Vendor Information that Supports Nuclear Power Plant Radiation Monitoring Systems

Purpose and Background

This white paper outlines vendor information related to nuclear power plant radiation monitoring systems (RMS) that should be available as part of a licensee's RMS program. In doing so, this paper describes the regulatory basis applicable to RMS instrumentation and the continuing importance of the original equipment manufacturer's (OEM) qualification, including "type test"[1], primary, and transfer calibration data. The intent is to provide an understanding of what OEM information should be available and how those documents support functionality of the system(s). Considerations are also provided for addressing missing OEM data.

The guidance in this document is derived from multiple regulatory and standards documents, including RG 1.21 [1], RG 4.15 [2], ANSI N42.18 [3], ANSI/HPS N13.1 [4], HPPOS-001 [5], HPPOS-040 [6], IN 2013.013 [7], portions of RG 1.97 [8] [9], and the content of EPRI CHEM 2023-018 [10].

Vendor-Produced Documentation

Effluent, process, and area radiation detection equipment is required to provide monitoring over a large range of conditions encompassing normal operating conditions and, in some cases, accident scenarios. As a result, OEM-produced documentation describing original design, calibration, intensity linearity, energy response, any detector specific response factors, and the dedication of solid transfer calibration sources is critical to demonstrating that the installed plant equipment meets the applicable regulatory requirements and performs as expected in support of plant effluent and emergency planning processes.

The following vendor-provided documentation (as applicable) should be available to personnel with responsibilities for using, maintaining, and assessing performance of installed effluent, process, and area radiation monitors. Except where accident monitoring instrumentation imposes additional criteria, the necessary vendor documentation described here should be available for all radiation monitors.

In some cases, portions of the documentation may cover multiple monitors of the same design whereas other aspects may be specific to an individual detector.

[1] A "type test" is a concept where the applicable monitor components are tested to qualify the monitor against various requirements. Type tests may be done using a single component or multiple duplicate components to determine the characteristics of the monitor design.

Vendor Equipment Manuals

Equipment manuals describe equipment design and operating specifications, intended installation information, component parts listings, and recommendations for calibration and maintenance. For skids containing multiple radiation (and other) detection elements, the relevant information may be contained in multiple equipment manuals specific to certain components of the skid. Vendor manuals should be updated to reflect any designs changes made to the radiation monitor and/or its components.

Type Test Report and Primary Calibration(s)

Primary calibration reports document the one-time calibration testing performed by, or for, the manufacturer prior to delivery to the licensee. These reports may include intensity linearity tests and energy response curves for relating detector response to various requirements and radionuclide mixes. In the case of effluent and process monitors, the primary calibration is essentially a geometry calibration that relates the detector response to a known radioactivity concentration within a sample chamber, vent duct or pipe. Primary calibrations are typically performed using only one or two individual radionuclides and the remainder of the detector energy response is determined using multiple solid sources of varied emission energies.

Primary calibrations and type-test reports establish the initial performance of the detector type and are considered to be representative of the production detectors delivered to the licensee. The validity of the primary-calibration-derived response factors remains intact as long as the fit, form and function of the geometry of the detector and other associated components is not altered. These reports will describe the testing performed and should include all source certificates for the sources used by the manufacturer and any reference[2] instrument calibration documentation. The primary calibration must provide energy response curve(s) for use in demonstrating the monitoring requirements.

Transfer Source Dedication

Following the primary calibration of an effluent or process monitor, the OEM will present one or more solid sources to that monitor. The calibrated detector's response to the source(s) is used to define the expected response(s) from subsequent detectors intended for distribution to customers. Typically, considering decay, the final response to the solid source(s) is verified to be within a small tolerance. This alignment step ensures that the detector response, when installed, will replicate the concentration response obtained during the primary calibration.

With the detector now aligned to the primary calibration, measurements of solid sources to be provided to the customer are performed. These customer sources are referred to as transfer sources and this process is referred to as transfer source dedication. The resultant transfer sources are now also traceable to the primary calibration. The transfer source dedication will describe the source(s) used, including radionuclide, activity, and

[2] Examples of reference instrumentation include NIST traceable ion chambers, thermometers, barometers, etc.

geometry relative to the detector. Transfer source documentation must include the source calibration certificates.

Use of the transfer source(s) for in-field calibrations must be consistent with the geometry described in the source dedication, and decay-corrections must be accurately determined over time. Best practices for decay correction include maintaining the reference response and date to when the original dedication was performed.

Note that some monitors may contain more than one detector type, for example effluent skids may contain multiple detector types to satisfy the normal, middle and/or high ranges of monitoring. Transfer source dedications for multiple detector types (and multiple radioactive source types) are likely described in different vendor reports.

As the continuing method of translating expected detector response to the original primary calibration(s), these transfer source dedication documents are critical to the pedigree of the instrument(s).

