing radioactive liquids can be reduced by: (1) the inclusion of design specifications such as the proper selection of materials (e.g., corrosion-resistant piping, double-walled pipes, and tanks with annulus monitoring); (2) improved protection of buried components (e.g., galvanic corrosion protection, coatings); (3) the use of industry consensus codes and standards for repair and/or replacement of SSCs; and (4) the application of rigorous quality control and quality assurance program requirements in procurement specifications and during installation of SSCs. 10 CFR 20.1406 applicants can decrease the probability of a release, the amount released, and the spread of a contaminant by: (1) temporary or supplemental ventilation systems, (2) treating the exhaust from vents and overflows, and (3) using techniques to control releases (i.e., capping or elevating uncontrolled drains, hard piping of drains to drain sumps, use of barriers or dikes, use of controlled sumps, and protection of SSCs from inclement weather).

### 1.6 Periodic Review of Operational Practices

Operational practices are another important consideration in meeting the requirements of 10 CFR 20.1406. These practices should be subjected to periodic review to ensure that (1) facility personnel follow the operating procedures, (2) operating procedures are revised to reflect the installation of new or modified equipment or facility processes, and (3) personnel qualification and training are kept current with the latest versions of operational programs and procedures. Operational programs and procedures should be subjected to review and evaluation following events that resulted in leaks and spills of radioactive materials. As part of the analysis, the evaluation should determine (1) whether procedures, equipment, and/or operator errors contributed to the event and releases, and (2) identify immediate and long-term corrective actions. The results of such lessons learned should then be assessed for their broader applicability to similar or related facility operations, and then incorporated as needed into revised programs and procedures.

## 2. Minimizing Contamination of the Environment

### 2.1 Development of a Conceptual Site Model Development

In general, system design features and operational procedures that prevent and/or control releases within the facility also contribute to minimizing contamination of the environment. For systems that directly interface with the environment, the first indication of a leak may be detection in an environmental monitoring system. To control and mitigate such events, it is prudent to have a comprehensive understanding of the interface with environmental systems and the features that will control the movement of contamination in the environment. A conceptual site model based on site characterization and facility design and construction can be a significant tool in (1) understanding the site, (2) planning and implementing a contaminant monitoring program, and (3) planning and implementing mitigative actions. Therefore, the site should be characterized before construction to assess the impact that the facility will have on the site hydrogeology following construction. In addition to the conceptual site model, attention should be given to identifying the potential release mechanisms, release scenarios, and possible location of contaminant releases.

### 2.2 Provision for Early Detection of Leakage and Contaminant Migration

Systems or structures that are buried or in contact with soil are particularly susceptible to undetected leakage. Undetected leakage commonly occurs in areas where it is not possible to conduct regular inspections; therefore, these leaks are often not identified in a timely manner. To minimize contamination of the environment, systems should be designed to facilitate early detection of leakage and contaminant migration.

### 2.3 Final Site Configuration

Applicants covered by 10 CFR 20.1406 should consider the site configuration following construction to aid in preventing the offsite migration of radionuclides via an unmonitored pathway. 10 CFR 20.1406 applicants should identify, as early as practical in the licensing process, the potential pathways of radioactive contaminants through the surface and subsurface. Applicants covered by 10 CFR 20.1406(a) should develop an onsite monitoring program, as an integral part of the radiological environmental monitoring program. The program should provide early detection and quantification of leaks and spills and maintain a current baseline of radiological and hydrogeological parameters. Plans for responding to the detection of leaks and spills should reflect the final facility design and site configuration.

## 3. Facilitation of Decommissioning

### 3.1 General Statement

In general, the means for facilitating decommissioning begins at the design stage and should be incorporated into the procedures and operations. The objective is to ensure that throughout the life of the facility, the design and operating procedures minimize the amount of residual radioactivity that will require remediation at the time of decommissioning.

### 3.2 Facilitation of Decommissioning with Proper Records

The provisions of 10 CFR 50.75(g) contain requirements for maintaining records "...of information important to the safe and effective decommissioning of the facility." These records are required to contain details on contaminating events and residual levels of contamination in the environment during the life of the facility. In addition, 10 CFR 30.35(g), 10 CFR 40.36(f), 10 CFR 70.25(g), and 10 CFR 72.30(d) have records retention requirements related to decommissioning. Records on events involving leaks or spills should be maintained and readily accessible to facilitate cleanup and eventual decommissioning of the facility.

