

INNOVATION AT WORK

Connecting Visionaries in Radiation Safety, Science and Industry

Conrad Orlando Resort, FL – July 28th – August 1st



RMS Design Optimization & Abandonment

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Mirion Connect | Annual Users' Conference 2025 Orlando, Florida



RMS Design and Selection





What goes into monitor design & selection

Monitor Design ←

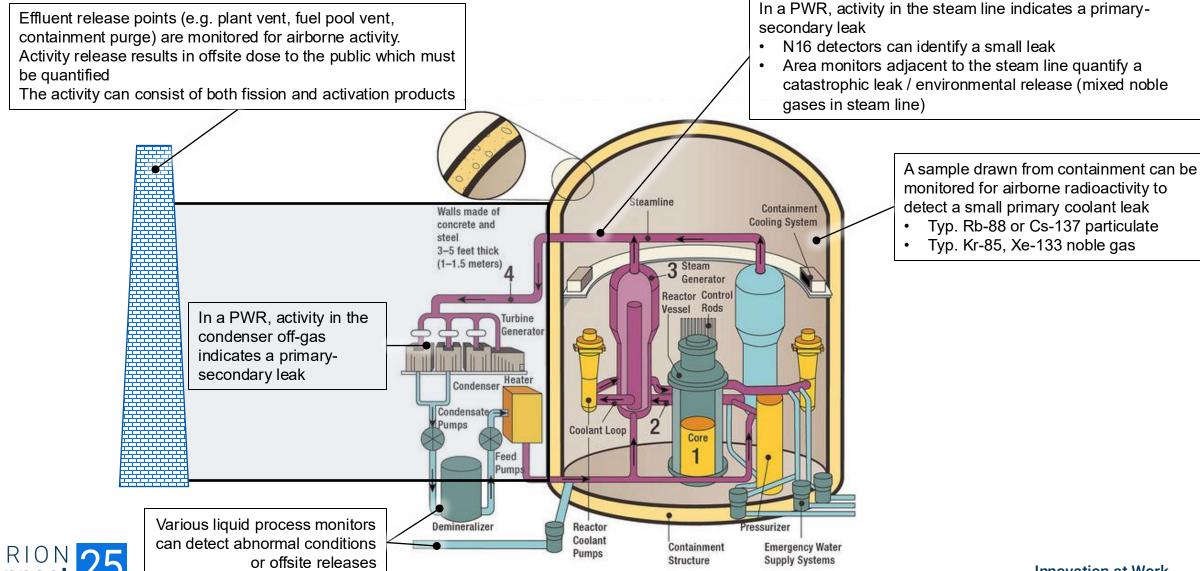
- Design Criteria (DCD)
- Design Function
- Defense-in-Depth Functions
- Process and Environmental Parameters
- Regulations
- Industry Codes and Standards

Monitor Selection

- Type of radiation to be detected
- Monitor range
- Desired monitoring configuration
- Process and Environmental Parameters (Within ratings? Mitigation needed?)
- Background radiation
- Critical dimension restrictions
- Additional details (e.g., flow rate, with or without pump, etc....)
- Cost
- Lead Time



Radiation Monitoring Examples (PWR Example)



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Radiation Monitoring Examples (PWR Example) (cont'd)

Gamma area monitors placed throughout the plant, including in containment, alert operators to high dose rates Steamline Containment Walls made of Cooling System concrete and 3-5 feet thick 3 Steam (1-1.5 meters) Generator Reactor Control Rods Generator Heater Condenser Control room ventilation is monitored for airborne noble Condensate = gas activity and can be Coolant Loop isolated upon alarm Feed Reactor Demineralizer Coolant Containment **Emergency Water** Supply Systems Structure

Area and/or airborne monitors at the plant boundary provide an indication of release to the environment and surrounding public (typically a separate system from the RMS)

During a severe accident, a LOCAqualified gamma detector inside containment is used to track the magnitude of the accident (this is not a personnel protection ARM)



(nrc.gov/reactors/pwrs.html)

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RMS Optimization and Abandonment – Identify the Regulatory and Site Requirements





Radiation Monitoring System – U.S. Nuclear Power Plant Requirements

What regulations drive the need for installed radiation monitoring systems at U.S. Nuclear Power Plants and other Utilization Facilities?

