Radiation Protection Technician Initial Training: Engineering Controls

ACADs (08-006) Covered

3.3.8.11 3.3.10.10 3.3.11.28.9 4.5.1 4.16.7 5.1.2.1.5 5.4.3.11

Keywords

Engineering controls, ventilation, radwaste, dose, exposure, ALARA.

Description

Supporting Material

RCNET
Regional Center for Nuclear Education & Training

TERMINAL OBJECTIVE

Upon completion of this course, the participants will demonstrate their knowledge and understanding of the information presented during RADCON Technician training by obtaining a score equal to or greater than 80% on a written examination. The information presented in this lesson plan may be part of an overall exam or be the only information for which the student is examined.

ENABLING OBJECTIVES

Standards and conditions apply to all enabling objectives. They include under the examination ground rules, without the use of training materials or outside assistance, and utilizing information presented in this lesson plan. Upon completion of this lesson each participant will be able to:

ENABLING OBJECTIVES

List the factors that must be considered when evaluating different methods of engineering controls.

Define engineering controls and list several that may be utilized in a nuclear power plant.

Discuss the ventilation and gaseous radwaste systems to include airflow, design, air reversal and minimization of personnel dose.

ENABLING OBJECTIVES

Identify two types of portable ventilation systems and describe when they would be utilized.

List the components and discuss the operation of a portable auxiliary ventilation system.

List factors which affect the efficiency of a carbon absorber.

ENABLING OBJECTIVES

State the advantages of a portable ventilation system.

List design features that minimize major dose accumulating factors. (RCT 014.190)

Identify access controls that prevent unnecessary exposure.

ENABLING OBJECTIVES

Discuss radiation shield design to include the following:

- Features of design that reflect ALARA.
- Exposure contributor in BWR's turbine building.
- Objective of valve galleries and design guides to achieve this objective.
- Streaming to include causes and methods to reduce.

ENABLING OBJECTIVES

Explain the design features of the monitoring systems.

Discuss isolation and decontamination designed features utilization.

List items considered in crud control.

ENABLING OBJECTIVES

Identify forms of total containment to include the following:

- Tasks
- Forms
- Design
- Operation
- Advantages
- Disadvantages

(RCT 008.230)

INTRODUCTION (Obj.1&2)

The primary function of an engineering control is to minimize dose to personnel without increased cost. A number of factors must be considered when evaluating different methods of engineering controls. These factors include initial cost of equipment, cost of repair and service of equipment, the number of personnel and time required to use the method, effectiveness of controlling radioactive contamination, and effectiveness in reducing radiation dose to personnel.

INTRODUCTION (Obj.1&2)

When a nuclear power plant is designed, consideration is given to the design features which help reduce or eliminate airborne radioactivity areas, radiation areas and contaminated areas whenever possible. Engineering controls such as the ventilation system, shielding, floor drains, leak collection, proper decontamination facilities, operational controls, radiation monitoring systems, resin and sludge treatment systems, crud control, isolation, decontamination and containments are only a small percentage of the design techniques used in the nuclear industry.

INTRODUCTION (Obj.1&2)

When engineering controls are not feasible, other controls (e.g., respiratory protection, stay times, limiting personnel access) should be used to lessen the potential dose to plant personnel. Vital information can be obtained from experiences of past designs and operating plants. The combination of information obtained from these sources can be utilized in developing improved radiation protection designs.

INTRODUCTION (Obj.1&2)

The objective of the plant's radiological control group is to maintain each individual dose and total person rem As Low As Reasonably Achievable (ALARA) and within the limits of 10CFR20. Within restricted areas, all plant sources of direct radiation, airborne radioactivity and contamination must be considered in nuclear power plant original design features.

Terms and Definitions

Engineering control - permanent or temporary features used to minimize personnel exposure to radiation and/or radioactive material.

HEPA filter - High Efficiency Particulate Absolute filter used to remove microscopic particles from the air. A DOP certified HEPA filter has a minimum efficiency of 99.97% for filtering 0.3 micron size particles.

Terms and Definitions

Capture velocity (C/V) - the velocity of air at a point in space sufficient to draw airborne contaminants into a flow-stream so that they can be removed by an air filtration system.