## 4. Minimizing the Generation of Waste

Minimizing the generation of radioactive waste is both a design and operational consideration. A life-cycle approach should be taken in identifying all components used in the facility and all waste that will result from system operations and processing. Life-cycle waste management planning should also be carried out for any new waste stream to define the strategy for its conditioning, storage, or disposal. System designs should enable operators to perform decontamination efficiently while minimizing collective dose and the production of radioactive waste. 10 CFR 20.1406 applicants should evaluate design and operational options to implement measures that minimize waste generation and radioactivity levels and that fit each phase of the expected life cycle of the facility. For each phase, the implementation of such measures should consider the merits of various technological options and lessons learned from the use of earlier or similar technology; assess public health and safety, and the protection of the environment; and confirm compliance with applicable Federal, State and local regulations governing the management of radioactive waste, and wastes characterized by the presence of hazardous chemicals and radioactivity.

While the measures identified in this guide focus on minimizing the generation of radioactive waste, NRC recognizes that constraints and competing factors may govern the selection of specific measures for waste minimization. In many instances, an applicant or licensee has no control over such constraints and may be forced to balance competing factors of operational flexibility and costs, while satisfying all applicable regulatory requirements at the same time. For example, access to or the availability of offsite low-level waste disposal capacity may be beyond the control of an applicant or licensee.

The methods chosen to manage radioactive waste should be carefully considered for the purpose of meeting regulatory requirements for transportation and the waste acceptance criteria of specific disposal or treatment outlets. For some waste streams, a processing method that may be used to reduce the overall volume of waste might result in an increase of the specific activity of the waste, thereby increasing the difficulty in finding appropriate disposal outlets for higher activity wastes, such as Class B and C wastes under the requirements of 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste." In other instances, the amount or volume of waste is not the issue. Rather the waste's radiological and chemical properties, such as for mixed waste, which may restrict options in finding treatment and disposal outlets unless one of the hazardous properties is delisted. NRC and U.S. Environmental Protection Agency regulations control the storage of mixed wastes. Some States impose additional regulations addressing the characterization, treatment, transportation, and disposal of mixed wastes.

When disposal or treatment outlets are not available, a 10 CFR 20.1406 applicant or licensee may be required to develop additional onsite storage capacity. The availability of waste disposal facilities depends on whether States or regional low-level waste compacts have provided facilities for long-term storage and disposal. For onsite storage, 10 CFR 20.1406 applicants and licensees should integrate the associated operations into existing waste management programs. They should also address decontamination and decommissioning of the storage facility and conduct periodic reassessments of waste already being stored, given that changes in future disposal requirements might possibly make stored wastes unacceptable for disposition.

## D. IMPLEMENTATION

The purpose of this section is to provide information to 10 CFR 20.1406 applicants regarding the NRC's plans for using this regulatory guide. The NRC does not intend or approve any imposition or backfit in connection with its issuance.

In some cases, 10 CFR 20.1406 applicants may use proposed or previously established acceptable alternative methods for complying with specified portions of the NRC's regulations. Otherwise, the methods described in this guide will be used in evaluating compliance with 10 CFR 20.1406.

# REGULATORY ANALYSIS

The NRC staff did not prepare a separate regulatory analysis for this regulatory guide. The regulatory basis for this guide is the regulatory analysis prepared for the amendments to 10 CFR Part 20 promulgated July 21, 1997 (62 FR 39058). That regulatory analysis examined the costs and benefits of the rule as implemented by this guide. A copy of that regulatory analysis is available for inspection and may be copied (for a fee) at the NRC Public Document Room, located at One White Flint North, 11555 Rockville Pike, Rockville, MD 20852.

# REFERENCES


1. 10 CFR Part 20, "Standards for Protection Against Radiation," U.S. Nuclear Regulatory Commission, Washington, DC. [1]

2. 10 CFR Part 50, Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission, Washington, DC.

3. Regulatory Guide 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC. [2]

4. Regulatory Guide 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable," U.S. Nuclear Regulatory Commission, Washington, DC.


