

U.S. Department of Energy Orders Self-Study Program

DOE O 5400.5

**RADIATION PROTECTION OF THE PUBLIC AND
THE ENVIRONMENT**



ALBUQUERQUE OPERATIONS OFFICE

Change No: 0 DOE 5400.5 Level: Familiar Date: 7/24/98
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DOE ORDER 5400.5
RADIATION PROTECTION OF THE PUBLIC AND THE ENVIRONMENT
FAMILIAR LEVEL

OBJECTIVES

Given the Familiar Level of this module and the resources listed below, you will be able to:

1. State the purpose of implementing DOE Order 5400.5.
2. Define the following terms.
 - Residual radioactive material
 - Settleable solids
 - Public dose
 - ALARA
 - Soil column (in the context of radiation protection of the environment)
 - Protective action guides (PAGs)
 - Stochastic biological effects of radiation
 - Nonstochastic biological effects of radiation
 - Derived concentration guide (DCG)
3. State the four sources of radiation exposure that are excluded from public dose.
4. In regard to the letter R (reasonable) in ALARA, state the five considerations used to decide if a particular reduction in radiation exposure is reasonable achievable.
5. Describe the limits for the following items.
 - Airborne radon decay products as residual radioactive material in an occupied or habitable structure (state the generic guideline concentration in working levels (WL)).
 - Average acceptable level of external gamma radiation (above natural background) inside a building or habitable structure on a site to be released without restrictions.
 - Allowable total residual removable surface contamination (dpm/100 cm²) for iodine – 131.
 - The upper bound on the temporary basic dose limit (mrem per year per person) under unusual circumstances for residual radioactive material.

Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

Note: If you think that you can complete the practice at the end of this level without working through the instructional material and/or the examples, complete the practice now. The course manager will check your work. You will need to complete the practice in this level successfully before taking the criterion test.

RESOURCES

DOE Order 5400.5, Radiation Protection of the Public and the Environment, Change 2, 1/7/93.

Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

INTRODUCTION

The Familiar Level of this module is divided into two sections. In the first section, we will discuss the purpose and definitions related to the Order. In the second section, we will discuss the requirements in Chapters I through IV. We have provided several examples and practices throughout the module to help familiarize you with the material. The practices will also help prepare you for the criterion test.

Before continuing, you should obtain a copy of DOE Order 5500.5. Copies of the Orders are available on the Los Alamos National Laboratory Website at <http://iosun.lanl.gov:1776/htmls/directives.html> or through the course manager. Several additional resources are cited in the Preamble, Section 8 of the Order. It is not necessary to obtain copies of these resources. However, you should have access to these resources and be familiar with their contents. You may need to refer to these documents to complete the examples, practice, and criterion test.

SECTION 1, OBJECTIVES AND DEFINITIONS

OBJECTIVES

It is DOE's objective to operate its facilities and conduct its activities so that radiation exposures to members of the public are maintained within the limits established in this Order and to control radioactive contamination through the management of real and personal property. It is also a DOE objective that potential exposures to members of the public be as far below the limits as is reasonably achievable (ALARA) and that DOE facilities have the capabilities, consistent with the types of operations conducted, to monitor routine and non-routine releases and to assess doses to members of the public.

Besides providing protection to members of the public, it is DOE's objective to protect the environment from radioactive contamination to a practical extent.

DEFINITIONS

As Low As Reasonably Achievable (ALARA)

A phrase used to describe an approach to radiation protection to control or manage exposures and releases of radioactive material to the environment as low as social, technical, economic, practical,

Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

and public policy considerations permit.

Derived Concentration Guide (DCG)

The concentration of a radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode would result in an effective dose equivalent of 100 mrem 0.1 rem (1 mSv).

Nonstochastic Effects are biological effects, the severity of which, in affected individuals, varies with the magnitude of the dose above a threshold value.

Protective Action Guides (PAG)

Projected numerical dose values established by EPA, DOE, or States for individuals in the population. These values may trigger protective actions that would reduce or avoid the projected dose.

Public Dose

The dose received by member(s) of the public from exposure to radiation and to radioactive material released by a DOE facility or operation, whether the exposure is within a DOE site boundary or off-site. It does not include dose received from occupational exposures, doses received from naturally occurring background radiation, doses received as a patient from medical practices, or doses received from consumer products.

Residual Radioactive Material

Any radioactive material that is in or on soil, air, equipment, or structures as a consequence of past operations or activities.

Soil column

An in situ volume of soil down through which liquid wastes percolate from ponds, cribs, seepage basins, or trenches.

Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

Stochastic Effects

Biological effects, the probability, rather than the severity, of which is a function of the magnitude of the radiation dose without threshold.

Note: You do not have to do Example 1 on the following pages, but it is a good time to check your skill and knowledge of the information covered. You may do the Example 1 or go to Section 2.

Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

EXAMPLE 1 SELF-CHECK

1. State in your words what the DOE hopes to achieve by implementing DOE Order 5400.5. It is DOE's objective to operate its facilities and conduct its activities so that radiation exposures to members of the public are maintained within the limits established in this Order and to control radioactive contamination through the management of real and personal property. It is also a DOE objective that potential exposures to members of the public be as far below the limits as is reasonably achievable and that DOE facilities have the capabilities, consistent with the types of operations conducted, to monitor routine and non-routine releases and to assess doses to members of the public. Besides providing protection to members of the public, it is DOE's objective to protect the environment from radioactive contamination to the greatest practical extent.

2. Define the following terms.
 - Residual radioactive material
 - Public dose

Residual radioactive material

Any radioactive material that is in or on soil, air, equipment, or structures as a consequence of past operations or activities.

Public dose

The dose received by member(s) of the public from exposure to radiation and to radioactive material released by a DOE facility or operation, whether the exposure is within a DOE site boundary or off-site. It does not include dose received from occupational exposures, doses received from naturally occurring background radiation, doses received as a patient from medical practices, or doses received from consumer products.

Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

SECTION 2, REQUIREMENTS

This Order is divided into four chapters. This section summarizes the requirements contained in each chapter.

CHAPTER I, GENERAL REQUIREMENTS

General

The Orders in this module adopt radiation protection dose standards consistent with the recommendations of the International Commission on Radiological Protection (ICRP). In 1977, the ICRP recommended a system of dose limitations that has been adopted and implemented by essentially all countries with nuclear programs. The ICRP system of dose limitations provides a scientific basis for health protection and the selection of dose limits. Although the ICRP system is based on sophisticated analytical models, the system reflects current information on health risks, dosimetry, and radiation practices, and promotes a more uniform and consistent application of radiation protection among diverse activities.