- Title 10 of the Code of Federal Regulations (CFR):
 Energy
 - Part 20, Standards for Protection Against Radiation
 - Part 50, Domestic Licensing of Production and Utilization Facilities
 - Part 70, Domestic Licensing of Special Nuclear Material



10 CFR Part 20, "Standards for Protection Against Radiation"

- 10 CFR 20.1201, "Occupational dose limits for adults"
 - (a)(1) An annual limit, which is the more limiting of-
 - (i) The total effective dose equivalent being equal to 5 rems (0.05 Sv); or
 - (ii) The sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye being equal to 50 rems (0.5 Sv).
 - (a)(2) The annual limits to the lens of the eye, to the skid of the whole body, and to the skid of the extremities, which are:
 - (i) A lens dose equivalent of 15 rems (0.15 Sv), and
 - (ii) A shallow-dose equivalent of 50 rem (0.5 Sv) to the skin of the whole body or to the skin of any extremity
- 10 CFR 20.1207, "Occupational dose limits for minors" limits are 10% of annual limits specified for adult workers
- 10 CFR 20.1208, "Dose equivalent to an embryo/fetus" limit occupational exposure of declared pregnant woman to less than 0.5 rem (5 mSv)



10 CFR Part 20, "Standards for Protection Against Radiation"

- 10 CFR 20.1301, "Dose limits for individual members of the public":
 - (a) Each licensee shall conduct operations so that
 - (a)(1) The total effective dose equivalent to individual members of the public from the licensed operation does not exceed
 0.1 rem (1 mSv) in a year, exclusive of the dose contributions from background radiation, from any medical administration
 the individual has received, from exposure to individuals administered radioactive material and released under §35.75, from
 voluntary participation in medical research programs, and from the licensee's disposal of radioactive material into sanitary
 sewerage in accordance with §20.2003, and
 - (a)(2) The dose in any unrestricted area from external sources, exclusive of the dose contributions from patients administered radioactive material and released in accordance with §35.75, does not exceed 0.002 rem (0.02 millisievert) in any one hour.
- 10 CFR 20.1302, "Compliance with dose limits for individual members of the public"
 - (a) The licensee shall make or cause to be made, as appropriate, surveys of radiation levels in unrestricted and controlled areas and radioactive materials in effluents released to unrestricted and controlled areas to demonstrate compliance with the dose limits for individual members of the public in § 20.1301.



10 CFR Part 20, "Standards for Protection Against Radiation"

- 10 CFR 20.1302, "Compliance with dose limits for individual members of the public"
 - (b) A licensee shall show compliance with the annual dose limit in § 20.1301 by -
 - (b)(1) Demonstrating by measurement or calculation that the total effective dose equivalent to the individual likely to receive the highest dose from the licensed operation does not exceed the annual dose limit.
 - (b)(2) Demonstrating that
 - (i) The annual average concentrations of radioactive material released in gaseous and liquid effluents at the boundary of the unrestricted area do not exceed the values specified in table 2 of appendix B to part 20; and
 - (ii) If an individual were continuously present in an unrestricted area, the dose from external sources would not exceed 0.002 rem (0.02 mSv) in an hour and 0.05 rem (0.5 mSv) in a year.



10 CFR Part 20, "Standards for Protection Against Radiation"

- 10 CFR 20.1501 (Subpart F Surveys and Monitoring), "General"
 - (a) Each licensee shall make or cause to be made, surveys of areas, including the subsurface, that -
 - (a)(1) May be necessary for the licensee to comply with the regulations in this part; and
 - (a)(2) Are reasonable under the circumstances to evaluate
 - (i) The magnitude and extent of radiation levels; and
 - (ii) Concentrations or quantities of residual radioactivity; and
 - (iii) The potential radiological hazards of the radiation levels and residual radioactivity detected
 - (c) The licensee shall ensure that instruments and equipment used for quantitative radiation measurements (e.g., dose rate and effluent monitoring) are calibrated periodically for the radiation measured.
- 10 CFR 20.1502, "Conditions requiring individual monitoring of external and internal occupational dose"
 - Each licensee shall monitor exposures to radiation and radioactive material at levels sufficient to **demonstrate compliance** with the occupational dose limits of this part. ...



