MODULE 5.0: EXTERNAL DOSE CONTROL

Introduction

Welcome to Module 5.0 of the General Health Physics Practices for Fuel Cycle Facilities Directed Self-Study Course! This is the fifth of seven modules in the self-study course. The purpose of this module is to assist the trainee in discussing the sources of external dose and to describe methods to minimize worker exposure. This self-study module is designed to assist you in accomplishing the learning objectives listed at the beginning of the module. There are seven 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

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

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. Contract 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.

MODULE 5.0: EXTERNAL DOSE CONTROL

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LEARNING OBJECTIVES

5.1 Upon completion of this module, you will be able to discuss the sources of external dose and describe methods to minimize worker exposure.

5.1.1 State the most common source of external dose as a result of handling uranium.

5.1.2 Given specific examples of workplace operations, recognize when chemical processes could result in higher external doses.

5.1.3 Compare the relative hazard of beta versus gamma radiation at uranium facilities.

5.1.4 State the appropriate personal protective equipment (PPE) to be used when directly handling uranium.

5.1.5 Identify appropriate survey instrumentation to assess external dose.

5.1.6 Identify methods used to reduce external dose at fuel cycle facilities.

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MODULE 5.0: EXTERNAL DOSE CONTROL

Learning Objectives

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

5.1.1 State the most common source of external dose as a result of handling uranium.

5.1.2 Given specific examples of workplace operations, recognize when chemical processes could result in higher external doses.

5.1.3 Compare the relative hazard of beta versus gamma radiation at uranium facilities.

OVERVIEW OF EXTERNAL DOSE HAZARDS

The external dose control program is also an important component of the health physics program at a nuclear fuel cycle facility. The internal hazard due to the inhalation or ingestion of uranium is typically viewed as the greatest hazard. However, at facilities that involve close contact with depleted, natural or low-enriched uranium, frequently the most significant radiation exposure is the external dose. This is primarily due to the skin, extremity, and lens of eye dose from beta radiation arising from decay products of uranium. (The alpha radiation from uranium will not penetrate the sensitive skin cell layer of 7 mg per square centimeter.)

The applicable annual limits for these organs are an eye dose equivalent of 15 rems and a shallow-dose equivalent of 50 rems to the skin or to any extremity. Extremity is defined as hand, elbow, arm below the elbow, foot, knee, or leg below the knee.
(Reference: 10 CFR Part 20)

Beta Radiation

Figure 5-1, Radiation Readings at Surface of Uranium Metal Versus Percentage Enrichment by Weight, shows the contact dose with uranium metal (and its associated decay products) versus the percentage enrichment. As can be seen, the contact dose is most significant at low enrichments due to the decay products of uranium-238.

Table 5-1, Beta Surface Dose Rates From Equilibrium Thickness of Uranium Metal and Compounds, shows the contact dose with a number of common uranium compounds such as those frequently found at fuel cycle facilities.

Figure 5-1. Radiation Readings at Surface of Uranium Metal Versus Percentage Enrichment by Weight

