

NUCLEAR INDUSTRY STANDARD PROCESS
Radiological Protection

Level 3 – Information Use

Portable Survey Instruments
NISP-RP-001

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This is an industry document for standardizing radiation protection processes. Standard processes and requirements are established to eliminate site-specific radiation protection procedures. The Institute for Nuclear Power Operations (INPO) maintains current procedures on the INPO website. Approval authority is granted by the industry contingent on a structured review and approval process by representatives of utility radiation protection organizations.

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1.0 Purpose

- 1.1 This procedure provides basic instructions to operate common instruments used for radiation and contamination surveys. General descriptions, operating characteristics and limitations of these instruments are provided as attachments.

2.0 Scope

- 2.1 This procedure provides guidance for the selection and operation of portable instruments that measure gamma, beta, alpha and neutron radiation. If supplemental personnel are expected to operate instruments beyond the scope of this procedure, additional training may be required consistent with the site training and qualification program.
- 2.2 The forms referenced by this procedure are examples used to describe the pertinent information that should be recorded for future reference. Plant procedures may specify the use of equivalent forms or the use of electronic media for the same purposes.
- 2.3 This procedure will be used to train supplemental radiological protection technicians. Current revisions are maintained on the INPO website.

3.0 Definitions

- 3.1 Terms, acronyms, and definitions are provided in NISP-RP-013, *Radiological Protection Glossary*.

4.0 Responsibilities

- 4.1 Radiation Protection is responsible for the implementation of this procedure per Efficiency Bulletin 17-01 and the Nuclear Industry Standard Process Initiative.

5.0 General Requirements

- 5.1 Ensure that selected survey instruments are appropriate and calibrated to detect the types of radiation present in the work area.
- 5.1.1 Ensure that instruments used to measure radioactivity count rate have a scale that reads in units of counts per minute (cpm) or a multiple of this unit.
- 5.1.2 Ensure that instruments used to measure gamma dose rate have a scale that reads in units of mR/hr or mrem/hr or a multiple of these units.
- 5.1.3 Refer to Attachment 1, "General Radiation Detector Types and Uses" for general information on instrument types and use.
- 5.1.4 Refer to Attachment 2, "Typical Portable Radiation Detection Systems in Use at Nuclear Power Stations" to obtain specific information about standard portable detection systems.

- 5.1.5 Read all tags and labels on an instrument to determine if the use of a scale is restricted.
- 5.2 When using an instrument model for the first time, review the applicable manufacturer technical or operational manual, or operating procedure to understand the data display, control adjustments, and limits.
- 5.3 Ensure the instrument is turned on prior to entering an area to survey. Zero the instrument, if applicable, and ensure operational and functional checks were performed prior to entering the radiation field.
- 5.4 Prevent contamination of an instrument by avoiding contact with contaminated surfaces or bagging the instrument prior to use in a contaminated area.
- 5.5 Prevent damage to thin window detectors by avoiding contact with small, sharp objects.
- 5.6 Apply appropriate correction factors as provided by site procedures.
- 5.7 When using an instrument with an internal detector, use case markings to align the detector with radiation sources.
- 5.8 When using an instrument with an analog meter, allow the meter to recover/stabilize from inertial effects on the needle.
- 5.9 If the instrument has a scale adjustment, set the instrument on a scale appropriate for the expected dose rates prior to exposing the instrument to the radiation field.
 - 5.9.1 Adjust scales with the objective to obtain a stabilized reading between 10% and 90% of the scale.
 - 5.9.2 Allow the meter to stabilize after switching scales due to the potential for electronic noise to cause a temporary meter deflection.
 - 5.9.3 Prevent instrument damage by avoiding exposure to excessive heat, moisture, and radiation fields that are significantly above full- scale of the instrument.

6.0 Process Instructions

- 6.1 Perform Pre-Use Instrument Inspections and Checks.
 - 6.1.1 Inspect instruments for physical damage prior to and during use.
 - 6.1.2 Ensure all cables are connected securely; verify no spikes or erratic results are displayed when moving cables.
 - 6.1.3 Ensure switches and knobs can be operated without restriction.

