

GLASS LEVEL MEASUREMENT

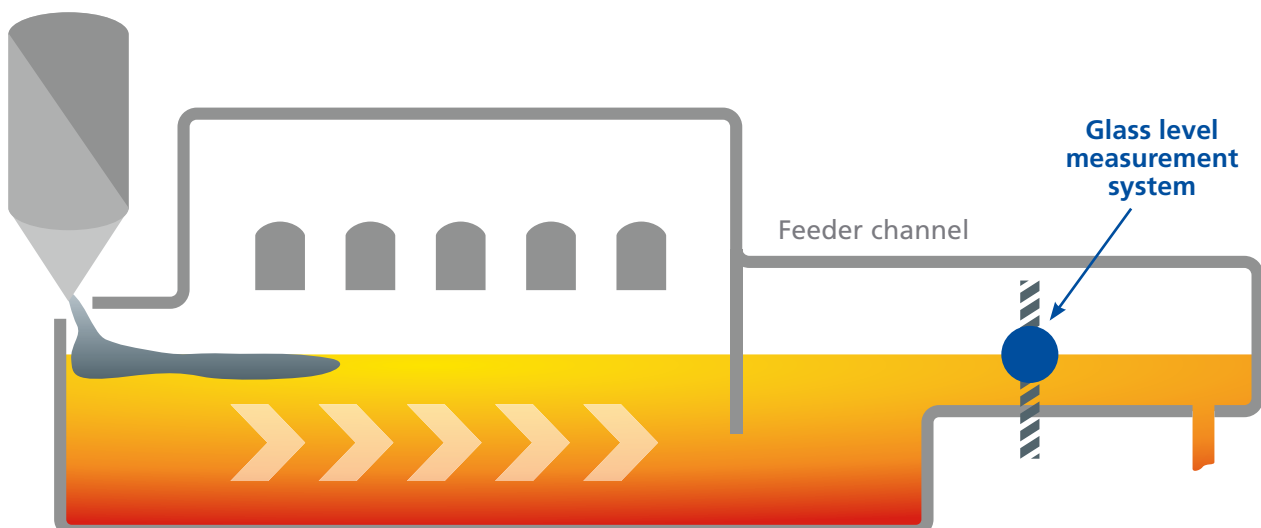
RELIABLE AND SAFE LEVEL MEASUREMENT TO IMPROVE THE GLASS PRODUCTION

Industrial glass melt furnaces are used in glass production to melt raw ingredients (batch) into a molten glass at temperatures exceeding 1200°C. Level control just after the outlet of the melt furnace is one of the main process control challenges to facilitate efficient and high-quality glass production. Due to the harsh conditions, non-contacting measurement methods are mandatory. Standard online furnace level control methods, such as optically based technologies like lasers, do not produce reliable and reproduceable results without constant, almost daily, maintenance and upkeep. Furthermore, optically based measurements require the refractory to be completely removed, hence exposing the furnace heat and gases to nearby workers what is creating a potential risk for workplace safety incidents.

Radiometric based level measurements offer best in class reliability and safety for the glass industry to aid in streamlining glass production and producing consistent quality glass while minimizing costs and maximizing throughput.

Glass level at the feeder channel

Glass comes in all shapes and sizes. From optical lenses, building materials and bottles, to toothpaste additives, glass is a part of our everyday lives. Glass manufacturing also takes many shapes and sizes, but to create glass, a raw ingredient mixture or “batch” must first be melted. Melt furnaces are large enclosures with dense refractory brick layers on all sides including at times a refractory roof.



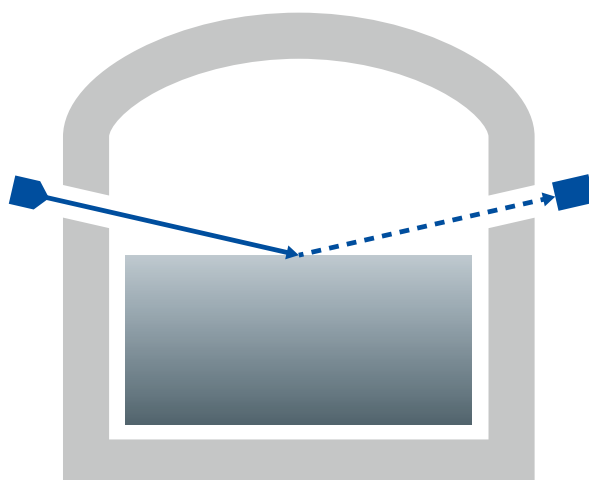
Such furnaces utilize gas or electric power to “fire” the raw ingredients into a molten state with process temperatures maintained above 1200°C during furnace operation. The molten “batch” slowly progresses and churns from one end of the furnace to the other over the course of a ~ 24 - 48 hour residence time. Upon leaving the furnace, the molten material enters what is known as the feeder channel. The feeder channel is the main channel that feeds any number of molten glass tributaries. At the end of each tributary is a glass “pull” where the molten glass is pulled via gravity from underneath the tributary and further processed depending on the form of the final product. The figure above gives an overview of the furnace and its control.