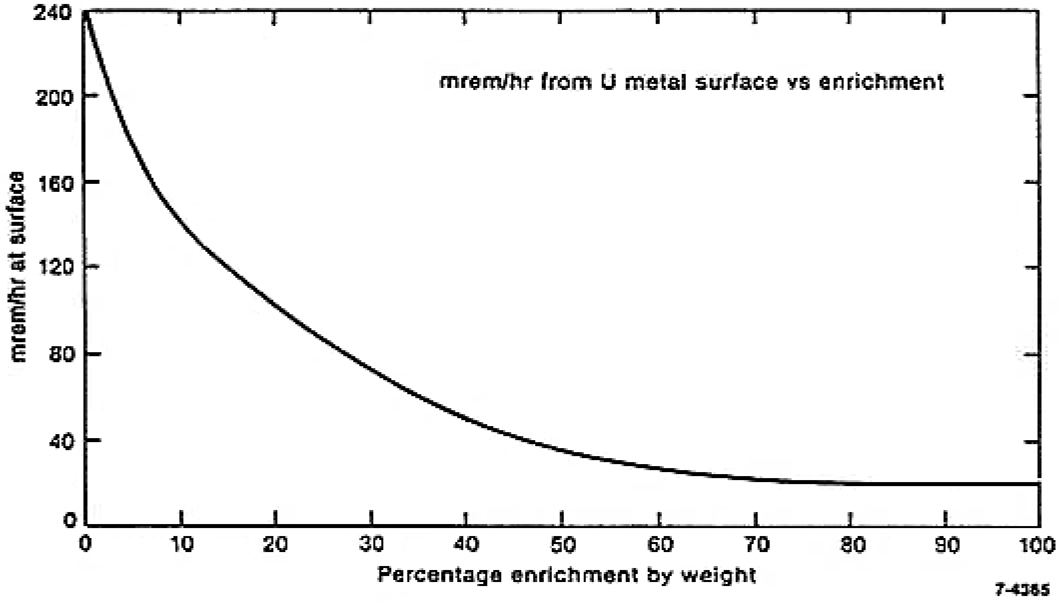


Table 5-1. Beta Surface Dose Rates From Equilibrium Thickness of Uranium Metal and Compounds

Source	Surface Dose Rate*(mrad/hr)
Natural U metal slab	233
UO_2	207
UF_4	179
$UO_2(NO_3)_26H_2O$	111
UO_3	204
U_3O_8	203
UO_2F_2	176
$Na_2U_2O_7$	167
*Beta surface dose rate in air through a polystyrene filter 7 mg/cm^2 thick.	

Workplace Examples

External gamma radiation is generally less of a problem than internal doses at uranium mining and recovery facilities; however, there are some areas of concern for external radiation at these facilities. Examples include:

- Radium filter press at in-situ leach (ISL) facilities. With accumulation of radium in the filter, radon progeny also build up in the filter.
- Large numbers of drummed yellowcake product stacked in a confined area (recovery).
- Process piping in recovery areas. Sediments, containing radionuclides, can accumulate in such piping. External hazards may increase during shutdown, when solutions are removed from the piping. Water in the solutions normally provides some shielding of the radiation.

In other fuel cycle facilities the external dose may arise largely from the decay products. For example, during operations that separate the uranium from its decay products, external dose rates can be considerably greater than those previously discussed. For example, during melting and casting operations, these decay products may concentrate on the surface of the castings and equipment, producing beta radiation fields of up to 20 rad/hr. A similar effect is observed when UF_6 cylinders are emptied. An emptied cylinder will typically have an external contact dose rate several times greater (50 to100 mrad/hr versus a few mrad/hr) due to the uranium decay products and Tc-99 left in the cylinder.

Significant exposure to beta radiation also occurs in fuel fabrication facilities at pellet stacking tables where pellets are "stacked", inspected, and measured prior to insertion into fuel rods. As a result, many of the fuel fabrication facilities have placed plastic barriers, similar to those found at food stores that have salad bars, in these areas.

These barriers reduce the beta radiation level to the eyes of the workers. Other facilities have reduced the size of the "slab" of pellets worked with to reduce the beta activity.

Relative Hazard of Beta versus Gamma Radiation

Beta radiation tends to create the most intense external dose problems in a fuel cycle facility. However, storage of large quantities of uranium can create widespread low-level gamma radiation fields.

Hazard of Neutron Radiation

In uranium processes involving fluoride compounds such as UF_6 and UF_4, the alpha-neutron reaction with fluorine can produce a measurable neutron radiation field. This neutron field will be a function of the uranium compound involved, the mixing of the material, storage configuration, and enrichment, but is typically low. For example, large quantities of low enrichment UF_6 ($< 5\%$) in storage can result in neutron radiation fields in the immediate area. This is normally not a limiting factor in the use of such material, but may need to be monitored in areas that are routinely occupied.

Higher enrichment uranium fluoride material will have correspondingly higher neutron dose rates. Large quantities of UF_6 enriched to 97% can create neutron fields on the order of 4 mrem/hr, which may be higher than the gamma dose present and be the limiting external dose hazard.

Self-Check Questions 5-1:

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

1. What types of facilities are likely to have some significant gamma radiation exposure?

2. What are the applicable annual limits for the following?

   Eye dose equivalent?

   Shallow-dose equivalent?

3. How is extremity defined per 10 CFR Part 20?

4. According to Figure 5-1, Radiation Readings at Surface of Uranium Metal Versus Percentage Enrichment by Weight, what comparison can you make between contact dose with uranium metal (and its associated decay products) and low enrichment?

