MODULE 6.0: ACCIDENTS AND EMERGENCIES AT FUEL CYCLE FACILITIES

Introduction

Welcome to Module 6.0 of the General Health Physics Practices for Fuel Cycle Facilities Directed Self-Study Course! This is the sixth of seven modules in this self-study course. The purpose of this module is to assist the trainee in describing the possible radiological effects resulting from accidents at fuel cycle facilities and the appropriate health physics role during an emergency. This self-study module is designed to assist you in accomplishing the learning objectives listed at the beginning of the module. There are four learning objectives in this module. The module has self-check questions to help you assess your understanding of the concepts presented in the module.

Before You Begin

It is recommended that you have access to the following materials:

- Trainee Guide
- 10 CFR Part 70.24, “Criticality Accident Requirements”
- Inspection Procedure 88050, “Emergency Preparedness”*
- NRC Management Directive (MD) 10.131, Volume 10, Part 5, “Protection of NRC Employees Against Ionizing Radiation, Handbook 10.131, Part V”*
- NUREG-1140, A Regulatory Analysis on Emergency Preparedness for Fuel Cycle and Other Radioactive Material Licensees
- Regulatory Guide 3.67, Standard Format and Content for Emergency Plans for Fuel Cycle and Materials Facilities (Draft revision in place as of May 2010)
- Regulatory Guide 8.31, Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Recovery Facility Will be As Low As Reasonably Achievable
- U.S. Nuclear Regulatory Commission Response Technical Manual (RTM-96)

Complete the following prerequisites:

- Module 1.0 Health Physics Fundamentals
- Module 2.0 Radiological and Chemical Properties of Uranium
- Module 3.0 Contamination Control
- Module 4.0 Internal Dose Control
- Module 5.0 External Dose Control

*Excerpts are included at the end of this module.

How to Complete this Module

1. Review the learning objectives.
2. Read each section within the module in sequential order.
3. Complete the self-check questions and activities within this module.
4. Check off the tracking form as you complete each activity within the module.
5. Contact your administrator as prompted for a progress review meeting.
6. Contact your administrator as prompted for any additional materials and/or specific assignments.
7. Complete all assignments related to this module. If no other materials or assignments are given to you by your administrator, you have completed this module.
8. Ensure that you and your administrator have dated and initialed your progress on your tracking form.
9. Go to the next assigned module.

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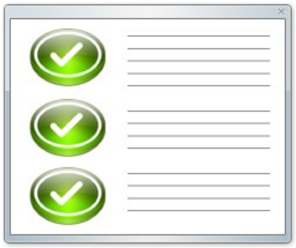

LEARNING OBJECTIVES

6.1 Upon completion of this module, you will be able to describe the possible radiological effects resulting from accidents at fuel cycle facilities and the appropriate health physics role during an emergency.

6.1.1 Describe health physics actions and activities related to emergency planning, preparedness, response, and recovery.

6.1.2 Identify the health physics role in accidents and emergencies at fuel cycle facilities.

6.1.3 Identify the types of accidents involving the release of radioactive materials that might occur at fuel cycle facilities.

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Learning Objective

When you finish this section, you will be able to:

6.1.1 Describe health physics actions and activities related to emergency planning, preparedness, response, and recovery.

EMERGENCY PLANNING, PREPAREDNESS, RESPONSE, AND RECOVERY

Planning

Guidance for fuel cycle facilities' licensees in preparing emergency response plans is located in Regulatory Guide 3.67, Standard Format and Content for Emergency Plans for Fuel Cycle and Materials Facilities.

The emergency response plan is the administrative document that establishes the licensee's commitments to emergency preparedness, response, and recovery during a radiological emergency. It provides a description of the site/facility(s) emergency preparedness program. The plan describes available personnel, organizations, facilities, equipment, and actions that are to be taken during an emergency.

The emergency response plan also provides information on the:

- Types of accidents that might occur
- Classification of postulated accidents

The types of activities in which emergency response health physics personnel may be involved are described in Radiological Assessment Procedures. These activities may include the following:

- **Post-Accident Sampling and Analysis** procedures to be used to assess the extent of damage and radiological hazards. These procedures describe the steps necessary to sample, transport, analyze, and store post-accident samples.
- **Emergency Radiological Monitoring and Environmental Sampling** procedures describe how to perform radiological surveys and emergency environmental sampling during and after an incident.

- **Radiological Dose Assessment** procedures provide steps for determining qualitative and quantitative assessments of the dose equivalent of radiation exposures resulting from accidental radiological releases. These procedures include estimation of the source term, release rate, and dose when primary assessment or techniques are not producing reliable results.
- **Personnel Protection** procedures assist in minimizing personnel exposure to radiation. Protective actions are selected with regard to adverse conditions such as release of toxic gases or inclement weather.
- **Decontamination** procedures provide for emergency decontamination of personnel, equipment, and facilities. Alternate personnel decontamination areas and how to relocate to these areas should be identified. These alternate areas should be used if the primary decontamination areas become uninhabitable.
- **Exposure Control** procedures provide guidance for exposure authorizations, dose guidelines, and post-exposure assessments. Guidelines for personnel contamination control and respiratory protection should be included.
- **Protective Action Recommendation** procedures provide the steps necessary to determine protective action recommendations for the public. Consideration should be given to projected site/facility conditions and offsite radiological assessments.