Glove Box - a rigid, sealed containment in which personnel, using gloves attached to and passing through openings in the box, can handle contaminated materials safely from the outside.

Regulatory Requirements

10CFR50.34a requires that the design objective of equipment for controlled releases of radioactive materials in effluents from nuclear power reactors must meet the following provisions:

All applications for a nuclear power reactor shall include a description of the preliminary design of equipment to be installed to maintain control over radioactive materials in gaseous and liquid effluents produced in normal operation, including expected operational occurrences.

Regulatory Requirements

Each application for a permit to construct a nuclear power reactor shall include the following:

- A description of the preliminary design of equipment to be installed.
- An estimation of the quantity of each principal radionuclide expected to be released annually to unrestricted areas in liquid effluents, gases, halogens and particulates, as well as the quantity expected to be released every day during normal operation.
- A general description of the provisions for packing, storage and shipment offsite of solid radioactive waste.

Objective 3
Discuss the ventilation and gaseous radwaste systems to include airflow, design, air reversal and minimization of personnel dose.

The design features of a nuclear power plant ventilation system and gaseous radwaste processing system should reflect the following considerations:

- Airflow rate in a nuclear facility is at an increased rate as compared to a non-nuclear facility.
- The spread of airborne contamination within the plant can be limited by maintaining air pressure gradients. Pressure boundaries ensure that airflow moves from clean areas, to regulated areas, to contaminated areas, and finally through a bank of high efficiency filters before being released to the environment. If releases should occur, the flow of air will thus be into areas where it can more easily be contained.

Objective 3 (cont.)

- Effectively designed gaseous radwaste treatment systems will also contain radioactive material that has been collected, deposited, stored or transported within the systems.
- Needed test, service, inspection, decontamination or replacement of parts can result in plant personnel exposure to radiation and to contamination from the ventilation or gaseous radwaste treatments systems.
- There is also a possibility of airflow reversal which can result in airborne radioactivity where it normally does not exist. Air reversals may be produced, for example, when a cubicle shield plug is removed or when a damper or fan malfunctions.

Objective 3 (cont.)

The potential dose from the ventilation and gaseous radwaste processing systems during normal maintenance activities can be minimized by the following conditions:

- Providing ready access to the system.
- Providing space to permit the activities to be accomplished expeditiously.
- Separating filter banks and components to reduce exposures to radiation from adjacent banks and components.
- Providing sufficient space to accommodate auxiliary ventilation or shielding of components.

Obj. 4
Identify two types of portable ventilation systems and describe when they would be utilized.

The auxiliary ventilation system augments the permanent system. It can provide local control of airborne radioactivity when equipment containing potential airborne sources is opened to the atmosphere.

Obj. 4

Two types of auxiliary ventilation systems have proven to be effective in controlling the release of airborne radioactivity to the work environment:

- In areas where contaminated equipment must be opened frequently, dampers and fittings can be provided in ventilation ducts to permit the attachment of flexible tubing without imbalancing the ventilation system.
- In areas where contaminated equipment must be opened infrequently, portable auxiliary ventilation systems may be used. These generally include a blower, prefilter, HEPA filter, and possibly an activated charcoal absorber.

Obj. 5

List the components and discuss the operation of a portable auxiliary ventilation system.

The portable auxiliary ventilation systems are used where the potential for high contamination exists, and may decrease the possibility of airborne radioactivity problems due to work being performed.

The components and operation of a portable auxiliary ventilation system include:

Obj. 5

- A prefilter is the first component through which contaminated air passes for cleaning. Prefilters are coarse filters used to collect large amounts of particulates. This extends the service life of the more expensive downstream filters.
- A High Efficiency Particulate Absolute (HEPA) filter is the second component in the air cleaning sequence, and is used to remove miscroscopic particulates (down to 0.3 micron).

Obj. 5

There are three types of HEPA filters:

- Type A HEPA filters are tested for penetration at 100% flow rate and are normally used in recirculating air systems.
- Type B HEPA filters are tested for penetration at 100% and 20% flowrate and are normally used on once through systems. Type B filters are best suited for portable ventilation in a nuclear power plant.
- Type C HEPA filters are scanned on the downstream face to detect leaks. Scanning a filter for leaks is usually performed on a filter used in a clean area. Type C filters are not usually used in nuclear power plants because of the high cost.

