Radiation Monitoring System Health Metrics

Purpose

This whitepaper provides expanded technical guidance on maintaining system health metrics for the Radiation Monitoring System (RMS). This topic was a recommendation identified from the 2023 EPRI document "Lessons Learned from Issues Affecting Radiation Monitors - White Paper". The goal is to provide a baseline template of system metrics and indicators specific to maintaining the reliability of the RMS. The performance areas outlined within this document include metrics, indicators, and monitoring parameters typically found in a system health report. Additionally, it extends to those areas unique to the RMS and incorporates them into a system health status dashboard or scorecard. This tool is intended to assist system engineers or designated system owners with maintaining an awareness for the health of the RMS system. It is also intended to help inform site leadership of issues and/or areas of concern by aiding in tracking and resolving system health and regulatory issues.

Background

Due to the relatively high number of findings related to RMSs and an increased inspection interest from the US Nuclear Regulatory Commission (NRC), EPRI conducted an analysis of US NRC inspection findings since 2013 to identify the technical issues or insights that may warrant additional guidance to improve industry performance in this area. This analysis is documented in EPRI technical document CHEM 2023-018, "Lessons Learned from Issues Affecting Radiation Monitors - White Paper". The data in the analysis comes from US nuclear power plants. However, the content of this analysis pertains to plants outside of the US as they also use radiation monitoring systems to support accident assessment and emergency response functions, and therefore may be susceptible to the issues and concerns discussed herein.

This system health metrics tool was identified as necessary based on the general concerns surrounding ownership as well as knowledge and expertise of the RMS. The RMS supports compliance with regulations in multiple areas, including emergency operating procedures, radiation protection, radiochemistry, effluent releases, and emergency preparedness. Ownership of the RMS includes the responsibility to not only maintain the health of the system but to also understand and protect the system design functions and basis.

System Health Metrics General Discussion

System health reports and scorecards are tools that provide analysis and reporting of monitoring parameters to communicate system performance. System health reports are a collection of system metrics and indicators obtained from various sources, such as

parameters monitored per the system monitoring plan, data from condition reports, etc. A typical system health report also includes a system description section documenting the system design basis and functions. This section usually contains the current health status, the results of the system scorecard, that is normally expressed as a color (typically green, white, yellow, red) and, if required, the return to green action plan status and timeline. Through system health reports, system owners can evaluate and document system health as well as communicate system status to site leadership to ensure a common understanding of any issues and actions needed to resolve adverse conditions and improve system performance.

The metrics and indicators are normally grouped into performance areas, with each area having a score and color rating attributed to them, in the form of a scorecard. Typical performance areas of system scorecards include Maintenance Rule, Performance Monitoring, Material Condition, Operations Impact, Configuration Management, Operating Experience, and Long-term Asset Management/Obsolescence. Some of these performance areas may be designated as key performance indicators, which can drive system color. System performance degradation (yellow or red) warrants a system recovery plan that has key actions and time frames to improve the overall health. The system engineer can override a color if it is believed that it does not accurately reflect the state of the system.

For a more in-depth guide on system health reports in general and their role in overall system monitoring, reference “Guideline for System Monitoring by System Engineers”, EPRI Report 3002026348.

Specific to RMS Health Attributes

Why It Matters

As part of work reduction efforts, many utilities have introduced system classification tiers to determine the applicability and update frequency of system health reports. Generally, these classification schemes require reporting on systems that are necessary to maintain capacity factor or are mitigating systems. Many of these classification schemes have not accounted for radiation monitoring systems' roles in ensuring radiation safety, and generally the system will be classified as a lower tier that does not require a system health report. There are, however, some utility procedures that allow management discretion when requiring health reports for lower tiered systems based on the number of issues with the system.

The generic health scorecard templates from system health reporting software rarely provide enough information for the RMS or for other I&C type systems. The generic templates are tailored toward mitigating systems and the power production balance of plant systems.