- 6.1.4 If using a scintillation detector, turn the instrument on and check for punctures in the detector window by exposing the detector to a light source. An increase in the background count rate may be indicative of a punctured window.
- 6.1.5 If damage is suspected, tag the instrument out of service and contact appropriate site instrument coordinator or supervisor.
- 6.1.6 Ensure the instrument has a calibration sticker affixed and that the calibration due date is in the future.
- 6.1.7 If the instrument has a Battery Check mode, perform a battery check and ensure that the reading is within the specified range.
- 6.1.8 When inspecting an instrument with an analog or digital meter, allow the meter to recover/stabilize from the inertial effects on the needle.
- 6.1.9 Ensure a source check per the required frequency has been performed on the scales expected to be used.
- 6.1.10 When performing source checks, use the identified source as provided in site specific procedures.
- 6.1.11 If the site uses an instrument accountability system, sign instruments out and in as appropriate.
- 6.2 Operate an Ion Chamber Survey Instrument
 - 6.2.1 Determine the gamma dose rate by holding the instrument in a steady position with the window closed and allowing the readout to stabilize.
 - 6.2.2 Determine the beta dose rate by obtaining open window and closed window readings with the instrument in the same position. Apply the following calculation:

$$\text{Beta Dose Rate} = ((OW - CW) \times CF_{\beta})$$

where:

OW= Open window

CW= Closed window

CF_β= Beta Correction Factor (provided on an instrument label or in station procedures)

- 6.2.3 Measure the activity on a highly contaminated smear (e.g. > 100,000 dpm) by placing the open window as close as possible to the smear without touching it and observe the digital display or meter indication.

- 6.2.4 Apply correction factors as provided by site procedures as needed to convert readings to dpm/100 cm² (e.g. 75,000 dpm/mR per hour of Cs-137).
- 6.3 Operate a GM Survey Instrument
 - 6.3.1 Determine the gamma dose rate by holding the instrument in a steady position and allowing the display to stabilize.
 - a. If the detector has a beta window, ensure the window is closed during gamma measurement.
 - 6.3.2 Exercise caution if a reading is off-scale high or low due to the potential for over-ranging conditions that may damage the instrument.
 - a. Remove the instrument from the radiation field and/or change scales to prevent over-ranging conditions.
- 6.4 Operate a Count Rate Meter with a GM Frisker Probe
 - 6.4.1 Turn on the count rate meter and allow approximately 10 seconds for an analog count rate meter to stabilize.
 - 6.4.2 Estimate background by setting the range switch on the lowest range with an on-scale reading and setting the response time to the slowest setting, if adjustable.
 - 6.4.3 Determine the count rate by multiplying the value indicated on the meter by the scale factor shown on the range selector switch.
 - 6.4.4 Frisk surfaces as instructed in NISP-RP-002, *Radiation and Contamination Surveys*.
 - 6.4.5 Convert count rate readings (CPM) to disintegration rate (DPM) as follows:
 - a. For pancake GM detectors, multiply the CPM meter reading by 10 or as directed by RP supervision.
 - 6.4.6 Press the reset button to clear alarms as needed.
- 6.5 Operate a Count Rate Meter with an Alpha, Beta, or Dual Scintillation Probe
 - 6.5.1 Turn on the count rate meter and allow approximately 10 seconds for an analog count rate meter to stabilize
 - 6.5.2 For instruments with multiple channels for alpha, beta, or dual response, ensure the instrument is set to appropriate mode corresponding to the probe being used.
 - 6.5.3 Maintain the protective cover over the detector when not in use to prevent puncturing the thin film window.

- 6.5.4 Estimate background radiation level by setting the range switch on the lowest range that provides an on-scale reading.
 - a. When using a dual scintillation probe for both alpha and beta readings, ensure that separate background readings are measured.
- 6.5.5 Determine the count rate by multiplying the value indicated on the meter by the scale factor shown on the range selector switch.
 - a. Some digital instruments may automatically switch ranges and directly show the corresponding cpm values.
- 6.5.6 Frisk surfaces as instructed in NISP-RP-002, *Radiation and Contamination Surveys*.
- 6.5.7 Convert count rate readings (CPM) to disintegration rate (DPM) as follows:
 - a. Multiplying the meter reading by the factor labeled on the instrument or as provided by RP supervision.
 - b. When using a dual alpha and beta scintillation probe, ensure that the appropriate factors are applied to alpha and beta readings.
- 6.6 Operate a Neutron Rem-meter
 - 6.6.1 Turn on the analog neutron rem-meter and allow approximately 10 seconds for the meter to stabilize.
 - 6.6.2 Determine the neutron dose rate by holding the instrument in a steady position allowing the readout to stabilize.
 - 6.6.3 If required by site procedures, apply correction factors to meter results to get corrected readings.