Obj. 5

- Carbon absorbers may be utilized in the air cleaning system. Carbon absorbers remove radioiodine (halogen) gas which is the main concern in nuclear air and gas cleaning.

- Carbon absorbers consist of a rigid external casing with perforated sheet inner casing filled with activated carbon. Activated carbon (charcoal heated in a steam atmosphere to clean out and enlarge the charcoal pores) is an effective absorber because of the large surface area.

Obj. 6
List Factors Which Affect the Efficiency of a Carbon Absorber

The efficiency of absorbers can be affected by the following factors:

- Activation of charcoal. *(should be impregnated with chemicals (triethylenediamine) to improve its ability to absorb radioiodine)*
- Type of impregnate.
- Amount of time contaminate lingers on absorber.

Obj. 6

The efficiency of absorbers can be affected by the following factors:

- Airflow rate
- Type of contaminate, such as paint fumes and solvents.
- Moisture and humidity
- Temperature

Obj. 6

- HEPA filters should always be installed upstream of an absorber to prevent dust accumulation, which could result in early depletion of the absorber. Carbon absorbers cost five to six times more than HEPA filters.

Objective 7
State the Advantages of a Portable Ventilation System

The advantages of a portable ventilation system:

- Decreases clean-up and radwaste
- Minimizes impact on nearby work operations
- Decreases laundry and respiratory cleaning

Objective 7

The advantages of a portable ventilation system:

- Increases worker’ s efficiency
- Decreases personnel exposure
- Provides better safety to personnel.

Objective 7

The portable ventilation system can be utilized, in various capacities. If a portable ventilation system is properly designed and utilized, it can be an important engineering control. The control of radioactive contamination during operation can greatly reduce the potential of airborne radioactivity and this contamination can be controlled by utilizing the portable ventilation system.

Objective 7

The following examples are some practical uses of the portable ventilation system.

Steam Generator Maintenance:

- Provides capture velocity (C/V) airflow into the component to control the spread of contamination
- Dries the flow tubes
- Removes radioiodine inventory

Objective 7

Glove Box/Ventilation Hoods:

- Isolates the worker during handling of contaminated materials
- Eliminates the spread of contamination
- Packages the job and not the worker.

Objective 7

Temporary Enclosure (Containment Tent)

- Minimizes impact on adjacent area
- Reduces respiratory protection equipment requirements
- Provides localized control for contaminated work operations.

Resin and Sludge Treatment Systems

- The resin and sludge treatment systems present hazards from the concentration of highly contaminated radioactive materials. The transport, storage and processing of these systems can result in high dose rates. Engineering controls will help eliminate these hazards.

- Using effective engineering controls in the design stage of a nuclear power plant will help eliminate accumulation of radioactive material in components of systems used to process resin and sludge.

Resin and Sludge Treatment Systems

The following design techniques should be considered upon initial selection of piping:

- Decrease the distance in which the piping runs
- Increase the diameter of pipes to minimize clogging
- Decrease the number of fittings and bends
- Avoid low points and dead legs in piping
- Use gravitational flow to the fullest extent possible
- Minimize flow restrictions of processed material.

Resin and Sludge Treatment Systems

The need for maintenance should also be incorporated in the design to reduce high radiation dose rates from localizing in piping.

- To prevent slurry from interfering with the opening and closing of the valves, use a full-ported valve

- Avoid cavities in valves

Resin and Sludge Treatment Systems

- Resin and sludge can be deposited in elbow fittings. This deposition can be reduced by using pipe bends of at least five pipe diameters in radius. Where pipe bends cannot be used, long radius elbows are preferred.

- Use piping with smooth interior surfaces at connections. This can be accomplished by using consumable inserts rather than backing rings.

Resin and Sludge Treatment Systems

- Avoid the use of tees whenever possible, but when the use of tees is necessary, line losses can be reduced if the flow is through the straight section of the tee. Accumulation of material in the tee branch can be reduced by orienting the tee horizontally or more preferably by locating the tee above the run of the slurry.

Resin and Sludge Treatment Systems

- Clogging in piping may require backflushing from the tank and equipment isolation valves by pressurization using water, nitrogen and air to "blow out" clogged lines. Pressurized gas can present a potential contamination source and it may not be an effective means of unclogging a line.

