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2. They are designed to offer a review of the study guide material.

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- Notification of such changes—including the rationale behind them—will be published on the [Downloads page](#) of RadiationProtectionTech.com.
- The updated document will be uploaded to our website, where it will be accessible to all interested parties. Concurrently, the revision number will be updated to reflect the most current version.

FUN 2 Review Notes

EO: 1.1 Authority and Responsibilities of the NRC

Main Idea

The NRC is responsible for regulating the safety of nuclear power and materials, succeeding the AEC, which initially had both promotional and regulatory roles.

Historical Background

- Atomic Energy Commission (AEC) initially established by the Atomic Energy Act of 1946.
- Atomic Energy Act of 1954 replaced the 1946 Act and enabled commercial nuclear power for the first time.
- AEC aimed to promote nuclear power while ensuring safety, a task that proved controversial.
- By the 1960s, critics argued AEC regulations were not rigorous enough in radiation protection, reactor safety, plant siting, and environmental protection.

Transition from AEC to NRC

- Due to increasing criticisms, AEC was abolished in 1974.
- Energy Reorganization Act of 1974 created the NRC, separating promotional and regulatory functions.
- NRC began operations on January 19, 1975.

Key Issues

- NRC focuses on broad issues essential to public health and safety, much like the AEC did.
- Main danger in using nuclear materials is hazardous radiation exposure to workers and the public.
- NRC publishes radiation protection standards, although these remain sources of debate.

Additional Regulations

State and local authorities can also implement or modify additional regulations.

EO: 1.2 Purpose and Significance of Site Technical Specifications

Main Idea

Technical Specifications are crucial elements of an NRC license for operating a nuclear facility. They outline requirements for safety limits, system settings, operational conditions, and more.

What Are Technical Specifications?

- Part of an NRC license for operating a nuclear facility.
- Establish requirements for:
 - Safety limits
 - Limiting safety system settings
 - Limiting control settings
 - Limiting conditions for operation
 - Surveillance requirements
 - Design features
 - Administrative controls

Impact on Radiation Protection Organization

Example: High Radiation Area controls

- a. Areas with radiation intensity greater than 100 mr/hr and up to 1000 mr/hr require barricades, postings, and Radiation Work Permits.
- b. Areas with radiation intensity greater than 1000 mr/hr require additional security measures like locked doors.

Variations and Site-Specific Requirements

- Technical Specifications offer an approved alternative to the 10CFR20 regulations.
- Site-specific procedures may differ based on the plant's Technical Specifications.

Standard Technical Specifications (STS)

- Published for each of the five reactor types as a NUREG-series publication.
- Plants must operate within these STS.
- Improved STS were developed based on criteria in the Final Commission Policy Statement.
- May contain additional site-specific requirements, e.g., off-site dose calculations.

EO: 1.3 Isotopes and Their Production Mechanism Contributing to Worker Exposures

Main Idea

Metallic surfaces in contact with coolant form CRUD (metal oxides), which increases radiation and fouls core heat transfer surfaces. Several isotopes contribute to worker exposures from gamma and neutron radiation.

Why CRUD is Undesirable

1. Increases general radiation levels (important during maintenance outages).
2. Fouling of the core heat transfer surfaces.

Common Corrosion Product Activations

- Cr-51: ${}^{50}_{24}\text{Cr} + {}^1_0\text{n} \rightarrow {}^{51}_{24}\text{Cr} + \gamma + \Delta E$
- Fe-59: ${}^{58}_{26}\text{Fe} + {}^1_0\text{n} \rightarrow {}^{59}_{26}\text{Fe} + \gamma + \Delta E$
- Mn-54: ${}^{53}_{25}\text{Mn} + {}^1_0\text{n} \rightarrow {}^{54}_{25}\text{Mn} + \gamma + \Delta E$
- Mn-56: ${}^{55}_{25}\text{Mn} + {}^1_0\text{n} \rightarrow {}^{56}_{25}\text{Mn} + \gamma + \Delta E$
- Co-58: ${}^{58}_{28}\text{Ni} + {}^1_0\text{n} \rightarrow {}^{58}_{27}\text{Co} + {}^1_1\text{p} + \Delta E$
- Co-60: ${}^{59}_{27}\text{Co} + {}^1_0\text{n} \rightarrow {}^{60}_{27}\text{Co} + \gamma + \Delta E$

Activated Trace Impurities in Water

- H-3: Origin from Lithium addition for pH control.
- Na-24: Origin from impurities in water.
- Ar-41: Origin from air dissolved in water.