The following considerations should be included in protective action recommendation procedures:

- Site/facility status
- Radiological conditions
- Meteorology
- Time of day
- Duration of release
- Evacuation time estimates
- Plume modeling and estimations
- Sheltering versus evacuation

The NRC license requires applicants to evaluate possible accidents. Potential significant accidents for fuel cycle facilities have been determined to be UF_6 releases, hazardous chemical releases (liquid and airborne), fires, and criticality accidents.

Protective action guides have been developed to provide projected doses and protective actions for personnel and the public in the event of a radiological accident. According to NUREG-1140, A Regulatory Analysis on Emergency Preparedness for Fuel Cycle and Other Radioactive Material Licensees, the Environmental Protection Agency (EPA) recommends that "protective actions should be considered by responsible officials if projected whole-body doses are in the range of 1 to 5 rems … protective actions may be considered optional at 1 rem, to be taken if readily feasible, but are highly recommended at 5 rems if at all feasible … the Commission's policy on the use of the EPA's protective action guides [follows] … for application to fuel cycle and by-product material licensees, the lower end of the range (1 rem) of the EPA's protective action guides is used in conjunction with calculations of releases and offsite radiation doses due to severe accidents, such as a major facility fire, to establish the need for a plan. Thus the lower range of the protective action guides is used to determine the need for offsite emergency preparedness."

Preparedness

Emergency training programs are established to ensure that facility personnel are prepared to respond to, manage, mitigate, and recover from emergencies.

Training of emergency response organization (ERO) health physics personnel should cover the following areas:

- Emergency responsibilities
- Emergency equipment
- Emergency facilities
- Key emergency personnel
- Training, drills, and exercises

Health physics personnel accomplish important tasks during emergencies at nuclear fuel cycle facilities. They have the formal job expertise required to provide assistance in the following areas:

- Timely initial assessment of the actual or potential consequences of an emergency
- Monitoring and evaluating the specific indicators necessary to continually assess the consequences of emergency events
- Monitoring and evaluating specific indicators related to safety, health, environmental, and security conditions that may affect or exacerbate the emergency
- Projection of potential consequences both onsite and offsite
- Activities to accomplish the following:
    - Locate and track hazardous materials released to the environment
    - Estimate the integrated impact of such releases on the public and the environment
    - Locate and recover materials

Emergency response health physics personnel may also be part of the field team responsible for field monitoring activities, including:

- The direct measurement of the radiation dose rate resulting from the presence of radioactive materials in air or on contaminated surfaces
- The sampling and appropriate analysis of air, water, soil, and vegetation to determine the concentration of radioactive or chemical contaminants. Such analysis should also confirm the absence of material.

Due to the nature of the role of emergency health physics personnel, formal job descriptions stating minimum qualifications and experience should be established. This helps to ensure that qualified personnel will be available to perform the required emergency response functions.

Often emergency functions are similar to those performed by the staff during normal operations; while other functions may be unique to the emergency environment. A training and qualification system for all members of the emergency response organization should be in place.

Response

The ERO shall include personnel available 24 hours a day to coordinate and implement the radiological field monitoring and environmental sampling efforts. The organization includes the following radiological response teams:

- Monitoring teams
- Sampling teams
- Staff to direct and coordinate team efforts
- Personnel to analyze the data, samples, and other information provided by the teams

Radiological response teams are responsible for sampling and monitoring in the field. The field teams also include a driver and dispatcher, who is designated to dispatch, control, and maintain field data upon receipt. The field team dispatcher(s) generally reports to the position responsible for offsite radiological assessment.

When a field team reports for activation, it receives a briefing and obtains equipment. Each team ensures the availability and operability of all required monitoring, sampling, communications, and transportation equipment by using inventory and operability checklists.

After a briefing and equipment check, field teams are dispatched to designated monitoring points to collect data.

Plume monitoring information is obtained by the field team to verify the adequacy of protective actions for the public and to confirm predicted dose conditions based on meteorological and plant release data. To the extent feasible, plume centerline and edges are determined to assess the extent and magnitude of the release.

Recovery

Recovery from an emergency event is initiated after the emergency conditions have been stabilized and the plant is in a moderately safe shutdown status. The recovery effort consists of returning the plant to its pre-emergency condition. Extra precautions should be taken during this period due to the potential or actual damage to safety systems, process equipment, and structures as a result of the emergency incident. Detailed planning prior to reentry is essential to ensure that adequate precautions and controls are established to protect the health and safety of workers.

Self-Check Questions 6-1:

INSTRUCTIONS: Complete the following questions. Answers are located in the answer key section of the Trainee Guide.

1. Name the Regulatory Guides that are available to provide guidance for fuel cycle facilities licensees in preparing emergency response plans.

2. What is an emergency response plan?

3. What information does an emergency response plan provide?

4. The types of activities in which emergency response health physics personnel may be involved include the following:

   - ___________________________ procedures assess the extent of damage and radiological hazards, describing the steps necessary to sample, transport, analyze, and store post-accident samples.
   - ___________________________ procedures describe how to perform radiological surveys and emergency environmental sampling during and after an incident.