The DOE and its contractors are required to comply with legally applicable rules and regulations of other Federal, State, and local agencies, including those that have not adopted the ICRP system.

Liquid Wastes and Effluents

Besides limiting doses to members of the public, additional controls are adopted on the release of liquid wastes to reduce the potential for radiological contamination of natural resources such as land, ground and surface water, and ecosystems. Standards for liquid effluent discharges are driven by the DOE ALARA policy and an objective to minimize contamination in the environment to the extent practicable. Order 5400.5 adopts the best available technology (BAT) as the appropriate level of treatment for liquid wastes containing radioactive material and requires that the BAT be phased in at the earliest practical time. The BAT treatment is intended to produce waste streams within the limits specified in the Order at the point of discharge to a surface waterway and will not normally require further treatment to reduce concentrations. The BAT treatment is provided to protect ground water and to prevent radionuclide buildup in soils.

Change No: 0 DOE 5400.5 Level: Familiar Date: 7/24/98
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The control of releases of liquid wastes to community sanitary sewer systems is designed to be consistent with requirements imposed by the Nuclear Regulatory Commission (NRC) on its licensees. The BAT selection process is applied to the treatment of liquid wastes released to sanitary sewerage when concentrations of radionuclides would otherwise exceed five times the reference values stated in the Order. Operators are expected to ensure that the total annual discharge of radioactive material to the sanitary sewer system will not cause exposures to members of the public that result in doses exceeding a small fraction of the basic annual dose limit.

Effluent Monitoring and Environmental Surveillance

Demonstrations of compliance with Order requirements are based on calculations using information obtained from monitoring and surveillance programs. The ability of these programs to detect, quantify, and adequately respond to unplanned releases of radioactive material into the environment is also dependent upon effluent and environmental transport, diffusion conditions monitoring, and assessment capabilities. It is DOE's intent that high-quality monitoring and surveillance activities are implemented to achieve uniform methods and performance in obtaining information. It is recognized that some differences result from specific site or activity conditions.

Dose Evaluations

Data developed by the department to demonstrate that DOE operations comply with applicable standards and requirements should be correct and representative. Accordingly, DOE Order 5400.5 requires that dose calculations of the public resulting from exposures from routine and unplanned activities be performed using standard Environmental Protection Agency (EPA) or DOE dose conversion factors or analytical models prescribed in regulations applicable to DOE operations. The dose conversion factors and derived concentrations necessary to make dose evaluations meet DOE requirements are provided in DOE Order 5400.5, Chapter II, and three supplemental documents. These supplemental documents are not part of this training module, although the dose conversion factors contained in these documents provide the primary bases for determining compliance with DOE Order 5400.5. Additionally, direction for evaluating potential doses from airborne releases is contained in models used by the EPA. The EPA models are referenced in DOE Order 5400.5 and are not suitable for calculating doses resulting from accidents.

Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

CHAPTER II, REQUIREMENTS FOR RADIATION PROTECTION OF THE PUBLIC AND THE ENVIRONMENT

Public Dose Limits

The primary public dose limits include consideration of all exposure modes from all DOE activities, including remedial actions. The primary dose limit is expressed as the effective dose equivalent, an ICRP term that requires a weighted summation of doses to various body organs. Additional public dose limits are established by EPA regulations for exposures to selected sources or exposure modes. Dose limits established by the EPA may or may not consider risk-based weighting or summation of doses, although they are sometimes expressed as effective dose equivalents. Order 5400.5 also references other legally applicable requirements such as 40 CFR Parts 61, 191, and 192 and 10 CFR Parts 60 and 72 which are not the subject of this training module. Such legally applicable regulations should be consulted for provisions not addressed in the Orders contained in this module.

The exposure of members of the public to radiation sources because of all routine DOE activities shall not cause an effective dose equivalent greater than 100 mrem (1 mSv) in a year. Experience suggests that this dose limit is readily achievable for normal operations at DOE facilities. Temporary increases in dose limits due to unusual circumstances may be requested by the Manager of the DOE Field Office in coordination with the applicable Program Office. Requests for authorization for a temporary public dose limit must be forwarded to the Assistant Secretary for Environment, Safety, and Health, accompanied by appropriate justification. Temporary public dose limits must not exceed 500 mrem (5 mSv) for the year.

The limit of 100 mrem (1 mSv) effective dose equivalent is the sum of the effective dose equivalent from exposures to radiation sources external to the body during the year, plus the committed effective dose equivalent from radionuclides taken into the body during the year. Other than for sources specifically excepted in applicable regulatory documents, doses to members of the public from all exposure modes that could contribute significantly to the total dose shall be considered for evaluation. Operators are required to report DOE-related effective dose equivalent contributions of 10 mrem (0.10 mSv) or more in a year. This public dose limit applies to doses from exposures to

Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

radiation sources from routine activities, including remedial actions and naturally occurring radionuclides released by DOE processes and operations. The dose limits also apply to the doses to individuals who are exposed to radiation or contamination by radionuclides at properties subsequent to remedial action and release of the property. Except for medical sources, consumer products, residual fallout from past nuclear accidents and weapons tests, and naturally occurring radiation sources, operators shall make a reasonable effort to be aware of the existence of man-made sources of radiation that, when combined with the DOE sources, might present the potential for exceeding contributions of 10 mrem (0.1 mSv) effective dose equivalent in a year. Reasonable efforts shall be made to limit dose to members of the public, from multiple sources of radiation, to 100-mrem (1 mSv) effective dose equivalent, or less, in a year. EH-1 and the appropriate Headquarters Program Offices shall be notified if the 100-mrem in a year dose limit cannot be achieved.

Order 5400.5 also discusses specific limits for

- airborne emissions;
- sources from managing and storing spent nuclear material, high-level, and transuranic wastes at disposal facilities; and
- drinking water.

Contractors are expected to implement programs to establish dose limits and compliance activities that are consistent with the requirements of the Orders contained in this module.

ALARA

Contractors are required to implement the ALARA process for all DOE activities and facilities that cause public doses. The ALARA process requires judgment regarding what is achievable. Factors relating to societal, technological, economic, and other public policy considerations shall be evaluated to the extent practicable in making such judgments. Factors to be considered, at a minimum, shall include:

- the maximum dose to members of the public;
- the collective dose to the population;
- alternate processes, such as alternate treatments of discharge streams, operating methods, or controls;

Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

- doses for each alternative;
- costs for each of the technological alternatives;
- examination of the changes in cost among alternatives; and
- changes in societal impact associated with process alternatives.