Activation of Water

- N-16: Origin from water molecule.
- N-17: Origin from water molecule.
- F-18: Origin from water molecule.
- N-13: Origin from water molecule.

Fission Products

- Cs-135: Half-life 9.2 hours
- Kr-88: Half-life 2.8 hours
- Kr-85: Half-life 10.7 years

Transuranics

Transuranic elements are heavier than uranium and are formed from neutron capture reactions. They can have significant radiological impact due to their alpha emissions.

- Includes: ^{239}U , ^{239}Np , ^{238}Pu , ^{240}Pu , ^{241}Pu , ^{241}Am , ^{242}Cm , ^{243}Cm , ^{244}Cm
- Formation Example: $^{238}\text{U}(n, \gamma)^{239}\text{U} \rightarrow \beta^- \text{ decays to } ^{239}\text{Np} \rightarrow \beta^- \text{ decays to } ^{239}\text{Pu}$

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EO: 1.4 Identify plant systems contributing to the radiological source term of a plant

Main Idea: There are two primary types of commercial reactors used in the US: Pressurized Water Reactor (PWR) and Boiling Water Reactor (BWR). Though system names may vary, the function of the system is the same.

Pressurized Water Reactor (PWR)

There are two major systems utilized to convert the heat generated in the fuel into electrical power for industrial and residential use. These are the primary and secondary systems.

- **Purpose:** The primary system transfers the heat from the fuel to the steam generator, initiating the secondary system. The steam generated is then converted into electricity.
- **Components:**
 - Primary Loop: Reactor, Steam Generators, Reactor Coolant Pumps, Pressurizer
 - Secondary Loop: Steam Generators, Turbines, Condenser, Condensate and Feedwater Pumps
 - Circulating Water Loop: Condenser, Cooling Towers, Circulating Water Pumps
- **Conditions Precluding Safe Work:** High pressure and temperature, radiation exposure
- **Radiological Precautions:** Use of shielding, restricted access, and monitoring

Primary Loop

The primary loop consists of a Reactor, Steam Generators, Reactor Coolant Pumps and a Pressurizer.

1. **Reactor:** Produces heat through fission of Uranium 235.
2. **Steam Generators:** Acts as heat exchangers, converting water to steam.
3. **Reactor Coolant Pumps:** Circulates the water through the loop.
4. **Pressurizer:** Maintains water in liquid state by controlling pressure.

Secondary Loop

The secondary loop consists of Steam Generators, Turbines, Condenser, Condensate and Feedwater Pumps.

1. **Steam Generators:** Receives heat from the primary coolant, creating steam.
2. **Turbines:** Converts thermal energy to mechanical energy.
3. **Condenser:** Condenses steam back to water.
4. **Condensate and Feedwater Pumps:** Returns water to the Steam Generator.

Circulating Water Loop

The circulating water loop consists of a Condenser, Cooling Towers, and Circulating Water Pumps.

1. **Condenser:** Cools down steam to water.
2. **Cooling Towers:** Transfers heat to the atmosphere.
3. **Circulating Water Pumps:** Returns cooled water to the condenser.

Reactor Coolant System

- **Function:** To cool the reactor core and transfer heat to the Steam Generators.
- **Components:**
 - Reactor Vessel and Internals
 - Steam Generators (S/Gs)
 - Reactor Coolant Pumps (RCPs)
 - Pressurizer (PZR)
- **Normal Operation:** At full power, hot water exits the core, flows to the Steam Generators to lose heat, and returns via Reactor Coolant Pumps. Pressurizer maintains the system pressure.