- ___________________________ procedures provide steps for determining qualitative and quantitative assessments of the dose equivalent of radiation exposures resulting from accidental radiological releases, including estimations of source term, release rate, and dose when primary assessment results are not reliable.
- ___________________________ procedures assist in minimizing personnel exposure to radiation, and are selected with regard to adverse conditions such as release of toxic gases or inclement weather.
- ___________________________ procedures provide for emergency decontamination of personnel, equipment, and facilities identifying alternate personnel decontamination areas and how to relocate to these areas if the primary decontamination areas become uninhabitable.
- ___________________________ procedures provide guidance for exposure authorizations, dose guidelines, and post-exposure assessments and include guidelines for personnel contamination control and respiratory protection.
- ___________________________ procedures provide the steps necessary to determine protective action recommendations for the public and should consider projected site/facility conditions and offsite radiological assessments.

Complete the following question.

5. What considerations should be included in protective action recommendation procedures?

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Fill in the blank. Choose from the following words.

consequences	hazardous	Indicators
initial assessment	offsite	recovering

6. During emergencies at fuel cycle facilities, health physics personnel provide assistance in the following areas:

   - Timely_______________ _______________of the actual or potential consequences of an emergency
   - Monitoring and evaluating the specific indicators necessary to continually assess the __________________of emergency events
   - Monitoring and evaluating specific _________________________ related to safety, health, environmental, and security conditions that may affect or exacerbate the emergency
   - Projection of potential consequences both onsite and ______________________
   - Locating and tracking of_________________________ materials released to the environment
   - Locating and______________________________ materials

7. In response to a radiological release, why would plume monitoring information be obtained by a field team?

8. When is recovery from an emergency event initiated?

You have completed this section.
Please check off your progress on the tracking form.
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NRC INSPECTION MANUAL

The NRC Inspection Manual provides procedures for inspectors to use when evaluating emergency preparedness at fuel cycle facilities. Inspection Procedure 88050, *Emergency Preparedness*, includes actions for "evaluating emergency planning involving offsite support agencies, emergency procedures, facilities and equipment, drills, and fire protection for all fuel cycle facilities." A copy of this procedure is located at the end of this module for your review.

Self-Check Questions 6-2:

INSTRUCTIONS: Complete the following question. The answer is located in the answer key section of the Trainee Guide.

1. What inspection procedure includes actions for “evaluating emergency planning involving offsite support agencies, emergency procedures, facilities and equipment, drills, and fire protection for all fuel cycle facilities”?

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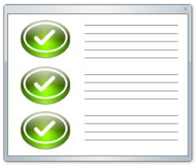

Learning Objective

When you finish this section, you will be able to:

6.1.2 Identify the health physics role in accidents and emergencies at fuel cycle facilities.

HEALTH PHYSICS ROLE IN ACCIDENTS AND EMERGENCIES

Emergency Facilities and Equipment

Emergency facilities and equipment are required to support the emergency response. The type and quantity required will depend on what hazardous materials exist at the site and the operations performed.

Emergency equipment for health physics emergency functions includes the following:

- Staged equipment necessary for offsite monitoring
  - Radiation survey equipment
  - Air sampling equipment
- Protective clothing
- Respiratory protection equipment
- Communication devices (e.g., radios, cell phones)
- Dosimetry devices
- Procedures
- Supplies for recording data

Emergency kits should be prepared and sealed to minimize tampering. Routine inventory and inspections should provide assurance of their readiness in the event of an emergency.

Consequence Assessment

Methods and equipment for monitoring and assessing actual or potential consequences of a radiological emergency shall exist at fuel cycle facilities for both onsite and offsite emergencies. Actual releases are generally determined by installed effluent monitoring systems when the releases are from monitored release points. Releases from unmonitored locations may be estimated from inventory data, nature of the event, and the physical characteristics of the released materials. Effluent monitoring data and release estimates should be verified and possibly modified by field measurements.

Field monitoring data are valuable in verifying that a release has occurred and in confirming the accuracy of source-term estimates. Field data may also be used to confirm or invalidate the need for protective actions and for changing emergency response levels.

Special Considerations

Special considerations should be given to the chemical toxicity of the released uranium and any accompanying toxic gases. Appropriate codes and models should exist for calculating actual and potential offsite doses. Real-time meteorological data should be available along with measured or estimated source terms and location and height of the release(s).

It is important to provide rapid dosimetry to identify persons having received >10 rads (10 CFR 70.24 (b) (1)).

Protective Action Responses

Protective responses are taken to avoid or minimize personnel and public exposures to a uranium release. These responses should concentrate on minimizing the inhalation or ingestion of materials.

The following three methods of protection should exist onsite:

- Evacuation of personnel from affected areas, or any area with a high potential for contamination
- Sheltering of personnel in a protected ventilation zone (onsite facilities designed to maintain safe habitability during postulated accident conditions should exist)
- Personal protective equipment (PPE)

Offsite responses are implemented by local authorities. The response usually involves one of two methods:

- Protective sheltering, in which residents in the affected areas shut down their ventilation systems, seal their homes and occupied structures, and remain inside those structures until instructed to leave. This method provides some protection from airborne contaminants, especially in the case of a quickly passing plume.
- Evacuation may be recommended by local authorities when there is a potential for release and there is adequate time for an effective evacuation.

Radiological Exposure Control

Radiological exposure control should be maintained during any accident or emergency occurring at a fuel cycle facility. The emergency plan should establish onsite emergency exposure guidelines consistent with federal regulations pertaining to the site/facility.

In order to ensure that normal exposure controls do not hinder the emergency mitigation efforts, it is important that a responsible person with the authority to approve emergency radiation exposures in excess of established limits be onsite continually during an emergency.