Except for meeting requirements of the National Environmental Policy Act, qualitative analyses are acceptable most often, especially where potential doses are well below the dose limit. The bases for such judgments should be documented. More detailed analyses should be considered if the decisions might result in doses that approach the limits.

Liquid Effluents

Further controls are imposed on liquid releases to protect resources such as land, surface water, ground water, and the related ecosystems from undue contamination.

The BAT is the prescribed level of treatment if surface waters would otherwise contain, at the point of discharge and before dilution, radioactive material at an average concentration greater than the values established in the Order. The BAT process shall be implemented according to the Order requirements. Although there is no known practical method for removing tritium from liquid waste streams, facilities and operations are to be designed and operated so that tritium sources and releases are considered in the ALARA process.

Selection of the BAT for a specific application will be made from candidate, alternate treatment technologies that are identified by an evaluation process including factors related to technology, economics, and public policy considerations. Factors to be considered in selection of BAT shall include:

- the age of equipment and facilities involved,
- the process employed,
- the engineering aspects of the application of various types of control techniques,
- process changes,
- the cost of achieving such effluent reduction,
- non-water quality environmental impact (including energy requirements),
- safety considerations, and

Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

- public policy considerations.

Plans and schedules for implementing the selected BAT should be prepared and submitted to the responsible DOE field office manager and updated annually. The plan should include an ALARA section on tritium, where applicable. Implementation of the BAT process is not required where radionuclides are already at a low. The limit guidance for liquid waste streams containing more than one type of radionuclide shall be evaluated by summing the fractional limit values. Measures should be taken to prevent buildup of settleable solid radioactive material in natural waterways and to protect aquatic life. Specific limits are established in the Order. New facilities should be designed and constructed to meet the discharge requirements of the Order.

Phaseout of Soil Columns

This Order discusses the phaseout of soil columns for retaining radionuclides present in waste streams and replacing the soil columns with BAT treatment. Activities currently discharging liquids containing radioactive materials to soil columns are required to develop acceptable alternate disposal processes. The BAT selection process shall be applied to liquid waste streams that continue to be discharged to soil columns for indefinite periods and that contain process-derived radionuclides. Plans implementing BAT must be approved by the DOE field office manager and updated annually. New and increased discharges to active soil columns are generally prohibited by the Order.

Discharge to Sanitary Sewerage Systems

The BAT selection process shall be implemented for discharges to sanitary sewerage systems where the radionuclide concentrations, averaged monthly, would otherwise be greater than five times the limits specified in the Order. Additional considerations include the following:

- Discharges to public sewers should be coordinated with the operators of the waste water treatment works.
- Concentrations shall be controlled so that long-term buildup of radionuclides in solids will not present a handling and disposal problem at sewage disposal plants.
- Liquid wastes containing concentrations or quantities greater than those specified in the Order may be discharged to a chemical or sanitary sewerage system owned by the Federal

Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

Government when ALARA process considerations are implemented and the system provides liquid waste treatment before discharge to surface waters.

- Operators should ensure that the total annual discharge of radioactive material to the sanitary sewer system will not cause exposures to members of the public that will result in doses exceeding a small fraction of the basic annual dose limit.

The Order also allows for specific exceptions and interim control strategies under control of the DOE field office manager and contains direction for dealing with tritium in liquid waste streams.

Release of Real Property

Release of real property shall be according to the guidelines and provisions for residual radioactive material presented in the Order. These guidelines and requirements apply to DOE-owned facilities and to private properties that are being prepared by DOE for release. Real properties owned by DOE that are being sold to the public are subject to the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, concerning hazardous substances, and to any other applicable Federal, State, and local requirements. The requirements of 40 CFR Part 192 are applicable to properties remediated under Title I of the Uranium Mill Tailings Radiation Control Act (UMTRCA). The requirements of CERCLA and UMTRCA are not the subject of this training module.

Personal property that potentially could be contaminated may be released for unrestricted use if the results of a survey with appropriate instruments indicate that the property is below the contamination limits specified in the Order. The Order describes, in detail, that the program for property release should address the following items.

- surface contamination levels
- potential for contamination
- surveys
- inaccessible areas
- volume contamination
- records. The records of released property shall include the following:
 - an identification description of the property
 - the date of the last radiation survey

Change No: 0 DOE 5400.5 Level: Familiar Date: 7/24/98
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- the identity of the organization and the individual who performed the monitoring operation
- the type and identification number of monitoring instruments
- the results of the monitoring operation
- the identity of the recipient of the released material

Compliance Demonstration

Compliance with the dose limits of the Order shall be demonstrated by documentation of an appropriate combination of measurements and calculations that evaluate potential doses and the results of evaluations.

- **Monitoring and Surveillance.** General requirements for routine effluent monitoring and environmental surveillance are contained in documents referenced in the Order that are not the subject of this training module. The monitoring requirements are applicable to all DOE and DOE contractor operations that are subject to the requirements of this Order.
- **Dose Evaluations.** Doses to members of the public near DOE activities shall be evaluated and documented to demonstrate compliance with the dose limits of the Order and to assess exposures to the public from unplanned events. Collective doses to the public within 80 kilometers (km) of the site shall also be evaluated and documented at least annually. The Order prescribes methods for modeling, uses of dose conversion factors, and parametric considerations applicable to dose evaluations. Contractor programs are expected to comply with the direction provided by the Order.

Reporting

Besides the reporting requirements of other Orders, the responsible DOE field office manager shall notify quickly the relevant Program Office(s) and the Deputy Assistant Secretary for Environment of actual or potential exposures of members of the public that result in either an effective dose equivalent from DOE sources exceeding 10 mrem (0.1 mSv) in a year; or exceeding any limit or not meeting any other requirement specified in the Order or any other legally applicable limits; or a combined dose equal to or greater than 100 mrem (1 mSv) effective dose equivalent in a year due to DOE and other man-made sources of radiation (excluding medical, consumer products, and natural sources). Guidance concerning reporting requirements of other documents not part of this

Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

training module are also addressed in the Order.

Records

Records developed shall include information and data necessary to identify and characterize releases of radioactive material to the environment, their fate in the environment, and their probable impact on radiation doses to the public. Basic information used to assess compliance with the requirements of this Order and the results of such assessments shall be incorporated as part of the record. Records shall be retained according to the requirements of DOE Order 1324.2A, which is not part of this training module. All reports, notifications, and records developed pursuant to DOE requirements shall present data in the units used in the applicable regulation or DOE Order.