Component Descriptions:

The primary system, also known as the Reactor Coolant System, consists of several key components. These include:

- Reactor Vessel
- Steam Generators
- Reactor Coolant Pumps
- Pressurizer
- Connecting Piping

Reactor Vessel and Internals

The Reactor Vessel and Internals consist of robust materials like stainless steel or carbon steel. These materials are then clad with stainless steel to provide corrosion resistance. The internals are divided into:

1. Lower Core Support Area
2. Upper Guide Structure

Radiological Precautions for Common Maintenance Tasks

- CEDM work - High Radiation Area and potential for high contamination levels
- Fuel Moves - High/Locked or Very High Radiation levels are the highest radiological concerns.
- Core offload and reload - potential for high dose rates, high contamination levels, and discrete radioactive particles or airborne
- ICI wires removal, cut-up - potential for high dose rates, high contamination levels, discrete radioactive particles or airborne

Reactor Coolant Pump

The primary purpose of the reactor coolant pump is to provide forced primary coolant flow to transfer the heat generated by the fission process.

Radiological Precautions for Common Maintenance Tasks

- Reactor coolant pump motor replacement - High Radiation Area
- Reactor coolant pump seal replacement - High Radiation Area, high contamination levels, and potential for > 1 DAC airborne

Steam Generators (S/Gs)

The purpose of the Steam Generators is to act as a heat exchanger between the primary and secondary systems.

Radiological Precautions for Common Maintenance Tasks

- Steam generator sludge lancing - High dose rates, high contamination levels, and discrete radioactive particles or airborne
- Steam generator nozzle dam install/removal - Potential for high dose rates, high contamination levels, and discrete radioactive particles or airborne
- Eddy Current Testing - High dose rates

Pressurizer

The pressurizer serves as the component responsible for controlling the system pressure. It utilizes various methods to maintain the system pressure, including electrical heaters, pressurizer spray, power-operated relief valves, and safety valves.

Radiological Precautions for Common Maintenance Tasks

- PZR manway removal / replacement - High Radiation Area, high contamination levels, and the potential for > 1 DAC airborne
- PZR insulation removal/install - High Radiation Area, high contamination levels, and the potential for > 1 DAC airborne
- Surge line shielding install / removal - High Radiation Area

Plant Operation

The reactor is normally operating at 100% power with all rods withdrawn above the fuel region. There is enough fuel loaded into the core for 12 to 18 months of operation at full power. Each day some of the fuel burns up and there is less fuel to compete for the neutrons. This adds negative reactivity to the core and the core will produce less power.

With less power being produced the temperature of the water leaving the reactor will decrease and colder water will be returned to the core to add positive reactivity to balance the total core reactivity. The plant cannot operate day after day with the temperature decreasing. This would cause steam pressure to decrease and also put the temperature out of the range that where the safety analysis was conducted.

To keep the temperature from lowering, some of the boron needs to be removed from the water in the Reactor Coolant System to add the positive reactivity. The Chemical Volume & Control System maintains the balance by receiving Letdown at the current Reactor Coolant System boron concentration and Charging back water into the Reactor Coolant System at a slightly lower concentration. This is the dilution process.

Decay Heat

Even when the reactor is shutdown, there is a large amount of energy (heat) that is still being produced for years. The energy produced is referred to as Decay Heat and it must be removed to protect the fuel.

Immediately upon a Reactor Trip the core is producing $\approx 7\%$ power, 1 hour after the reactor is shutdown $\approx 1\%$ power, and the power being produced goes down by $\frac{1}{2}$ for every time interval. 1 hour = 1%, 1 day = .5%, 1 week = .25%, 1 month = .125%, etc.

Detailed System Operation

The reactor is normally operating at 100% power with all rods withdrawn above the fuel region. The core heats up the borated water to $\approx 615^\circ\text{F}$ and delivers it to the Steam Generators through two hot legs. The Steam Generator is a big u-tube heat exchanger.

1. **Primary coolant** is on the inside of the tubes and secondary feedwater is on the shell side.
2. **Primary piping** is the SECOND Fission Product Barrier.
3. The primary coolant heats the feedwater and causes it to boil, generating steam to drive the Main Turbine (MT).
4. The now colder primary coolant leaves each Steam Generator through 2 cold legs at $\approx 555^\circ\text{F}$.
5. The water enters each Reactor Coolant Pump and is then pumped backed to the core.

The plant consists of 3 loops when operating and 3 different loops when shutdown. Although the goal above concentrates on operating the plant, it's just as important, if not more, to understand how the plant works when shutdown because there are fewer systems available and the potential for core damage still exists.

Plant Operating

When the plant is operating there are 3 loops working together to take the heat generated in the core from fission and convert it into electrical energy.