Reliable glass level measurement and control at the beginning of the feeder channel is necessary for a streamlined and efficient glass production as well as consistent glass quality. Traditional offline glass level measurements or dip checks are performed manually on a schedule. To perform such a dip check an operator inserts a metal rod into the molten glass to the bottom of the feeder channel (typically 200...400 mm in depth). After a short time has passed, the rod is removed and placed in a steel V-channel with a ruler for glass level measurement. Along with offering only a “snapshot in time” measurement, manual dip checks can vary from operator to operator by the method of dipping. Furthermore, relying exclusively on manual dip checks for level control creates unnecessary potential for workplace safety incidents. In contrast, online glass level measurements offer non-contacting, continuous glass level readings with an increase in accuracy, reliability, and a reduced feedback loop that allows for improved response time. With an improved response time, process upsets such as low or high batch bin level or glass pull runaway can be assessed in seconds rather than in hours. When compared to traditional offline level measurements, online glass level measurements provide superior safety and process reliability to aid in optimizing the production process and producing consistent quality glass.

Non-contacting measurements: optical vs nuclear:

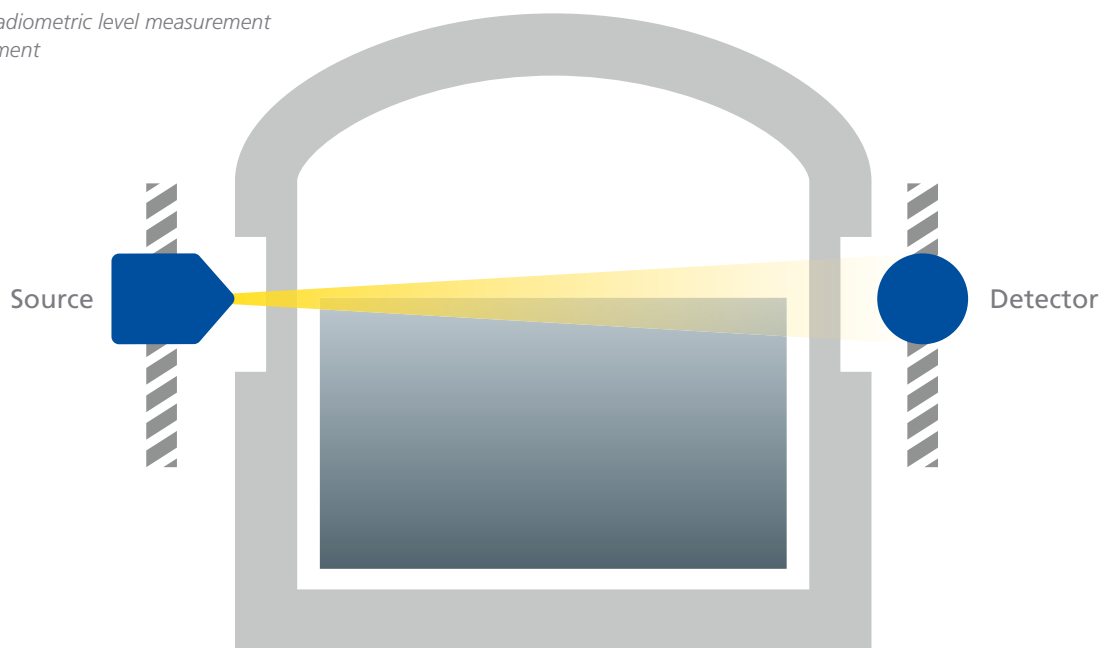
Standard non-contacting, online glass level measurements have historically been optically based. Such measurements require furnace refractory to be removed completely on one or even both sides of the furnace, creating an open “window” to the furnace that allows for the travel path of the laser or camera. The laser or camera is transmitted at an angle along the width of the furnace reflecting off the molten glass level. The receiver of the optical signal evaluates the reflection or interaction of the optical signal and the molten glass level to provide the online level reading. Optical glass level measurements are sensitive to dusty environments inside or around the furnace as well as dust coating on the lens of the transmitter and receiver. Gases and dust inherent of glass furnaces create scenarios in which optical level measurements can become unreliable even with daily lens cleaning. Seemingly aware of these inefficiencies, some optical level measurement manufacturers have recently discontinued glass level product lines with no replacement planned (1).