# BIBLIOGRAPHY

**American National Standards Institute/American Nuclear Society (ANSI/ANS) Documents** [2]

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1 All NRC regulations listed herein are available electronically through the Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/reading-rm/doc-collections/cfr/. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or (800) 397-4209; fax (301) 415-3548; and e-mail PDR@nrc.gov.

2 All regulatory guides listed herein were published by the U.S. Nuclear Regulatory Commission. Most are available electronically through the Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/reading-rm/doc-collections/reg-guides/. Active guides may also be purchased from the National Technical Information Service (NTIS) on a standing order basis. Details on this service may be obtained by contacting NTIS at 5285 Port Royal Road, Springfield, VA 22161, online at http://www.ntis.gov, by telephone at (800) 553-NTIS (6847) or (703)6 05-6000, or by fax at (703) 605-6900. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555-0001; telephone (301) 415-4737 or (800) 397-4209; fax (301) 415-3548, and e-mail PDR@nrc.gov.

2 Copies of American National Standards may be purchased from the American National Standards Institute, 1819 L Street, NW, 6th floor, Washington, DC 20036, telephone (202) 293-8020. Purchase information is available through the ANSI Web site at http://webstore.ansi.org/ansidocstore/.

ANSI/ANS-40.37-1993, "Mobile Radioactive Waste Processing Systems," American National Standards Institute, Washington, DC, 1993.

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10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste," U.S. Nuclear Regulatory Commission, Washington, DC.

3 All NUREG-series reports listed herein were published by the U.S. Nuclear Regulatory Commission. Most are available electronically through the Public Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/ reading-rm/doc-collections/nuregs/. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or (800) 397-4209; fax (301) 415-3548; and email PDR@nrc.gov. In addition, copies are available at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328, telephone (202) 512-1800; or from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161, online at http://www.ntis.gov, by telephone at (800) 553-NTIS (6847) or (703) 605-6000, or by fax to (703) 605-6900.

# APPENDIX A

## EXAMPLES OF MEASURES TO CONTROL CONTAMINATION

The measures that follow are intended to be examples of measures which should be considered to address the requirements of 10 CFR 20.1406. This listing is not intended to be complete and comprehensive, nor is it intended to be a checklist of minimally acceptable facility design features and operational procedures. A risk-informed approach (considering the kind of facility, materials and hazards involved) should be used by 10 CFR 20.1406 applicants when deciding on the extent to which the measures described in this guide would apply to a specific situation.

### A-1. Minimizing Facility Contamination

To minimize facility contamination, 10 CFR 20.1406 applicants should consider the following specific measures (or a combination thereof):

a. The interface between structures, systems, and components (SSC) important to radiological safety and nonradioactive SSCs should be minimized. Necessary interfaces should have a minimum of two barriers, including one that can be a pressure differential, and should have instrumentation for prompt detection and control of cross-contamination.

b. Processing areas for radioactive material should be isolated from other areas within the facility through the use of compartmentalization and access controls to reduce the potential for cross-contamination.

c. A maintenance and inspection program should be applied to radioactive SSCs that have a potential for leakage of radioactive material to the site environs (i.e., onsite and offsite locations outside of the facility SSCs).

d. Leak or spill collection systems should be provided to protect against leakage and/or to isolate the release of liquid contamination using redundancy concepts such as the use of multiple piping enclosures with pans/trays or drainage to channel contamination for collection and processing.

e. Floor liners and catch basins should be used for SSCs that have a high potential for periodic leakage during routine operations and/or maintenance. Floor liners and catch basins should be impermeable, durable, and have readily cleanable surfaces. Concrete structures and walls near these SSCs should be sealed to facilitate cleaning and decontamination.

f. A leak identification program should be developed for components containing radioactive materials to prevent unnecessary contamination of equipment and surrounding areas and to minimize radioactive waste. Provision should be made to allow for the timely identification of leak locations. Structures and components, such as a spent fuel pool and associated piping, should be designed to permit the isolation of clearly defined zones within that system and should be provided with the capability to detect and quantify small leakage rates (e.g., several gallons per week) from each zone.