- Primary Loop
- Secondary Loop
- Circulating Water Loop

Radiological Conditions during normal operations

- Extremely high dose rates due to gamma radiation from fission and Nitrogen-16 (fast) neutrons from the reactor. Only the upper Pressurizer is accessible at 100% power due to dose rates. Other areas like the inside of the Pump Bays and Reactor cavity have dose rates too high for personnel access.
- RCS Leaks would contain short lived nuclides, but the long lived nuclides would result in mrad/hr contamination levels depending on the leak severity. Technical specifications will determine the leak rates for identified and unidentified leak rates.
- Normally, only noble gases (Xe-133 and Kr-85) but more significant leaks could result in iodine or particulates. Containment airborne levels are less than 1 DAC at 100% power. This includes little or no detectable particulates, little or no detectable iodines, and noble gas levels up to 1 DAC.

Plant Shutdown

When the plant is shutdown, there are 3 different loops that work together to remove the heat from the core from prior fission events and transfer that heat to the atmosphere.

- Shutdown Cooling Loop

- Essential Cooling Water Loop
- Ultimate Heat Sink Loop

Residual Heat Removal (RHR) Loop or Decay Heat Removal or Shutdown Cooling

The shutdown cooling loop consists of a Reactor, a Residual Heat Removal Pump (this can be a Low Pressure Safety Injection Pump or a Containment Spray Pump), and a Residual Heat Removal Heat Exchanger.

Component Cooling Water (CCW) Loop

The component cooling water loop consists of a Residual Heat Removal Heat Exchanger, a Component Cooling Water Pump, and a Component Cooling Water Heat Exchanger.

Service Water (SW) Loop

The Service Water loop consists of a Service Water Pump, a Component Cooling Water Heat Exchanger, and the ultimate heat sink may be an ocean, river, sea, or an onsite cooling pond.

Chemical and Volume Control System or Makeup and Purification System

The chemical volume and control system has two subsystems, letdown and charging.

1. Letdown Subsystem
 - Purpose
 - Components
 - Radiological Precautions
2. Charging Subsystem
 - Components
 - Radiological Precautions
3. Make-up Modes
 - Manual
 - Borate
 - Dilute
 - Auto

Radiological Precautions

The radiological precautions associated with most common maintenance tasks are as follows:

- Letdown heat exchanger maintenance
- Letdown flow control valve maintenance
- CVC filters removal maintenance
- CVCS filter replacement
- CVCS Ion exchanger transfers
- VCT area work
- Charging pump maintenance

Chemical Additions

The chemical addition tank provides the ability to add chemicals like the following:

- Lithium - PH Control
- Hydrazine - Oxygen removal
- Boric Acid - Reactivity control
- Hydrogen Peroxide - Source term control

The zinc addition skid adds zinc to the RCS to prevent stress corrosion cracking and to replace CO-58 in the RCS piping crud layers for source term reduction.

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Residual Heat Removal (RHR) Loop or Decay Heat Removal or Shutdown Cooling

The shutdown cooling loop consists of a Reactor, a Residual Heat Removal Pump (this can be a Low Pressure Safety Injection Pump or a Containment Spray Pump), and a Residual Heat Removal Heat Exchanger.

Even with the reactor shutdown, there is a considerable amount of heat still being generated for years, called decay heat, that must be removed. Hot water is taken from the core by the Residual Heat Removal Pump and sent to the Residual Heat Removal Heat Exchanger. The decay heat is transferred to the essential cooling water loop in the Residual Heat Removal Heat Exchanger and the cooled water is sent back to the core.

Liquid Radwaste

The purpose of the RC waste system is to provide controlled handling and disposal of radioactive liquid waste from the reactor coolant system. This is accomplished by providing temporary storage for reactor coolant waste, processing liquid waste prior to disposal to minimize releases to the environment, and keeping effluence concentrations below regulatory limits.

Sources of Reactor Coolant Waste

- Reactor coolant drain tanks
- Regenerative heat exchanger drain
- Safety injection system tank

Waste Processing Steps

1. Degasifier Filters:

These remove suspended impurities from waste liquid prior to it entering the degasifier tanks. Both waste from the reactor coolant drain tank and the letdown diversion pass through these filters.

Radiological Concerns

- Pump and valve overhaul and filter replacements - high levels of contamination, high dose rates, work in high dose-rated areas, and potential for airborne radioactivity.
- Resin transfers - high dose rates and work in high dose-rated areas.