CHAPTER III, DERIVED CONCENTRATION GUIDES FOR AIR AND WATER

The DCG values listed in this chapter are provided as reference values for conducting radiological environmental protection programs at operational DOE facilities and sites.

The DCG values are presented for each of three exposure modes:

- ingestion of water
- inhalation of air
- immersion in a gaseous cloud

Exposure Conditions for Ingestion of Water and Inhalation

Under conditions of continuous exposure, members of the public are assumed to ingest 730 liters of drinking water or to inhale 8,400 cubic meters of air (for exposure of 24 hours per day, 365 days per year). Only single modes of exposure were considered in the calculation of the DCGs. That is, they apply to either inhalation or ingestion, not to a combination of both.

Exposure Conditions for Air Immersion

The air immersion DCGs were calculated for a continuous, nonshielded exposure via immersion in a semi-infinite atmospheric cloud.

Three classes of radionuclides are included in the air immersion DCGs given in Figure III-3.

Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

- Class 1. The first class of radionuclides includes selected noble gases and short-lived activation products that occur in gaseous form. For these radionuclides, inhalation doses are negligible compared to the external dose from immersion in an atmospheric cloud.
- Class 2. The second class of radionuclides includes those for which a DCG value for inhalation has been calculated, but for which the DCG value for external exposure to a contaminated atmospheric cloud is more restrictive. These radionuclides generally have half-lives of a few hours or less, or are eliminated from the body following inhalation sufficiently rapidly to limit the inhalation dose.
- Class 3. The third class of radionuclides includes selected isotopes with relatively short half-lives. These radionuclides typically have half-lives that are less than 10 minutes, they do not occur as a decay product of a longer-lived radionuclide, or they lack sufficient decay data to permit internal dose calculations. These radionuclides are also typified by a radioactive emission of highly intense, high-energy photons and rapid removal from the body following inhalation.

The values given in Figures III-1 and III-3 in the Order account for only three exposure pathways and do not include other potentially significant pathways. When more complex environmental pathways are involved, a more complete pathway analysis is required for calculating public radiation doses resulting from the operation of DOE facilities.

CHAPTER IV, RESIDUAL RADIOACTIVE MATERIAL

This chapter presents radiological protection requirements and guidelines for cleanup of residual radioactive material and management of the resulting wastes and residues and release of property. These requirements and guidelines are applicable at the time the property is released. Property subject to these criteria includes sites identified by the Formerly Utilized Sites Remedial Action Program and the Surplus Facilities Management Program. The topics covered are basic dose limits, guidelines and authorized limits for allowable levels of residual radioactive material, and control of the radioactive wastes and residues.

Types of Guidelines

A guideline for residual radioactive material is a level of radioactive material that is acceptable for use of property without restrictions due to residual radioactive material. Guidelines for residual

Change No: 0 DOE 5400.5 Level: Familiar Date: 7/24/98
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radioactive material presented herein are of two kinds, generic and specific. The basis for the guidelines is generally a presumed worst-case plausible-use scenario for the property.

Generic guidelines, independent of the property, are taken from existing radiation protection standards.

Specific property guidelines are derived from basic dose limits using specific property models and data. Procedures and data for deriving specific property guideline values are available in DOE/CH-8901.

Guidelines for Residual Radioactive Material

Airborne Radon Decay Products

Generic guidelines for concentrations of airborne radon decay products shall apply to existing occupied or habitable structures on private property that are intended for release without restriction.

Structures that will be demolished or buried are excluded. The applicable generic guideline is: In any occupied or habitable building, the objective of remedial action shall be, and a reasonable effort shall be made to achieve, an annual average radon decay product concentration not to exceed 0.02 WL. [A working level (WL) is any combination of short-lived radon decay products in 1 L of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.] In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL.

Remedial actions by DOE are not required to comply with this guideline when there is reasonable assurance that residual radioactive material is not the source of the radon concentration.

External Gamma Radiation

The average level of gamma radiation inside a building or habitable structure on a site to be released without restrictions shall not exceed the background level by more than 20 micro R/h and shall comply with the basic dose limit when an appropriate-use scenario is considered. This requirement shall not necessarily apply to structures scheduled for demolition or to buried foundations. External gamma radiation levels on open lands shall also comply with the basic limit and the ALARA process, considering appropriate-use scenarios for the area.

Surface Contamination

The generic surface contamination guidelines provided in Figure IV-1 are applicable to existing

Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

structures and equipment. These guidelines are generally consistent with standards of the NRC. These limits apply to both interior equipment and building components that are potentially salvageable or recoverable scrap. If a building is demolished, the guidelines are applicable to the resulting contamination in the ground.

Basic Dose Limits

The basic public dose limit for exposure to residual radioactive material, in addition to natural occurring background exposures, is 100 mrem (1 mSv) effective dose equivalent in a year. If, under unusual circumstances, it is impractical to meet the basic limit based on realistic exposure scenarios, the respective project and/or program office may request a specific authorization for a temporary dose limit higher than 100 mrem (1 mSv), but not greater than 500 mrem (5 mSv), in a year. Such unusual circumstances may include temporary conditions at a property scheduled for remedial action or following the remedial action.

Note: You do not have to do Example 2 on the following page, but it is a good time to check your skill and knowledge of the information covered. You may do the Example 2 or go directly to the practice.
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Change No: 0
DOE 5400.5
Level: Familiar
Date: 7/24/98

4. Describe the three classes of radionuclides included in DCGs for air immersion.

Note: When you are finished, compare your answers to those contained in the Example 2 Self-Check. When you are satisfied with your answers, go on to the practice.

Change No: 0 DOE 5400.5 Level: Familiar Date: 7/24/98
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EXAMPLE 2 SELF-CHECK

1. State four sources of radiation that are excluded from public dose.
Medical exposures
Consumer products
Exposures due to accident conditions, where controls of exposures cannot be maintained
Doses from naturally occurring radiation sources
2. List the two components that comprise the effective equivalent dose limit of 100 mrem (1mSv).
The limit of 100 mrem (1 mSv) effective dose equivalent is the sum of the effective dose equivalent from exposures to radiation sources external to the body during the year, plus the committed effective dose equivalent from internally deposited radionuclides.
3. List five factors that should be considered in selecting a BAT for liquid effluents.
Factors to be considered in selection of BAT for liquid effluents include:
 - the age of equipment and facilities involved,
 - the process employed,
 - the engineering aspects of the application of various types of control techniques,
 - process changes,
 - the cost of achieving such effluent reduction,
 - non-water quality environmental impact (including energy requirements),
 - safety considerations, and
 - public policy considerations.

