White Paper

Revolutionary Hybrid Survey Meter Technology for Versatile Medical and Industrial Use

Introduction

Radiation safety is crucial in both medical and industrial environments, especially for professionals regularly exposed to scattered X-rays.

For occupational groups such as medical physicists and radiation safety officers, the primary goal is to monitor, control, and minimize unnecessary radiation exposure for both patients and staff. Achieving this requires a clear understanding of radiation properties, including energy range, dose rate, and type of radiation. This is where radiation survey meters become essential.

This white paper offers an in-depth analysis of the RaySafe 452 survey meter and its innovative hybrid technology, comparing its performance with traditional ion chamber technology. This white paper highlights advancements in accuracy and versatility, demonstrated across various medical and industrial applications.

Figure 1: Survey meter used for detection of possible wall leakage from a room equipped with a CT machine.

Figure 2: Survey meter used for control of a nuclear level gauge within the oil & gas industry.

The multi-purpose RaySafe 452 features advanced measurement capabilities, offering a robust solution to the complex requirements of radiation monitoring.

It marks a significant step forward in helping to ensure safety and precision when measuring ionizing radiation.

Common Survey Meter Technologies

Radiation survey meters are based on various technologies, each with its strengths and limitations.

- **Ionization Chambers:** Measure radiation by ionizing gas within a vented or pressurized chamber. Vented chambers offer a flat response but require corrections for temperature and pressure. Larger chambers provide greater sensitivity. Pressurized chambers can be smaller, but their thicker walls may attenuate low-energy photons, and they could be classified as hazardous materials, complicating transportation.

- **Geiger-Müller (GM) Tubes:** Primarily used for measuring contamination, GM tubes count ionization events rather than providing energy information. They do not offer spectral data. During an ionizing event, the GM tube experiences a “dead time” where it cannot register additional radiation. At high dose rates, this dead time can cause the tube to saturate. Additionally, GM tubes exhibit significant energy dependence at low photon energies.

- **Semiconductor Diodes:** Provide up to one million times higher sensitivity than an ion chamber of the same volume, allowing for much smaller detectors. Although robust, their high sensitivity comes with temperature dependence. Since the sensitivity also varies with photon energy, filtration is required.

- **Scintillators:** Emit light when exposed to radiation, which is then converted into an electrical signal. Key considerations include temperature dependence, sensitivity to humidity, and the decay time of the scintillating material.

Challenges with Traditional Survey Meters

Medical and industrial environments present unique challenges for radiation measurement:

- **Energy Dependence:** Traditional meters may struggle with varying photon energies, requiring complex correction factors.

- **Pulse Radiation:** Measuring scattered radiation from pulsed sources, such as fluoroscopy and linear accelerators, can be challenging due to high dose rates and short pulse durations.

- **Low Dose Rate Sensitivity:** Meters may become unstable at low dose rates, making it difficult to detect minor increases in radiation.

- **Practicality:** The need for multiple instruments to address diverse measurement requirements may complicate usage and maintenance.

Hybrid Technology: A Breakthrough in Radiation Measurement

All survey meters have a varying energy response in parts of their measurement range due to the individual properties and limitations of each instrument type and technology. If the survey meter does not have a flat energy response, correction factors can be used, but this is challenging. Therefore, the technology inside a survey meter used to determine its usage; ion chambers for leakage and scatter measurements, and GM tubes for detection of spilled isotopes and other contamination.

The RaySafe 452 introduces another approach by integrating two types of sensors:
a semiconductor detector and a Geiger-Müller (GM) tube. This hybrid technology was developed to enhance measurement accuracy by combining the benefits of both sensors, offering high sensitivity and stability across a wide energy range and dose rates. The silicon diodes in the detector provide an excellent energy response and engage instantly to capture short pulses of high intensity, while the GM tube offers rapid response even at low levels, making the RaySafe 452 suitable for comprehensive radiation monitoring.