g. For areas not readily or frequently accessed, consideration should be given to the use of remote monitoring systems such as television cameras. Use of such remote monitoring would aid in the early identification of leaks, which could serve to minimize contamination of plant areas. The use of cameras could also result in lower radiation exposures to personnel during operations.

h. Monitoring instrumentation (e.g., level sensors, flow meters, pressure sensors, temperature indicators) should be designed to allow replacement.

i During design and/or process selection, where applicable, processes should be selected that eliminate streams that have the potential for the encrustation of precipitates or crystallization at ambient temperatures. The latter would eliminate the need for heat tracing, the failure of which could result in line blockages.

j. Pipes should be adequately sized to minimize the potential for blockage by the encrustation of precipitates and to facilitate the removal of such blockage from the pipes.

k. The initial facility design should include system decontamination facilities/provisions that enable the timely reduction of the buildup of radioactive source terms that could potentially lead to facility contamination.

l. Radioactive SSCs should be designed for the lifetime of the facility, thus avoiding the necessity to replace these SSCs and lessening the potential for system leakage and contamination of nonradioactive systems/components. Materials used in radioactive SSCs should be compatible with processing/disposal options.

m. Considering the expected life cycle of the facility, the design should include provisions to facilitate the maintenance, inspection, and removal of radioactive components.

n. The design of areas that may become highly contaminated (e.g., refueling canals, valve alleys) should include provisions for decontamination methods specifically designed for those areas.

o. In areas where the potential for a spill exists, floors should be appropriately sloped to floor drains that lead to the radioactive waste system, thus limiting the extent of contamination.

p. The necessity for decontamination can be reduced by limiting, to the extent practicable, the deposition of radioactive material within processing equipment, particularly in the "dead spaces" or "traps" (i.e., zones of low fluid flow where contaminants settle out) in components where substantial accumulation can occur. Tank and piping systems used for liquid radioactive systems should take advantage of gravity flow (e.g., pipes and tank bottoms should be sloped) to reduce the potential for contamination buildup. The deposition of radioactive material in piping can be reduced and decontamination efforts enhanced by avoiding stagnant legs, locating connections above the pipe centerline, using sloping rather than horizontal runs, and providing drains and flushing capabilities (which are routinely inspected and maintained) at low points in the system.

q. Piping which may require eventual decontamination should be designed for readily available access to permit the use of high-pressure hydrolyzing and chemical decontamination methods.

r. Potentially radioactive lines in temporary and/or mobile systems should have self-sealing quick disconnects as well as a means to promptly isolate leaks. These systems should incorporate operational interlocks to minimize the possibility of leakage and contamination. Designs should ensure that spills and leaks from skid-mounted systems will be contained and routed to radioactive waste drains.

s. Material selection for SSCs should consider the operating environment and intended means of disposal. The design and materials for reinforced concrete structures as well as piping, liners, bolts, and other items used for the storage and transport of radioactive liquids should be appropriate to mitigate cracking, adverse chemical reactions, and other degradation mechanisms that can result in leakage. The selection of radiation-damage-resistant materials for use in high-radiation areas can reduce the need for frequent replacement and can decrease the probability of contamination from leakage. Where appropriate, the surfaces of concrete structures and components should be sealed to facilitate cleaning and decontamination.

t. Surfaces and expansion joints can be decontaminated more expeditiously if they are pretreated to provide a smooth, nonporous surface that is free of cracks, crevices, and sharp corners. These desirable features can be achieved by specifying appropriate design instructions, giving attention to finishing work during construction or manufacture, and using appropriate sealers on surfaces where contamination can be anticipated. Seals should be maintained over the life of the facility, and their integrity should be routinely inspected, to ensure that spills and leaks on the floors do not enter unmonitored areas beneath the floors and foundations.

u. 10 CFR 20.1406 applicants should also ensure that concrete block walls designed to enable the future removal of large components for maintenance or replacement are completely sealed to prevent the intrusion of radioactive materials into the block interiors. Tops of block walls that are not connected to the ceiling should be sealed to prevent contamination from entering the block interiors. Porous, unsealed blocks should not be used in areas subject to contamination.