The purpose of this whitepaper is to provide a more useful RMS scorecard template. It contains appropriate metrics, indicators, and monitoring parameters, while maintaining the normal performance areas, for RMS engineers to track and trend for system status

reporting. The intent is for system owners to use this tool for 1) their system health reports, if required per procedure or management discretion or 2) an internal use health scorecard or system status dashboard.

It is highly recommended for the system engineer/designated owner of the RMS to have some method of maintaining the health status of the system. This can be in the generic scorecard templates used in system health reporting software or a "home-made" status report, such as a spreadsheet, dashboard, database, or a section of the system notebook. These reports are intended to be for internal use if being performed outside of site health reporting procedures.

System health reports are one of the main tools used by system engineers to communicate system health status and current issues, therefore it is important that the reports have up to date and useful information. Tracking the system health status for the RMS can help avoid extra work when performing self-assessments or compiling system information for regulatory inspections or system audits. A system health scorecard or dashboard can assist in tracking system issues and driving action plans to resolution which can prevent operational challenges, Emergency Plan (EP) implications, or regulatory violations.

How to Use This Tool

The intent of this document is not to enforce a standard onto nuclear power plants but to empower the system owners to advocate for the Radiation Monitoring System. This tool is not meant to be all-inclusive but rather be a starting point – system health reports should convey what the system engineer needs in order to get the attention and support needed. Remember when maintaining a system health report, the system's color can be overridden if necessary. For instance, if regulatory issues have occurred with the RMS or actions remain open to resolve a violation, the system color should reflect that. System health reports and scorecards are a tool – they should be used to convey the current health of the system as well as what needs to be done to maintain regulatory compliance.

This tool is presented as a health status dashboard or health scorecard to accommodate both utilities that do and do not require system health reporting for the RMS.

System Description

Good system health monitoring tools include a system description that describes the design basis functions and identifies regulatory and industry commitments for the system. For the RMS, this should describe the different required radiation monitors, both process and area (Main Steam Line, Building Vents, etc.), what their functions are (isolation, post-accident monitoring, etc.) and the applicable regulatory requirements and commitments. Some may want to perform separate health monitoring for the area

radiation monitors (ARMs) and process radiation monitors – for the purposes of this document they will be presented together.

The system design basis should come from license basis documents such as the Updated Final Safety Analysis Report (UFSAR); this should already be documented in other system documents such as the system notebook or system monitoring plan. It should be a listing of the function the radiation monitors perform such as post-accident monitoring, isolation functions, use in emergency operations procedure (EOPs), etc. Regulatory commitments should be included in the system description as well to ensure that system performance monitoring commitments are being met and any issues are getting the necessary attention. The regulatory guides and industry standards the plant is committed to should be listed in the UFSAR and other license basis documents. Reference EPRI Report "Area and Process Radiation Monitoring System Guide" Section 4.2 for further guidance on RMS design basis.

Metrics/Indicators/Monitoring Parameters

Maintenance Rule*/Key Equipment Performance

Indicators/metrics tracked in the Maintenance Rule performance area include overall system Maintenance Rule Status, (a)(2) for normal monitoring/acceptable performance (green) or (a)(1) unacceptable performance (red). The Maintenance Rule is a Key Performance Indicator (KPI) at most plants, so an (a)(1) status (or multiple key equipment failures) would drive the overall system status color to red.

Other metrics tracked in this performance area are Maintenance Rule Functional Failures, including any repeat or maintenance preventable failures, and Condition Monitoring Events. If the system is in the (a)(1) or unacceptable status, the open actions for resolution should be documented and tracked here.

* Plants not implementing Maintenance Rule or plants whose radiation monitoring system is excluded from the Maintenance Rule should still track radiation monitors that provide post-accident Control Room indication or provide input for Emergency Operating Procedures in the health report. These radiation monitors are important to protecting the health and safety of the public and should be maintained functional, thus it is important to track equipment health. The focus of Maintenance Rule is to ensure that in-scope systems are meeting established performance criteria and if not, action is taken to return the system to acceptable performance. Including Maintenance Rule or key equipment performance in the system scorecard is to ensure the reliability of the key system functions of the RMS.