This hybrid approach offers several advantages over traditional ion chamber technology, which has been the standard for decades.[1)2)]

Figure 3: The active sensor area of the RaySafe 452 features a GM pancake detector behind a steel grid, encircled by a semiconductor detector consisting of a cluster of solid-state sensors under a carbon fiber cover. The full version of the RaySafe 452 includes two interchangeable lids: Ambient and Air Kerma. When either lid is mounted, the device measures dose and dose rate. Without a lid, it measures counts of α, β, and γ radiation.

1. Japanese Journal of Radiation Safety Management, “Fundamental Characteristics of a Hybrid Survey Meter —Measurement of Scattered Radiation”.

2. For detailed information, also see the Fluke Biomedical White Paper, “Radiation survey meters in hospitals: technology, challenges, and a new approach”.

Hybrid Technology Advantages over Ion Chambers – RaySafe 452 Key Features

RaySafe 452 complies with IEC 60846-1 and incorporates advanced measurement capabilities, offering broad usability.

Versatile Measurement Capabilities with a Single-device Solution

The RaySafe 452 integrates multiple measurement capabilities into a single instrument, simplifying both usage and maintenance. It is designed to measure alpha, beta, gamma, and X-ray radiation, making it suitable for a wide range of applications.
This versatility is crucial for various settings, from medical diagnostics to industrial safety and environmental monitoring. In contrast, ion chambers are typically limited to specific types of radiation and may require additional equipment to cover the same range of measurements.

Ease of Use

The RaySafe 452 requires minimal setup. Simply turn on the device, and it's ready to measure within seconds. There's no need for complex settings or calibrations, allowing users to quickly and efficiently obtain accurate readings. This ease of use enables users to focus on radiation protection rather than operational complexities.

Intuitive User Interface

Featuring a large display, the RaySafe 452 shows all measurement parameters in a single view.

Figure 4: The RaySafe 452 is designed for easy handling, featuring an intuitive interface that displays all parameters in one view. It requires no corrections or manual settings, allowing you to focus on radiation protection rather than setup. Simply turn on the instrument, and within a few seconds, you're ready to measure.

Enhanced Sensitivity and Accuracy

- **Low Dose Rate Detection:**
  The RaySafe 452's GM tube is designed to detect low dose rates, and deliver accurate measurements at minimal radiation levels. This enhances its applicability in both medical and industrial settings. In contrast, traditional ion chambers may struggle with stability at these low dose rates.

- **Wide Energy Range and Flat Response:**
  RaySafe 452's hybrid technology offers a flat response across a broad energy range, from low-energy X-rays to high-energy gamma rays. This helps ensure accurate measurements regardless of radiation type.
  In contrast, pressurized ion chambers can have inadequate response at low energies, while vented ion chambers may sacrifice sensitivity.

Faster Response Time

The combination of silicon diodes and a GM tube in the RaySafe 452 provides a rapid response, even at low dose rates. This is important for detecting leaks and transient radiation levels. In contrast, ion chambers may have slower response times due to their reliance on gas ionization, which can delay measurements.

Robust and Reliable

- **Automatic Data Storage and Transfer:**
  The RaySafe 452 automatically stores measurement data every second, ensuring that no critical information is lost.
  The included RaySafe View software simplifies data transfer to a PC for further analysis and long-term storage, enhancing workflow efficiency.

- **Environmental Robustness:**
  Designed for stable operation under fluctuating conditions, the RaySafe 452 features an IP64 rating, which means it is dust-proof and water-resistant. This durability helps ensure reliable measurements in various environmental conditions, outperforming many ion chamber devices that are more sensitive to environmental changes.[3)] Its robust design offers reliable performance both indoors and outdoors, across a wide range of temperatures.

3. "Investigation of thermal and temporal responses of ionization chambers in radiation dosimetry", https://pubmed.ncbi.nlm.nih.gov/22467281/.