v. A program should be developed for maintaining control over the storage and use of radioactive materials in the restricted area outside the physical facility structures. For example, areas in which waste is to be stored should be evaluated and approved for storage and have appropriate design and control features. Administrative controls (e.g., controls on packaging and transport of radioactive material in and around the facility) should be established to prevent the spread of contamination when radioactive material or contaminated equipment must be transported from one station location to another within the facility and when the route of transport through lower radiation zones cannot be avoided.

w. Drains from locker rooms and cleanup showers in personnel decontamination areas should be routed to radwaste processing facilities to prevent the re-concentration of radioactive materials in onsite sewage plants.

x. Ventilation system designs should confine airborne radioactive materials within the process areas and as close to the point of origin as practicable. Construction materials for the ventilation systems should be carefully selected and have smooth internal and external surface finishes to aid in decontamination. The length of ventilation stacks and duct work, and the number of abrupt changes in direction, should be minimized to reduce the potential plate-out of contamination. Designs should permit convenient inspection, maintenance and decontamination, and facilitate replacement of critical components such as filters, fans, and dampers. Maintaining air pressure gradients and airflows from areas of low potential airborne contamination to areas of higher potential contamination can limit the spread of airborne contamination within the facility. Maintenance programs should include periodic checks of ventilation systems to ensure that the design pressure differentials, direction of flow, and flow rates are being maintained and that the design continues to be adequate for controlling contamination.

y. To prevent uncontrolled release through ventilation systems, condensation from all coolers handling potentially contaminated air should be collected and routed to a monitored liquid effluent discharge.

z. Provisions should be made for containing and controlling potential tank overflow through the tank vent discharge piping. Such provisions may include the use of a receiving tank or indoor sump to catch any overflow, and high-level alarms on the source tank to indicate overflow occurrences.

aa. Tank sampling stations should be designed to minimize the possibility of sample fluid leaking to the ground or to the underlying pad surface.

## A-2. Minimizing Contamination of the Environment

To minimize contamination of the environment, 10 CFR 20.1406 applicants should consider the following specific measures (or a combination thereof):

a. Applicants should evaluate the system design with respect to the hydrogeology of a site before construction to (1) gather information for inclusion in a conceptual site model, (2) identify potential migration and ground-water transport pathways for potential environmental contaminating events, and (3) assess the effect of construction on the hydrogeological characteristics of the site. The conceptual site model should address both the horizontal and vertical variability of the onsite hydrogeology and the potential effect of the layout of structures, foundations, footings, and backfills. A plan for implementing and updating the conceptual site model should comprise one component of the proposed facility operating procedures. Specifically, following facility construction, any impacts of site construction activities on final site hydrogeological characteristics should be identified. If there are significant changes at the site during the operating life of the facility, the conceptual site model should be reevaluated and adjusted, and appropriate adjustments/changes should be made to the onsite and offsite monitoring program.

b. As a general design consideration, any SSCs containing radioactive material should have at least two impermeable boundaries to the environment with the capability for periodic testing and inspection. If the design cannot incorporate such features, the applicant should propose specific environmental monitoring (e.g., sampling of ground water in close proximity to potential sources) to periodically verify the integrity of the system.

c. Tanks, sumps, and ponds containing radioactive materials should have at least two impermeable boundaries to the environment, with an integrated leak detection system capability that triggers an alarm at an operator station. Tank catch basins should be of solid construction, sealed, and leakproof, and they should have a capacity sufficiently larger than the maximum tank volume to accommodate the contents of the tank, including the contents of related piping, and in the event of a system failure.

d. Exterior tanks should be located on or above bermed concrete pads. The berms should have a capacity sufficiently larger than the maximum tank volume to accommodate the contents of the tank, including the contents of related piping, in the event of a system failure. Each concrete pad should be lined or sealed with an impermeable membrane. Each bermed area should have provisions for the sampling and release of rainwater.

e. Monitoring systems and programs to detect the source and extent of leakage of radioactivity from SSCs, particularly those located below grade, should be deployed as close as possible to the SSC and should be designed to expedite early detection so that remedial action can be taken if necessary.

f. To the extent practical, systems containing, transporting, or processing radioactive liquids should not use buried or embedded piping and drains. Underground piping containing radioactive liquids should be enclosed within structured pipe chases with provisions for periodic inspection (visual) or surveillance (leak detection system) to verify piping integrity. For those situations in which pipe chases are not feasible, the use of double-walled lines with built-in leak detection capability should be considered.