10 CFR Part 20, "Standards for Protection Against Radiation"

10 CFR Part 20 includes the baseline requirements for surveying and monitoring radiation levels for facilities regulated by the U.S. NRC. It also includes requirements for limiting annual doses and dose rates to facility personnel and the public, including important effluent release concentration limits for radionuclides (and mixes of radionuclides)

 10 CFR 20 Appendix B "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage"

 Occupational Limits and Effluent Concentration Limits may form the bases of setpoints for radiation monitoring equipment and typically are based on ensuring the releases to the environment do not exceed the values in this table (or a fraction / multiple of these limits)

For example, for I-131 and Xe-133:

		Table I Occupational Values			Table 2 Effluent Concentrations		Table 3 Releases to Sewers	
		Col. 1 Oral	Co1. 2	Co1. 3	Co1. 1	Col. 2	Monthly	
Atomic Radionucli	de Class	Ingestion ALI (µCi)	ALI (µCi)	DAC (µCi/ml)	Air (µC1/m1)	Water (µCi/m1)	Average Concentration (µCi/ml)	



10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities

- 10 CFR 50.34, "Contents of applications; technical information"
 - (a) *Preliminary safety analysis report*. Each application for a construction permit shall include a preliminary safety analysis report. The minimum information to be included shall consist of the following: ...
 - (a)(3) The preliminary design of the facility including:
 - (i) The principal design criteria for the facility. Appendix A, General Design Criteria for Nuclear Power Plants
 establishes minimum requirements for the principal design criteria for water-cooled nuclear power plants similar in
 design and location to plants for which construction permits have previously been issued by the Commission and
 provides guidance to applicants for construction permits in establishing principal design criteria for other types of
 nuclear power units;
 - (ii) The design bases and the relation of the design bases to the principal design criteria; ...
 - (b) *Final safety analysis report*. Each application for an operating license shall include a final safety analysis report. The final safety analysis report shall include information that describes the facility, presents the design bases and the limits on its operation, and presents a safety analysis of the structures, systems, and components and of the facility as a whole, and shall include the following: ...
 - (b)(3) The kinds and quantities of radioactive materials expected to be produced in the operation and the means for controlling and limiting radioactive effluents and radiation exposures within the limits set forth in part 20 of this chapter.



10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities"

- (b) *Final safety analysis report*. Each application for an operating license shall include a final safety analysis report. The final safety analysis report shall include information that describes the facility, presents the design bases and the limits on its operation, and presents a safety analysis of the structures, systems, and components and of the facility as a whole, and shall include the following: ...
 - (b)(6)(vi) Proposed technical specifications prepared in accordance with § 50.36 ...
- (f) Additional TMI-related requirements. In addition to the requirements of paragraph (a) of this section, each applicant for a light-water-reactor construction permit or manufacturing license whose application was pending as of February 16, 1982, shall meet the requirements in paragraphs (f)(1) through (3) of this section. ...
 - Only those items related to radiation monitoring equipment are included here:
 - (f)(2)(xvii) Provide instrumentation to measure, record and readout in the control room:
 - (D) containment radiation intensity (high level)
 - (E) noble gas effluents at all potential, accident release points. Provide for continuous sampling of radioactive iodines and particulates in gaseous effluents from all potential accident release points, and for onsite capability to analyze and measure these samples. (II.F.1)
 - (f)(2)(xxvii) Provide for monitoring of inplant radiation and airborne radioactivity as appropriate for a broad range of routine and accident conditions. (III.D.3.3)



10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities"