5. According to Table 5-1, Beta Surface Dose Rates From Equilibrium Thickness of Uranium Metal and Compounds, which source has the highest surface dose rate (mrad/hr)?

   Which source has the lowest surface dose rate?

6. Where are two areas in a recovery facility where external radiation could be a problem?

7. What have many fuel fabrication facilities done to reduce beta radiation exposure at pellet stacking tables?

8. Beta radiation tends to create the most intense external dose problems in fuel cycle facilities. However, storage of large quantities of uranium can create widespread low-level __________ radiation fields.

9. Large quantities of low enrichment UF_6 (< 5%) in storage can result in neutron radiation fields in the immediate area. What kind of neutron dose rates can higher enrichments have for uranium fluoride material?

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

Learning Objectives

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

5.1.1 State the most common source of external dose as a result of handling uranium.

5.1.2 Identify appropriate survey instrumentation to assess external dose.

SOURCES AND DETECTION OF BETA RADIATION

The beta dose rate in handling low-enriched uranium comes primarily from protactinium-234m (Pa-234m), with a much smaller component coming from thorium-234 (Th-234). Both are decay products of uranium-238 (U-238). (See Tables 5-2, Major Uranium Beta and Gamma Emissions [MeV], and 5-3, Beta Emissions From Uranium and Daughter Radionuclides.) This accounts for the fact that the beta radiation dose rate drops at higher enrichments since there is correspondingly less U-238 to produce this decay product.

The relatively high energy of this beta emitter makes it easy to detect with any G-M detector, ionization chamber, or similar instrument with a "beta window." However, as with any beta-detection instrument, conversion of the response to an absorbed dose rate must be done with care to include factors such as energy dependence, angular response, and detector construction.

Table 5-2. Major Uranium Beta and Gamma Emissions (MeV)

Radionuclide	Beta (Max)	Gamma
U-238	None	None
Th-234	0.103 (21%) 0.193 (79%)	0.063 (3.5%) 0.093 (4%)
Pa-234m	2.29 (98%)	0.765 (0.3%) 1.00 (0.6%)
U-235	None	0.144 (11%) 0.186 (54%) 0.205 (5%)
Th-231	0.287 (41%) 0.305 (35%) 0.205 (15%)	0.026 (15%) 0.084 (10%)
U-234	None	0.053 (0.2%)

Table 5-3. Beta Emissions From Uranium and Daughter Radionuclides

Radionuclide	Maximum Beta Energy (MeV)	Decay Fraction	MeV per Transformation	%MeV per Transformation
U-238	None	0.00	0.00	0.0
Th-234	0.103	0.19	0.020	0.8
Th-234	0.193	0.73	0.141	5.9
Pa-234m	2.29	0.98	2.244	93.3
Total MeV/Transformation = 2.405				
U-235	None	0.00	0.00	0.0
Th-231	0.14	0.45	0.063	28.9
Th-231	0.22	0.15	0.033	15.1
Th-231	0.305	0.40	0.122	56.0
Total MeV/Transformation = 0.218				
U-234	None – no significant beta contributions			
Assumption: The mix of radionuclides seen above is what might be expected from the "pure" uranium isotope in which the short-lived daughters have had time to grow.				

Beta Correction Factors

Beta correction factors must be applied to most instruments. These factors account for the window thickness of the detector being greater (or less) than the ideal for a human response, the attenuation of the beta radiation in a large detector, and the fact that many detectors show a high angular dependence to beta radiation due to the thicker walls around the "beta window."

Table 5-4, Instrument Response to Uranium Beta Fields, shows several beta correction factors that have been determined for instruments measuring beta radiation fields around uranium. Ideally, each facility would determine such correction factors based on the types of instruments they have and the types of uranium compounds that they are measuring.

Another problem that may exist arises from the fact that because the beta from Pa-234m is sufficiently high in energy, it can be detected to a limited extent by some detectors even with the "beta window" closed. In some cases, 10% to 20% of the "gamma only" reading may be due to the Pa-234m beta emission.