Transfer Source Decay and Degradation

Radioisotopes selected for use as a transfer source are typically chosen to have reasonably long half-lives (e.g., cesium-137); however, it is likely that source replacement will eventually be necessary due to decay or source degradation (e.g., damage to the active area may deplete the activity). To evaluate for potential source degradation over time, some form of verification of source strength is encouraged, such as a periodic re-calibration of source activity with a source manufacturer.

When new transfer sources are implemented, great care is necessary to ensure that the new sources are accurately related to the original primary calibration and that the documentation of the dedication is captured in the licensee's program. New transfer sources should be procured with an identical geometry using both the same backing and covering. If new sources are not provided by the vendor, then before dedication of new transfer sources, the old transfer sources should be sent to a source manufacturer to re-certify the activity.

Source Calibration Certificates for Transfer Sources

Calibration certificates should accompany sources delivered to the licensee. These documents provide important information characterizing the specific source, including radionuclide, half-life, emission rate, calibrated activity, and uncertainties in these values. Source certificates also provide instructions from the manufacturer, such as appropriate leak testing techniques, when applicable.

Detector Replacement

When replacement detectors with detector-specific calibration factor(s) are delivered to the licensee, instructions must be provided to update the calibration factor and to provide guidance on adjusting the end-user transfer source response criteria. Documentation should be available to show the adjustment made to include the relationship to the original dedication of the end-user transfer source. Site personnel

should ensure vendor manuals are supplied for each detector. When a new detector is installed (like for like), station personnel should obtain and incorporate any changes to the vendor manuals.

Testing Criteria Specific to Accident Monitoring Instrumentation

In addition to the above vendor documentation, certain additional documentation is required for accident monitoring documentation (reference NUREG-0737 and RG 1.97).

Due to ALARA and other practical considerations, the use of a one-time primary calibration utilizing type-testing methods is acceptable to the NRC. Subsequent licensee calibration activities use secondary sources for which the expected response of the monitor is tied to the original primary calibration using transfer source dedication.

Containment High-Range Monitors

Type-testing document(s) should be available to demonstrate:

- the intensity linearity of detector exposure-rate response at sufficient points through the entire detection range up to 10^6 R/h,
- the ability to detect 60 keV to 3 MeV photons with linear energy response for photons from 100 keV to 3 MeV is ± 20%,
- monitors should have an energy response accuracy of ± 20%. and
- overall monitoring system accuracy should be within a factor of 2.

For each production detector,

- response testing should be available on at least one point per decade of range between 1 R/h and 1000 R/h.

  Note that this three-decade test is a separate detector-specific test for each production detector (not part of a type test). The licensee should receive a separate report for this three-point test for each detector in service and any spares in inventory.

High-Range Noble Gas Effluent Monitors

Type-testing report(s) should be available to demonstrate:

- A calibration to NBS [NIST]-traceable[3] radioactive gas sources at a minimum of three on-scale values separated by not less than two decades of scale (e.g., 1E-5, 1E-3, 1E-1 µCi/cm3).

[3] Prior to 1988, the National Institute of Standards and Technology (NIST) was known as the National Bureau of Standards (NBS). As a result, radioactive sources used for calibration or energy-response testing would be either "NIST-traceable" or "NBS-traceable" depending on the reference date of the source.

    - Xenon-133 is typically used for gamma-monitoring systems and krypton-85 for beta-monitoring systems. Gases with higher concentrations should be used if reasonably available.
- The energy response testing using solid laboratory standard sources (traceable to NBS [NIST]) of varying gamma energies.
    - This testing demonstrates the continued capability of the monitor to detect and measure radioactive gaseous effluent concentrations throughout an accident sequence when the radionuclide mix is changing significantly due to decay of shorter-lived nuclides.
    - The testing should support the capability of the monitor to detect and measure radioactive gaseous effluent concentrations with compositions ranging from fresh equilibrium noble gas fission product mixtures to 10-day-old mixtures, with overall system accuracies within a factor of two (2). Effluent concentrations may be expressed in terms of Xe-133 equivalents or in terms of any noble gas nuclide(s).

Note that some monitors may contain more than one detector type, for example effluent skids may contain multiple detector types to satisfy the normal, middle and/or high ranges of monitoring. The primary calibration(s) for multiple detector types are likely described in different vendor reports.

Response to Missing Vendor Documentation

In some instances, OEM-produced documentation related to effluent and area monitors has not been readily retrievable for review by program owners and/or regulators. Success in locating the information may require understanding of station records retention requirements and norms (both current and past). The documentation types listed above may be stored in different locations from each other.

Licensees have had success using the following:

- Review basis documents at the station. Formal design processes were involved in the original installation of RMS systems. As such, relevant information (or references to applicable documents) can often be found in original design and basis documents, such as: engineering analyses and radiation protection, chemistry, or emergency planning documents (such as setpoint calculations, dose assessment algorithm/software evaluations and other program bases).