For more information of Maintenance Rule, reference 10CFR50.65 Requirements for monitoring the effectiveness of maintenance at nuclear power plants, Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants Revision 4F, NUMARC 93-01, or Monitoring the Effectiveness of Nuclear Power Plant Maintenance, Revision 0, NEI 18-10.

Performance Monitoring

Monitoring and trending system performance is necessary to identify degrading equipment and system performance issues. System monitoring plans are used to document which key equipment and parameters of the system are monitored. They describe the method of monitoring, normal operating bands, data collection frequency, and alarm or alert limits for notification before the normal band is exceeded. The metrics for the performance monitoring area on the system health scorecard should come from the normal system monitoring of the RMS. The data that feeds into this area should align with the system monitoring plan and may include the following: surveillances, preventive maintenance (PM) tasks, operator rounds, system walkdowns, plant process computer data, chemistry data, effluent reports, operating experience (OE), regulatory violations, vendor service letters/part 21s. For further input to RMS monitoring plans reference, Section 5.2.3.1 of EPRI Report 3002010580, Area and Process Radiation Monitoring System Guide, which discusses parameters for RMS trending performance.

Performance criteria for the RMS monitoring plan should be based on reliability, such as no unanticipated failures of monitored equipment, and on condition, i.e., negative trends from calibration surveillances or PM tasks such as instrument drift or changes in detector sensitivity. For more information on RMS trending specific to calibration and instrument drift, reference Section 5 of EPRI Report 3002010581, Calibration of Radiation Monitors at Nuclear Power Plants Calibration Guide.

The results from system monitoring should be reflected in the system health scorecard to ensure system performance trends are being documented and communicated. Performance monitoring for the RMS should also include regulatory performance trending. Any issues or violations with the regulator should be reflected in this section on the system health scorecard – it is also recommended this metric be made a key performance indicator and drive system overall color. For US Plants, reference the NRC RP Inspection Procedures, 71124.05 and 71124.07, and review to ensure the radiation monitors within inspection scope are monitored.

All radiation monitors included in the Area and Process RMS should be included in the system monitoring plan; some radiation monitors may have more frequent monitoring and different alert levels based on function. For instance, the High-Range Containment/Drywell Radiation Monitors should be monitored more frequently, and calibration data trended to ensure proper functionality. Area radiation monitors that are not tech spec or do not fall into Maintenance Rule scope may only be monitored annually or once per cycle. Components that should be monitored at a minimum include those in scope of the Maintenance Rule, post-accident monitoring, EOP, EITER, and Technical Specifications.

Material Condition

This section is for tracking work order backlogs (both outage and online), open key system health (KSH) work orders, deferred preventive maintenance tasks, Operational Decision Making (ODMs) or Adverse Condition Monitoring Plans (ACMPs), existing degraded or nonconforming conditions, and conditions from walkdown results or operator rounds. Plants should verify radiation monitors are classified correctly (tech spec, safety related, ODCM, MR, EITER, etc.) to ensure work requests are prioritized appropriately. Consider making this performance area a key performance indicator.

RMS specific metrics and criteria that may be tracked in this performance area:

- Work orders that are for resolving RMS equipment and/or regulatory issues
- License extension requirements, such as cable testing
- Out-of-service radiation monitors that may not fall under maintenance rule scope, tech specs, or another performance area
- Any radiation monitors on the EITER report
- Any open actions from equipment issues that don't fall under maintenance rule but require maintenance to prevent recurrence, such as tech spec surveillance issues or non-tech spec ARMs that fail channel check
- Corrective, deficient, key system health work orders, and longstanding issues

Operations Impact

The metrics in this performance area have to do with equipment operability and equipment issues that negatively impact operators. This section should track open or active, unplanned Tech Spec Limiting Condition of Operation (LCO) action statement entries related to radiation monitors and should document the compensatory measures that have to be in place. Any open operability concerns, such as operable degraded non-conforming condition should be tracked in this area.