To achieve dose control for emergency workers, personnel dose information should be current and available at all times. The ability to process personnel dosimeters and to have information available promptly and on a continued basis is essential.

Accidental Criticality

At some uranium enrichment or fuel fabrication facilities, high levels of external radiation exposures during emergencies could occur from an accidental criticality. Special precautions must be exercised to ensure the following:

- The neutron dose is considered.
- The reaction has ceased.
- The emergency actions do not reinitiate the criticality.

Limitation of Exposure to Ionizing Radiation

The National Council on Radiation Protection and Measurements (NCRP) Report Number 116, *Limitation of Exposure to Ionizing Radiation*, states the following:

> "Normally, only actions involving lifesaving justify acute exposures that are significantly in excess of the annual effective dose limit. The use of volunteers for exposures during emergency actions is desirable. Older workers with low lifetime accumulated effective doses should be chosen from among the volunteers whenever possible. Exposures during emergency actions that do not involve lifesaving should, to the extent possible, be controlled to the occupational dose limits. Where this cannot be accomplished, it is recommended that a limit of 0.5 Sv (50 rad) effective dose and an equivalent dose of 5 Sv (500 rad) be applied to the skin, which is consistent with the International Commission on Radiological Protection (ICRP) recommendations (ICRP, 1991a).
>
> When, for lifesaving or equivalent purposes, the equivalent dose may approach or exceed 0.5 Sv to a large portion of the body in a short time, the workers need to understand not only the potential for acute effects but they should also have an appreciation of the substantial increase in their lifetime risk of cancer. If internally deposited radionuclide exposures are also possible, these should be taken into account."

Note: NRC Management Directive (MD) 10.131 has a somewhat different guidance for emergency doses. MD 10.131 applies only to NRC employees. See Volume 10, Part 5, Protection of NRC Employees Against Ionizing Radiation, Handbook 10.131, Part VI, at the end of this module.

Medical and Health Support

Standard medical services for injured personnel during an emergency always take precedence over radiation exposure concerns to medical providers. Exposures to medical providers are small, if detectable. Precautions should be taken to ensure that the spread of contamination is minimized. It is also important to avoid the spread of uranium contamination to open wounds.

Decontamination

Procedures shall be established for monitoring personnel exposed to toxic and radioactive materials and for decontaminating personnel and equipment. Normal facility procedures should be used with provisions for the abnormal conditions so that personnel are familiar with implementation.

Self-Check Questions 6-3:

INSTRUCTIONS: Complete the following questions. Answers are located in the answer key section of the Trainee Guide.

1. List at least five emergency equipment needs for health physics emergency functions.

2. Why should emergency kits be prepared and sealed?

3. What can be done to provide assurance of emergency kit readiness in the event of an emergency?

4. Actual releases are generally determined by installed effluent monitoring systems when the releases are from monitored release points. How are releases from unmonitored locations estimated?

5. How is field monitoring data used?

6. What special considerations should be given in the event of a uranium release?

7. Protective responses are taken to avoid or minimize personnel and public exposures to a uranium release. What three methods of protection should exist onsite at a fuel cycle facility?

8. What are two offsite response methods that could be implemented by local authorities in an emergency situation?

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Fill in the blanks. Choose from the following words:

contamination	current	decontaminating	dosimeters	excess
exposure	guidance	injured	neutron	open wounds
plan	reaction	reinitiate		

9. Radiological ______________ control should be maintained during any accident or emergency occurring at a fuel cycle facility.

10. The emergency _____________ should establish onsite emergency exposure guidelines consistent with federal regulations pertaining to the site/facility.

11. In order to ensure that normal exposure controls do not hinder the emergency mitigation efforts, it is important that a responsible person with the authority to approve emergency radiation exposures in _____________ of established limits be onsite continually during an emergency.

12. To achieve dose control for emergency workers, personnel dose information should be ______________ and available at all times.

13. The ability to process personnel ______________ and to have information available promptly and on a continued basis is essential.

14. High levels of external radiation exposures could occur from an accidental criticality. Special precautions must be exercised to ensure the ______________ dose is considered, the ______________ has ceased, and the emergency actions do not _______________ the criticality.

15. NRC Management Directive (MD) 10.131 provides _______________ for emergency doses.

16. Medical services for ________________ personnel during an emergency take precedence over _________________ control, although precautions should be taken to ensure that the spread of contamination does not occur.

17. It is important to avoid the spread of uranium contamination to ________________ .

18. Procedures shall be established for monitoring personnel exposed to toxic and radioactive materials and for _________________ personnel and equipment.

You have completed this section.
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MODULE 6.0: ACCIDENTS AND EMERGENCIES AT FUEL CYCLE FACILITIES

Learning Objective

When you finish this section, you will be able to:

6.1.3 Identify the types of accidents involving the release of radioactive materials that might occur at fuel cycle facilities.

ACCIDENTS

Once the accident history of fuel cycle and by-product material licensees is determined, theoretical calculations of releases and offsite doses for possible accidents can be determined. This provides the basis for emergency planning and for the development of plans and procedures for emergency preparedness, response, and recovery.

Mining and Recovery Facilities

Historically, accidents at uranium mining and recovery operations have not been serious radiological problems, even though some of the accidents have been severe. This is primarily the result of the low specific activity of uranium and the low volatility of the uranium compounds present at these sites.