- Review historical calibration and maintenance records for the monitor(s). Information may be included with original installation work orders, calibration data, or routine and corrective maintenance records.
- Contact the OEM vendor. Licensees have had success contacting original OEM vendors for copies of documentation originally delivered with the detectors, including primary calibration and transfer source evaluations. Vendors may make updates/changes to parts and/or vendor manuals without contacting station

personnel. A good practice is to periodically contact the vendors to ensure information remains current.

- Contact prior program owners. Some licensees performing assessments of their RMS programs have had success reaching out to retirees or other former employees having experience with the programs to gain insights into prior practices, including records retention.
- Review radiation protection source records. Radiation Protection is typically assigned responsibilities for radioactive source inventory and leak testing. As such, source certificates (and other records) associated with RMS detector surveillances are often stored with the certificates from other inventoried (e.g., non-RMS) sources.

Vendor Documentation Checklist

As a summary, the above discussion provides detailed descriptions of the vendor-provided information that should typically be available for RMS systems. While the specific details of an RMS implementation may differ based on equipment differences, the following checklist is offered to assist with assembling information for use during a program assessment.

For each RMS monitor:

- ☐ For each skid/detector model, a vendor equipment manual.
- ☐ For each detector model, the primary calibration document.
  - Note that some monitors may contain more than one type of detector, for example skids containing low-, mid-, and high-range detectors. The primary calibrations for these detectors may be in different vendor reports.
- ☐ For each detector model, the transfer calibration document to the site's transfer sources.
  - Note that some monitors may contain more than one type of detector covering different ranges. Transfer source dedications for multiple detector types (and multiple radioactive source types) are likely described in different vendor reports.
- ☐ For any new transfer sources (i.e., replacements for original transfer sources), documentation of how these sources were qualified as being equivalent to the original transfer sources in fit, form, and function.
- ☐ Source certificates for transfer sources.
  - These are typically attached to the primary calibration and the secondary transfer source dedication. If they are not attached to the primary calibration and secondary source dedication documents, they should otherwise be readily retrievable.
- ☐ For any replacement detectors, vendor instructions required to update the calibration factor and to adjust the transfer source response criteria should be retained. Documentation should be available to show the adjustment made to include the relationship to the original dedication of the end-user transfer source.
- ☐ Consider grouping documents together for easier cross-reference.

For Containment High-Range Monitors:

- ☐ Documentation of type-testing demonstrating:
  - intensity linearity up to 10^6 R/hr,
  - linearity of energy response with accuracy of ± 20%,
  - overall monitoring system accuracy should be within a factor of 2.
- ☐ For each detector, detector-specific testing documenting three-decade response between 1 R/hr and 1000 R/hr.

For High-Range Effluent Monitors:

- ☐ Documentation of calibration to NBS [NIST]-traceable radioactive gas sources.
- ☐ Documentation of energy-response testing using solid laboratory standard sources (traceable to NBS [NIST]) of varying gamma energies.
    - Note that some monitors may contain more than one type of detector, for example skids containing low-, mid-, and high-range detectors. The energy-response testing for these detectors may be in different vendor reports.

References

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4. American National Standards Institute, Inc. Sampling and Monitoring Release of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities. ANSI/HPS N13.1-2021, April 9, 2021.
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6. U. S. Nuclear Regulatory Commission NUREG/CR-5569. “Health Physics Position Database”. Revision 1, February 1994, ML 093220108. Health Physics Position Paper-040, page 93, “Effluent Radiation Monitor Calibrations”.
7. U.S. Nuclear Regulatory Commission Information Notice 2013-13. “Deficiencies with Effluent Radiation Monitoring System Instrumentation”. Revision 1, April 15, 2015, ML14253A270.
8. U.S. Nuclear Regulatory Commission Regulatory Guide 1.97. “Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident”. Revision 2, 1980, ML060750525.
9. U.S. Nuclear Regulatory Commission Regulatory Guide 1.97. “Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident”. Revision 3, 1983, ML003740282.
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Acronyms/Abbreviations

µCi/cm^3	Microcuries per cubic centimeter
ALARA	As Low As Reasonably Achievable
ANSI	American National Standards Institute
e.g.	For example
EPRI	Electric Power Research Institute
i.e.	That is
keV	Kilo electron volt
MeV	Mega electron volt
NBS	National Bureau of Standards
NIST	National Institute of Standards and Technology
NRC	Nuclear Regulatory Commission
NUREG	NRC Reports or brochures on regulatory decisions, results of research, results of incident investigations, and other technical and administrative information
OEM	Original Equipment Manufacturer
R/h	Roentgen per hour
RG	Regulatory Guide issued by the Nuclear Regulatory Commission
RMS	Radiation Monitoring System