Table 5-4. Instrument Response to Uranium Beta Fields

Instrument	Window (mg/cm^2)	Beta*Correction Factor	Exposure Geometry
Victoreen 471	1.1	1.4	30 cm from U foils
Eberline RO-2A	7	4.0	Contact with depleted uranium (DU) slab
Al walled GM	30	1.7	30 cm from U foils
“Teletector”	30 (low range)	50	Contact with DU slab
Eberline PIC-6A	30	40	Contact with DU slab
*True reading/measured value.			

Survey Instrumentation for Technetium-99 (Tc-99)

In addition to the beta radiation primarily coming from uranium, facilities handling recycled uranium (all fuel fabrication facilities) would also need to survey for Tc-99 to verify that it is not present or determine the levels observed. The technetium beta is nearly an order of magnitude lower in energy than the Pa-234m beta (0.292 MeV versus 2.29 MeV). As a result of this lower energy and the fact that it is normally only present in small amounts, Tc-99 is often not the limiting hazard. However, Tc-99 can be the dominant radiation in empty UF_6 cylinders. Both of the gaseous diffusion plant facilities (especially Portsmouth) have a significant problem with the quantity of Tc-99 and other fission products at the withdrawal end of the cascade.

If levels of Tc-99 are found to be significant, care should be taken in the selection of dosimetry and survey instrumentation, since beta correction factors determined for Pa-234m would not apply to the Tc-99. In particular, survey instruments with relatively thick "beta windows" (> 30 mg/cm2) would not readily detect the low-energy Tc-99 beta radiation.

Self-Check Questions 5-2:

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

1. When handling low-enriched uranium, what decay products from U-238 produce a beta dose?

2. Why does the beta radiation dose rate drop at higher enrichments?

3. As with any beta-detection instrument, conversion of the response to an absorbed dose rate must be done with care to include what factors?

4. Why should beta correction factors be applied toward most instruments?

5. Fuel cycle facilities that handle recycled uranium may need to survey for technetium-99 (Tc-99) to verify that it is not present or to determine the levels observed. Where in a gaseous diffusion plant are you likely to find Tc-99?

6. Can beta correction factors determined for Pa-234m apply to Tc-99? Why or why not?

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

Learning Objectives

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

5.1.3 Compare the relative hazard of beta versus gamma radiation at uranium facilities.

5.1.4 Identify appropriate survey instrumentation to assess external dose.

SOURCES AND DETECTION OF GAMMA RADIATION

Comparison of the Relative Hazard of Beta Versus Gamma Radiation

Gamma radiation is also emitted by a number of uranium decay products (see Table 5-2, Major Uranium Beta and Gamma Emissions [MeV], presented earlier, and Table 5-5, Major Emissions from Uranium and Daughter Radionuclides), but the energies and effective yields are low, resulting in relatively low radiation fields. However, in facilities where the radioactive material is well-contained, the penetrating ability of the gamma radiation may result in its being the most significant hazard.

Note: A portion of the low radiation fields in facilities where the uranium is well-contained is due to bremsstrahlung radiation from the containment, drums, cylinders, etc.

Table 5-5. Major Emissions from Uranium and Daughter Radionuclides

Radio-nuclides	Gamma Energy (MeV)	Branch Fraction	Decay Fraction	Effective Yield	MeV per Transforma-tion	% MeV per Transforma-tion
U-238	None	1.00	0	0	0	0.0
U-235	0.143	1.00	0.11	0.11	0.0157	11.66
U-235	0.185	1.00	0.54	0.54	0.100	74.29
U-235	0.204	1.00	0.05	0.05	0.010	7.43
Th-231	0.026	1.00	0.02	0.02	0.0005	0.37