7.0 Records/Documentation

NONE

8.0 References

8.1 Commitments

NONE

8.2 General

8.2.1 NISP-RP-002, Radiation and Contamination Surveys

9.0 Attachments

9.1 Attachment 1: General Radiation Detector Types and Uses

9.2 Attachment 2: Typical Portable Detection Systems in Use at Nuclear Power Stations

ATTACHMENT 1
General Radiation Detector Types and Uses
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General Types of Radiation Detectors

There are several types of radiation detectors used in the nuclear industry, some of the more common detector types are listed below along with general information on detector type, their operation, and use. This list of instruments is not all inclusive, other types of instruments may be used provided they are in accordance with manufacturers recommendations or site specific procedures.

Gas-filled Detectors

All gas-filled detectors require a voltage be applied between a center anode and the detector chamber (cathode). As a radiation particle or photon enters the chamber, it ionizes gas atoms creating positive ions and free electrons which are captured by the positive charge on the anode and negative charge on the cathode. The collection of these ions and electrons creates a pulse which is sensed and converted by the instrument's electronic circuitry to provide an accurate display of the measured contamination or radiation fields depending on the type of instrument. By varying the voltage on the chamber, three useful types of gas-filled detectors can be created; Geiger-Mueller (GM) detectors, proportional counters, and ionization chambers.

The gas inside the detectors can vary depending on design and use. Certain gas-filled detectors operate on normal air while others use specialty gas.

GM detectors have a relatively high voltage (approximately 1000 - 1400 volts) applied to the chamber and as such, every particle or photon entering the chamber creates enough secondary ionizations that the entire chamber is ionized producing one large pulse.

Proportional counters have typically less voltage applied than GM detectors (approximately 300 –800 volts) which can vary depending on its use. Because the voltage is typically less, proportional detectors can be set up to produce pulses that are proportional to the energy of the incident radiation and therefore can be used to differentiate between alpha and beta particles. Common hand-held proportional detectors include both gas-flow and sealed chambers. Gas-flow proportional detectors require a constant flow of gas through the chamber in order to operate.

Ionization chambers require varying amount of voltage (approximately 50 - 300 volts) and are designed to produce outputs which are relative to the incident energy of the photons or particles and thus can be calibrated to be relatively energy independent.

Ionization chambers are one of the preferred detectors for measuring gamma dose rates because they can measure deep dose equivalent and tend to be accurate over a wide range of gamma energies. Ionization chambers have varying responses to neutron radiation due to recoil protons

Scintillation Detectors

Certain crystals, plastics, liquids and other materials will “scintillate”, or give off visible light, when they absorb ionizing radiation. The amount of light emitted is proportional to the amount and energy of ionizing radiation that they absorb. When coupled with a photomultiplier tube or photo cathode (devices which convert visible light into electronic pulses) these materials make very useful radiation detectors. Scintillation detectors are widely used to detect alpha, beta, and gamma radiation and can be used to measure gamma dose rate and contamination.

Because the properties of certain materials allow them to absorb radiation differently, certain scintillation detectors are more useful than others for specific radiation types. There are many types of scintillation materials and detectors, but the common ones used for hand-held applications in the nuclear power industry are:

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General Radiation Detector Types and Uses
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Zinc Sulfide (ZnS) Detectors are generally used to measure alpha contamination. A thin layer of ZnS effectively absorbs the energy from alpha particles and produces light but the ZnS layer does not have the characteristics to efficiently absorb beta particles or photons. ZnS detectors are excellent detectors for detecting low levels of alpha particles because of their inherently low response to background.

Plastic Scintillator Detectors are typically used to detect beta and gamma radiation. *Thin* layers of plastic scintillators are very effective in measuring beta particles and very low energy photons, such as those emitted from Iodine-125. Thin plastic scintillators are too thick to produce light from alpha particles and are not large enough to absorb gamma rays of moderate energy and thus are very good beta detectors.