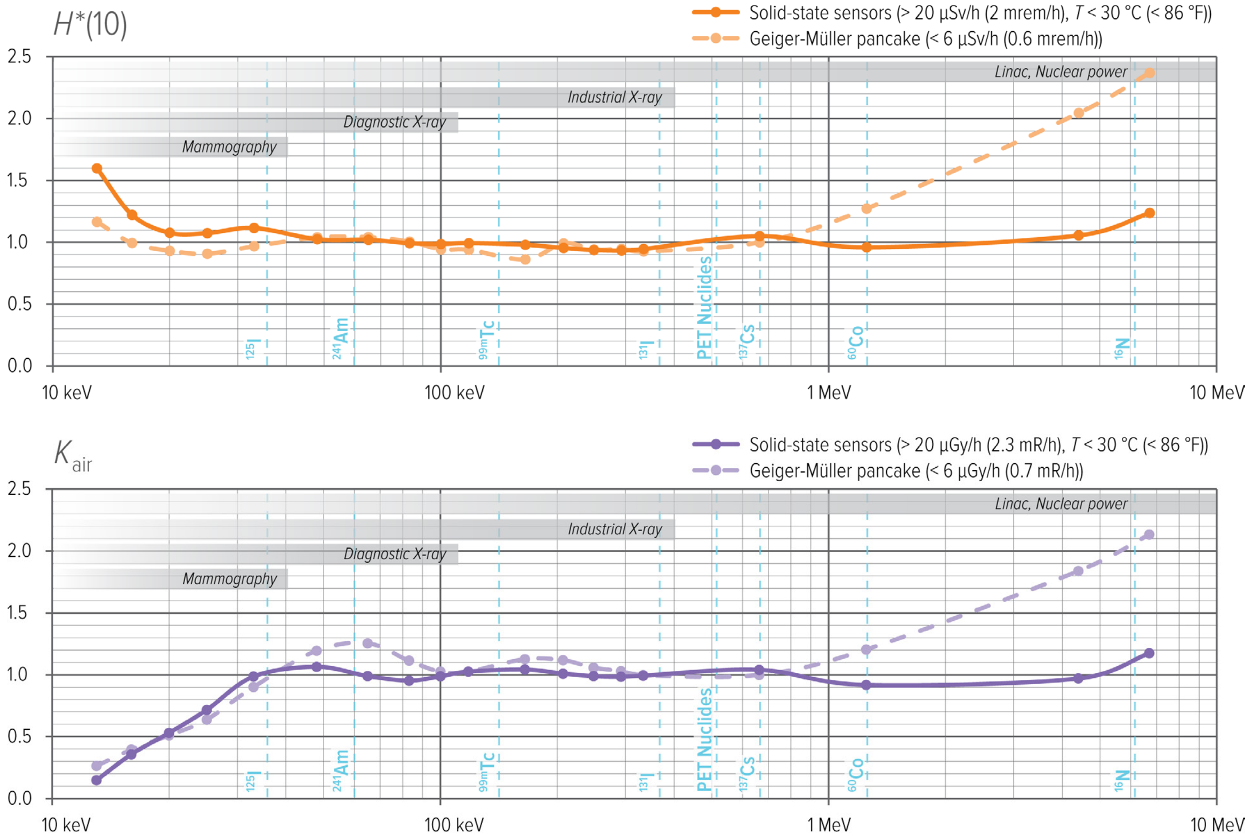

Figure 5: The typical energy response of the RaySafe 452 is shown for narrow beam series N-15 to N-400 and S-Cs, S-Co, R-C, and R-F. Top: Ambient dose equivalent, H*(10). Bottom: Air kerma, Kair. The gray markings indicate the approximate energy ranges of common applications, while the blue dashed lines represent the decay energies of common radionuclides.

The integration of two different technologies allows for a balanced performance. The GM pancake detector is utilized for its speed and sensitivity at low dose rates, where solid-state sensors may suffer from thermal noise. Frequent dead-time corrections from the GM pancake help ensure a flat response even at short radiation pulses. Conversely, the solid-state sensors handle high dose rates effectively, where the GM pancake might otherwise saturate.

Figure 6: The RaySafe 452 survey meter was tested outdoors for approximately two and a half years, demonstrating its ability to withstand challenging environmental conditions, including summer heat, winter cold, rain, storms, and everything in between.