For this area it is important to understand the definitions of the metrics/indicators that fall under it, for instance, the difference between operator workaround and operator burden - these are defined in INPO 19-002, Industry Reporting and Information System (IRIS) Reporting Requirements. Any RMS issues causing operator impacts that fall under the definition of an operator burden or workaround should be tracked in this performance area. This also includes control room deficiencies. For instance, any radiation monitor indication in the control room that is not functioning would be tracked here. Validate that applicable plant effect codes are applied to work orders impacting operations.

Configuration Management

The configuration management performance area should track issues or open actions for open temporary modifications, 10 CFR Part 21* issues, or any issues with design functions not being met.

This performance area should be utilized to ensure what is documented in license basis documents is being met. Review the UFSAR and other documents for specific requirements, especially pertaining to RMS calibrations.

This section should also document any open items pertaining to setpoint changes or calibration factor updates and be used to ensure the station's tracking means, whether using a database or procedure, is maintained.

*10 CFR Part 21 Reporting of Defects and Noncompliance – Manufacturer reports that a component supplied to plant contains defects, which could create a substantial safety hazard.

Operating Experience

This performance area is for tracking open action plans to address operating experience. This should reflect if there are open actions needed to be implemented by the station to address not only INPO/WANO OE reviews but any industry issues that require station action. This could include service bulletins from vendors, NRC findings, or OE from peer groups. For instance, if the station is susceptible to recent regulatory issues from the industry related to RMS and has not addressed it or has open actions to address it, this metric should reflect that.

Long-term Asset Management/Obsolescence

The metrics in this performance area normally include long-term asset management issues, availability of critical spares, and obsolescence issues. This section of the scorecard is for documenting statuses and ages of pending modifications necessary to improve system reliability, availability, or operability. If upgrading to digital RMS or already upgraded, this section should track a digital lifecycle plan for the system as well. It also should include bridging strategy status and what actions are in place to manage any obsolescence and spare parts availability issues.

ERPI Report 3002005269, Radiation Monitoring Systems Obsolescence Management Guide provides further guidance on obsolescence plans as well as bridging strategies for the RMS.

Radiation Monitoring System Health Metrics Dashboard

System Description/System Design Basis Functions

Sources for the system description include: UFSAR, Technical Specifications and Bases, Offsite Dose Calculation Manual (ODCM), EP documents such as Emergency Action Levels (EAL) and Equipment Important to Emergency Response (EITER), and EOPs.

Functions: PAM, isolation, EOPs/EALs. RG 1.97, RG 1.45, NUREG-0737 (Response to TMI), 10 CFR 20.1501(c), Tech Spec, TRM, ODCM, EITER

Area Radiation Monitors

High-Range Containment/Drywell Radiation Monitors

Process Radiation Monitors

Main Steam Line, N16, Condenser Off-Gas, Liquid, Building Vents, Effluents, etc.

Maintenance Rule/Equipment Performance

Maintenance Rule System Status – key performance indicator
Maintenance Rule Failures (system functional failures, with emphasis on repeat and maintenance-preventable failures)
Condition Monitoring Events
Action Plan if applicable

Performance Monitoring

(At minimum, radiation monitors whose functions fall within – MR, PAM, EOP, EP, tech spec should be monitored)

Surveillance and PM task calibration trending - instrument drift, detector efficiency, background changes, equipment degradation, check sources
Open corrective actions
Actions for resolving regulatory issues – key performance indicator
Actions for equipment issues with impact on EOPs/EALs/EP – key performance indicator
Open self-assessment actions
Repetitive equipment or system performance issues
Condition report tracking
Effluent reports trending (for awareness)
Regulatory Performance – key performance indicator

Material Condition

System walkdown results/material condition
Outage and online backlogs
Open KSH WOs
Deferred PMs
ODMs/ACMPs
Existing degraded or nonconforming conditions
Corrective maintenance/deficient maintenance work order totals