Thick plastic scintillators absorb moderate to higher energy photons effectively and can be used for measuring gamma dose rate and gamma rays from contamination but are too thick to effectively absorb alpha or beta particles and convert them to measurable light. Plastic scintillator detectors are very popular because plastic can be molded in a variety of configurations to provide specialty application. Thick plastic scintillation detectors are often used in vehicle monitors, tool monitors, and some hand-held instruments, such as micro-rem meters.

Sodium Iodide Detectors (NaI)

Sodium Iodide (NaI) crystals are used in a variety of applications and are very effective in detecting gamma photons. Thick NaI detectors are very sensitive to gamma radiation and can be used for gamma monitoring and gamma spectroscopy. Detectors with thin NaI crystals can be effectively used to measure lower energy photons and are mostly used in medical applications.

Cesium Iodide Detectors (CsI)

Cesium Iodide (CsI) crystals are used in some portable detectors for measuring gamma radiation. Handheld systems with CsI detectors are also used to perform gamma spectroscopy and can be used for underwater applications.

Dual Scintillation Detectors




Some detector probes contain a combination of scintillation material allowing them to detect more than one type of radiation simultaneously. Common types of dual scintillation probes contain a thin plastic scintillator with a coating of ZnS. These probes are effective in surveying for both alpha and beta particles at the same time and if used with the appropriate electronics, can provide a separate readout for alpha and beta count rate.

Semi-Conductor Detectors

Semi-conductor detectors (sometimes referred to as “solid-state” detectors) have properties midway between a good conductor and a good insulator and can act much like an ionization chamber. Common materials used to make semi-conductor detectors includes Germanium and Silicon. Germanium detectors are often used for gamma spectroscopy and laboratory applications; however, Silicon has been widely used to make portable detection systems including alarming dosimeters, air monitors, and some area monitors.

Nuclear Industry Standard Process Portable Survey Instruments

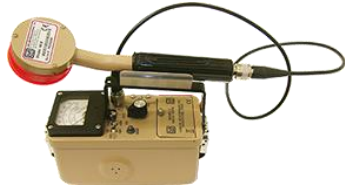


ATTACHMENT 2 Typical Portable Detection Systems in Use at Nuclear Power Stations Page 1 of 7

Manufacturer	Model(s)	Detector Type	Typical Use	Typical Range	Notes and Special Considerations	Image
Ludlum	12-4	Internal He ³ Proportional Counter	General area neutron dose rate surveys	4 Ranges 0 to 10,000 mRem/hr	<ul style="list-style-type: none"> Instrument provides gamma background rejection up to 12 R/hr. 	
Ludlum	14-C	Internal GM Probe for dose rate monitoring External Pancake GM Detector for count rate monitoring	Internal probe can be used for dose rate monitoring External Pancake probe used for beta contamination monitoring	Internal Probe: 5 Ranges 0 to 2 R/hr External Probe: 4 Ranges 0 to 660K cpm	<ul style="list-style-type: none"> Ensure that the selector switch is set to the correct detector (i.e. internal vs. external) to ensure proper result. 	
Ludlum	177	Beta + Gamma	GM	0 cpm - 500k cpm	<ul style="list-style-type: none"> Meter face can have both mR/hr and cpm readouts. User must be aware of the probe and calibration and use proper scale 	



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Manufacturer	Model(s)	Detector Type	Typical Use	Typical Range	Notes and Special Considerations	Image
Ludlum	3	External Pancake GM Detector for count rate monitoring	External Pancake probe used for beta contamination monitoring	External Probe: 4 Ranges 0 to 500K cpm	<ul style="list-style-type: none"> Meter face can have both mR/hr and cpm readouts. User must be aware of the probe and calibration and use proper scale 	
Ludlum	3	Gamma	GM	0 - 200 mR/hr	<ul style="list-style-type: none"> Meter face can have both mR/hr and cpm readouts. User must be aware of the probe and calibration and use proper scale 	
Ludlum	9-7	Beta + Gamma	Ion Chamber, 2 detectors	LOW: 0.001 – 1.99 R/hr MID: 0.1 - 199.9 R/hr HIGH: 0.01- 19.9 KR/hr	<ul style="list-style-type: none"> Can be used with low, mid, and high range probes Digital readout Similar controls to RO-7 	