Comparative Performance Study – Key Findings

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新型ハイブリッドサーベイメータの基本特性
—空間散乱線量の測定に関して—

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Fundamental Characteristics of a Hybrid Survey Meter —Measurement of Scattered Radiation—

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The exposure of workers in general medicine is mainly X-ray exposure due to scattered rays from the subject. Therefore, the measurement of such scattered radiation is necessary for confirmation of exposure situation and radiation protection. Recently, the new hybrid survey meter RaySafe 452 was released by Unfors RaySafe. However, there are no detailed reports regarding the performance, which includes reproducibility and angular dependence, of RaySafe 452 survey meter. The purpose of this study was to evaluate the performance of RaySafe 452 survey meter. Experiments were conducted to compare the performance of RaySafe 452 survey meter with that of an ionization chamber survey meter. The results showed that the basic performance of the RaySafe 452 survey meter was good compared with the calibrated ionization chamber survey meter.

Key words: scattered radiation, radiation protection, occupational exposure

[doi:10.11269/jjrsm.21.2]

Figure 7: "Fundamental Characteristics of a Hybrid Survey Meter – Measurement of Scattered Radiation"[1)] issued by the Department of Radiological Examination and Technology at Tohoku University School of Medicine, Japan, September 2021.

A study by Tohoku University[1)] compared the RaySafe 452 with traditional ion chamber meters, highlighting several key performance advantages:

- **Reproducibility:**
  The RaySafe 452 showed consistent performance across different voltages, matching the reliability of ion chambers.
- **Energy Dependence:**
  It maintained accuracy within ±5% across the 50-110 kV range.
- **Dose Rate Dependence:**
  Variations were within ±2% across various dose rates.
- **Dose Linearity:**
  The RaySafe 452 exhibited nearly equivalent linearity to ion chambers, but excelled in measuring low doses, detecting as low as 0.013 µSv, compared to 0.1 µSv for ion chambers.
- **Angular Dependence:**
  It maintains high sensitivity from various angles, enhancing its utility in complex measurement scenarios.

Applications in Medical Fields

Ionizing radiation is essential in medical procedures, including diagnostic imaging, nuclear medicine, and radiotherapy. Despite its benefits, exposure to ionizing radiation poses health risks, making it crucial to monitor and control radiation levels to help protect both patients and healthcare workers.

Radiation survey meters are vital for detecting and quantifying radiation, helping to minimize unnecessary exposure. In medical settings, the RaySafe 452 is a convenient instrument for radiation safety measurements:

- **Monitor Radiation Levels:** In diagnostic radiology, including checking for X-ray tube and wall leakage to help ensure radiation exposure remains within safe limits.
- **Measure Scattered Radiation:** In operating rooms and areas with X-ray machines and linear accelerators, helping to maintain safe working conditions.
- **Detect and Quantify Contamination:** In nuclear medicine departments to help ensure radioactive materials are properly contained and managed safely.

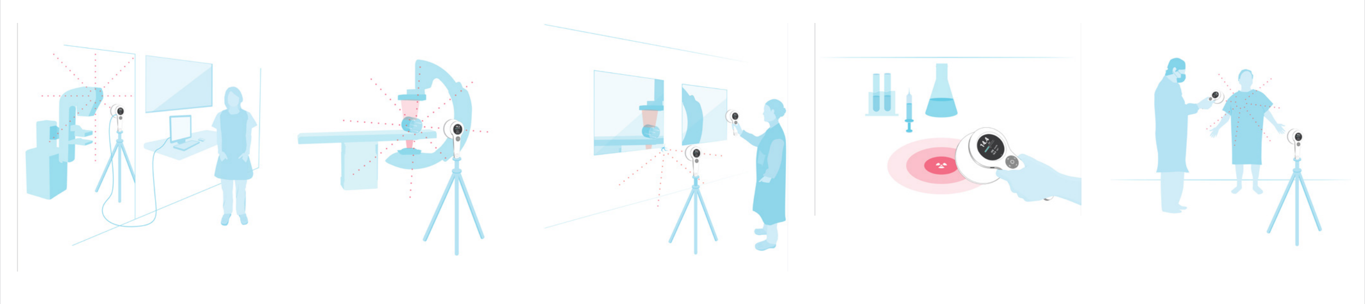

Figure 8: Medical measurement applications, from left to right:
Tube Leakage, Scattered Radiation in the Room, Wall Leakage, Contamination, Control of Treated Patient.