Radioactive Gas Storage

The waste gas system's purpose is to provide controlled handling and disposal of radioactive gaseous waste from the unit. This includes containment and auxiliary building sources.

Waste Gas Handling

1. Containment Collection Header:

This will transfer gaseous waste from the reactor coolant drain tank and the quench tank vents.

Radiological Concerns

- Maintenance activities on the waste gas surge tank - high dose rates and the potential for airborne radioactivity concerns.

Basic Plant Components

In its simplest terms, the plant operates by moving water from one location to another. To achieve this, a variety of components are used to move water through a system, from one system to another, control the temperature or phase of the water, or stop the flow of water altogether.

Valves and pumps were covered in the RP Junior Fundamental training. Other key components include heat exchangers and demineralizers.

Heat Exchanger

A heat exchanger is a component that transfers heat between two substances at different temperatures. Heat is transferred from the hotter substance to the colder one.

Heat Transfer Mechanisms

- **Convection Heat Transfer:** A combination of conduction heat transfer through a solid and the transfer of heat with a fluid in motion.
- **Conduction:** Metals are generally the best conductors of thermal energy due to their metallic bonding and crystalline structure.
- **Forced Convection:** Occurs when a pump, fan, or other means is used to propel the fluid and create the convection current.
- **Natural Convection:** Driven by buoyancy, a result of differences in fluid density in the presence of gravity or any form of acceleration.

Types of Heat Exchangers

Most of the heat exchangers in use are of the counter-flow type, where the fluid being cooled and the cooling medium enter from opposite ends and travel towards each other.

Pressure Considerations

- Higher-pressure fluid is usually inside the tubes, and the lower pressure is on the shell side.
- The fluid can pass straight through the tubes, or be directed via a divider to mix and then return.
- U-tube configurations can also be used.

Cooling Water Systems

- **Open Cooling Water Systems:** Open to atmosphere and require a regular source of makeup water.
- **Closed Cooling Water Systems:** May need makeup water occasionally but generally rely on a surge tank to compensate for small volume changes.

Water

In typical usage, water refers only to its liquid form or state. However, water also exists in a solid state (ice) and a gaseous state (water vapor). Water's chemical formula is H_2O , consisting of two hydrogen atoms bonded to a single oxygen atom.

Major Chemical and Physical Properties of Water

- **Incompressibility:** Water is virtually incompressible, allowing for pressure increase with minimal work.
- **Specific Heat Capacity:** Water has the second-highest specific heat capacity of any known compound, next to ammonia.
- **Electrical Conductivity:** Pure water has low electrical conductivity, but this increases with the addition of ionic material.
- **Saturation Temperature (T_{Sat}):** Also known as the boiling point, it is the temperature at which water vaporizes.
- **Saturation Pressure (P_{Sat}):** The pressure at which water vaporizes. Directly related to T_{Sat} .
- **Boiling Point:** 212 °F at sea level, but varies with pressure.
- **Surface Tension and Adhesion:** High, due to strong intermolecular forces.
- **Solvent Properties:** Known as the universal solvent.
- **Density:** Maximum density at 39.16 °F.

Water is a critical component in plant operation, central to achieving various tasks by moving it around or changing its state.

Steam

Steam refers to vaporized water and is a pure, completely invisible gas. In standard conditions, steam occupies about 1,600 times the volume of liquid water.

Common Misconceptions About Steam

- The white mist above boiling water is not steam but tiny droplets of liquid water.
- True steam is invisible and can be found in areas where no condensed water vapor is visible, such as in the spout of a steaming kettle.

Uses of Steam

- Steam engines use the expansion of steam to drive turbines and perform mechanical work.
- High energy reservoir due to water's high heat of vaporization.

- Condensed steam can be returned to the boiler at high pressure with minimal pumping power.

Understanding these basic components is essential for understanding the plant. The various systems within the plant use these components in different combinations to fulfill their functions.

Fuel Assembly Construction

Basics

The primary fuel used is Uranium 235, which in its natural form contains ~ 0.7% U^{235} and ~ 99.3% U^{238} . Enrichment processes increase the U^{235} concentration to approximately 4%.