g. To minimize the leakage of radioactive fluids to ground water, and the leakage of ground water into buildings, system and structural designs should avoid the use of below-grade conduit and piping penetrations through walls that form exterior boundaries. This is particularly applicable to penetrations at or through the floor level. Penetrations through outer walls of a building containing radioactive systems should be sealed to prevent leaks to the environment. The integrity of such seals should be periodically verified.

h. If a building design includes foundation drains, it should also include the capability for sampling and processing the effluent of those drains.

i. To minimize the potential for spreading solid or liquid contamination into the environment, radioactive material handling, staging, storage, and decontamination areas (to support refueling, maintenance and operational activities) should be located inside buildings or in contained areas.

j. The radioactive liquid waste treatment system should not include any bypasses or drains that would allow waste to inadvertently circumvent treatment system components or to be released directly to the environment.

k. Drain systems for storm water and sanitary sewage should be separate from contaminated waste drain systems.

l. The design for any sump or retention pond that has the potential to become contaminated (even if it is not considered a radioactive system) should include a liner and the capability for isolation or collection/routing of overflow to a monitored release path.

m. All ingress/egress points for facilities containing radioactive systems should include provisions for preventing leakage/seepage to the outside environment. For example, the use of sills at outside ingress/egress locations or floor grades sloped toward drain channels can help to prevent leakage/seepage to outside grounds/soil.

n. Design and construction specifications for major radioactive system barriers such as spent fuel pools and transfer canals should consider measures to minimize the need for seals (e.g., continuous concrete pours). Alternatively, clear separation between major structures should be considered, with both visual and integrated leak detection.

o. The design of excavations and backfill, and the selection of backfill material for SSCs containing radioactive materials should: (1) prevent or minimize the ability of leaking contaminants from the facility to reach natural permeable layers or fractured rock; and (2) in the event of leakage to the environment, facilitate the migration of leakage contaminants to designated locations and systems of the facility (e.g., radioactive external waste drains or sumps) for eventual extraction and treatment.

p. Backfill material should not contain concentrations of radioactive material above natural background levels at the site.

q Proposed operating procedures should include the monitoring of backfill or structural fill designed to transport leakage from radioactive systems for evidence of clogging (e.g., blockage by migrating fines from surrounding soil).

r. Potential leakage from any existing adjoining nuclear facility should be prevented from migrating into the excavation and backfill of a new nuclear facility.

s. The design ground-water level should be located below the foundation of SSCs containing radioactive liquids so that any leakage is not directly introduced into saturated soils below the foundation.

t. Plans for the extraction of ground water or leaked liquid radioactive effluent should consider the potential impact of extraction on the SSC foundation support.

u. Monitoring programs should allow for the reevaluation of the location of monitoring sensors and sampling frequency if contaminants are detected. This analysis should provide the technical basis for determining the need for further action.

v. Procedures for mitigation if contamination is detected should include use of the conceptual site model and monitoring information to develop event-specific models of contaminant migration before the selection of a remediation strategy.

w. When deemed appropriate, ground-water capture zones surrounding SSCs should be designed and operated to provide effective means to isolate and collect liquid contaminants escaping to the subsurface. Groundwater and/or soil remediation will not be necessary for every detection of contamination. A risk-informed approach may be implemented to assess the applicable site-specific parameters (e.g., kind of facility, materials, and hazards involved) for consideration in decommissioning activities.

x. In general, onsite disposal of radioactive material [i.e., disposal of waste under Title 10, Section 20.2002, "Method for Obtaining Approval of Proposed Disposal Procedures," of the *Code of Federal Regulations* (10 CFR 20.2002)], should be avoided or minimized as described in a license application. Such disposals should be located in areas not susceptible to surface-water flooding or occasional water-table rise creating local saturation of the waste, and they must have proper monitoring to detect potential radionuclide migration. If the applicant chooses to pursue waste disposal under 10 CFR 20.2002, all the required documentation relating to onsite disposal should be maintained in the facility records until the license is terminated.