- Another method used in unclogging slurry piping is by manually routing out the lines, using snakes. This method can result in high doses to plant personnel and airborne radioactivity problems.

Resin and Sludge Treatment Systems

- Water, air or nitrogen for sparging is used to fluidize resins or sludge tanks. Gases can present an airborne problem or the tank could rupture from over-pressurization.
- Resin and sludge overflows and vents can cause the spread of contamination. This can be reduced by using screens and filters. Screens and filters require cleaning by remote flushing, or by rapid changing.

Obj. 8
List Design Features That Minimize Major Dose Accumulating Factors

A nuclear power plant shall be designed so that major dose accumulating factors are considered in the plant design and the potential radiation dose from these activities will be kept ALARA. Such design features may include the following:

- Provide ease of accessibility to work and inspection of sampling areas
- Reduce source intensity

Obj. 8

Nuclear Power Plant Design Features

Additional design features may include the following:

- Make design measures to reduce the production, distribution and retention of activated corrosion products
- Reduce time required in a radiation field
- Provide provisions for portable shielding and remote handling tools.

Obj. 9

Identify Access Controls That Prevent Unnecessary Exposure

- Avoid unnecessary dose to plant personnel. The maximum dose rate at all locations should be estimated during the design of the plant

- Decrease radiation areas where plant personnel have access for long periods of time to the lowest practical dose rate.

Obj. 9

Control of access to radiation areas should also reflect the following procedures to prevent unnecessary dose to plant personnel:

- Plant features such as platforms, walkways, stairs or ladders that permit easy accessibility for servicing or inspection of components located in high radiation areas can reduce dose to plant personnel.

Obj. 9

Additional procedures to prevent unnecessary dose to plant personnel:

- Administrative controls, such as standard operating procedures, should be enforced when radioactive material or contaminated equipment is to be transported from one location to another. Avoid low radiation areas and clean areas if possible

- Extraordinary design features are warranted to avoid any potential dose to personnel that is large enough to cause acute biological effects. Access control to areas, permanent shielding, source removal or a combination of these can reduce the dose potential.

Objective 10
Discuss Radiation Shield Design to Include the Following:

- Features of design that reflect ALARA.
- Exposure contributor in BWR's turbine building.
- Objective of valve galleries and design guides to achieve this objective.
- Streaming to include causes and methods to reduce.

Objective 10

Plant shielding shall be designed to protect the general public and plant personnel from exposure to radiation. Shielding shall also be designed to meet the following criterion set forth in the following regulations:

- 10CFR20 – Standards for Protection Against Radiation
- 10CFR50 – Domestic Licensing of Production and Utilization Facilities
- 10CFR100 – Reactor Site Criteria

Objective 10

The philosophy of maintaining radiation exposures As Low As Reasonably Achievable (ALARA) is integrated into all shielding and design considerations. Shielding design features should reflect the following considerations in order to maintain occupational exposure ALARA:

Plant personnel servicing equipment should be protected by shield walls from other equipment containing radioactive material.

Objective 10

When permanent shielding is not feasible around components of high substantial radiation sources, plant personnel exposure can be maintained by using the following guidelines:

- Provide as much distance as possible between substantial radiation sources and plant personnel servicing equipment.
- Provide temporary shielding around components that contribute substantially to dose rates.
- Decrease potential exposure of plant personnel to radiation from certain systems by the plant layout design.

Objective 10

Radiation from an operating BWR turbine can result in a substantial amount of dose to plant personnel with access to the area for extended periods of time.

The activity enters the Turbine Building with steam from the reactor. The activity is primary N13, N16, N17, O19, fission product gases, and some carryover of other activity.

Objective 10

Shielding of the following Turbine Building equipment may be necessary:

- Main steam lines and valves
- Main turbine
- Main condenser hotwell area
- Moisture separator
- Reactor feedwater heaters
- Reactor feed pump turbines
- Extraction steam piping
- Air ejectors and steam packing exhauster
- Condensate demineralizers and backwash equipment

Objective 10

The first objective used to design a valve gallery is to allow valve maintenance without first removing the source from the process equipment.

