Managing Interference Radiation in Nucleonic Level Measurements

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***Abstract*—In this paper we will identify common sources of interference radiation, and explain how they affect nucleonic measurements. Also we will elaborate how Berthold with its highly sophisticated RID feature helps plant operators to maintain a reliable and repeatable measurement.**

I. Introduction

Radiometric measurements for industrial processes have been around for many years. They are a mainstay in making the most difficult level, density and bulk flow measurements. Nuclear measurement gauges work where no other technology will. They give excellent performance under hostile and rugged conditions. High temperatures, pressures and other difficult industrial processes usually pose no problem for a nuclear measurement. Typical measurement tasks include level measurement in reactors, any kind of vessels or tanks, density measurement, phase separation levels in oil separators or measurement of moisture content. Also, they can be used as contactless limit switch.

A. *What is a Radiometric Measurement?*

Nuclear measurement gauges operate on a simple yet sophisticated concept – the principle of attenuation. A typical radiometric measurement consists of

- A source that emits γ-radiation, produced from a nuclear radioisotope
- A vessel or container with process material under investigation
- A detector capable of detecting γ-radiation.

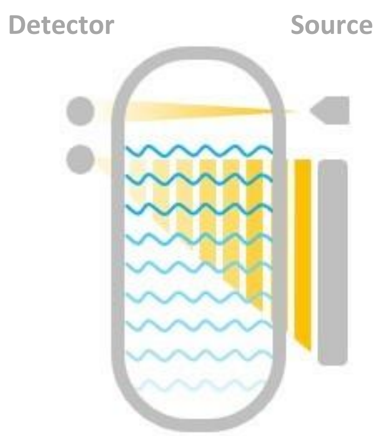


Fig. 1. Schematic of Radiometric Measurement

If there is no or little material in the pathway of the radiation beam, the radiation intensity will remain strong. If there is something in the pathway of the beam, its strength will be attenuated. The amount of radiation detected by the detector can be used to calculate the desired process value. This principle applies to virtually any nuclear measurement.

Nuclear measurement technology is highly reproducible. Using the laws of physics and statistics as well as sophisticated software, the success of making any nuclear-based measurement is almost 100 percent. Considering the benefits of a totally non-contacting and non-intrusive technology, nuclear measurement technology becomes the number one method for the most difficult and challenging process measurement applications.

1) *Radiation Sources*

There are many known natural and artificial isotopes, not all of them are used for radiometric measurement. In industrial applications only, a few nuclides are really used for measurement purposes. The radioactive isotope is usually placed in a rugged, steel-jacketed, lead housing for maximum safety. The housing shields the radiation, emitted from a radioactive isotope, except in the direction where it is supposed to travel. Using a small collimated aperture in the shielding, the beam can be projected at various angles into the pipe or vessel. This warrantees a high quality of measurement with minimal exposure of personnel to radiation. Basically, the ALARA (As Low As Reasonably Achievable) principle for maximum work safety applies on everything that has to do with nuclear isotopes.

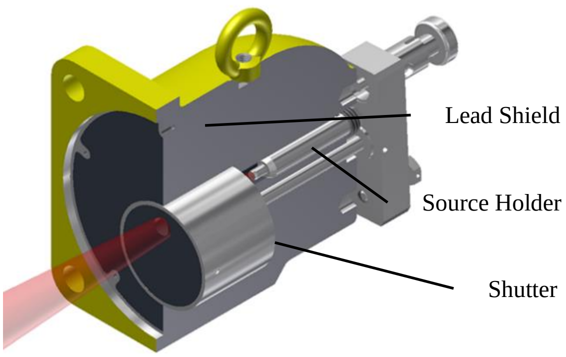


Fig. 2. Source container (shield) of a point source

2) Detectors

The radiation detector contains a crystal made from a special polymer material or an inorganic crystal, like doped sodium iodide – the so-called scintillator. The scintillator converts the incoming gamma particles into flashes of visible light. The crystal is optically coupled to a photo multiplier tube, which converts light into electrical pulses. While the vacuum photomultiplier has been used successfully for decades, nowadays silicon photomultipliers (SiPM) are also available and have made their way to being used in industrial detectors.

