WhitePaper

RADIATION INTERFERENCE DISCRIMINATION (RID)

Managing interference radiation in radiometric level measurements

BERTHOLD

Introduction

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

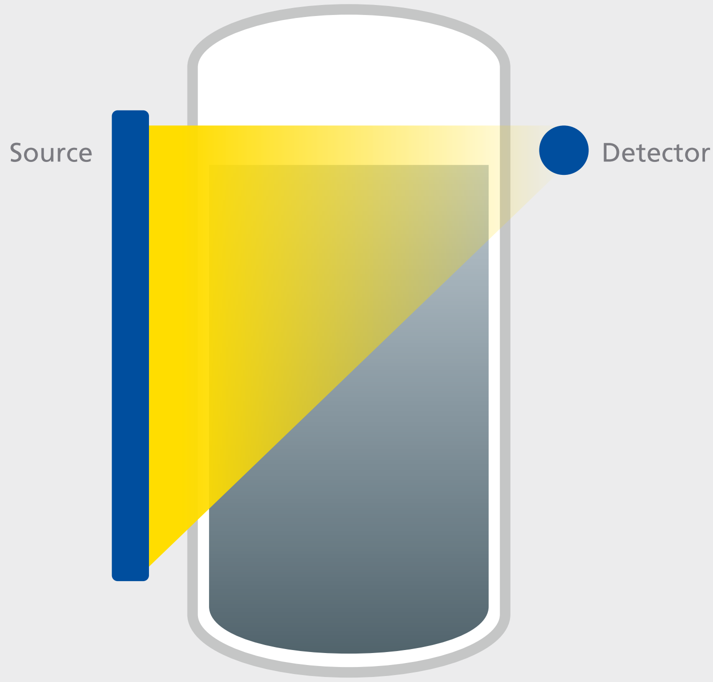
What is a radiometric measurement?
Nuclear measurement gauges operate on a simple yet sophisticated concept – the principle of attenuation. A typical radiometric measurement consists of

- 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.

If there is no or little material in the pathway of the radiation beam, the radiation intensity will remain strong. If there is any material 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, nuclear based measurements are extremely successful. Considering the benefits of a totally non-contacting and non-intrusive technology, nuclear measurement technology is the number one method for the most difficult and challenging process measurement applications.

Fig. 1 Schematic of radiometric measurement



Radiometric Measurement

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 actually 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 to everything that has to do with nuclear isotopes.

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 photomultiplier tube, which converts light into electrical pulses. While the vacuum photomultiplier has been used successfully for decades, nowadays silicon photomultipliers (SiPM) are equally available and are widely used in industrial detectors.

Figure 2 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 material 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 ɣ-radiation reaching the scintillator, without distinction of "useable count rate" deriving from the source or natural background radiation from the environment. We will not only learn later on how interference radiation coming from weld inspection can be handled for example, but also how changes in natural background radiation, etc. can be dealt with.

There are two different types of detectors available: Point and rod 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.