- Penetrations through the shield wall between the equipment enclosure and valve gallery should be placed as near the ceiling and as close to the corner of the equipment as practical.
- Piping in the valve gallery containing radioactive material should be kept as short as practical for isolation of the control valve during maintenance.

Objective 10

Some additional design guides are:

- Excessive annular spaces between pipe and pipe sleeve in the wall and between equipment and valves are avoided.
- The advantage of designing valve galleries are that hand operated valves can be operated remotely. The shield wall eliminates unnecessary exposure to plant personnel performing this procedure.

Objective 10

Streaming or scattered radiation is the passage of a narrow beam of radiation through a deficiency AND can result from poor or inadequate shielding design which leaves a gap in the shield.

- Streaming can also be caused by the movement of existing shielding or result from a void in shielding material. Voids are sometimes created during shield fabrication. This can occur when pouring concrete shield walls.

Objective 10

When streaming occurs, surveys must be performed near any seams and corners in shielding material as well as near pipe penetrations in shield walls. Streaming of radiation into accessible areas such as penetrations for pipes, ducts, and other shield discontinuities can be reduced by the following methods:

- Design plant layout so that sources of high radiation levels are not aligned with penetrations.
- Use shielding of limited size to attenuate direct radiation from a component.

Objective 10

Streaming also can occur through roofs or floors unless adequate shielding encloses the source from all directions.

Objective 10

Plant shielding shall be designed to protect the general public and plant personnel from exposure to radiation. Shielding shall also be designed to meet the following criterion set forth in the following regulations:

- 10CFR20 – Standards for Protection Against Radiation
- 10CFR50 – Domestic Licensing of Production and Utilization Facilities
- 10CFR100 – Reactor Site Criteria

Objective 11
Explain the Design Features of the Monitoring Systems

- Monitoring systems are centrally located throughout the plant to provide constant information on dose rates and airborne radioactivity (i.e., CAMs, ARM, process monitors).

- Central monitoring systems are less expensive if they are incorporated in the original design of the plant.

- The central monitoring systems can provide timely information on changes in area conditions.

Objective 11

The central monitoring systems designers should:

- Use local and control room alarms and readouts.
- Use circuitry which indicates component failure.
- Place detectors in locations for appropriate coverage of an area.
- Use clear and unambiguous readouts.
- Provide readout capability from minimum to maximum levels.
- Provide readout capability at the main radiation protection access control point.
- Provide capabilities to record the readout of all systems.

Objective 12
Discuss Isolation and Decontamination Designed Features Utilization

- Plants should be designed to provide leak collection trays under pumps, where leakage from pump seals are contained to a small area.

- Slope floors so spills run to local drains. Valves or pumps should be equipped with leak-off piping to carry leakage to a sump.

- Overhead leakage can be contained by placing small sleeving attached to a funnel up to the leak and run the sleeving to a floor drain or bottle. (This is commonly called the Witches Hat). This method is only used on a temporary basis until a leak can be repaired.

Objective 12

•Mount pumps on individual pedestals so that a spill from one component will not contaminate other components. The pedestal will also permit quicker cleanup of the floor, since the equipment is not directly on the floor.

•Surface decontamination can be completed quickly if the surface is smooth, nonporous, free of cracks, crevices and sharp corners. Sealers can prevent surface contamination.

Objective 12

- Decontamination facilities are designed to provide facilities for decontamination of tools and equipment in a specified area. The facility will prevent the spread of contamination and airborne activity by providing sinks which are used to submerge equipment into water.
- Plants are designed for storing highly contaminated components such as spent fuel and reactor internals under water. When the components are removed from the reactor, the water acts as a shield to prevent airborne radioactivity and high dose levels. Treatment systems are incorporated in the design to remove contaminants from the water.

Objective 13
List Items Considered in Crud Control

Crud control is an important part of engineering controls. If the proper materials which come in contact with primary coolant are selected in the construction stage of a nuclear facility, this will reduce the accumulation of crud in piping thereby reducing personnel dose.

Objective 13

The following items should be considered in crud control.

- The cleanup system should utilize graphite or magnetic filters.
- Corrosion can be reduced by constant monitoring to control the oxygen concentration and the pH in primary coolant. Using bright hydrogen-annealed tubing and piping in primary coolant and feedwater systems will help eliminate corrosion.
- Erosion of hard surfaces can be reduced by using favorable geometrics and lubricants. Controlling leakage purge across a rotating shaft will prevent entry of particles into primary coolant.