Change No: 0 DOE 5400.5 Level: Familiar Date: 7/24/98
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4. Describe the three classes of radionuclides included in DCGs for air immersion.

The three classes of radionuclides are included in the air immersion are:

- Class 1. The first class of radionuclides includes selected noble gases and short-lived activation products that occur in gaseous form. For these radionuclides, inhalation doses are negligible compared to the external dose from immersion in an atmospheric cloud.
- Class 2. The second class of radionuclides includes those for which a DCG value for inhalation has been calculated, but for which the DCG value for external exposure to a contaminated atmospheric cloud is more restrictive. These radionuclides generally have half-lives of a few hours or less, or are eliminated from the body following inhalation sufficiently rapidly to limit the inhalation dose.
- Class 3. The third class of radionuclides includes selected isotopes with relatively short half-lives. These radionuclides typically have half-lives that are less than 10 minutes, they do not occur as a decay product of a longer-lived radionuclide, or they lack sufficient decay data to permit internal dose calculations. These radionuclides are also typified by a radioactive emission of highly intense, high-energy photons and rapid removal from the body following inhalation.

Change No: 0 DOE 5400.5 Level: Familiar Date: 7/24/98
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PRACTICE

This practice is required if your proficiency is to be verified at the Familiar or General Level. This practice will prepare you for the criterion test that will be required if your proficiency is to be verified at the General Level. You will need to refer to the Orders to answer the questions in the practice correctly. The practice and criterion test will also challenge additional skills that you have acquired in other formal and on-the-job training.

PRACTICE

1. Define the following terms.
 - ALARA
 - Soil column
 - Protective action guides

2. Describe the ICRP system of dose limitations.

Change No: 0 DOE 5400.5 Level: Familiar Date: 7/24/98
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3. Describe the purpose of the BAT treatment for liquid effluents.
4. State three considerations for selecting a BAT process for the discharges of liquid waste to sanitary sewerage.
5. Differentiate between generic and specific guidelines for residual radiation material.

Note: The course manager will check your practice and verify your success at the familiar level. When you have successfully completed this practice, go to the general level module.

Change No: 0 DOE 5400.5 Level: General Date: 7/24/98

DOE ORDER 5400.5
RADIATION PROTECTION OF THE PUBLIC AND THE ENVIRONMENT
GENERAL LEVEL

OBJECTIVES

Given the Familiar Level of this module, a scenario, and an analysis, you will be able to perform the following:

1. List the key elements you would look for in the contractor's action plan to correct the situation described in the scenario; and
2. State which requirements, sections, or elements of U.S. Department of Energy (DOE) Order 5400.5 apply to the situation described in the scenario.

<p>Note: If you think that you can complete the practice at the end of this level without working through the instructional material and/or the examples, complete the practice now. The course manager will check your work. You will need to complete the practice in this level successfully before taking the criterion test.</p>
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RESOURCES

DOE Orders Self-Study Program, DOE Order 5400.5, Familiar Level, 7/24/98.

DOE Order 5400.5, Radiation Protection for the Public and the Environment, Change 2, 1/7/93.

Change No: 0 DOE 5400.5 Level: General Date: 7/24/98

INTRODUCTION

The familiar level of this module introduced the purpose and scope of DOE Order 5400.5. Several definitions and the requirements associated with the Order were discussed. In the general level of this module, students are asked to apply the information contained in the familiar level and the Order to a series of questions related to the Order. Students are also presented with some scenarios depicting work situations related to the Order. Each scenario will include a situation, the actions taken to remedy the situation, and the requirements related to the situation. Students will be asked to review the contractor's actions and decide if they are correct. Students will also be asked to decide if the correct DOE requirements were cited in each situation. Please refer to the Order to make your analysis and answer the questions. You are not required to complete the example. However, doing so will help prepare you for the practice and criterion test.

Note: You do not have to do the example on the following page, but it is a good time to check your skill and knowledge of the information covered. You may do the example or go on to the practice.
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Change No: 0 DOE 5400.5 Level: General Date: 7/24/98

EXAMPLE SCENARIO

Please review the following scenario, and then answer these questions.

1. Is the contractor's action plan correct? If not, state what should have been done.
2. Were the correct DOE documents or requirements cited? If not, state the correct documents or requirements.

SCENARIO

On February 27, 1996, facility management was notified that a radiological control technician (RCT) had detected two spots of alpha contamination on the personal clothing of a laboratory employee while the employee was at his home. The contamination measured 1,200 disintegrations per minute (dpm) on the heel of the employee's shoe and 300 dpm on the employee's right pant leg. The contaminant on the employee's shoe was plutonium-239. The contaminants on the employee's pants were isotopes of uranium.

Following the discovery of the contamination, the RCT removed and properly packaged the contaminated clothing. No other contamination was detected on the employee. Extensive surveys were performed in the employee's home and automobile, and in areas where the employee had been since leaving work before the discovery of the personal contamination. No activity was detected. The employee also submitted nasal smears. Results were no detectable activity.

BACKGROUND

In the morning of February 27, 1996, four employees began work on process equipment. The equipment is used to perform vacuum transfers of uranium hexafluoride from research containers to laboratory-approved storage vessels or Department of Transportation-approved shipping containers. The work performed by the employees involved the replacement of the vacuum pump associated with the transfer equipment. Because the pump and its internals are known to be contaminated with isotopes of uranium, the work was performed in a radiological hood.

Change No: 0 DOE 5400.5 Level: General Date: 7/24/98

The employees were performing the work according to safe operating procedure. Two of the employees (E1 and E3) wore a lab coat, two pairs of gloves, and booties for the replacement of the pump. The other two employees (E2 and E4) wore a lab coat, one pair of gloves, and booties for the pump replacement.

After replacing the pump and associated valves, the employees started the new pump, observed the vacuum in the transfer system, and cleaned up the work area. At approximately 14:45, E1 left the area for a break, while E2 and E3 remained in the room to finish the cleanup of the area. E4 had left the area at 13:30. E1 returned to the area at approximately 15:15.