Table 6-1, Fires in Uranium Recovery Facilities through 1986, and Table 6-2, Uranium Recovery Tailings Releases, 1959-1986, from NUREG-1140, *A Regulatory Analysis on Emergency Preparedness for Fuel Cycle and Other Radioactive Material Licensees*, list a number of accidents that have occurred at recovery facilities including fires and recovery tailings releases.

Despite the serious nature of some of these accidents, offsite doses were not significant. In NUREG-1140, a fire in the solvent extraction circuit was postulated as having the greatest significance for emergency preparedness. Based on this assumption, a worst-case scenario would result in an offsite dose of less than 100 mrem.

Note that to reduce the amount of material likely to be released during a fire, Regulatory Guide 8.31, *Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Recovery Facilities Will be As Low As Reasonably Achievable*, makes the following recommendations for fire control:

- Design features should include automatic fire detection and suppression equipment in high fire-potential areas (e.g., solvent extraction area)

- In the event of fire, there should be provisions for drainage of solvent to sumps or to outside lined ponds
- Appropriate caution signs should be posted in areas of fire hazard
- Fire detection systems should be checked weekly and fire drills performed at a minimum of semiannually

Health physics actions taken during an accident would primarily involve the assessment of contamination (airborne and surface) both onsite and potentially offsite, and protection of accident responders to ensure that they are wearing proper protective equipment to prevent inhalation or ingestion of materials.

Note: Not only could conventional mines experience these types of accidents, but in situ solution mines may also. Additionally, in situ solution mines may experience the rupture of pipes between well fields and main process buildings.

Table 6-1. Fires in Uranium Recovery Facilities through 1986

Date	Recovery	Fire Description	Offsite Release
3-19-59	Vanadium Corporation of America Durango, Colorado	Fire in yellowcake dryer	None detected
6-25-65	American Metal Grand Junction, Colorado	Fire in ore dryer for 3 to 5 minutes, $2,600 damage	None detected
2-68	Western Nuclear Jeffery City, Wyoming	Workers started a fire to thaw a frozen ore dryer; fire ignited propane from a leaking tank	None detected
11-10-68	Petromics Company Shirley Basin, Wyoming	Solvent extraction circuit, $300,000 damage	None detected
12-25-68	Atlas Corporation Moab, Utah	Solvent extraction circuit, cause unknown, $1,000,000 damage	None detected
10-23-80	Minerals Exploration Sweetwater, Wyoming	Major fire burned in recovery before it started operation	None; radioactive material was not yet being processed
1-2-81	Atlas Corporation Moab, Utah	Fire in yellowcake scrubber stack for 15 minutes	None detected

Table 6-2. Uranium Recovery Tailings Releases, 1959-1986

Date	Recovery	Type of Incident	Release
8-19-59	Union Carbide Green River, Utah	Tailings dam washed out	~15,000 T sands lost to river in flash floods; no increase in dissolving radium (Ra) was noted in river
8-22-60	Kerr-McGee Shiprock, New Mexico	Raffinate pond dike failure	240,000 gallons of raffinate released into river ~50×10^{-8} µCi/ml Ra-226; river samples collected several days after release showed no increase in Ra-226 background
12-6-61	Union Carbide Maybell, Colorado	Tailings dike failure	~500 T solids released from tailings area; 200 T reached unrestricted area; no liquid reached any stream
6-11-62	Mines Development, Incorporated Edgemont, South Dakota	Tailings dike failure	200 T solids washed into creek and some carried 25 miles into reservoir
8-17-62	Atlas-Zinc Minerals Mexican Hat, Utah	Slurry pipeline rupture	Estimate 280 T solids + 240 T liquids released from broken tailings discharge line into draw 1.5 miles from river
6-16-63	Utah Construction Riverton, Wyoming	Precautionary release	Material released by 2-foot drainage cut made to prevent cresting due to heavy rains; material released below 10 CFR Part 20 values

Table 6-2. Uranium Recovery Tailings Releases, 1959-1986

Date	Recovery	Type of Incident	Release
11-17-66	VCA Shiprock, New Mexico	Raffinate line failure	Estimated 16,000 gallons of liquid lost because of break in raffinate line; material spread over 1/4 acre; break occurred 1 mile from river with some small amount reaching river
2-6-67	Atlas Corporation Moab, Utah	Line failure	440,000 gallons lost; average Ra-226 concentration was 5.5 x 10^{-8}mCi/ml
7-2-67	Climax Uranium Grand Junction, Colorado	Tailings dike failure	Dike failure released 1-10 acre-ft of waste liquid into Colorado River; no indication the Ra concentration in river exceeded 10 CFR Part 20 limits
11-23-68	Atlas Corporation Moab, Utah	Slurry pipeline rupture	35,000 gallons of tailings slurry lost; flowed ½ mile to Colorado River; most solids settled out in drywash
2-16-71	Petromics Shirley Basin, Wyoming	Secondary tailings dike failure	2,000 gallons of liquid lost to unrestricted area; spill froze in place
3-23-71	Western Nuclear, Incorporated Jeffrey City, Wyoming	Tailings line and dike failure	Break in slurry line caused a dike failure, allowing sand tails to flow into natural basin adjacent to tailings site on licensee's property