Operations Impact

Unplanned Tech Spec LCOs
Compensatory Actions in place – grab samples, temporary monitoring, RP surveys
Control room deficiencies
Operator work arounds
Operator burdens
Open operable degraded non-conforming conditions

Configuration Management

Any issues with design functions not being met – USFAR, other license basis requirements
Open Temporary Modifications
Open items for - setpoint logs, calibration factors database/procedure/whatever means of tracking
Part 21 issues

Operating Experience

Open actions to address INPO/WANO OE reviews

Open actions to address service bulletins from vendors

Regulatory violations and findings – open actions to address susceptibility to recent industry regulatory issues.

Industry issues that require station action; examples - INPO SOER 93-01 RMS leak detection, High-Range Containment Drywell radiation monitor cables thermally induced currents (TIC)

Long-term Asset Management/Obsolesce

Long range plan status

Bridging Strategy status

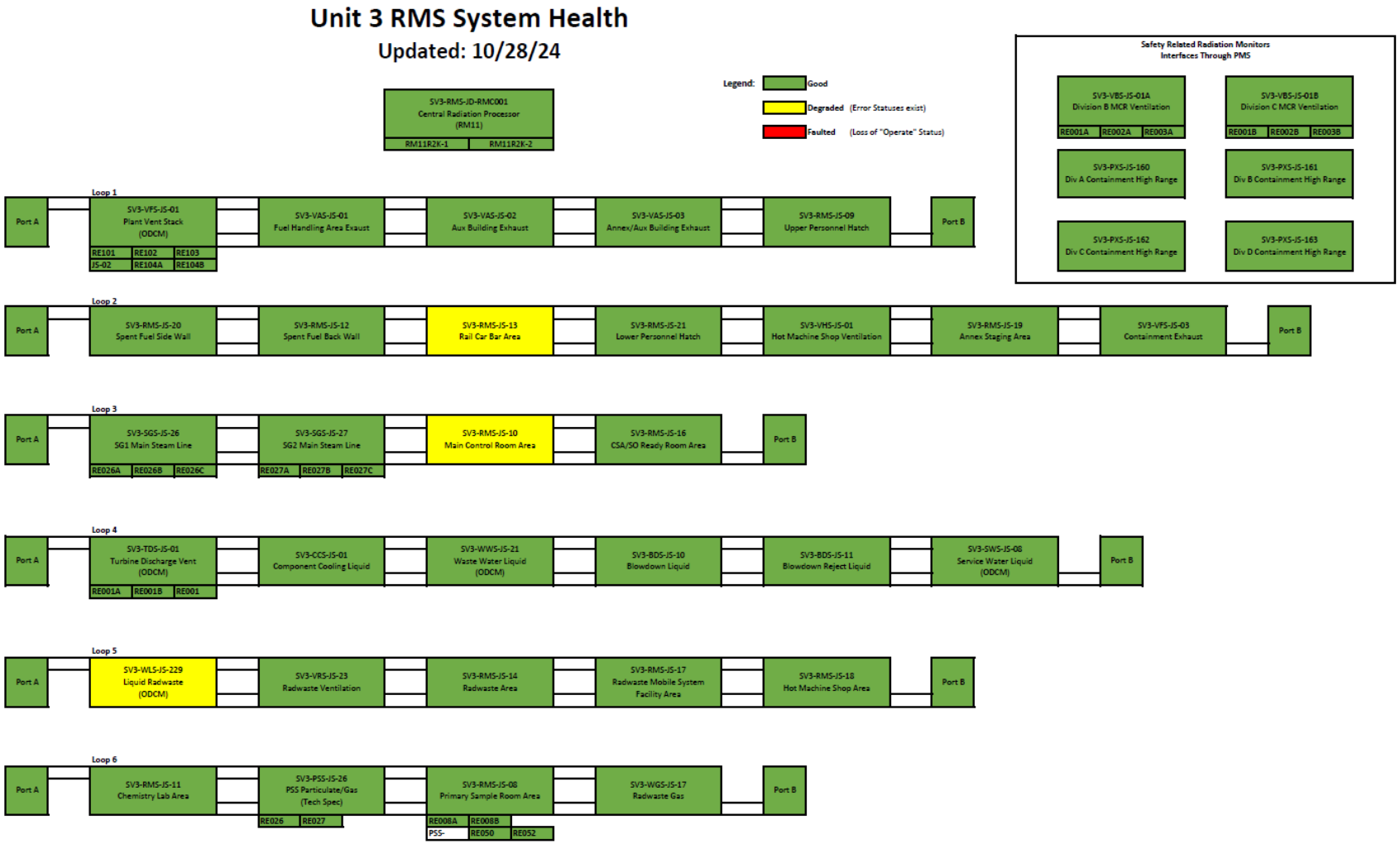
Obsolescence Plan status - can include retiring unnecessary radiation monitors to use parts for required radiation monitors (reference the EPRI RMS Guide and the RMS Obsolescence Guide for information on retiring radiation monitors).