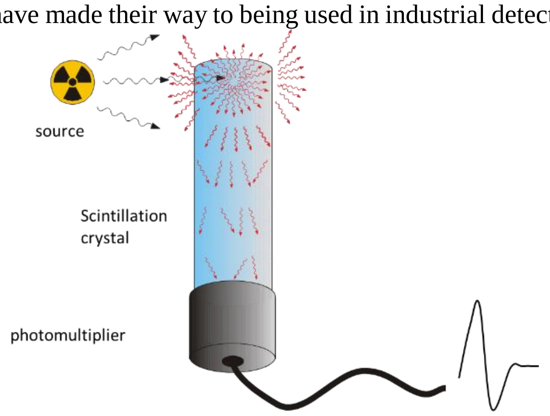


Fig. 4. Detector Makeup

Fig.4. shows schematically how a detector works. When the radioactive beam strikes the crystal, after having passed through the walls of the vessel, pipe and the process itself, each gamma photon in the beam generate a light flash, resulting in thousands of subsequent light pulses that are recorded by the photomultiplier tube. Each light pulse is converted into electrical pulses by the photomultiplier. After digitizing of the signal, these pulses are counted to determine a so-called count rate, which is typically expressed as counts per second (cps) or frequency (Hz). The intelligence that distinguishes between various measurement tasks (i.e. level or density) with the designated media, is implemented in the transmitter or control unit. The count rate is used to deduct a process related signal which can be used for a display, an analogue current output or bus connections into a DCS or PLC.

The detector measures any γ-radiation arriving in the scintillator, without distinction of "useable count rate" deriving from the source or natural background radiation from the environment. We will learn later how interference radiation coming from weld inspection but also changes in natural background radiation, etc. can be handled.

a) Point Detectors

Detectors with a small scintillator are called point detectors. They often employ a small cylinder as scintillator, e.g. 50 mm diameter and 50 mm in height. They are typically used for density applications but also for level switch or continuous level measurements. Depending on the measurement task other scintillator sizes may be used. Due to the small sensitive volume of a point detector, the effect of background radiation is small. Additionally, point detectors can be easily equipped with a lead collimator to further suppress sensitivity to background radiation.

b) Rod Detectors

In some cases, it is beneficial to have the scintillator covering a longer range, this is called a rod detector. Typically, in level measurements either source or detector span the whole measuring range. Their length can be up to 8 m. The main benefit of a rod detector is its lower cost compared to a rod source. Albeit, the rod source would be the technologically superior system. The gamma radiation, which a rod detector is able to detect, is influenced by the geometry of the radiation array.

However, as rod detectors are typically not shielded (and shielding would diminish the cost advantage) they are much more sensitive for changes in natural background radiation making this effect dominant to most other errors. Especially considering that fluctuations of ±15% through accumulation of Radon-222 and its decay products, e.g. after rain, are possible.

3) Calibration

Nuclear gauges work with the principal of attenuation. Basically, every matter interacts with γ-radiation and has an attenuating effect. Under process control perspective, this is not only the media to be measured, it is also the steel walls of the vessel, potential inside construction, insulation, framework, etc.

In every measurement it is necessary to manage the statistical and systematic~~al~~ errors, by applying stochastic methodologies. Besides that there are other error sources, that cannot be handled without additional provisions.

4) Temperature and Aging Effects

Can be reduced by applying top notch compensation methods. Sophisticated algorithms and methods independently measuring the sensitivity of a detector by comparing the signal to a known reference can be used to compensate for these effects. Such an automatic gain control or high voltage control should be included into the measurement system. For example, the algorithms used by Berthold Technologies rely on a spectral analysis of either the radiation received from used primary radioisotope or – even more sophisticated – of cosmic radiation.