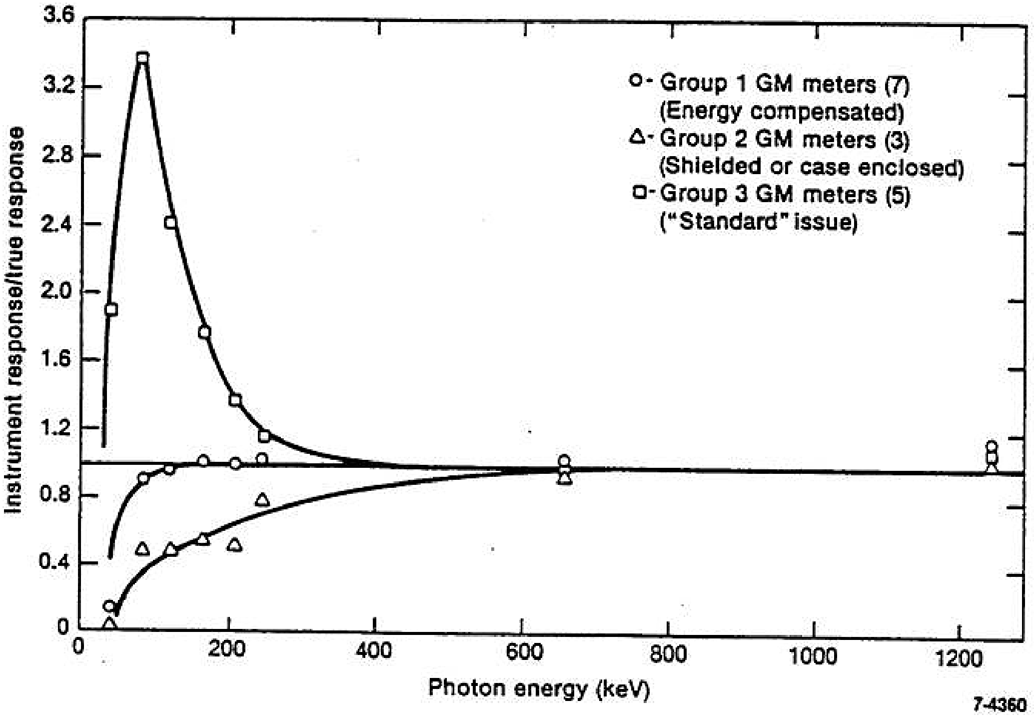
Table 5-5. Major Emissions from Uranium and Daughter Radionuclides

Radio-nuclides	Gamma Energy (MeV)	Branch Fraction	Decay Fraction	Effective Yield	MeV per Transforma-tion	% MeV per Transforma-tion
Th-231	0.084	1.00	0.10	0.10	0.0084	6.24
U-234	0.053	1.00	0.002	0.002	0.0001	100.0
Assumption: The mix of radionuclides seen above is what might be expected from the "pure" uranium isotope in which the short-lived daughters have had time to grow.						

Survey Instrumentation for Uranium Gamma Radiation

Because of the low energies of most of the gamma radiation emitted, proper measurement instrumentation must be carefully selected. Survey instruments are frequently calibrated with sources such as cesium-137 (Cs-137) or cobalt-60 (Co-60), which have relatively high gamma energies (662 keV for cesium-137, and 1,173 and 1,332 keV for cobalt-60). The uranium gamma radiation in general is less than 250 keV. In this low energy range, many survey instruments, especially G-M detectors, show a variable response from the true reading, frequently showing a sizeable over-response (see Figure 5-2, Average G-M Survey Meter Photon Energy Responses by Group). Survey instruments such as ionization chambers or energy- compensated G-M detectors should be used to measure dose rates.

Figure 5-2. Average GM Survey Meter Photon Energy Responses by Group



Other Sources of Gamma Radiation

Other sources of gamma radiation will exist at mining and recovery operations as well as at later stages of the fuel cycle, if recycled uranium is used.

In mining and recovery operations, one of the primary sources of gamma radiation is radium and its decay products, especially lead-214 (Pb-214) and bismuth-214 (Bi-214). The radiation level will depend upon whether these decay products are in equilibrium with the parent radionuclides. In many cases, they will result in the most significant gamma exposures at these facilities.

Significant quantities of gamma radiation will be found in fuel fabrication facilities that store large numbers of completed fuel assemblies, i.e., in fuel bundle "forest" locations where the gamma radiation level can be as high as 15 to 20 mrad/hr.

Recycled uranium will also have an increased gamma radiation dose due to U-232 and its immediate decay product, Th-228. The major exposure increase is expected to be in handling UF_6 cylinders. External dose rates could increase by a factor of 5 or more around cylinders containing recycled uranium.

Self-Check Questions 5-3:

INSTRUCTIONS: Fill in the missing words in each statement. Answers are located in the answer key section of the Trainee Guide.

Choose from the following words:

5 or more
15 to 20
bremsstrahlung
Co-60
fuel fabrication
gamma
ionization
measurement
mining and recovery
recycled

1. In facilities where the radioactive material is well-contained, the penetrating ability of the ___________________ radiation may result in it being the most significant hazard.