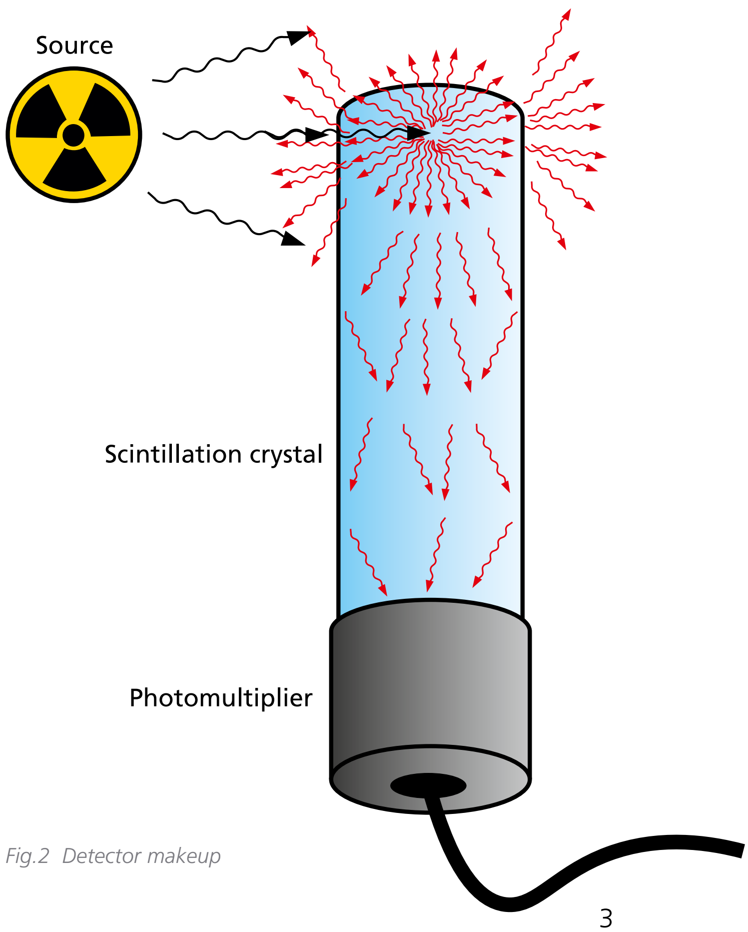


Fig.2 Detector makeup

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 (shielding would also diminish the cost advantage) they are much more sensitive to changes in natural background radiation making this effect the most dominant error. Especially considering that fluctuations of ±15% through intensification of Radon-222 and its decay products, e.g. after rain, are possible.

Calibration

Nuclear gauges work with the principal of attenuation. Basically, every matter interacts with ɣ-radiation and has an attenuating effect. From process control perspective, this is not only the media to be measured, but also the steel walls of the vessel, potential inside construction, insulation, framework, etc. Therefore it is mandatory to calibrate the measurement system on site.
In every measurement it is necessary to manage the statistical and systematic errors, by applying stochastic methodologies. Besides this, there are other error sources that cannot be handled without additional provisions.

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 these effects. An automatic gain control or high voltage control should be included in the measurement system. For example, the algorithms used by Berthold rely on a spectral analysis of either the radiation received from the used primary radioisotope or – even more sophisticated – from cosmic radiation.

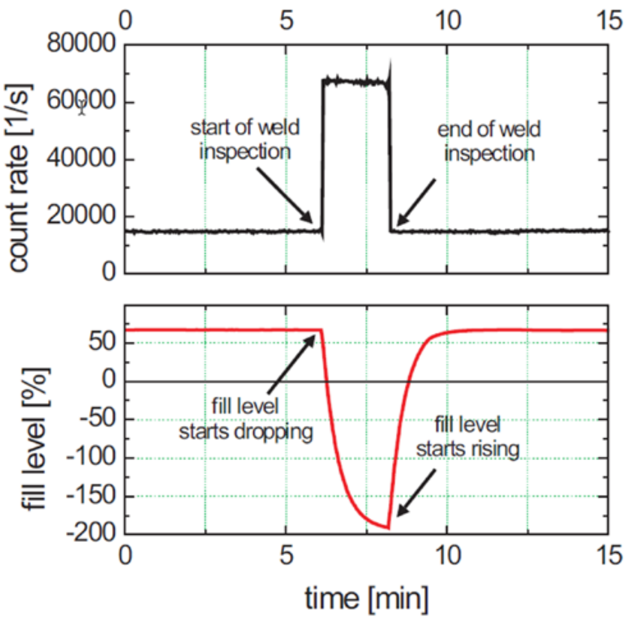
Natural Background Radiation

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. For example, 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.

Interference Radiation

Another unpredictable cause of interferences are ongoing pipe inspections in the plant or complex. 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, generating false readings of the process value and a seemingly dropping fill level.
In case the detector is not well-engineered the signal might go missing much longer than the actual disturbance is present and might even cause permanent damage to the detector.

Fig.3 Behavior of counting rate or filling level during weld inspection



Dealing with interference radiation

One way to reduce background radiation is to protect the detector from noise by using huge lead shields. However from a customer's point of view this is not very commercially attractive, neither from a mechanical engineering nor from an installation perspective. An independent measurement of the background radiation with a separate detector (not exposed to the radiation of the nuclear gauge) can also help to detect and suppress the interference. However, this increases the cost and adds to the complexity of the system and the probability of errors – simply through statistics.