Global Uranium Production

- Canada: 27.9%
- Australia: 22.8%
- Kazakhstan: 10.5%
- Russia: 8.0%
- United States: 2.5%

Cladding Material

Cladding is usually made of a high-temperature alloy, often zirconium. It serves as the first barrier to the release of fission products. Advances in manufacturing have reduced contamination known as "tramp uranium."

Processing

The mined ore, Pitchblende, undergoes a series of processing steps:

1. Sorting
2. Crushing
3. Grinding
4. Leaching
5. Thickening and Precipitation
6. Conversion to UF_6
7. Enrichment
8. Fabrication

Boiling Water Reactor (BWR)

In a BWR, very pure water moves upward through the core, absorbing heat and forming a steam-water mixture. The unique aspect of BWRs is the steam void formation in the core.

Operation

The steam-water mixture exits the top of the core, goes through moisture separation, and then drives the main turbine connected to the electrical generator. Unused steam is condensed and recycled back to the reactor vessel.

Components

- Reactor Vessel and its Internal Components
- Core Support Structures
- Moisture Removal Equipment
- Jet Pump Assemblies

Functionality

The reactor vessel assembly has several functions:

- Housing the reactor core
- Serving as part of the coolant pressure boundary
- Supporting and aligning fuel and control rods
- Removing moisture from exiting steam
- Providing a refloodable volume for a loss-of-coolant accident

Emergency Core Cooling

Several emergency core cooling systems automatically provide makeup water to the core, ensuring adequate cooling in case of a loss of reactor coolant.

Fuel Channel and Control Rods

Unlike pressurized water reactors, BWR fuel bundles are enclosed in a fuel channel. Control rods enter from the bottom and are used to regulate core power.

Reactor Water Cleanup System (RWCU)

The purpose of the RWCU is to:

- Maintain a high reactor water quality
- Remove fission products
- Remove corrosion products
- Remove other soluble and insoluble impurities

It achieves these goals by following a specific process:

1. Taking water from the recirculation system and the vessel bottom head
2. Pumping the water through heat exchangers to cool the flow
3. Sending the water through filter/demineralizers for cleanup
4. Returning the water to the reactor vessel via the feedwater piping

Decay Heat Removal

Even when the reactor is shut down, the core continues to generate decay heat. This section covers how the heat is managed:

1. Bypassing the turbine and dumping the steam directly to the condenser
2. Using the shutdown cooling mode of the residual heat removal (RHR) system to complete the cooldown process when pressure decreases to approximately 50 psig

Reactor Core Isolation Cooling (RCIC)

The RCIC system serves a crucial function when the main steam lines are isolated and the normal supply of water to the reactor vessel is lost. The key components are:

- Turbine-driven pump
- Piping
- Valves

The system operates as follows:

1. Steam from the main steam lines drives the turbine
2. The turbine-driven pump supplies makeup water from the condensate storage tank or from the suppression pool to the reactor vessel via the feedwater piping

Standby Liquid Control System

This system is designed to inject a neutron poison (usually boron) into the reactor vessel to shut down the chain reaction independently of the control rods. It is manually initiated and provides a slow method for achieving reactor shutdown conditions.

Emergency Core Cooling Systems (ECCS)

The ECCS provide core cooling under loss of coolant accident conditions. The ECCS consist of:

- Two high pressure systems: High Pressure Coolant Injection (HPCI) system and the Automatic Depressurization System (ADS)
- Two low pressure systems: Low Pressure Coolant Injection (LPCI) mode of the Residual Heat Removal system and the Core Spray (CS) system

These systems operate based on the rate of coolant loss, ensuring that the temperature rise in the core is limited to less than regulatory requirements.

High Pressure Emergency Core Cooling Systems

The high pressure coolant injection (HPCI) system is an independent emergency core cooling system requiring no auxiliary ac power, plant air systems, or external cooling water systems to perform its purpose of providing make up water to the reactor vessel for core cooling under small and intermediate size loss of coolant accidents. The high pressure coolant injection system can supply make up water to the reactor vessel from above rated reactor pressure to a reactor pressure below that at which the low pressure emergency core cooling systems can inject.

The automatic depressurization system (ADS) consists of redundant logics capable of opening selected safety relief valves, when required, to provide reactor depressurization for events involving small or intermediate size loss of coolant accidents if the high pressure coolant injection system is not available or cannot recover reactor vessel water level.