- 10 CFR 50.47 "Emergency plans"
 - (b)(4) [Onsite and offsite emergency plans must meet the following standards:] A standard emergency classification and action level scheme, the bases of which include facility system and effluent parameters, is in use by the nuclear facility licensee, and State and local response plans call for reliance on information provided by facility licensees for determinations of minimum initial offsite response measures.
 - (b)(8) Adequate emergency facilities and equipment to support emergency response are provided and maintained.
 - (b)(9) Adequate methods, systems, and equipment for assessing and monitoring actual or potential offsite consequences of a radiological emergency condition are in use.
- 10 CFR 50.54 "Conditions of licenses"
 - 10 CFR 50.54(q) Addresses changes to site Emergency Plans. Licensee may make a change to the Emergency Plan as long as the change does not reduce the effectiveness of the plan and the plan, as changed, continues to meet the requirements of 10 CFR Appendix E.
 - If this is not met, licensee must submit a license amendment per 10 CFR 50.90 for the NRC to approve and, as appropriate, approve the amendment. For example, a change to the NRC-approved Emergency Action Level (EAL) scheme will always require a license amendment. Improper radiation monitor selection can negatively impact the Emergency Plan and could result in additional licensing costs and schedule delays for a replacement project.



10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities"

- 10 CFR 50, Appendix A: Listing those that pertain to radiation monitoring equipment
 - General Design Criteria 13, "Instrumentation and Control"
 - General Design Criteria 30, "Quality of Reactor Coolant Pressure Boundary"
 - General Design Criteria 60, "Control of Releases of Radioactive Materials to the Environment"
 - The nuclear power unit design shall include means to control suitably the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences. ...
 - General Design Criteria 63, "Monitoring Fuel and Waste Storage"
 - General Design Criteria 64, "Monitoring Radioactivity Releases"
 - Means shall be provided for monitoring the reactor containment atmosphere, spaces containing components for recirculation of loss-of-coolant accident fluids, effluent discharge paths, and the plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents.



10 CFR Part 70, "Domestic Licensing of Special Nuclear Material"

10 CFR Part 70 imposes requirements on licensees that store and use special nuclear material (SNM) (e.g., Pu, U enriched in ²³³U or ²³⁵U). As it applies to the RAMSYS RMS equipment, this involves monitoring of areas that store SNM, such as the spent fuel pool.

- 10 CFR 70.24, "Criticality accident requirements":
 - (a) Each licensee authorized to possess special nuclear material in a quantity exceeding 700 grams of contained uranium-235, 520 grams of uranium-233, 450 grams of plutonium, 1,500 grams of contained uranium-235 if no uranium is enriched to more than 4 percent by weight of uranium-235 is present, 450 grams of any combination thereof, or one-half such quantities if massive moderators or reflectors made of graphite, heavy water or beryllium may be present, shall maintain in each area in which such licensed special nuclear material is handled, used, or stored, a monitoring system meeting the requirements of either paragraph (a)(1) or (a)(2), as appropriate, and using gamma- or neutron-sensitive radiation detectors which will energize clearly audible alarm signals if accidental criticality occurs. ...
 - (a)(1) The monitoring system shall be capable of detecting a criticality that produces an absorbed dose in soft tissue of 20 rads of combined neutron and gamma radiation at an unshielded distance of 2 meters from the reacting material within one minute. Coverage of all areas shall be provided by two detectors.
 - (a)(2) Persons licensed prior to December 6, 1974, to possess special nuclear material subject to this section may maintain a monitoring system capable of detecting a criticality which generates radiation levels of 300 rems per hour one foot from the source of the radiation. The monitoring devices in the system shall have a preset alarm point of not less than 5 millirems per hour (in order to avoid false alarms) nor more than 20 millirems per hour. ...