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 genuine state of the measurement as long the measurement is frozen. The operator is informed about the XIP event by a warning signal. Thus operators are always aware of an unplanned process condition and can react accordingly to the frozen signal reading. After the disturbance has come to an end, the measurement continues automatically. Typical exposure times of weld inspections are no more than 2-5 minutes; accordingly the measurement process is only frozen for a limited time period, which does not pose too many problems for most applications.

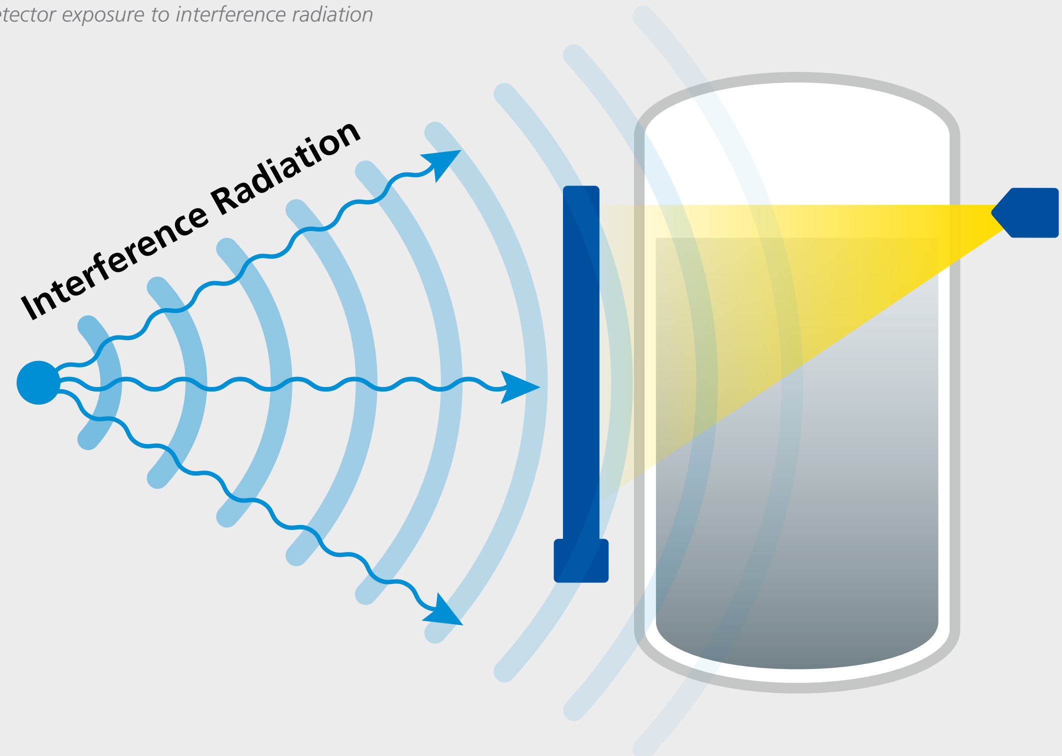
Please note, that the XIP feature is implemented in every nuclear gauge coming from Berthold.

RID

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

The RID feature is based on a complex algorithm that distinguishes between interferences and the real count rate radiated from a Cobalt-60 source of the nuclear based measurement. Using this feature the measurement will even continue when interference radiation is present.

Fig.4 Detector exposure to interference radiation



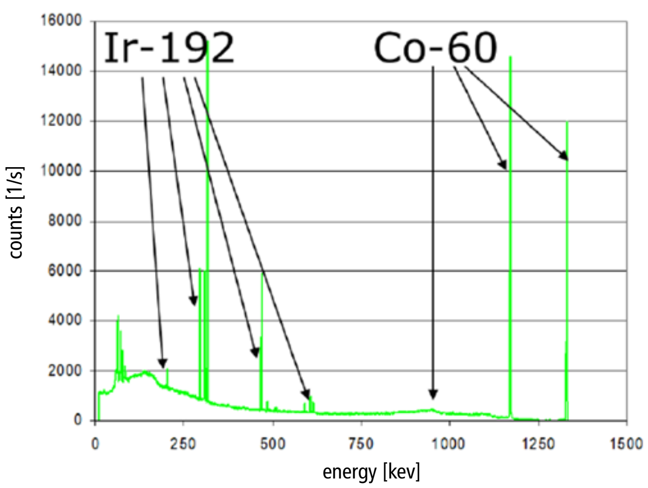
The nuclide makes the difference

The nuclides employed for weld inspections have different properties from the ones typically used in radiometric level gauges. The Berthold RID feature exploits these differences 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 (<600 keV) is low 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.