Objective 13

The following items should be considered in crud control.

- Crud deposits in the primary coolant system can be reduced by smooth surfaces, laminar flow, and minimizing crud traps.
- Low nickel or cobalt bearing materials can help to eliminate crud. Alternative materials with hard facing and long wear should be considered (i.e., source term reduction).
- Increasing service and repair of existing equipment can decrease crud buildup. Replace old materials with new more reliable materials.

Objective 14

Identify forms of total containment to include the following:

- Tasks
- Forms
- Design
- Operation
- Advantages

Objective 14

- Containment devices such as glove bags, tents, and rigid structures (glove boxes) will control contamination and airborne radioactivity if installed and used properly.
- Containment devices can reduce or eliminate the need for respiratory protection. Those cost involved with these devices is often worth the time savings which these devices will generate.

Objective 14

- Glove bags are used to totally enclose a component. The glove bag provides a method to control, confine and prevent the spread of contamination from radioactive systems leaks.
- Glove bags serve as a form of isolation by isolating the worker from the source of contamination.
- Glove bags are available in various sizes and shapes. They are constructed of flexible plastic which are partially or completely transparent. Glove bags can easily conform to the task.

Objective 14

Glove bags can be used to complete the following tasks:

- Grinding or cutting on valves, pipes, etc.
- Breaching small radioactive or potentially radioactive systems
- Disassembling and reassembling valves and their internals
- Hydrostatic test of systems
- Purge of contaminated systems
- Decontamination

Objective 14

- Containment tents are also used to totally enclose a work area. The tents are used to perform tasks on large equipment which is too large for a glove bag.
- Tents are constructed of herculite or polyethylene using a wood or metal frame. A HEPA unit is also used to maintain a negative pressure inside the tent.
- A tent is an effective method used to control, confine and prevent the spread of area contamination, leakage from radioactive systems, and airborne radioactivity to the surrounding work area.

Objective 14

Tents can be used for the following:

- Enclosures for large jobs such as S/G work.
- Provide temporary hot machine shop.
- Remote maintenance shop.

Unlike the glove bag, the tent does not isolate the worker from the work being performed.

Objective 14

- When using a tent, only the personnel working inside the tent need protective clothing and equipment.
- Tents can serve as an excellent asset during S/G work in the laydown area. A tent surrounded by lead blankets can be used for highly contaminated eddy current equipment.
- A shielded tent is also used as a waiting area for RADCON, laborers and S/G jumpers. The tent offers a low dose waiting area.

Objective 14

- Rigid structures are used as a permanent structure and are suitable for hot work, such as grinding or machining.
- A rigid structure can be modular, solid steel or plastic construction. The modular construction allows various shapes and sizes. Power, lighting, air and ventilation can be made available.
- A distinct advantage that rigid structures have over tents is that they can be disassembled, decontaminated and stored for future use. Tents are normally single use items.

Objective 14

- The rigid structure, unlike the tent, isolates the worker from sources of contamination.
- Rigid structures can be used to complete the following tasks:
    - Remote maintenance work area.
    - Portable deacon room.
    - Hot machine shop.
    - Clean machine shop.

Objective 14

Advantages of Total Containment:

- Improves worker comfort.
- Reduces cost when compared to other forms of contamination control.
- Requires smaller area decontamination.
- Maintains equipment cleanliness.
- Reduces interferences with other jobs in the area.
- Reduces the spread of contamination and airborne radioactivity.

Objective 14

Disadvantages of Total Containment:

- Sensitive to high temperature conditions.
- Installation in a high radiation area can increase exposure to personnel installing the device.
- It may not be practical to install containment devices in a highly contaminated area.
- Some dose will be lost by maintaining a containment device in good condition.
- Containment limits personnel manual dexterity and visibility; therefore work progression may be slower.

Summary

RADCON Specialists must be aware that specialized jobs call for extraordinary measures to ensure that the workers involved are protected from the harmful effects of ionizing radiation. The control of radiological work is paramount in ensuring that this occurs. Using the Human Performance tools as well as the skills acquired during training and the in-plant phase will help aid the Specialist in providing this protection.