10 CFR Part 70, "Domestic Licensing of Special Nuclear Material"

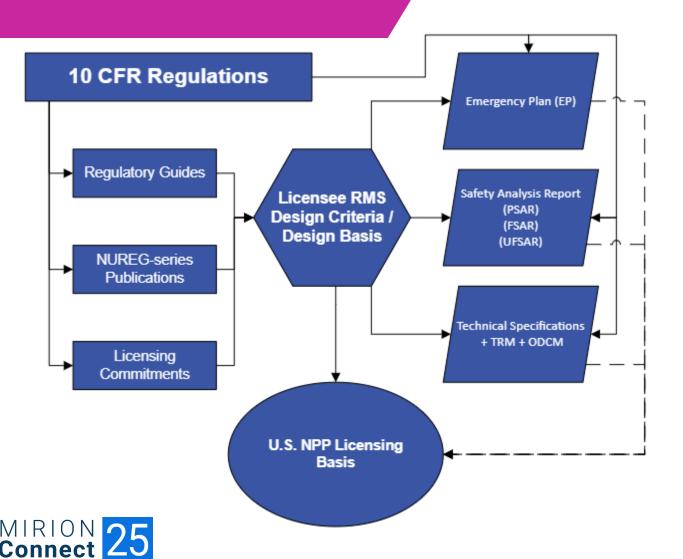
- 10 CFR 70.24, "Criticality accident requirements":
 - (d)(1) The requirements in paragraphs (a) through (c) of this section do not apply to a holder of a construction permit or operating license for a nuclear power reactor under part 50 of this chapter or a combined license issued under part 52 of this chapter, if the holder complies with the requirements of paragraph (b) of 10 CFR 50.68.
 - (d)(2) An exception from § 70.24 held by a licensee who thereafter elects to comply with requirements of paragraph (b) of 10 CFR 50.68 does not exempt that licensee from complying with any of the requirements in § 50.68, but shall be ineffective so long as the licensee elects to comply with § 50.68.

NOTE:

10 CFR 50.68, "Criticality accident requirements" states in summary that holders of construction permits or operating licenses under 10 CFR 50 or combined licenses under 10 CFR 52 must comply with either 10 CFR 70.24 or 10 CFR 50.68(b). As it relates to radiation monitoring 10 CFR 50.68(b)(6): "Radiation monitors are provided in storage and associated handling areas when fuel is present to detect excessive radiation levels and to initiate appropriate safety actions." The other subparts of 50.68(b) address storage and handling requirements of fuel assemblies and establish limits for k-effective in fuel racks under different moderation conditions, as well as mass of SNM.



U.S. NPPs – Reg Req Structure



- U.S. NPP RMS Regulatory Basis Structure shown on the left (not all encompassing)
- Regulations found within Title 10 (Energy) of the CFRs must be met by the licensee (our customers)
- The method by which these regulations are met is defined in our customer's Licensing Basis & Licensing Basis Documents (LBDs).
- The U.S. Nuclear Regulatory Commission (NRC) provides Regulatory Guides (RGs) to provide guidance to licensees on methods found acceptable to the NRC staff to meet the regulations.
- The U.S. NRC also provides NUREG documents, such as NUREG-0800 and NUREG-0737, which clarify requirements, present summaries of U.S. NRC regulatory research, and provide instructions to the NRC staff to review licensing applications.

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Important Regulatory Guides

U.S. NUCLEAR REGULATORY COMMISSION REGULATORY GUIDE RG 1.21, REVISION 3

Issue Date: September 2021 Technical Lead: Steven Garry

MEASURING, EVALUATING, AND REPORTING RADIOACTIVE MATERIAL IN LIQUID AND GASEOUS EFFLUENTS AND SOLID WASTE

- RG 1.21, "Measuring, Evaluating, and Reporting Radioactive Material in Liquid and Gaseous Effluents and Solid Waste"
- RG 1.45, "Guidance on Monitoring and Responding to Reactor Coolant System Leakage"
- RG 1.89, "Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants"
- RG 1.97, "Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants"
- RG 1.100, "Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants"
- RG 1.105, "Setpoints for Safety-Related Instrumentation"
- RG 1.152, "Criteria for Programmable Digital Devices in Safety-Related Systems of Nuclear Power Plants"
- RG 4.15, "Quality Assurance for Radiological Monitoring Programs (Inception through Normal Operations to License Termination) – Effluent Streams and the Environment"
- RG 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable"
- RG 8.25, "Air Sampling in the Workplace"



NUREGs To Know



NUREG - 0800

U.S. NUCLEAR REGULATORY COMMISSION STANDARD REVIEW PLAN

11.5 PROCESS AND EFFLUENT RADIOLOGICAL MONITORING INSTRUMENTATION AND SAMPLING SYSTEMS

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of the design and performance of radiation monitoring instrumentation and sampling systems used to monitor and control radioactivity in process streams and effluent releases from radioactive waste management systems.