Fig.5 Energy spectrum of nuclides typical for industrial use

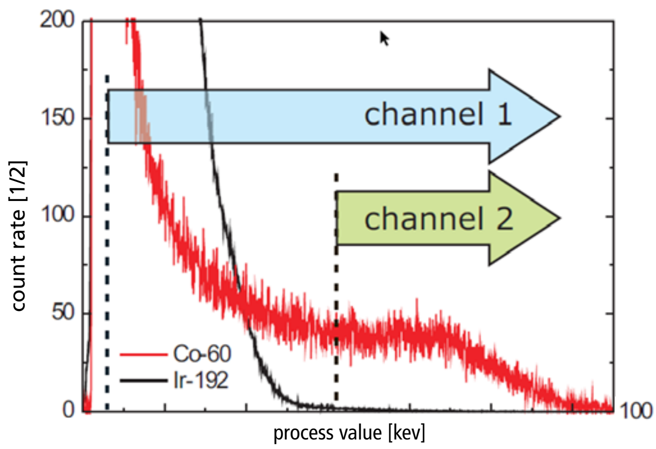


In theory Iridium-192 and Cobalt-60 have their own distinct energy spectrum as can be seen in the above picture. In reality, not every gamma particle deposits its complete energy in the scintillator. Depending on how the gamma quant hits the scintillator, it leaves without having transformed the full amount of energy. Thus, a real energy spectrum looks like the graph in figure 6. Hence it is not that simple to distinguish a clear energy signature per nuclide, the result is more of a continuous energy spectrum.

Always in control

The RID feature basically analyses the energy spectrum of the detected radiation by introducing two measurement channels (see figure 7).

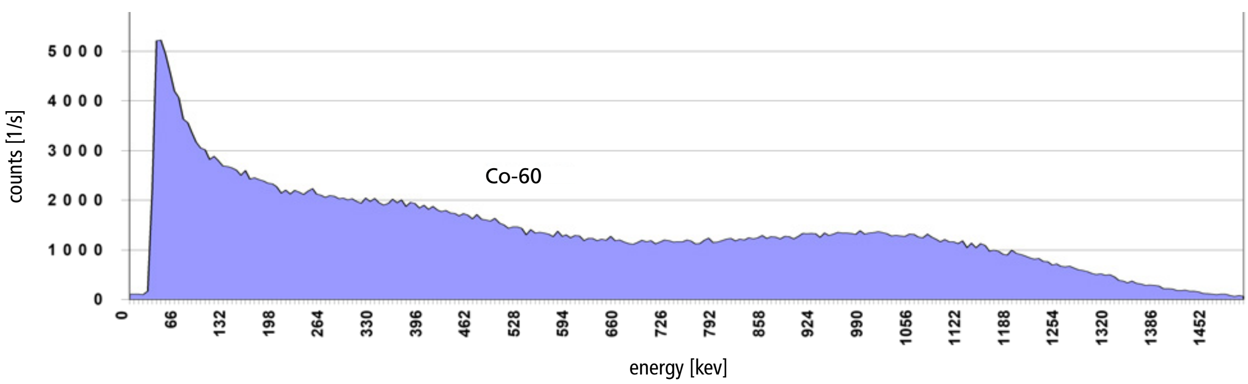
Fig.7 Separation of energy spectrum in two mesurement channels



One channel (channel 1) covers the whole spectrum, meaning every recognized gamma particle is counted. A second 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 energy are not recorded in channel 2. All pulses above the threshold for channel 2 are exclusively from the Co-60 source of the measurement system.

The system is self-learning and over time the device adapts the process value rate for both channels.