Typical optical level measurement arrangement



Non-contacting, nuclear glass level measurements use gamma radiation directed across the width of the feeder channel to correlate changes in measured radiation with a rise or fall in molten glass level. The figure below shows a typical arrangement of a radiometric level measurement at the feeder channel. Gamma radiation interacts with matter by transferring energy in an “everything or nothing” phenomenon (2). This phenomenon has a greater propensity to occur as the density of the opposing medium increases. Thus, the amount of radiation present at the radiation detector depends on the intensity of the gamma energy as well as the density and thickness of the medium opposing the gamma radiation. Due to the relatively high energy of gamma rays and the low density of dust and gas, gamma-based measurements are not affected by dust or gases associated with glass melt furnaces. The resolution and working life of any nuclear glass level measurement depends entirely on a sufficient radiation “delta” at the radiation detector. This radiation delta is the difference in radiation between the two extreme conditions of furnace level operation.

Typical radiometric level measurement arrangement



With this in mind, it is common with nuclear glass level measurements to remove some, but not all of the sidewall refractory layers on either side of the width of the feeder channel furnace to allow for sufficient radiation delta. Removing some, but not all of the sidewall refractory layers also allows design engineers to match the working life of the nuclear level measurement with the expected length of the furnace campaign (up to 15 years).

The amount of radiation detected by the detector can be used to calculate the process value. Nuclear measurement technology is highly reproducible and reliable. Using the laws of physics and statistics, as well as sophisticated software, the success of any nuclear-based measurement is almost granted. However, correct and exact application information is imperative for the design of an accurate and reproducible measurement.

The nuclide makes the difference – the case for Co-60:

In industrial applications just a few nuclides are actually used for measurement purposes. The most commonly applied isotopes are Cesium-137 and Cobalt-60. They differentiate from each other in half-life time, but also by the emitted gamma energy.

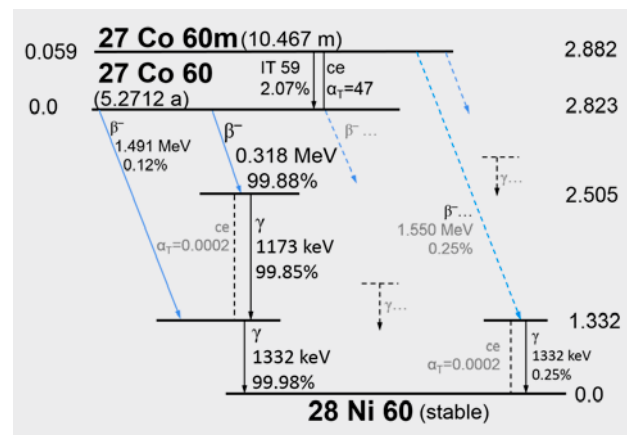
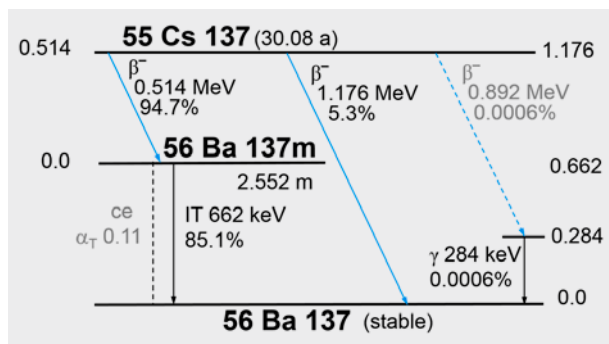
It is very easy to confuse the meaning of “activity” and “energy” of the emitted radiation from a source. It is important to understand that the number of emitted gamma quanta – and hence the activity – has nothing to do with their energy. This is similar to the colour of light which is not linked to its brightness.