Secondary - Organization responsible for the review of instrumentation and control design features, including alarm and automatic control functions.

AREAS OF REVIEW

For a reviews of an early site permit (ESP), construction permit (CP), standard design certification (DC), or a combined license (COL) that does not reference a DC, the U.S. Nuclear Regulatory Commission (NRC) staff reviews the information in the applicant's Safety Analysis Report (Preliminary Safety Analysis Report (PSAR) or Final Safety Analysis Report (FSAR)) as it relates to the process and effluent radiological monitoring instrumentation and sampling systems (PERMISS). For operating licenses (OL) or COLs that reference a DC, the staff confirms that the information accepted at the CP or standard DC stage is appropriately

Revision 6 – January 2016

- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition"
 - Often referred to as the SRP (Standard Review Plan)
 - Revision-specific for each licensee. New revisions show general direction of NRC staff thought process
- NUREG-0737, "Clarification of TMI Action Plan Requirements"
 - Added requirements for containment high range area monitors
 - Added requirements for extended ranges for effluent radiation monitors and post-accident P&I sampling
- NUREG-0696, "Functional Criteria for Emergency Response Facilities"
 - Requires Technical Support Centers and Emergency Offsite Facilities to have airborne iodine monitoring and dose rate monitoring as part of habitability.



Table 1: Provisions for Monitoring and Sampling Gaseous Process and Waste Streams (*

No.		<u>ln</u>	In Effluent		In Process	In Effluent	
NO.	Process Systems(**)	Process Conti	ACFj	Conti	Grabk	Grabk	Contl
1.	Waste Offgas Holdup System ^a	NG	NG	(NG)		(NG,H3)	(1)
2	Condenser Evacuation System ^b	NG	(NG)	(NG)	1	(NG,H3)	(I)
3.	Building Vent and Stack Release Point and Systems ^c	-	-	NG		H3	(1)
4.	Containment Purge Systems and Isolation Condenser Exhaust Systems	NG	NGm	(NG)	I	(NG,I,H3)	(1)
5.	Auxiliary or Service Building System	_	_	(NG)	1	(NG,H3)	(I)
6.	Fuel Storage Area Ventilation System ^e	(NG)	NGm	(NG)	1	(NG,H3)	(I)
7.	Radwaste Area Vent Systems	_	_	(NG)	1	(NG,H3)	(I)
8.	Turbine Gland Seal Condenser Vent System	-	-	(NG)	I	(NG,H3)	(1)
9.	Mechanical Vacuum Pump Exhaust(Hogging System)	-	-	(NG)	I	(NG,H3)	(1)
10.	Evaporator Vent Systems	_	_	(NG)	1	(NG,H3)	(I)
11.	Vents from Liquid Radwaste Tanks and Components	-	-	(NG)	(I)	(NG,H3)	(1)
12.	Steam Generator Systems and Generator	-	-	(NG)	I	(NG,H3)	(1)
	Blowdown and Degasifier Systems						
13. 14.	Treatment Systems Turbine Building Vent Systems Pressurizer and Boron Recovery Vent Systems	_	_	(NG) (NG)	1 1		(l) (l)
15.	Ventilation from Waste Compactors, Shredders, Etc.(as Permanently Installed or Mobile Systems)	R	-	I	I	1	(1)
16.	Exhausts from compressed air and instrument air systems with potential for radioactive contamination	R	-	I	I	I	(1)

^(*) For the key to legend, see the notes on the page following Table 2.