Appendix A – Radiation Monitoring System Health Status Scorecard Example – Plant A

Plant A RMS Health Status - September 2024

Channel Description	Significance	Unit 1					Unit 2				
		Channel Health	Replaced/ Upgraded (Y/N)	Pending Actions	Comments	Work Week and Notes	Channel Health	Replaced/Upgraded (Y/N)	Pending Actions	Comments	Work Week and Notes
Control Room Area	EITER	G	Y		Replaced under WO 60128765		W	Y	60160017	Troubleshoot failed remote ratemeter	WW438
Control Room Ventilation	Tech Spec MRule	W	Y		LCM Issue S-19-0046 including ER strategy funded to start 2024		W	Y		LCM Issue S-19-0046 including ER strategy funded to start 2024	
Containment General Area	EITER MRule	G	Y				G	Y			
Chemistry Lab Area	MRule	G	Y								
Charging Pumps Area	MRule	G	Y				G	Y			
FHB Spent Fuel Area	EITER Tech Spec MRule	G	Y				G				
Primary Sample Lab Area	MRule	G	Y								
In-Core Seal Table Area	MRule	G	Y				W	Y	60159512	Checksource failed; need to replace detector	2R27
FHB - New Fuel Area	EITER Tech Spec MRule	W	Y	60161635	Checksource failing; need to replace detector	WW451	G	Y			
Containment Personnel Hatch 100'	MRule	G	Y				G	Y			
Containment Personnel Hatch 130'	EITER MRule	G	Y		Replaced under WO 60138144		W	Y	60154425	Troubleshoot 2R10B ratemeter	WW510

Appendix B – Radiation Monitoring System Health Status Scorecard Example – Plant B



Acronyms

ACMP Adverse Condition Monitoring Plan

ARM Area Radiation Monitor

CFR Code of Federal Regulations (U.S.)

EAL Emergency Action Level

EITER Equipment Important to Emergency Response

EOP Emergency Operating Procedure

EP Emergency Plan

EPRI Electric Power Research Institute

FSAR Final Safety Analysis Report

INPO Institute of Nuclear Power Operations

IRIS Industry Reporting and Information System

KPI Key Performance Indicator

KSH Key System Health

LCM Life-Cycle Management

LCO Limiting Condition of Operation

MR Maintenance Rule

NRC U. S. Nuclear Regulatory Commission

ODCM Offsite Dose Calculation Manual

ODM Operational Decision Making

OE Operating Experience

PAM Post Accident Monitoring

PM Preventive Maintenance

PMBD Preventive Maintenance Basis Database

RM Radiation Monitor

TIC Thermally Induced Currents

TMI Three Mile Island

TRM Technical Requirements Manual

TS Technical Specification

UFSAR Updated Final Safety Analysis Report

US United States

WANO World Association of Nuclear Operators

WO Work Order

References

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