Nucleonic Measurement - Safer and More Reliable Than Ever

No need for fear of gamma rays: new developments make nucleonic measurement still safer

Nucleonic gauges can be found everywhere where extreme conditions would mean the end for any other measurement technology. That’s because nucleonic devices measure contactlessly, which makes the measuring systems wear free and practically maintenance free as well. However, since this technology uses radioactive radiation, safety is the top priority. New developments provide not only improved radiation protection, but also optimized process reliability.

The use of radioactivity for level, limit level, density or mass flow measurement has many advantages in comparison with other measuring methods, but also two disadvantages: nucleonic instruments are somewhat expensive and their operation requires special permits and safety precautions. That’s why nucleonics is only used in measurement engineering when measuring probes that protrude into the vessel are not able to handle the measuring task. Indeed, to this day, some areas of application do not allow any alternative to nucleonic measurement. Because only measurement technology using gamma radiation is completely unaffected by high vessel pressures, corrosive media, extreme temperatures or problematic physical product characteristics and able to continuously deliver exact and reliable measuring results. Such demanding measurement applications, which require media to be detected without contact and without gauge maintenance, can be found primarily in large processing installations in the chemical and petrochemical industry, but also in the offshore and oil industry and in cement, power generation and sewage treatment plants.

In 1896, the French physicist Antoine Henri Becquerel discovered the radioactive radiation of uranium, and thus radioactivity itself. But the specific use of radioactivity in industry and technology started only after people were able to produce artificial radioisotopes through nuclear fission. Today, more than 100 years after the discovery of radioactivity, it’s hard to imagine life without it. In medicine, it has revolutionized many areas of diagnosis and therapy, particularly cancer therapy. In industry, it is used for examining welded seams or for quantitative and qualitative substance analysis. But also in the area of industrial measurement, control and process automation, it would hardly be possible to do without radioactive radiation: measurement engineering utilizes the steady, uniform radiative properties of beta and gamma rays for level, density and thickness measurement. Compared with some other applications of radioactivity, nucleonic measurement gets by with radiation sources of relatively low intensity. If protection regulations are adhered to, a radiation hazard is practically non-existent. The radiation intensity of nucleonic devices for measurement of level, limit level, density or mass flow is so low today that a conventional "Geiger counter" does not respond to it at all. But it is nonetheless radioactivity. Therefore, nucleonic gauges must be one thing above all: safe.

All over the world, the so-called ALARA principle applies to radiation protection: "As Low As Reasonably Achievable." This means: radiation exposure has to be kept as low as possible. But what if a malfunction occurs that perhaps at first doesn’t have anything to do with the radioactive part of the measuring device ? The built-in safety functions must then take over. A sign of the high quality of the safety functions of a device is the SIL mark. "SIL" stands for

“Safety Integrity Level” and serves as an evaluation of electronic systems with regard to the reliability of their safety features. Only if the entire system, including the software, provides a maximum degree of safety, not only in normal operation but also in case of failure, will the device receive the SIL certificate. There are two ways to get the SIL certificate: one is through so-called "service-proven technology", i.e., a defined minimum number of devices is already in use over a defined time period, so the device is considered reliable in its function. The second way is SIL-certified device development. Here, the international norm IEC/EN 61508 precisely defines the strategy in the individual development stages. All devices developed according to SIL operate with the proverbial "belt and braces" approach: security-relevant functions and components are often redundant, so that the device can fall back on the twin function automatically if the first one fails.

Until now, point level sensors were the only nucleonic gauges that did justice to the high requirements of the SIL certificate. As of late however, nucleonic devices developed according to SIL specifications for continuous level measurement and level detection as well as interface and density measurement are also available on the market. To provide that plus in safety, which was the decisive factor for SIL certification of these nucleonic gauges, new developments have focussed on three points. First: enhancement of the responsitivity of the scintillation detector. Second: improvement of the radiation protection containers. Third: selection of a suitable radioactive material.

But back to the beginning: the nucleonic measuring principle is based on the fact that gamma rays are weakened when they penetrate matter. At first glance, a nucleonic gauge is not really that much different from other gauges which operate according to the same principle, using radar, ultrasound or microwaves: they consist of a transmitter, a receiver and a processing electronics which converts the measured signals into correct level, limit level, density or mass data. The transmitter sends signals in the direction of the medium that is to be measured. These signals are picked up by the receiver installed on the opposite side of the medium. The larger the amount or density of the medium, the more the signals are attenuated on their way to the receiving device. From the strength of the incoming waves, impulses or beams, the software can calculate how full a container is, how great the density of a medium is – and much, much more.

The difference between nucleonic and other gauges: the first obvious thing is of course the radiation protection container, which encloses the capsule with the barely rice-grain-sized particle of radioactive isotope. This radiation protection container allows the radiation to exit only in the direction of the receiver (detector) and shields off the radiation in all other directions. Modern detectors contain a scintillator, a photomultiplier and an evaluation electronics. Scintillators are some of the most sensitive nuclear-physical measuring instruments: they react to even the tiniest amounts of radioactive radiation, which allows comparatively weak radioactive preparations to suffice as a radiation source. Impinging gamma radiation generates flashes of light in the crystal or plastic scintillator. These flashes of light reach a photomultiplier, which amplifies them and converts them into electrical impulses. The impulse rate, that is, the number of impulses per second, is a measure of the intensity of the radiation. Depending on how the device was calibrated, the impulse rate is converted by the processing electronics into a level, switching, density or concentration signal.