Low Pressure Emergency Core Cooling Systems

The low pressure emergency core cooling systems consist of two separate and independent systems, the core spray system and the low pressure coolant injection (LPCI) mode of the residual heat removal system. The core spray system consists of two separate and independent pumping loops,

each capable of pumping water from the suppression pool into the reactor vessel. Core cooling is accomplished by spraying water on top of the fuel assemblies.

The low pressure coolant injection mode of the residual heat removal system provides makeup water to the reactor vessel for core cooling under loss of coolant accident conditions. The residual heat removal system is a multipurpose system with several operational modes, each utilizing the same major pieces of equipment. The low pressure coolant injection mode is the dominant mode and normal valve lineup configuration of the residual heat removal system. The low pressure coolant injection mode operates automatically to restore and, if necessary, maintain the reactor vessel coolant inventory to preclude fuel cladding temperatures in excess of 2200 °F.

During low pressure coolant injection operation, the residual heat removal pumps take water from the suppression pool and discharge to the reactor vessel.

Boiling Water Reactor Containments

The primary containment package provided for a particular product line is dependent upon the vintage of the plant and the cost-benefit analysis performed prior to the plant being built. During the evolution of the boiling water reactors, three major types of containments were built. The major containment designs are the Mark I, Mark II, and the Mark III. Unlike the Mark III, that consists of a primary containment and a drywell, the Mark I and Mark II designs consist of a drywell and a wetwell (suppression pool). All three containment designs use the principle of pressure suppression for loss of coolant accidents.

- The primary containment is designed to condense steam and to contain fission products released from a loss of coolant accident so that offsite radiation doses specified in 10 CFR 100 are not exceeded and to provide a heat sink and water source for certain safety related equipment.
- The Mark I containment design consists of several major components, including:
 - The drywell, which surrounds the reactor vessel and recirculation loops,
 - A suppression chamber, which stores a large body of water (suppression pool),
 - An interconnecting vent network between the drywell and the suppression chamber,
 - The secondary containment, which surrounds the primary containment (drywell and suppression pool) and houses the spent fuel pool and emergency core cooling systems.
- The Mark II primary containment consists of a steel dome head and either a post-tensioned concrete wall or reinforced concrete wall standing on a base mat of reinforced concrete. The inner surface of the containment is lined with a steel plate that acts as a leak-tight membrane. The containment wall also serves as a support for the floor slabs of the reactor building (secondary containment) and the refueling pools.
- The Mark III primary containment consists of several major components, including:
 - The drywell is a cylindrical, reinforced concrete structure with a removable head.
 - The suppression pool contains a large volume of water for rapidly condensing steam directed to it.
 - A leak tight, cylindrical, steel containment vessel surrounds the drywell and the suppression pool to prevent gaseous and particulate fission products from escaping to the environment following a pipe break inside containment.

Main Steam System

The BWR Main Steam System directs the flow of steam, which has been produced in the reactor, to the main turbine and other equipment which make use of the primary steam.

- As water boils in the reactor, steam flows through the Moisture Separator and the Steam Dryer before exiting the reactor via the main steam lines.
- Main Steam Isolation Valves (MSIV) inside and outside containment ensure that containment can be isolated, and the flow of steam positively stopped.
- Safety Relief Valves and Emergency Relief Valves are located on the steam lines to exhaust the reactor in case of over-pressurization.
- A series of valves control the flow of steam to the turbines, maximizing driving force and minimizing strain.
- The Main Steam System contains highly radioactive steam, requiring strict controls for radiation safety.

Main Condenser

The BWR Main Condenser condenses and de-aerates exhaust steam and serves as a heatsink for hot water/steam from various systems. It drains to the hotwell, which provides suction head for the condensate pumps. This system is radioactive and presents radiation hazards.

Air Ejector System

Non-condensable gases are removed by the Steam Jet Air Ejectors. These gases are highly radioactive and create Locked High Radiation Areas.

Condensate and Feedwater Systems

The Condensate and Feedwater Systems in a BWR are responsible for purifying and heating water to be returned to the reactor. These systems contain radioactive water, requiring strict controls for radiation safety.

- The Feedwater System heats water to a temperature suitable for reintroduction to the reactor.
- Water in these systems remains radioactive and presents a contamination hazard.