## A-3. Facilitating Decommissioning

To facilitate decommissioning, 10 CFR 20.1406 applicants should consider the following specific measures (or a combination thereof):

a. To facilitate decommissioning, all information relating to the facility design, facility construction, facility design changes, site conditions before and after construction, onsite waste disposal, onsite contamination, and results of monitoring and radiological surveys should be centrally located and readily recoverable.

b. Applicants should establish procedures to ensure adequate and complete documentation of corporate knowledge of instances of facility and environmental contamination and operational events over the lifetime of the facility, in accordance with applicable information collection requirements such as 10 CFR 70.50, "Reporting Requirements"; and Subpart D, "Records, Reports, Inspections, and Enforcement," of 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste, and Reactor-Related Greater than Class C Waste." In addition, 10 CFR 30.35(g), 10 CFR 40.36(f), 10 CFR 50.75(g), 10 CFR 70.25(g), and 10 CFR 72.30(d) have recordkeeping requirements important to decommissioning. This program can provide information that will be important in preparing an historical assessment of a nuclear facility, which can save time and effort during decommissioning planning.

c. Decommissioning activities in the past have been complicated by radioactivity that was not adequately documented before decommissioning began. Applicants covered by 10 CFR 20.1406 are encouraged to consider maintaining records of instances of facility and environmental contamination events that result in residual contamination that may complicate the decommissioning process.

d. Plans and procedures to facilitate decommissioning should include (1) comprehensive video records of the equipment layout in areas where radiation fields are expected to be high following operations, and (2) as-built drawings of the facility. Furthermore, the records should include global positioning system readings that pinpoint all buried component locations, particularly components in the site environs. However, it is recognized that obtaining reliable ground positioning system readings within certain SSCs is not practical because of structural interference with signal quality.

e. Facility designs should minimize the use of embedded pipes in facility walls, floors, and the like to the extent practicable, consistent with maintaining radiation doses as low as is reasonably achievable during operations and decommissioning. Embedded pipes, especially those that are small in diameter (e.g., less than 6 inches), could complicate decommissioning activities because they can be very difficult to remove or survey. Their location should be carefully documented to facilitate eventual decommissioning.

f. Temporary piping installed during construction should be removed to avoid undocumented random piping in the field that, when uncovered, will raise questions about the extent of site contamination during decommissioning. Construction debris should not be disposed of within the controlled area.

g. During the design stage, consideration should be given to facilitating the removal of any equipment and/or components that may require removal and/or replacement during facility operation or decommissioning. When designing buildings or enclosures for large equipment (e.g., steam generators, large piping, tanks), an applicant should determine how the equipment will be removed for replacement/repair or how it will be permanently removed at the time of facility decommissioning. 10 CFR 20.1406 applicants should evaluate the following:

   - size/space clearances
   - installation of removable roofs/walls
   - placement of cranes and lifts for replacement or removal of heavy equipment or components
   - installation of lifting lugs
   - design of anchor points for lifts
   - use of shearable nuts and bolts
   - use of quick-disconnect components
   - ease of insulation removal
   - setdown areas

## A-4. Minimizing the Generation of Waste

To minimize the generation of waste, 10 CFR 20.1406 applicants should consider the following specific measures (or a combination thereof):

a. Since the minimization of radioactive waste is both a design and an operational consideration, a life-cycle approach should be taken to waste management, with attention given to eventual decommissioning of the facility. Life-cycle planning for waste management should define the strategy for its conditioning, storage, or disposal, and this strategy should be applied to any new waste stream during operation of the facility.

b. System designs should enable operators to perform decontamination efficiently while minimizing collective dose and the production of radioactive waste.

c. Onsite decontamination facilities and/or waste segregation facilities should be provided for the orderly management and segregation of large quantities of radioactive material/waste. The design and operation of such facilities, even if temporary, should follow the guidance contained in this document.

d. Although continuous concrete pours for structures eliminate potential leakage paths through seams used for non-continuous concrete pours, structures using continuous concrete pours are difficult to dismantle and could create significant quantities of contaminated waste at decommissioning. Consideration should be given to modular construction for those structures in which liquid leakage is not a concern. Modular designs permit the removal of separate layers of contaminated material, thereby minimizing the volume of contaminated waste.