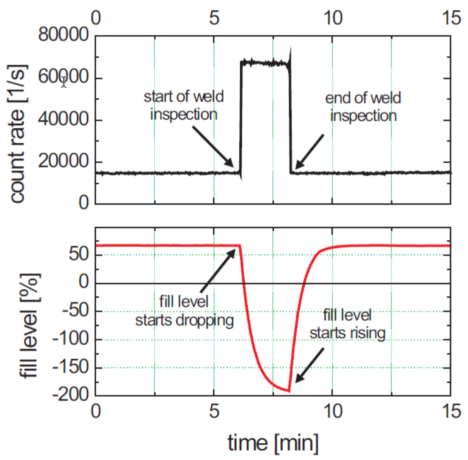
5) *Natural Background Radiation*

Background radiation is mainly caused by cosmic or terrestrial radiation. While the effect from cosmic radiation is very constant, the terrestrial background radiation can vary much depending on your geographic location, as one of the decay products the noble gas Radon-222 (Rn-222) and its decay products, play a major role in the strength of the background radiation. Also, rain can cause a temporary increase of Radon and its decay product's concentration on the ground which inevitably leads to a higher background radiation.

Thus, point detectors are often installed with a collimator to suppress background radiation whereas rod detectors are usually unshielded.

6) *Interference Radiation*

Another unpredictable cause of interferences are ongoing pipe inspections in the plant or complex. Often, gamma sources (i.e. Iridium-192), sometimes with a 10,000 times higher activity than the source of the measuring system, are used. This significant increase of background radiation causes the measured signal to change quickly and drastically, yielding to false readings of the process value and a seemingly dropping fill level.



In case the radiation detector is not well-engineered the signal might go missing much longer than the actual disturbance is present and might even yield to permanent damage of the detector's components.

II. Dealing with Interference Radiation

One way to reduce background radiation, is to protect the detector from noise by applying massive lead shields. But from a customer's point of view this is not very attractive commercially, neither from a mechanical engineering and installation perspective. Also, an independent measurement of the background radiation with a separate detector (not exposed to the radiation of the nuclear gauge) can help to detect and suppress the interference. However, this increases the cost and boosts the complexity of the system and the probability of errors - simply through statistics

A. XIP

Devices using Berthold's X-Ray Interference Protection (XIP) feature, will detect interference radiation independently and freeze the measurement signal during the disturbance. Therefore, the process is not affected by an unrealistic signal reading, however, the measurement does not represent the actual state of the measurement as long the measurement is frozen. The operator is informed about the XIP event by a warning signal. Therefore operators are always aware of a unplanned process condition and can react accordingly to a frozen signal reading. After the disturbance has disappeared the measurement will continue automatically. Typical exposure times of weld inspections are not more than 2-5 minutes, thus that the measurement process is only frozen for a limited time period, which does not pose a problem to most applications.

Please note, that the XIP feature is implemented in every nuclear gauge coming from Berthold Technologies.

B. RID

In applications where process changes happen rapidly or the frozen process signal is not acceptable, the sophisticated RID feature comes to play.

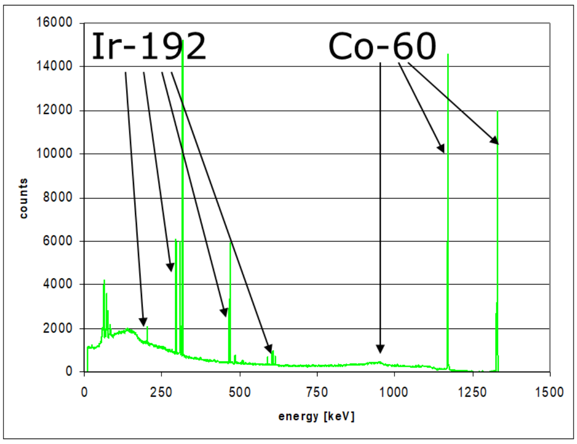
The RID feature (Radiation Interference Discrimination), which is based on a complex algorithm that allows to distinguish between interferences and the real count rate radiated from a Cobalt-60 source of the nuclear gauge. Using this feature the measurement will even continue during the presence of interference radiation.

1) *The nuclide makes the difference*

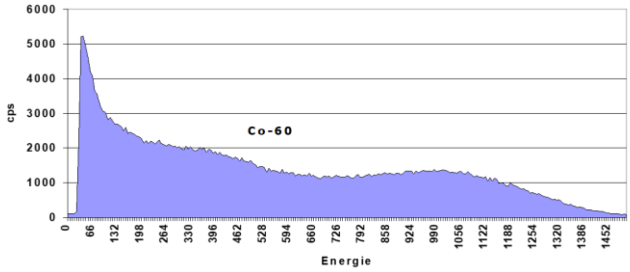
The nuclides employed for weld inspections have different properties from the ones typically used in radiometric level gauges. Berthold Technologies' RID feature exploits this difference to suppress the influence of interference radiation on the measurement. Nearly all weld or material inspections are performed with Iridium-192 or Selenium-75 sources.