At approximately 15:30, E2 prepared to exit the buffer area by removing his lab coat and gloves and then washing his hands in an approved sink. E2 then exited the room and self-monitored his booties and bare hands with a Ludlum 214 hand and foot monitor located just outside the room's exit. When E2 monitored his booties, the instrument alarmed, indicating the presence of contamination on the bottom of one of his booties. E2 then removed both booties and put on a clean pair of booties. After putting on the clean booties, E2 placed the contaminated bootie in a plastic bag and placed the bag inside the room. E2 did not contact an RCT when he discovered the contaminated bootie.

After placing the bag in room 5068, E2 exited the buffer area and entered the corridor outside the room. The corridor is a controlled area for radiological purposes. E2 then proceeded to the controlled area exit, removed his booties, and exited the controlled area. E2 then self-monitored with an Eberline HFM-7 hand and foot monitor located just outside the controlled area. No activity was detected. E2 then proceeded down the hallway in the basement, exited the hallway up a flight of stairs, and proceeded to Wing 9 of the building. E2 then entered Wing 9, put on a lab coat and booties, and entered the Wing 9 buffer area to inspect equipment. E2 did not touch any equipment in Wing 9.

After inspecting the equipment, E2 prepared to exit the buffer area. At the buffer area exit, E2 self-monitored with an HFM- 7 instrument. The instrument alarmed, indicating the presence of alpha contamination on both of his hands. E2 then self-monitored a second time. The instrument did not alarm. RCTs in the area heard the first alarm and responded as E2 performed the second self-

Change No: 0 DOE 5400.5 Level: General Date: 7/24/98

monitor. Under RCT supervision, E2 then exited the buffer area, removed his labcoat and booties, exited the controlled area, and self-monitored just outside the exit of the controlled area. The instrument alarmed, indicating the presence of contamination on E2's left hand. One of the RCTs then performed alpha and beta surveys of E2's hand. The RCT verified 300 dpm of alpha contamination in a localized spot on E2's hand. Due to relatively high background in the area, the beta survey was inconclusive. The RCT also contacted his Health Physics Operations (ESH-1) supervision. The time was approximately 16:00.

An RCT supervisor quickly responded and E2, wearing a labcoat and booties, was escorted back into the buffer area. After a smear survey of E2's hand revealed no loose contamination, the RCT supervisor decontaminated E2's hand to NDA with a cleaning solution and water. At this time, E2 informed the RCT supervisor that he did not believe the contamination came from his last work station but probably the station before that. The RCT supervisor then asked E2 who he had been working with so that he could have the other people surveyed. E2 then informed the RCT supervisor of the other three employees he had been working with. The RCT supervisor then notified facility management of the contamination incident.

Another RCT then performed a whole-body survey of E2. The survey revealed a small amount of alpha contamination on the left cuff of E2's shirt. The supervisor then had E2 remove the shirt and provided him with modesty clothing. The RCT supervisor also had E2 submit nasal smears. The results were negative.

The RCT supervisor then had E2 self-monitor. E2 was then escorted to a unit for additional whole-body monitoring. Results of the survey were negative. E2 then self-monitored. Results were negative.

Prior to escorting E2 to Wing 5, the RCT supervisor contacted E1 (E1 was in his office in an uncontrolled area of Wing 4). The RCT supervisor asked E1 to go to the PCM-2 in Wing 5 for whole-body monitoring. E1 then exited his office, and prior to exiting Wing 4, self-monitored with an HFM-7 located at the exit to the Wing. The instrument alarmed, indicating the presence of contamination on E1's right hand.

Change No: 0 DOE 5400.5 Level: General Date: 7/24/98

Immediately after the alarm, an RCT sent by the RCT supervisor to escort E1 to Wing 5 arrived. E1 told the RCT that the instrument had alarmed. The RCT then escorted E1 to Wing 5 where E1 self-monitored with the PCM-2. No activity was detected. The RCT then had E1 self-monitor with another HFM-7 instrument in Wing 5. The instrument alarmed, indicating the presence of contamination on both of E1's hands. The RCT had E1 self-monitor a second time with the HFM-7. The instrument alarmed again, indicating the presence of contamination on E1's right hand. The RCT then surveyed E1's hands with an NE-Tech. The RCT verified alpha contamination measuring from 1,700 to 2,300 dpm in localized spots on the palms of E1's hands. The RCT supervisor, who had just arrived in Wing 5 with E2, told the RCT to escort E1 to a controlled area for decontamination of E1's hands.

At 16:30, the RCT supervisor notified facility management of the contamination on E1's hands. Group management was also notified of the incident at this time.

After several washings with a cleaning solution and water, the RCT successfully decontaminated E1's hands to NDA. Following the last washing and verifying survey, the RCT had the employee submit nasal smears and then self-monitor with the HFM-7 and PCM-2 instruments in Wing 5. No activity was detected. The RCT then performed a whole-body survey of the employee with an NE-Tech. No activity was detected. Results of the nasal smears were NDA.

As E1 self-monitored for the last time, E4 arrived on scene after being contacted by his group management. After arrival, the RCT supervisor had E4 self-monitor with the PCM-2 and an HFM-7 instrument. No activity was detected. E4 also submitted nasal smears. Results were NDA.

The RCT supervisor then released E1, E2, and E4.

Unaware of the initial personal contamination incident in Wing 9, E3 had gone home at approximately 16:00. E4 attempted to contact E3 at his home at 16:30 and again at 17:30, with no answer. The RCT supervisor also repeatedly attempted to contact E3.

Change No: 0 DOE 5400.5 Level: General Date: 7/24/98

When E3 arrived at his house, he noted no-one else was home and went to a local barber shop. After getting a hair cut, E3 returned home at 18:00. The RCT supervisor contacted E3 at his home at 18:0 and informed him of the contamination incident and that an RCT was being sent to his home to perform surveys. E3 acknowledged this and sat on his couch to await the RCT.

After reaching E3, the RCT supervisor contacted his ESH-1 team leader and informed her of the incident, that E3 had been contacted, and that an RCT had been sent to E3's home.

At approximately 18:45, the RCT arrived at E3's home. Upon arrival, the RCT performed a whole-body, alpha and beta survey of E3 with an NE-Tech. The RCT detected 300 dpm of alpha contamination on a small spot on the right knee of E3's pants, and 1,200 dpm of alpha contamination on the heel of E3's right shoe. No other contamination was detected on E3.

Upon finding the contamination, the RCT taped over the contamination on E3's pants, had E3 remove his shoe, and then bagged the shoe. The RCT also had E3 submit nasal smears. Results were NDA. The RCT then informed the RCT supervisor of the discovery of the contamination. The RCT supervisor then contacted his ESH-1 team leader. The team leader told the RCT supervisor to contact facility management and recommended that facility management contact the laboratory's emergency management & response (EM&R) team. The RCT supervisor then contacted facility management, who then contacted EM&R.