Fig.6 Engery spectrum detected with a scintillation detector

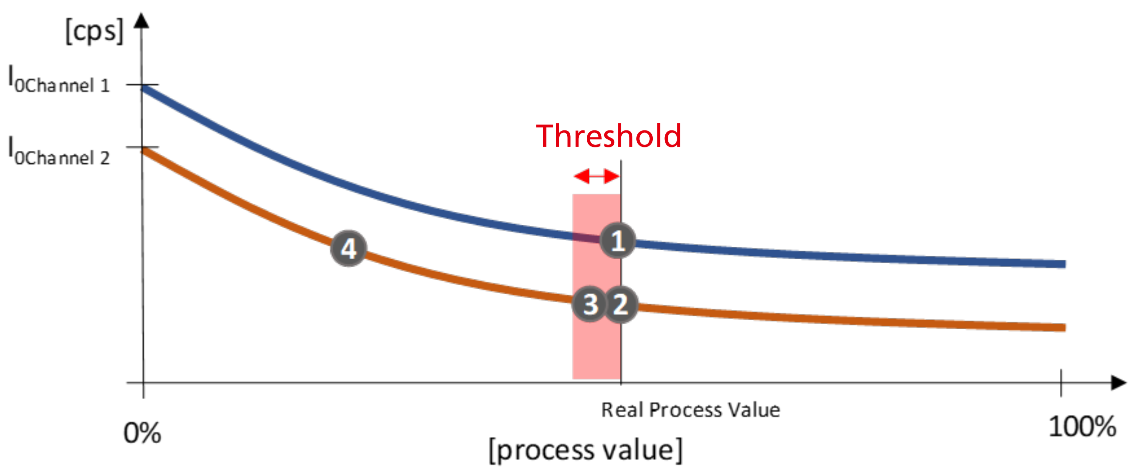


It records the readings of both channels separately and compares them. If the process value for channel 1 and channel 2 is identical or within the threshold (measurement point 1 and 2 or 1 and 3 in figure 8), the system treats this as a normal process condition.
In case of a difference in process value greater than the configured threshold, the system automatically identifies this as an interference radiation event and switches measurement to channel 2 (i.e. measurement points 1 and 4 of figure 8).
The threshold of this switch over can be adjusted in the system setting.
Obviously, this statistically reduces the overall accuracy of the system, however a correct and reproducible value is still provided for the fill level and assures there is no inconsistency in process control.
In case the system does not detect any more interference radiation, it automatically switches back to normal operation. The great benefit of RID is a continuous and reliable measurement despite 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 extremely long duration of an interference radiation event, may cause a failure in recognising this as an abnormal event.

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. The threshold to activate channel 2 is pre-set with a default value, but can be changed if required.

Fig.8 Working principle of the RID feature



Summary

As we have elaborated in this abstract, Berthold offers sophisticated products that manage interference radiation and provide the customer with a stable and reliable measurement that ensures a continuous process, avoids unscheduled shut downs and therefore generate a real benefit for the customer. We help our plant operators to get "RID" of problems caused by interference radiation and in doing so, we save money for our customers.

THE EXPERTS
IN MEASUREMENT TECHNOLOGY

Berthold Technologies stands for excellent know-how, high quality and reliability. The customer is always the focus of our solution. We know our business!
Using our varied product portfolio, our enormous specialized knowledge and extensive experience, we develop suitable solutions together with our customers for new, individual measurement tasks in a wide variety of industries and applications. Berthold Technologies is specialised in radiometric process measurements for 70 years. This is our core competence with state-of-the-art and cutting edge products and solutions covering a vast range of industries and applications.

We are here for you – worldwide!
The engineers and service technicians from Berthold Technologies are wherever you need them. Our global network assures you fast and above all competent and skilled assistance in case of need. No matter where you are, our highly qualified experts and specialists are ready and waiting and will be with you in no time at all with the ideal solution for even the most difficult measurement task.

Whitepaper Radiation Interference Discrimination · DC00620PR2 · Rev.00 · 02-2020

Berthold Technologies GmbH & Co. KG

Calmbacher Straße 22 · 75323 Bad Wildbad · Germany
+49 7081 1770 · industry@berthold.com · www.berthold.com

BERTHOLD