Table 6-2. Uranium Recovery Tailings Releases, 1959-1986

Date	Recovery	Type of Incident	Release
2-5-77	United Nuclear - Homestake Partners Grants, New Mexico	Slurry pipeline rupture	50,000 tons of solids and slimes and somewhere between 2 and 8 million gallons of liquid were released. All material was confined to company property
4-77	Western Nuclear, Incorporated Jeffrey City, Wyoming	Failure of tailings pond embankment	~2 million gallons of liquid tailings and 55 yd^3 of solids were released. No material was released to unrestricted areas
9-26-77	United Nuclear Church Rock, New Mexico	Release from tailings slurry line	Approximately 1 ton of solids and 900 gallons of liquid entered the watercourse
7-16-79	United Nuclear Church Rock, New Mexico	Tailings dike failure	100,000,000 gallons of tailings solution and 1,100 tons of tailings solids were released. Most of the solids were deposited near the impoundment, but much of the solution reached a river

Conversion Facilities

The primary accidents of radiological concern at conversion facilities are spills and/or releases of the various uranium compounds present at the facilities. In most cases, these spills would represent more of a nuisance than a serious radiological or health hazard due to the low specific activity and generally low volatility of most uranium compounds.

However, the release of UF_6 at the end of the conversion process can present a serious hazard due to its volatility and the potential for a large release of easily dispersable UO_2F_2 particulates. In the event of a significant release of UF_6, health physics personnel need to be prepared and equipped to collect air samples over an extensive area, including offsite. Extensive bioassays are required to assess the intake of uranium, primarily by onsite workers and emergency responders. It should be noted that the primary health hazard will result from HF formation by released UF_6.

Inhalation of uranium due to a UF_6 release can be verified by measurements of uranium concentrations in urine collected within 48 hours of the exposure. Collecting numerous samples within a relatively short time following the accident is required due to the rapid clearance time of uranium from UF_6 (4 to 6 hours). For the collection of samples to occur quickly, plans need to be in place prior to an accident.

In the event of a major release, the U.S. Nuclear Regulatory Commission Response Technical Manual (RTM-96) provides the following:

- Simple methods to assess the dose at various distances from the release point
- Recommended evacuation distances if the plume has not arrived
- A list of health effects for various intakes of uranium

The accompanying information in Appendix C, *Uranium Hexafluoride (UF_6) Release Assessment*, from RTM-96 provides practice in an approved assessment methodology for a UF_6 release.

Table 6-3, *Accidents Involving UF_6 Releases through 1986*, lists a number of accidents involving the release of UF_6 from a variety of facilities.

Table 6-3. Accidents Involving UF_6 Releases through 1986

Date	Facility	Type of Facility	Quantity of UF_6 Released	Cause and Consequence
9-2-44	Philadelphia Naval Yard	R&D for thermal diffusion	200 kilograms (kg) accompanied by live steam	Rupture or explosion of large tank; two workers killed; three other workers seriously injured; 13 others less seriously injured or not injured
Pre 1949	AEC facility	Not identified	Believed to be 13 kg	Sudden leak in a hot cylinder; one worker received injury to respiratory tract, eyes, and kidneys
5-10-60	Babcock & Wilcox Apollo, Pennsylvania	Fuel fabrication	Not reported	Leak in heat exchanger allowed UO_2F_2 to escape to river water; 60 x MPC at discharge point
11-17-60	Union Carbide Oak Ridge, Tennessee	Uranium enrichment	Not reported	Rupture of 10-ton cylinder
5-25-62	Nuclear Fuel Services Erwin, Tennessee	Fuel fabrication metal	15 kg HEU in 5 minutes, 6 kg recovered in plant	An overheated 15-kg cylinder ruptured and released its contents in the building
3-20-64	Nuclear Fuel Services Erwin, Tennessee	Fuel fabrication metal	1 kg in 2 hours, half recovered onsite	Over-pressure burst tube

Table 6-3. Accidents Involving UF_6 Releases through 1986

Date	Facility	Type of Facility	Quantity of UF_6 Released	Cause and Consequence
2-14-66	National Lead Fernald, Ohio	Feed material production	2,300 kg in 1 hour, much absorbed by water spray	Operator accidentally removed valve on a hot 10-ton cylinder, developed lung edema, hospitalized 6 days; no observed injury to kidney
6-29-67	Kerr-McGee Gore, Oklahoma	UF_6 conversion	45 kg in 15 to 20 minutes	Gasket leaked due to overheating
7-19-68	Kerr-McGee Crescent, Oklahoma	Fuel fabrication	45 kg of 1.6% enriched U in 15 to 20 minutes	Valve accidentally left open during heating
11-12-68	Allied Chemical Illinois	UF_6 conversion	43 kg	Valve failure
5-2-73	Goodyear Atomic Oak Ridge, Tennessee	UF processing	100 kg in 20 minutes (inside)	Worker broke valve on 10-ton cylinder
4-20-74	Numec Apollo, Pennsylvania	Mixed oxide fuel fabrication	6 kg, slightly enriched	---------
12-2-78	Exxon Nuclear Richland, Washington	Fuel fabrication	Small	Worker disconnected line but had forgotten to close valve
3-7-78	Portsmouth Gaseous Diffusion Plant Portsmouth, Ohio	Enrichment plant	9500 kg in ½ hour to 1 hour	Rupture of dropped hot 14-ton cylinder
12-3-78	GE	Fuel fabrication	Not known	Block valve opened
8-7-79	Nuclear Fuel Service Erwin, Tennessee	Fuel fabrication	<3 kg	Accidental venting of cylinder to stack
5-20-80	GE	Fuel fabrication	<1kg	Pipe flange failure