An investigation of the situation revealed the following.

- During the critique, E3 stated that after he had worked in room 5068, he removed his lab coat and gloves and washed his hands. He then exited the room and self-monitored his hands and booties with the Ludlum 214 instrument. No activity was detected. E3 then exited the controlled area and self-monitored his hands and booties with the HFM-7 instrument located just outside the controlled area. No activity was detected. E3 then removed and discarded his booties and exited the building via Wing 4. E3 did not self-monitor his shoes with the booties off before he exited the building.

Change No: 0 DOE 5400.5 Level: General Date: 7/24/98

- Through isotopic analysis, ESH-1 determined the contaminant on the bottom of E3's shoe to be plutonium-239. The source of the plutonium contamination could not be determined for the following reasons:
 - The work performed in room 5068 involved alpha and beta emitting uranium isotopes. The work did not involve plutonium.
 - Analysis of swipe and masslinn surveys of equipment and surfaces in room 5068 (including the vacuum pump) showed uranium-234 and 235. No plutonium contamination was detected.
 - Numerous direct and large area masslinn surveys were performed in the basement corridors outside room 5068 and other areas where E3 had walked. No activity was detected.
 - The plutonium contamination could not be linked to any current radiological processes performed in the basement
- Because the source of the plutonium contamination could not be identified, and because the contamination could not be linked to any current radiological processes, facility management and ESH-1 believe the plutonium contamination to be historical and not related to the work performed by E3 or the other three employees.
- Although the time that E3's shoe became contaminated could not be positively determined, facility management and ESH-1 believe that the shoe contamination occurred sometime after 12:00 on the day of the incident. This belief is based on the fact that no activity was detected on E3's shoes when he last self-monitored with an HFM-7 in Wing 4 at approximately 12:00 on the day of the incident. Had the contamination been present on his shoe at that time, the HFM-7 probably would have detected it. Therefore, at some point after 12:00 on February 29, 1996, E3 unwittingly stepped on a small particle of legacy plutonium-239 contamination.
- Adherence to policy and proper self-monitoring in those instances included removing all protective clothing before exiting a controlled area and then using the instrumentation.
- In the late afternoon on the day of the incident, E3 exited the controlled area outside room 5068 and then self-monitored with the HFM-7 located in the uncontrolled area at the exit of the Wing 5 basement. However, E3 did not follow the policy that required booties to be removed prior to exiting a controlled area and proceeded to self-monitor with the HFM-7 while still wearing his booties. In addition, E3 did not adhere to the posted survey

guidelines that also specified that booties were to be removed before self-monitoring with the HFM-7. If the plutonium-239 contamination was present on E3's shoe at this time, had E3 removed his booties as required prior to self-monitoring with the HFM-7, it is probable that the contamination would have been detected and the incident would not have occurred.

The failure to remove the booties before self-monitoring with the HFM-7 was therefore determined to be a contributing cause.

- Isotopic analysis of the contamination on E3's pants and E2's bootie, and of swipe and masslinn surveys of equipment and surfaces in room 5068 (including the vacuum pump) showed that the contaminants in all instances were isotopes of uranium. Although no isotopic analysis of the contamination on E1's and E2's hands could be performed because all material was removed and discarded during decontamination, the contaminants are presumed to also be isotopes of uranium. The internals of the vacuum pump and associated transfer equipment, as well as the surfaces in the radiological hood in room 5068, are known to be contaminated with isotopes of uranium.
- The standard operating procedure (SOP) did not provide any guidance for pump replacement work.
- The SOP specified a lab coat, booties, and two pairs of gloves for routine maintenance on the transfer equipment. Although all four of the employees had been trained on the SOP, two of the four wore only one pair of gloves for the work.
- Policy specifies that ESH-1 personnel must be immediately notified when contamination is detected during self-monitoring with a Ludlum 214. E2 did not contact ESH-1 when he discovered his bootie was contaminated during self-monitoring with the Ludlum 214 after exiting room 5068.
- When E1 exited the controlled area outside room 5068 and self-monitored with the same HFM-7 that E3 used, he also did not follow policy or posted survey guidelines and self-monitored with the HFM-7 while still wearing his booties.
- The HFM-7 had recently been located within the controlled area, and at that time, personnel self-monitored their hands and booties with the HFM-7. The change of location of the HFM-7 to the uncontrolled area was not adequately communicated to applicable personnel.

Change No: 0 DOE 5400.5 Level: General Date: 7/24/98

- Policy specified that when working with radioactive materials or on contaminated equipment, personnel shall frequently self-monitor with proper instrumentation to minimize the spread of contamination. However, appropriate survey instrumentation was not available in room 5068 to allow personnel to perform the self-monitoring.
- The HFM-7 instrument located in the uncontrolled area at the exit of the Wing 5 basement did not detect contamination on the hands of E1 or E2 when they self-monitored with the instrument after exiting room 5068. However the contamination was later detected on E1's hands with HFM-7 instruments in Wings 4 and 5 and on E2's hands with an HFM-7 instrument in Wing 9. A reason the contamination may not have been detected by the first HFM-7 was because the employees' hands were not completely dry when the instrument was used. Both employees self-monitored with the first HFM-7 shortly after they had washed their hands in room 5068 (the employees routinely wash their hands after removing their gloves). Moisture that remained on the employees palms after they dried their hands may have masked the small amount of alpha contamination that was present and prevented the first HFM-7 from detecting the contamination. Later, when their hands were dry, the other HFM-7 instruments used by the employees were able to detect the contamination.
- Less than two weeks prior to the occurrence, facility management directed ESH-1 to move the HFM-7 located outside room 5068 from the controlled area to the uncontrolled area to be consistent with other facility monitoring requirements. Prior to the move, because the HFM-7 was located inside the controlled area, personnel wore their booties while self-monitoring with the instrument. Because the HFM-7 was located inside the controlled area for quite some time, personnel were accustomed to self-monitoring with their booties on. When the instrument was moved (a move of only a few feet), facility management did not adequately communicate that the self- monitoring requirements had changed and that personnel were now required to remove their booties before self-monitoring with the HFM-7. Because of the inadequate communication of the change, E3 did not recognize that the instrument was located in an uncontrolled area and that booties were to be removed before self-monitoring. Policy specifies that when practicable, facility management will notify affected personnel before any requirements change. Had facility management followed the policy and adequately communicated the change, the plutonium-239 off-site contamination incident could possibly have been avoided.
- Management did not recognize the need for an radiological work permit and the assistance

Change No: 0 DOE 5400.5 Level: General Date: 7/24/98

of ESH-1 in planning pump replacements or other similar maintenance or repairs on equipment known to be internally contaminated.