Area	Example of applications	Radiation type	Measurement quantity (units)	Approximate energy range (min-max)
Diagnostic imaging	Tube leakage and scatter from X-ray machines	X-rays	• Air kerma, K_{air} [Gy] • Exposure, X [R] • Absorbed dose to air, D_{air} [rad, Gy] • Ambient dose equivalent, $H^*(d)$ [Sv, rem] • Directional dose equivalent, $H'(d)$ [Sv, rem]	10 – 150 keV
Nuclear medicine	Contamination from radioactive isotopes Control of patients with an intake of radioactive isotopes	α, β, γ	• Counts [cps, cpm] • Activity [Bq/cm^2] • Directional dose equivalent (β), $H'(d)$ [Sv, rem]	α: 5 – 8 MeV β: 30 keV – 3 MeV γ: 30 keV – 1.25 MeV
Radiotherapy	Leakage and scatter from medical linear accelerators	X-rays (Neutrons)	• Air kerma, K_{air} [Gy] • Exposure, X [R] • Absorbed dose to air, D_{air} [rad, Gy] • Ambient dose equivalent, $H^*(d)$ [Sv, rem] • Directional dose equivalent, $H'(d)$ [Sv, rem]	100 keV – 24 MeV

Table 1: Examples of radiation survey meter applications in hospitals, including measurement quantities, units, and approximate energy ranges. The depicted energies span from scattered radiation to the maximum setting on the machine.

Industrial Applications

The versatility of the RaySafe 452 extends beyond medical applications into various industrial fields, helping to ensure that equipment and environments are safe for workers. Below are some examples of its applications.

Non-Destructive Testing (NDT)

- **Checking Material & Components:** X-rays are used to detect defects in materials, components, and assemblies in industries such as automotive, plastics, aerospace, and electronics.
- **Construction:** X-rays are used to identify cracks and other issues in materials or welds in various construction, including pipes, vessels, bridges, and buildings.

Scanning

X-rays are used for scanning in airport and border controls, as well as in the food and pharmaceutical industries.

Measurements Using Radioactive Sources

Nuclear gauges are used to measure liquids and solids in storage tanks across industries such as oil & gas, metals, and mining.

Environmental Radiation Monitoring

Radiation detection instrumentation is crucial for first responders to help ensure safety before entering an emergency scene.
Environmental radiation measurements are also conducted around nuclear facilities to help ensure compliance with safety regulations and protect the public from a potentially harmful exposure.

Figure 9: The RaySafe 452's ability to measure different types of radiation in any environment makes it suitable for detecting hazards.

Conclusion

The RaySafe 452 Radiation Survey Meter represents a significant advancement over traditional ion chamber devices through its hybrid sensor technology. By combining semiconductor and GM tube technologies, it offers high accuracy and repeatability across a wide range of measurement conditions. This hybrid approach makes the RaySafe 452 a robust, reliable, and versatile solution for complex radiation measurement tasks.[1)4)]

Its user-friendly design, high sensitivity, broad energy range, fast response time, and comprehensive measurement capabilities make the RaySafe 452 an essential tool for both medical and industrial professionals.

The hybrid technology not only matches but often exceeds the performance of traditional ion chamber survey meters. By addressing the limitations of ion chambers, the RaySafe 452 enhances the effectiveness of radiation exposure monitoring and control, helping to ensure safety across various applications.

For detailed specifications and resources, visit www.RaySafe.com/RaySafe452.

4. "RaySafe 452 Radiation Survey Meter Product and Specification Brochure"

RaySafe

We empower our everyday heroes to focus only on protecting lives.

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