The energy of their radiation is low (<600 keV) compared to Co-60 (>1000 keV), commonly used in level gauges.

Berthold detectors measure the energy of each incoming gamma event, and therefore only use events generated through the source of the measurement system.



In theory Iridium – 192 and Cobalt – 60 have their distinct energy and an energy spectrum looks like the above picture. In reality, not every gamma particle deposits his complete energy in the scintillator. Depending how the gamma quant hits the scintillator it leaves without having transformed the full amount of energy. Thus, a real energy spectrum looks like the following graph:

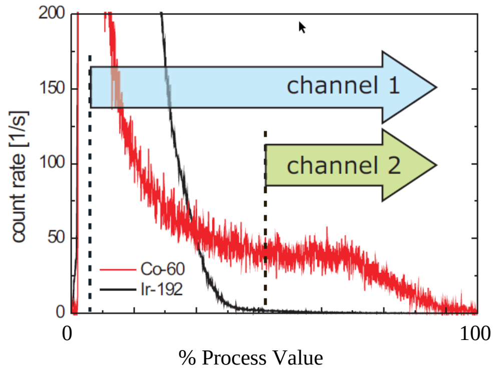


Hence it is not that simple to distinguish a clear energy signature per nuclide, the result is more of a continuous energy spectrum.

2) Always in control

The RID feature basically analyses the energy spectrum of the detected radiation by introducing two measurement channels.

One channel (Channel 1) covers the whole spectrum, means



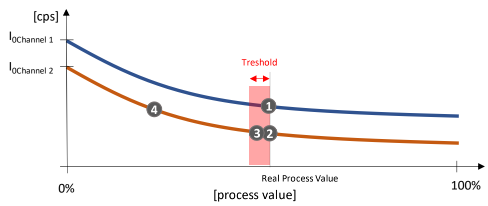
every recognized gamma particle is counted. Another channel (Channel 2) covers the higher energetic pulses only. Thus, lower energy pulses i.e. from weld inspection sources, which do not exceed a certain height are therefore not recorded in channel 2. All pulses above the threshold for Channel are exclusively from the C-60 source of the measurement system.

The system is self-learning and over time the device teaches-in the process value rate for both Channels.

It separately records the readings of both channels and compares them. If the process value for channel 1 and channel 2 is identical or within the threshold (measurement point 1 and 2 or 1 and 3 in the graph below), the system treats that as normal process condition.

In case of a difference in process value greater than the configured threshold, the system automatically identifies that as an interference radiation event and switches measurement to Channel 2 (i.e. measurement points 1 and 4).

The threshold of this switch over can be adjusted in the system setting.



Obviously, this is statistically reducing the overall accuracy of the system, but it is still delivering a correct and reproducible value for the fill level and assures there is no gap in the process control.

In case the system does not detect interference radiation anymore, it automatically switches back to normal operation. The great benefit of RID is a continuous and reliable measurement even under an interference radiation event.

Prerequisite however is, that the energy per gamma quant of the nuclide used for measurement can be distinguished from the interference. Hence, Berthold uses Cobalt – 60 sources together with the RID feature. Due to the continuous self-learning of both channels an extreme long duration of an interference radiation event, would be a limitation to the automatic event recognition.

3) Ease of operation

With the latest Berthold LB 470 – RID product, the configuration of the RID feature has become extraordinarily easy and customer friendly. The operator just needs to tick a checkbox to activate the system. While the second entry, the threshold to activate Channel 2, is pre-set with a default value it could be changed if required.

III. Summary

As we have elaborated in this abstract, Berthold Technologies offers sophisticated products that manage interference radiation and provide the customer with a stable and reliable measurement that allows continuing process, avoids unscheduled shut downs and therefore generate a real value for the customer. We help our plant operators to get RID of their problems with interference radiation and by that, we produce cash for our customers.