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Manufacturer	Model(s)	Detector Type	Typical Use	Typical Range	Notes and Special Considerations	Image
Ludlum	3000	The Model 3000 utilizes an external radiation detector to detect alpha, beta, or gamma radiation.	Geiger-Mueller (GM), scintillator, or proportional	0.0 cps to 99.9 kcps & 0.00 cpm to 999 kcpm 0.00 Bq to 99.9 kBq & 0.00 dpm to 999 kdpm 0.00 μ R/h to 999 R/h & 0.00 μ Sv/h to 999 Sv/h	<ul style="list-style-type: none"> • Auto Ranging • Rate, Max, and Count Modes of Operation • All-Digital Calibration 	

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Manufacturer	Model(s)	Detector Type	Typical Use	Typical Range	Notes and Special Considerations	Image
Mirion	AMP-50/100/200	Internal Energy Compensated GM Tube	Remote area monitor or underwater detector	AMP-50: 10uR/hr to 4 R/hr AMP-100: 0.005 R/hr to 1,000 R/hr AMP-200: 0.5 R/hr to 10,000 R/hr	<ul style="list-style-type: none"> Cables can be up to 350' long Unit can be used with WRM wireless transmitters 	
Mirion	Ram Gam-1	Internal energy compensated GM tube	General area and contact gamma dose rate surveys. Often used for shipping surveys since it can get close to packages for contact readings.	0.05mR/hr to 999mR/hr	<ul style="list-style-type: none"> Digital Instrument 	
Mirion	RDS-30	Internal energy compensated GM tube	General area and contact gamma dose rate surveys. Often used for shipping surveys since it can get close to packages for contact readings.	1 uRem/hr to 10 Rem/hr	<ul style="list-style-type: none"> Digital instrument Needs factory software to calibrate 	






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Manufacturer	Model(s)	Detector Type	Typical Use	Typical Range	Notes and Special Considerations	Image
Mirion	RDS-31	Internal energy compensated GM tube	General area and contact gamma dose rate surveys. Often used for shipping surveys since it can get close to packages for contact readings.	1 uRem/hr to 10 Rem/hr	<ul style="list-style-type: none"> Digital instrument Needs factory software to calibrate 	
Mirion	Telepole	2 Internal energy compensated GM tubes 1 high range, 1 low range	General-area and contact gamma dose rate surveys. Can be used for shipping surveys since it can get close to packages for contact readings	0.05 mR/hr to 1000 R/hr	Pole extends 11'	
Thermo Eberline	6112B Teletector	2 internal GM Detectors for Low and High Range	General-area and contact gamma dose rate surveys	5 Ranges 0.1 mR/hr to 1000R/hr	<ul style="list-style-type: none"> Detectors extend to approximately 13' 	

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Manufacturer	Model(s)	Detector Type	Typical Use	Typical Range	Notes and Special Considerations	Image
Thermo Eberline	E-140	External GM probe	General area and contact gamma dose rate surveys. Often used for shipping surveys since it can get close to packages for contact readings.	0 to 200 mR/hr when calibrated to dose rate	<ul style="list-style-type: none"> Meter face has both mR/hr and cpm readouts. User must be aware of the probe and calibration and use proper scale. 	
Thermo Eberline (formally Bicon)	Microrem	Gamma + X-Ray	TEP Scintillator	5 Ranges 0 - 200 mRem/hr	<ul style="list-style-type: none"> Tissue equivalent and flatter energy response than Ludlum Micro-R 	
Thermo Eberline	RM-14	External Pancake GM Detector for count rate monitoring	External Pancake probe used for beta contamination monitoring	External Probe: 3 Ranges 0 to 50K cpm	<ul style="list-style-type: none"> Can be used with both a GM pancake probe or with an end-window GM probe in a fixed counting holder 	



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Manufacturer	Model(s)	Detector Type	Typical Use	Typical Range	Notes and Special Considerations	Image
Thermo Eberline	RO 2/2A	Internal Ion Chamber	General-area gamma and beta dose rate surveys	RO-2: 4 Ranges 0.1 mR/hr to 5 R/hr RO-2A 4 Ranges 1 mR/hr to 50 R/hr	<ul style="list-style-type: none"> • Has two battery checks for each of the two batteries • Significant changes in atmospheric pressure or temperature can affect reading and require re-calibration 	
Thermo Eberline	RO 20	Internal Ion Chamber	General-area gamma and beta dose rate surveys	5 Ranges 0.1 mR/hr to 50 R/hr	<ul style="list-style-type: none"> • Updated model of the RO-2 which includes the additional RO-2A range 	