Table 6-3. Accidents Involving UF_6 Releases through 1986

Date	Facility	Type of Facility	Quantity of UF_6 Released	Cause and Consequence
9-15-81	GE	Fuel fabrication	<74 kg	Gasket leak
10-12-81	Nuclear Fuel Service Erwin, Tennessee	Fuel fabrication	0.05 to 0.1 kg, HEU	Release via main scrubber stack
2-25-82	Exxon	Fuel fabrication	<25 kg	Gasket leak
12-83	Edlow International, East St. Louis, Illinois	Warehouse	Not known	Fire in warehouse
1-4-86	Sequoyah Fuels Corporation Gore, Oklahoma	UF_6 conversion	14,000 kg in less than a minute; between 10% and 50% of the uranium became airborne	Heating of overfilled cylinder; one worker killed; several injured from HF

Enrichment Facilities

The only chemical form of uranium present at enrichment facilities is UF_6; therefore, the most likely accident of radiological concern would be a release of UF_6 to the plant and/or environment. Thus the health physics concerns and preparation at a conversion facility for a UF_6 release would also apply to an enrichment facility.

In addition, an enrichment facility also has the potential for criticality accidents. While criticality accidents have historically not occurred at enrichment facilities, the potential exists; therefore, the health physics group needs to be trained and equipped to respond properly. Because the radiological concerns of a criticality accident are so different from those of the daily operation of an enrichment plant, careful planning, procedures, and forethought are needed. Specifically, instrumentation to detect high levels of gamma and/or neutron radiation will need to be in place anywhere that a criticality can occur. High-range portable survey instruments are also required to measure the potentially high levels of radiation following an accident. Also, criticality dosimetry that can respond to neutron and gamma radiation is required for anyone working in a potential criticality area.

Regulatory requirements stated in 10 CFR Part 70.24, *Criticality Accident Requirements*, include the following:

- Audible alarm systems capable of detecting a nuclear criticality
- Capability for rapid dosimetry to identify persons having received > 10 rads

- Evacuation training and drills
- Maintenance of personnel decontamination facilities
- Arrangements and plans for services of a physician qualified to handle radiation emergencies
- Arrangements for transportation of contaminated persons to treatment
- Arrangements for treatment of affected individuals at offsite medical facilities

Fabrication Facilities

The accidents of radiological concern at fuel fabrication facilities are spills and releases of materials, fires, and criticality accidents. Depending upon the processes involved, uranium exists in several different forms at a fuel fabrication facility, beginning with UF_6 and ending with UO_2. The most serious spill would result from a release of UF_6, due to its volatility. This type of accident would be similar in consequence to a UF_6 release at an enrichment facility or conversion facility.

Several fires involving uranium have been reported at fuel fabrication and similar facilities. See Table 6-4, Fires and Explosions Involving Uranium and Thorium through 1986. In some instances, flammable material in close proximity caused the fire, but in other cases the pyrophoric nature of some forms of uranium resulted in fires. For example, uranium metal will spontaneously ignite when it is in finely divided pieces or when it is heated. Also, UO_2 when finely divided can be pyrophoric, oxidizing to U_3O_8. Uranium fires can be very difficult to extinguish. Neither water spray, carbon dioxide (CO_2), nor halon extinguishers are effective in fighting uranium metal fires, and they may produce greater hazards. Small uranium metal fires can be smothered by MET-L-X extinguishers that use a mixture of sodium chloride and potassium carbonate. Larger fires require large quantities of water to cool the material below its ignition temperature. Health physics concerns in such fires would be directed toward assessing releases to the air and surfaces nearby, ensuring the protection of emergency responders through the proper use of protective equipment, and determining the radiation exposures.

Criticality concerns would also be a factor in the health physics programs at fuel fabrication facilities. Proper radiation detection equipment should be available to provide alarms in the event of a criticality, assess the radiation levels following a criticality, and determine the radiation doses to nearby personnel from the gamma and neutron radiation levels anticipated during a criticality.

The following information in Table 6-5, Summary of Potential Accidents at Fuel Cycle Facilities, provides a summation of potential accidents and radiation concerns at fuel cycle facilities.

Note: Supplemental reading on recent fires can be found at the end of this module.

Table 6-4. Fires and Explosions Involving Uranium and Thorium through 1986

Date	Facility	Release	Description
6-27-49	Los Alamos National Laboratory New Mexico	None reported	Fire broke out in a drum containing uranium metal turnings
10-29-52	Truck Kansas City, Missouri	Considerable	Truck carrying uranium metal burned; uranium ignited and much was lost
12-9-52	AEC facility	None	Molten uranium metal was being cast in a vacuum; spill ruptured vacuum; uranium then burned
6-12-53	U.S.	Onsite contamination up to 15,000 dpm/100 cm^2	Explosion of powdered uranium and CCl_4 in glove box
8-20-56	AEC contractor	100,000 dpm/100 cm^2 onsite. 500 dpm/100 cm^2 offsite	Thorium explosion
9-21-56	Truck Detroit, Michigan	None	Drum containing thorium metal started to burn; no contamination; no exposures
6-23-58	AEC contractor Attleboro, Massachusetts	No material loss	Fire in slightly enriched uranium scrap in perchloroethylene
9-26-60	M&C Nuclear Attleboro, Massachusetts	Enriched uranium, no exposures	Magnesium explosion in vacuum induction furnace
9-20-63	Controls, Incorporated Attleboro, Massachusetts	None detected	Fire in filter box exhausting enriched uranium; no contamination on or offsite
6-29-67	Kerr-McGee Crescent, Oklahoma	Minor	Explosion in ion exchange column
9-2-72	United Nuclear Fuel Fabrication Facility	Uranium at 15 times MPC	Flash fire caused by organic contaminants in ductworks; considerable damage
3-12-81	Nuclear Metals Concord, Massachusetts	Minor inplant contamination	Fire in scrap packaging building from spontaneous combustion of 10 lbs of uranium turnings; no over exposures