Reactor Feedwater

BWR Reactor Feed Pumps (RFP) return the feedwater to the reactor. These pumps may be driven by main steam or other forces. The system is radioactive and requires strict controls for radiation safety.

Traversing In-core Probes (TIPs)

The TIPs in a BWR are used to provide calibration data for Power Range Monitors. These detectors are radioactive and create high radiation areas requiring strict safety controls.

- The TIP detectors become activated themselves and may create Very High Radiation Areas.
- Extreme caution must be exercised by personnel entering areas where TIPs are located.

EO: 1.5 Discuss the normal uses, locations, advantages, disadvantages, and relative sensitivity of a portable frisker, whole-body contamination monitor, portal monitor, bag counters, tool monitors, and conveyor type contamination monitors

Whole Body Contamination Monitors (WBCM)

Prior to exiting a radiologically controlled area, workers normally self-monitor using non-portable contamination monitors.

Most WBCMs are microprocessor-based radiation detection systems that use an array of gas flow proportional detectors. These detectors provide an excellent geometry for surface beta-gamma contamination detection with options for alpha capabilities.

1. The normal monitoring process consists of a two-part (front – back) survey that ensures the whole body is monitored.
2. When an individual enters the WBCM and is properly positioned, the counting process will begin.
3. If no alarm set points are exceeded, the unit will inform the individual to reposition to begin the second count.
4. If no alarms are exceeded, the individual is cleared to exit.
5. Body position indicators will stop the count if an individual does not maintain the proper position relative to the detectors.
6. If any alarm set points are exceeded, the WBCM will inform the individual that they are contaminated. Radiation Protection technicians can review the WBCM display to determine the general location and levels of contamination on the individual.

Portal monitors

The Gamma-Sensitive portal monitor (PM) provides personnel with an external whole-body monitoring system.

- These automated systems typically provide a more reliable method of locating personnel contamination over handheld instruments.
- The portal monitor is a "door frame" type device which provides a final monitoring point to ensure contamination is not spread outside the facility to other facilities or the general public.
- These types of monitors are typically used only for gamma monitoring.
- Portal Monitors are micro-process controlled units containing five to eight gamma-sensitive plastic scintillation detectors.
- Photo-electric switches sense when individuals enter the portal and will initiate the counting process.
- If contamination is detected, the unit will alarm and indicate which detectors are in alarm.
- If no contamination is detected, the individual will be directed to exit the PM.

Tool Monitors

Tool Equipment Monitors (TEM) are normally used to monitor small hand-held items for unconditional release from radiologically controlled areas. Additionally, there are larger TEMs that have the capability to monitor large items, such as bags and drums.

- These monitors use four to six large-area gamma scintillation detectors to monitor items that can be placed inside the sample chamber.
- The chamber is lined with lead and the monitor is extremely heavy.
- Individuals exiting the RCA are normally permitted to place personal items inside the TEM prior to release.
- Items that alarm the TEM shall be dispositioned by an ANSI qualified Radiation Protection technician.

Portable Frisker

Portable friskers are used for beta, gamma, or alpha contamination surveys and may be Geiger-Mueller or scintillation detectors.

1. General guidelines for handheld monitoring include:
 - Verify the instrument is on, set to the proper scale, and within the calibration date.
 - Verify instrument response and source check.
 - Ensure the audible function of the instrument is on and can be heard.
 - Determine the instrument background. (Insert facility/site-specific information concerning acceptable background rates).
 - Survey hands before picking up the probe.
 - Hold the probe approximately $\frac{1}{2}$ " from the surface being surveyed for beta/gamma and $\frac{1}{4}$ " for alpha radiation.
 - Move probe slowly over the surface, approximately 2" per second.
 - If the count rate increases during frisking, pause for 5 to 10 seconds over the area to provide adequate time for instrument response. When scanning for contamination, there is a delay in instrument response and the cause of the increased count rate might be back a short distance from where the increased count rate was observed.
2. The consequences of not performing an adequate contamination survey may include:
 - Unnecessary dose to the worker
 - Spread of contamination
 - Potential for inadvertent release of RAM
 - Regulatory action and potential for violations

The preferred method for exiting a radiologically controlled area is via the Whole-Body Contamination Monitor (WBCM) and Gamma Sensitive Portal Monitor (PM), with the frisker as the least preferred.