VEGA Grieshaber KG in Schiltach – widely known as the technology leader in the area of radar level measurement – recently extended its line of products with the "PROTRAC" series of nucleonic gauges. In the process, the company actually improved the established safety standards for nucleonic gauges. This resulted in the first nucleonic devices to be developed in compliance with SIL specifications for continuous level measurement, level detection as well as interface and density measurement.

The developers began with the points already mentioned: as a first step they increased the responsitivity of the scintillation detector. This way, radiation sources with low radiation activity suffice for the new devices. By way of comparison: the natural radioactive radiation present at an altitude of about 3000 meters is more intensive than the radiation the new detector needs to provide high-precision measuring results. Next, the VEGA developers focussed on the radiation protection container. This component has two functions: on the one hand, it protects the surroundings from the radiation. On the other, it protects the capsule containing the radioactive material from mechanical or chemical damage. With the new radiation protection container generation SHLD, which already today fulfills the radiation protection requirements of tomorrow, the capsule is safely "wrapped" in every respect: the radioactive preparation is completely enclosed by multiple, hermetically welded stainless steel capsules, which satisfies the highest classification and strictest safety criteria according to ISO 2919. The capsule is then placed in a cast metal housing, where it finally receives a protective cast lead mantle. As a result of its design, the radiation protection container offers maximum protection with minimal weight. Only a narrow slit remains open through which the radiation can exit, focussed in the direction of the detector. The radiation outlet is adapted to the respective application and can be closed off completely when required: the SHLD radiation protection container can be pneumatically or electrically closed, for example when maintenance work has to be carried out on the vessel the nucleonic gauge is mounted on. It is no longer necessary to have people come into direct contact with the detector: thanks to bus systems and DTM/EDD, the detector can be parameterized directly from the process control system.

From a safety-engineering standpoint, the most important element in a nucleonic gauge is of course the radioactive preparation itself. That’s why the measurement technology experts have taken a very close look at the different radionuclides that come into question as possible radiation sources. They came to the realization that each measurement application requires an individual decision about which factors are important for the measurement. "Until now, we always had to do a balancing act with respect to the time constants in the measurement", says Winfried Rauer, project manager for nucleonic sensors at VEGA. "There were either exceedingly precise or exceedingly fast results. Whoever wanted both had to go for a stronger radioactive radiation source."

To fulfill both wishes at the same time with low radiation intensity, the measurement technology specialists at VEGA have developed a special adaptive measuring filter that automatically determines the optimal time constant: if the measured medium changes fast, the filter switches over to a short integration time. Slow measured value changes, however, lead to a longer time constant in the detector and therefore to high measuring precision. "This way, the cesium isotope Cs-137 is adequate in 80 to 90 per cent of all applications", explains Winfried Rauer. "We use the more strongly radiating cobalt-60 isotopes almost only when baked-on deposits are expected or when very thick vessel walls have to be penetrated." The weaker cesium-137 preparation has two decisive advantages: Firstly, cesium-137 can be shielded much better than cobalt-60 in the radiation protection container. Secondly, the long half-life of a radioactive Cs-137 source makes possible a long service life without source exchanges. In the case of Co-60 radiators, a source exchange is necessary after about seven years due to the shorter half-life. "And every source exchange means additional exposure to radiation", says Rauer.

Nucleonic gauges are being used in more and more areas of process engineering. They are no longer used only for level detection and continuous level measurement under extremely difficult measuring conditions but also for interface, density and concentration measurement in connection with toxic or abrasive liquids, for mass flow measurement, e.g. on dredgers, or as belt weighers for throughput measurement in mines, among other places. This means more and more people are handling these devices. As a result of safety-related improvements, the detector is more sensitive; therefore, the dose rate that operating staff are exposed to in the vicinity of the PROTRAC detector is considerably less than 1 microsievert per hour (µSv/h). Again a comparison: every person on earth is exposed to a natural radiation dosage that is far higher. In Germany, the average value of terrestrial radiation exposure is 350 µSv per year. The consumption of 170 liters of mineral water in one year exposes us to, believe it or not, an average of 100 µSv, which is just about as much as a flight from Frankfurt to New York and back. And one single CAT scan in the area of the abdomen exposes us to a dosage of 10,000 to 25,000 microsieverts.

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Photo 1:

More sensitive detectors, sources with lower radiation intensity, improved radiation protection containers: that’s the look of nucleonic gauges of the future.

Photo 2:

Because it’s scorching hot in the production processes of some industries, there is no alternative to nucleonic measurement. So it’s all the more important that, in the development of nucleonic gauges, safety takes center stage.

Photo 3:

Under lock and key: The radioactive source sits in a multi-layered radiation protection container which protects the source capsule from damage. The radiation is focussed and directed in a narrow beam to the detector.