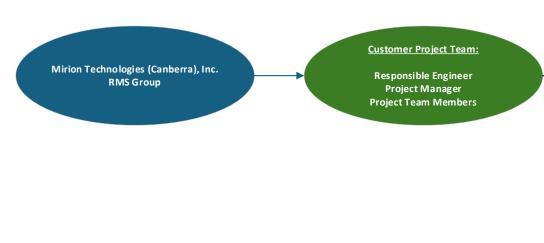
^(**) The listing is not considered to be all inclusive. Applicant should identify process and effluent systems that are unique to the specific type of reactor technology described in the application.



RMS Design Basis

- This is defined by the licensee's design but is often based on the sections of NUREG-0800 that pertain to the RMS, including Section 11.5 (Process and Effluent Radiological Monitoring Instrumentation and Sampling Systems) and Section 12.3 (Radiation Protection Design Features Area Radiation and Airborne Radioactivity Monitoring Instrumentation)
- PERMISS Extract a representative sample from a process or effluent stream for direct measurement and reporting of radiation levels or for sampling with subsequent detailed laboratory analysis.
 Provide alarms on preset levels of radiation and provide for trip signals to maintain releases to the environment below regulatory limits defined in the site ODCM (or similar)
- Area and Airborne Monitors Measure direct radiation fields for area monitors and airborne levels of radionuclides to provide an indication of radiation levels triggering early warnings (alarms) to protect plant personnel from developing radiation hazards.

U.S. NPPs – Customer Stakeholders (Typ.)







RMS Study – Optimizations & Abandonments

Identify the regulatory requirements and classify monitors into a list of monitors for further evaluation.

Look for monitor redundancies. Determine why redundancies exist. Many times redundancies are part of the plant design (e.g., defense-in-depth, independence requirements), but sometimes there are unintentional redundancies.

EXAMPLE: Two area monitors on either side of the same general area on an Aux Building floor.

EXAMPLE: Design modification has changed the way the Control Room HVAC works such that an off-line configuration noble gas monitor no longer serves as a way to measure low levels of intake air for early warning capability. Upstream in-duct monitors serve as safety-related monitors with control actions to active CREFS.

EXAMPLE: Non-Safety Related Worker Protection PING that measures a more dilute concentration of gases from the same upstream source that is being monitored. Evaluate replacement monitor sensitivity improvements possible to use only a single monitor. Evaluate if RP / I&C uses these worker protection PINGs and why they are in the licensing basis.

Look for monitors that have been out of service for a long time. The site hasn't needed to rely on them. Why are they there? Ask maintenance technicians! Most of the time they know better than engineers!



RMS Study - Optimizations

Are the monitors correctly selected? Are there failures to be aware of? Temporary conditions like elevated indication due to resin transfer on floor above monitor?

Not always a cost reduction up front but can result in improvements by reducing excessive maintenance costs, unexpected failures, overall better design.

Example: Hypothetical ion chamber (mid range to high range) design as part of the Post Accident Sampling Facility needed for post-accident mission (originally). Post Accident Sampling Facilities have been abandoned by many sites. As part of that abandonment, then the need to perform a post-accident mission to that building was eliminated. The monitor design was not questioned. Could be replaced with standard personnel protection area radiation monitor (e.g., Mirion GIM 204K).

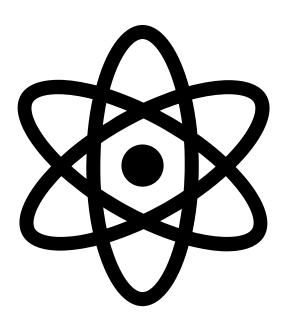
Example: Consider regulatory requirements for monitor ranges. Can a less expensive monitor still meet regulatory requirements even if it doesn't meet existing range?

Example: Consider OE from other sites. For example, post-accident area monitors outside containment for RG 1.97. Many sites took exception to this their initial responses demonstrating compliance with RG 1.97 / PAMS. These monitors listed as C and E type variables had high dose rate requirements; however, licensees would not be sending personnel into these post-accident and have other methods of detecting breach of containment, etc. These would be more expensive monitors to replace.



RMS Study - 10 CFR 50.69

Recategorization will save money as well (detailed in other presentations). Largest savings for replacements will be for standard SR -> RISC-3





Thank you