2. A portion of the low radiation fields in facilities where the uranium is well-contained is due to ____________________ radiation from the containment, drums, cylinders, etc.

3. Because of the low energies of most of the gamma radiation emitted, proper ______________________ instrumentation must be carefully selected.

4. Survey instruments are frequently calibrated with sources such as Cs-137 or ____________, which have relatively high gamma energies.

5. Survey instruments such as ____________________ chambers or energy-compensated G-M detectors should be used to measure uranium gamma radiation dose rates.

6. In __________________________operations, one of the primary sources of gamma radiation is radium and its decay products, especially Pb-214 and Bi-214.

7. Significant quantities of gamma radiation will be found in _____________________ facilities that store large numbers of completed fuel assemblies where the gamma radiation level can be as high as ___________________ mrad/hr.

8. _____________________ uranium will also have an increased gamma radiation dose due to U-232 and its immediate decay product, Th-228.

9. External dose rates could increase by a factor of ______________ around cylinders containing recycled uranium.

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

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Learning Objectives

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

5.1.4 State the appropriate personal protective equipment (PPE) to be used when directly handling uranium.

5.1.5 Identify appropriate survey instrumentation to assess external dose.

5.1.6 Identify methods used to reduce external dose at fuel cycle facilities.

PERSONAL DOSIMETRY

Appropriate Personal Equipment

Personal dosimetry for the radiation hazards at fuel cycle facilities is generally very similar to that found at other nuclear facilities and consists of a standard dosimeter for measuring total body exposure (most commonly a thermoluminescent dosimeter [TLD]) and extremity dosimeters, as necessary. However, these dosimeters have some of the same problems in responding to beta radiation that the survey instruments have, namely energy and angular dependence.

Problems with Thermoluminescent Dosimeter Instrumentation

TLD chips of lithium fluoride (LiF) frequently are thick enough to attenuate the beta dose significantly as it passes through the chip, resulting in an under-response. To correct for this problem, the principal dosimeters for measuring personnel dose are often composed of several detector components including thin chips or powdered LiF that will more accurately measure beta dose.

Also, badge holders sometimes create angular dependence problems, especially around beta radiation sources. Care should be taken to ensure that badges are properly worn to expose any thin "beta windows."

Problems with Extremity Dosimeter Instrumentation

Extremity dose measurements may also suffer from the same problems as the previously mentioned TLD dosimeters. These dosimeters frequently do not contain the multiple chips that allow for more accurate beta dose determination. However, with careful consideration of the typical exposure conditions and calibration of the dosimeters with appropriate sources such as uranium plate sources, extremity doses can be measured with acceptable accuracy for protective purposes.

EXTERNAL DOSE REDUCTION

Reduction Principles

Reduction of external doses to personnel depends largely on the application of the principles of time, distance, and shielding.

Reduction of exposure time will reduce the dose accordingly; therefore, operations involving exposure to high dose rates (direct handling of uranium metal) or long-term exposure to low dose rates should be examined to determine if the exposure time can be reduced.

For example, avoid exposure time to drummed yellowcake product areas. To avoid long-term exposures to low levels of gamma and/or neutron radiation, work stations (such as guard houses) should not be constructed near large storage areas of UF_6 cylinders.

Increasing the distance from sources of beta radiation can decrease the doses significantly due to air shielding and geometry. Techniques to allow workers to handle uranium materials semi-remotely can result in large reductions in personnel doses.

Shielding is one of the most widely used and effective methods for reducing radiation doses at fuel cycle facilities. Table 5-6, Uranium Beta Shielding, gives the approximate thickness of material to stop the high-energy betas emitted from Pa-234m. As can be seen, approximately 1 cm or less of most solid materials will stop these betas very effectively. In general, the use of lower density material such as lucite or other plastics is preferable to reduce the production of bremsstrahlung x-ray radiation in the shielding. Also, careful planning in the storage of uranium materials can result in significant self-shielding, particularly of the beta component. For example, storing plates of uranium metal in racks such that personnel are only exposed "edge-on" will result in lower beta (and gamma) radiation fields.