Table 6-5. Summary of Potential Accidents at Fuel Cycle Facilities

Facility	Common Radioactive Material	Incidents	Radiation Concerns
Mining/Recovery	Uranium ores and yellowcake	Fires, recovery tailings release	The spread of contamination in the air from fires and to the ground from spills
Conversion	Yellowcake and UF_6	Spills of various uranium compounds; release of UF_6 as a gas	The spread of contamination locally from most spills and potentially widespread from UF_6
Uranium Enrichment	UF_6 (depleted, natural, and enriched)	UF_6 release; criticality potential	Potentially widespread airborne and surface contamination due to UF_6, high radiation doses due to criticality
Fuel Fabrication	UF_6 and UO_2	UF_6 release; uranium fires; criticality potential	Potentially widespread airborne and surface contamination due to UF_6, high radiation doses due to criticality, plus spills of UO_2

Self-Check Questions 6-4:

INSTRUCTIONS: Complete the following questions. Answers are located in the answer key section of the Trainee Guide.

1. What health physics actions should be taken during a mining or recovery accident?

2. In the event of a significant release of UF_6 at a conversion facility, health physics personnel need to be prepared and equipped to do what?

3. How and when should inhalation of uranium due to a UF_6 release be verified?

4. Within a relatively short time following an accident, why is it necessary to collect numerous urine samples?

5. In the event of a major release of UF_6, what NRC document provides simple methods to assess the dose at various distances from the release point, recommends evacuation distances if a plume has not arrived, and has a list of health effects for various intakes of uranium?

6. Since a uranium enrichment facility has the potential for a criticality accident, what health physics instrumentation should be present and why?

7. In case of a fire at a fuel fabrication facility, what would be the health physics concerns?

8. Match the facility in column A with the types of incidents listed in column B.

Column A **Facility**		**Column B** **Types of Incidents**
A. Mining/Recovery	1._____	Spills of various uranium compounds; release of UF_6 as a gas
B. Conversion	2._____	UF_6 release; uranium fires; criticality potential
C. Uranium Enrichment	3._____	Fires, recovery tailings release
D. Fuel Fabrication	4._____	UF_6 release; criticality potential

You have completed this section.
Please check off your progress on the tracking form.
Go to the next section.

It's time to schedule a progress meeting with your administrator. Review the progress meeting form on the next page. In Part III, as a Regulator, write your specific questions to discuss with the administrator.

PROGRESS REVIEW MEETING FORM

Date Scheduled: ________________________________**Location:**______________________

I. The following suggested items should be discussed with the administrator as to how they pertain to your current position:

- Emergency Planning
  - Regulatory Guide 3.67
- Emergency Preparedness
  - NUREG-1140
  - Protective actions
- Response
  - Sampling and monitoring in the field
- Recovery
- NRC Inspection Procedure 88050
- Health physics role in accidents and emergencies
- NRC Management Directive (MD) 10.131

II. Use the space below to take notes during your meeting.

MODULE 6.0: ACCIDENTS AND EMERGENCIES AT FUEL CYCLE FACILITIES

III. As a Regulator:

- Show me a licensee emergency plan that relates health physics actions and activities for mining and recovery, conversion, uranium enrichment, and/or fuel fabrication facilities.
- Tell me how the health physics role in accidents and emergencies at fuel cycle facilities were similar. . . . were different.
- Tell me about the types of accidents involving the release of radioactive materials that might occur at particular fuel cycle facilities.

Use the space below to write your specific questions.

IV. Further assignments? If yes, please note and complete. If no, initial completion of progress meeting on tracking form.

Suggested reading may include:

- 10 CFR Part 70.24, Criticality Accident Requirements
- Inspection Procedure 88050, *Emergency Preparedness*
- NRC Management Directive (MD) 10.131, Volume 10, Part 5, *Protection of NRC Employees Against Ionizing Radiation*, Handbook 10.131, Part VI
- NUREG-1140, *A Regulatory Analysis on Emergency Preparedness for Fuel Cycle and Other Radioactive Material Licensees*

- Regulatory Guide 3.67, *Standard Format and Content for Emergency Plans for Fuel Cycle and Materials Facilities*
- Regulatory Guide 8.31, *Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Recovery Facilities Will be As Low As Reasonably Achievable*
- U.S. Nuclear Regulatory Commission Response Technical Manual (RTM-96)

Ensure that you and your administrator have dated and initialed your progress on your tracking form for this module.
Go to the module summary.

MODULE SUMMARY

At fuel cycle facilities, emergency radiological assessment is an integral functional area of the emergency response. The sense of urgency and timeliness become issues that may have profound impact during emergencies. Emergency health physics workers need the appropriate professional and job skills to be an effective part of the emergency response organization. It is essential that personnel responsible for responding during a radiological emergency receive training and exercise their radiological emergency response functions.

Congratulations! You are ready to go to the next assigned module.