The following additional actions were taken in this situation.

- Upon notification, EM&R contacted the team leader for the laboratory's radiological assistance program (RAP). The RAP team leader then contacted the RCT supervisor. After being apprised of the situation, the RAP team leader notified DOE Albuquerque. EM&R also contacted the DOE/LAAO duty officer. The time was approximately 20:00.
- The RCT (who was still at E3's home), upon instructions from the RCT supervisor, had E3 remove the contaminated pants. The RCT then placed the pants in the bag with the shoe. The RCT then surveyed other clothing worn that day by E3, the furnishings touched by E3, and E3's automobile. No activity was detected. After the surveys, the RCT took the bag containing the contaminated shoe and pants and went back to the facility. At this time, other ESH-1 personnel were called in to perform isotopic analysis of the contamination on E3's clothing.
- On February 28, 1996, at 1000, a critique of the occurrence was convened.
- Facility management decided to stand-down programmatic, maintenance, and construction activities on March 1, 1996, to give managers an opportunity to discuss this incident and other radiological control issues with employees. Programmatic, maintenance, and construction activities were temporarily suspended on Friday, March 1, 1996.
- A restatement of the radiological protection policy and employee accountability to that policy was made.
- A review of existing requirements was conducted for adequacy in addressing hazards, too few or too many requirements, and inconsistencies.
- A policy was established that required employees to routinely self-survey with alpha instrumentation during operations that have the potential for contamination and before exiting the room.

Change No: 0 DOE 5400.5 Level: General Date: 7/24/98

- A policy was restated that made the minimum required PPE for any maintenance performed to be safety goggles, Tyvek coveralls (taped at the wrists), two pairs of gloves, and booties.
- Contact an (ESH-1) RCT for evaluation and implementation of an RWP for replacement of defective valves (routinemaintenance) on the transfer cylinders/vessels.
- Management trained applicable employees on the procedural modifications.
- ESH-1 provided additional self-monitoring equipment in room 5068, and then trained applicable personnel in the operation of the new equipment.
- Conduct training, that specifies that personnel will allow moist skin to air-dry before self-monitoring.

The following requirements are related to this situation.

- The exposure of members of the public to radiation sources as a consequence of all routine DOE activities shall not cause, in a year, an effective dose equivalent greater than 100 mrem (1 mSv). (DOE Order 5400.5, Chapter II, paragraph 1.a.)
- The public dose limits apply to doses from exposures to radiation sources from routine activities. [DOE Order 5400.5, Chapter II, paragraph 1.a. (3)]

Take some time to review the example scenario and the actions the contractor took to correct the situation. Then decide if the contractor's actions were complete and correct. Finally, determine if the requirements, sections, or elements of DOE Order 5400.5 that were cited in this scenario are correct.

Write your answers below and then compare your answer to the one contained in the example self-check.

Change No: 0 DOE 5400.5 Level: General Date: 7/24/98

EXAMPLE SELF-CHECK

Your answer does not have to match the following exactly. You may have added more corrective actions or cited other requirements from the Order that apply. To be considered correct, your answer must include, at least the following.

All of the actions taken in this situation were appropriate. One additional action should have been taken.

- The barber shop should have been surveyed.

The correct requirements are cited.

Change No: 0 DOE 5400.5 Level: General Date: 7/24/98

PRACTICE

This practice is required if your proficiency is to be verified at the General Level. The practice will prepare you for the criterion test. You will need to refer to the Orders and the Implementation Guide to answer the questions in the practice correctly. The practice and criterion test will also challenge additional analytical skills that you have acquired in other formal and on-the-job training for the technical representative position.

Please review the following scenario and answer the following questions.

1. Was the situation handled correctly? If not, what should have been done?
2. Was the list of requirements, sections, and elements complete and correct? If not, state the correct or omitted requirements.

SCENARIO

During your Monday morning walkthrough of the Annular Core Research Reactor (ACRR) health physics technicians advise you that water overflowed the ACRR thermal expansion tank. The reactor was not critical and no experiments were taking place. Facility staff estimates that less than 5000 gallons of water was discharged to a storm drain. It appears that the water had been running through the past weekend. Approximately 10 days later you are advised that commercial laboratory tests indicated tritium contamination of 9 pCi/ml. This spill is similar to one that occurred approximately seven months earlier at the same facility.

Immediate actions:

- Operating personnel isolated the system and stopped the discharge.
- Health physics personnel sampled the overflow water for radioactivity with no contamination detected from gamma spectroscopy.
- The New Mexico Environment Department was notified of the discharge.
- Water samples were taken and sent to a commercial laboratory for analysis.

Planned actions:

- Reassess the Environment, Safety, and Health vulnerabilities at the ACRR, including an evaluation of periods when the facility is unattended, and prepare an action plan.

Change No: 0 DOE 5400.5 Level: General Date: 7/24/98

- Review the procedure for adding make-up water to the ACRR pool (which overflows to the expansion tank), placing emphasis on monitoring the pool, securing the facility at the end of the workday, and response during unattended periods.
- Ensure that all ACRR personnel are aware of the method for adding makeup water to the ACRR pool and the various environmental considerations of this activity.
- Evaluate the design of the ACRR pool overflow system paying particular attention to the high-level alarm for the overflow tank, contamination of the equipment pit, and release of water to the ground surface.
- Revise training materials to reflect lessons learned from this incident.

DOE requirements related to this situation.

Chapter I, paragraph 5.a.

In addition to limiting dose to members of the public (on-site or off site) to the primary radiation protection standards established in this Order and to the applicable limits of EPA and State regulations, additional controls on the release of liquid wastes are adopted to reduce the potential for radiological contamination of natural resources such as land, ground and surface water, and ecosystems.

Chapter II, paragraph 3.a. (1)

Although there is no known practical method for removing tritium from liquid waste streams, facilities and operations are to be designed and operated so that tritium sources and releases are considered in the ALARA process.

Write your answers to questions 1 and 2 below and on the next page and then bring the completed practice to the course manager for review.

Change No: 0
DOE 5400.5
Level: General
Date: 7/24/98

Note: The course manager will check your practice and verify your success at the general level. When you have successfully completed this practice, the course manager will give you the criterion test.