Table 5-6. Uranium Beta Shielding

Material	Approximate Material Thickness Required to Stop Pa-234m Betas (cm)
Air	850.0
Aluminum	0.41
Lead	0.10
Lucite	0.92
Pyrex Glass	0.49
Polyethylene	1.2
Stainless Steel (347)	0.14
Water	1.1
Wood	1.7 (approximate)
Uranium	0.06

Protective Clothing

Unfortunately, the thickness of material to stop the Pa-234m betas results in relatively bulky and impractical protective clothing. Table 5-7, Uranium Beta Dose Penetration Factors, gives the uranium penetration factors for various examples of protective clothing.

Table 5-7. Uranium Beta Dose Penetration Factors

Item	Penetration Factor
Vinyl surgeon’s gloves	0.95
Latex surgeon’s gloves	0.87
Lead loaded (10 mil Pb equivalent)	0.77
Lead loaded (30 mil Pb equivalent)	0.13
Pylox gloves	0.62
Leather (medium weight)	0.62
White cotton gloves	0.89
"Tyvek" coveralls	0.98
"Durafab" paper lab coat	0.96
65% Dacron/35% cotton lab coat	0.91

Table 5-8, Reduction of Beta Radiation Dose, demonstrates the effectiveness of various combinations of protective clothing. As can be seen, most protective clothing offers only limited protection from the beta dose. One exception to this is the protection of the lens of the eye. Safety glasses and or face shields can significantly reduce this radiation exposure and should be used when workers are in areas of potential high beta exposures. For example, beta emission hazard to the lens of the eye is a problem in pellet stacking. Licensees have added plastic shields to protect workers' eyes.

Table 5-8. Reduction of Beta Radiation Dose*

Table 5-8. Reduction of Beta Radiation Dose*		
Absorber	**Dose Rate (mrad/hr)**	**Percent Transmitted (%)**
None	199	100
2 pairs coveralls	160	80
2 pair gloves + liner	120	60
Face shield	81	41
*Source: Natural Uranium Metal Slab at 1 cm		

Self-Check Questions 5-4:

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

1. What personal dosimeters should employees wear at fuel cycle facilities?

2. What kinds of problems are prevalent with TLD instrumentation and what can be done by the employee to prevent these problems?

3. What should be considered when using extremity dosimeter instrumentation to ensure acceptable accuracy for protective purposes?

4. Reduction of exposure ________ will reduce the dose accordingly.

5. Increasing the _________ from sources of beta radiation can decrease the doses significantly due to air shielding and geometry.

6. ___________ is one of the most widely used and effective methods for reducing radiation doses at fuel cycle facilities.

7. ______________________ and or face shields can significantly reduce radiation exposure and should be used when workers are in areas of potential high beta exposures.

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:

- Sources of external dose
- Workplace examples of external dose exposure
- Relative hazard of beta versus gamma radiation
- Hazard of neutron radiation
- Sources and detection of beta radiation
- Beta correction factors
- Instrument response to uranium beta fields
- Sources and detection of gamma radiation
- Problems with extremity dosimeter instrumentation
- Reduction principles
- Protective clothing

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

III. As a Regulator:

- What should I be aware of when I am around full UF_6 cylinders versus empty at a particular facility?
- Where are the low gamma radiation fields located at a particular facility?
- Does the facility that I am working with deal with uranium fluoride? If yes, in what areas does low-level neutron radiation exist? What enrichment level is involved?
- What are some examples of where basic principles of time, distance, and shielding reduce exposure to external dose at a particular facility?

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.

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

External dose control plays an important part in the overall reduction of radiation exposure at fuel cycle facilities. External dose control is most important at facilities involving close contact with uranium. The major source of beta radiation is from the uranium decay product Pa-234m. This relatively high-energy beta represents a hazard to the skin, the extremities, and the lens of the eye. Operations that separate uranium from its decay products can result in high external radiation levels in "empty" casks or cylinders.

Facilities handling large quantities of uranium can also have low-level gamma radiation fields that must be controlled to limit total body exposures. These fields can be the limiting external dose control factor at sites where the beta radiation is shielded by container walls. In addition, low-level neutron radiation fields may exist in areas containing large quantities of uranium fluoride. This neutron radiation may be the controlling external dose factor when high-enrichment uranium is involved.

The basic principles of time, distance, and shielding for external radiation dose reduction apply to all of these sources of external dose. Each principle can be used to effectively control external exposures.

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

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