- Activity describes the average number of the isotope’s nuclear decays that result in an emitted gamma quantum. Or in other words: the amount of radioactive material.
- Each gamma quantum has a specific energy. The energy distribution of an emitted gamma quant is characteristic for each isotope. The gamma energy is directly linked to the ability of the radiation to penetrate through materials (media, vessel, etc.).

Historical nuclear glass level measurements were made using Cs-137 as radiation source. Cs-137 is a common isotope used for nuclear industrial process control measurements and most radiation based industrial measurements can be performed with a Cs-137 activity in the range of 100 – 250 mCi per measurement. For comparison, nuclear glass level measurements have been noted to be installed with as much as 8000 mCi of Cs-137 activity. Taking in account that for nucleonic measurements the ALARA (as low as reasonably achievable) principle should apply, this discrepancy is alarming.

Glass melt furnaces consist of dense refractory brick up to 4000 kg/m^3 (3) with molten glass filling the channel width at densities of $\sim 2200 \text{ kg/m}^3$ (4). Understanding that the probability of gamma radiation interacting with matter increases as the matter’s density increases, glass melt furnaces represent a challenging application for gamma radiation to penetrate and produce a reliable level measurement. Isotope selection provides the key in designing an effective nuclear glass level measurement system.

To understand this further it is worth reviewing the Cs-137 and Co-60 decay scheme:



Cs-137, undergoes two beta decays, one to Barium 137 – not useable for measurement- and one to a metastable Barium, which has a further gamma decay, releasing an energy of 662 keV.

In comparison, Co-60 undergoes a beta decay to metastable Nickel 60, but two separate and measurable gamma decays are following, releasing gamma energies of 1173 keV and 1332 keV. With two measurable gamma releases both having energies roughly twice the gamma energy of Cs-137, Co-60 gamma radiation better penetrates glass feeder channels including dense refractory walls. Hence, the use of Cobalt-60 allows designing systems with a significant lower activity.

The greater penetration power of Co-60 vs. Cs-137 is further illustrated by each isotope’s half value layer (HVL). The half value layer of any isotope is the thickness of shielding that must be in place to reduce the radiation entering the shielding by half. According to the United States Occupational Safety and Health

Administration (OSHA), the steel HVL of Cs-137 is 1.6 cm and the steel HVL of Co-60 is 2.1 cm (6). Thus, a > 30% thicker piece of steel is needed to reduce Co-60 radiation entering by half versus Cs-137 radiation entering. Co-60 gamma radiation more readily penetrates glass feeder channels that include dense refractory walls and can be used to produce reliable and safe non-contacting nuclear glass level indication and control.

Alignment and calibration:

Glass melt furnaces require high resolution and repeatable level control of the feeder channel to ensure stable charging, flow, and glass pull. Accurate alignment and calibration of any glass level measurement system is critical to the performance of the measurement. Given the harsh conditions in and around the furnace, robust and stable mounting equipment and an effective calibration procedure is required.

Glass measurement systems are typically mounted via external steel structures. In most applications, heat deformation of the external steel mounting structure is not an issue. But in glass level applications, the heat can introduce an error to measurement, mounted on extended or cantilevered steel pipes, such as some optical glass level measurement solutions. Some optical glass level systems are designed to account for up to 0.1 mm of heat deformation in the mounting structure while still maintaining reasonable accuracy. However, around glass furnaces conditions that can cause up to 0.6 mm of heat deformation are frequent (5). This introduce significant error into the measurement.

Due to the weight and close proximity of nuclear glass level systems to the furnace exterior, heat deformation of the larger structural mounting members required to mount the nuclear system is generally a non-issue. The alignment challenge with nuclear glass level measurements is to ensure the source and the middle of the 50 mm by 50 mm sensitive area of the radiation detector are aligned both vertically and horizontally at the designed "glass level". This can and has been done effectively by using common reference points outside of the furnace. By using a 360° laser level and a rod inserted into the dip check hole in the roof of the furnace, the source and detector can be aligned effectively both horizontally and vertically at the designed glass level.

Calibration of nuclear glass level measurements can be performed in cold furnace conditions, but a final calibration must be performed under hot furnace, steady glass conditions to ensure system performance. Typically, calibration points are taken at the glass level, the maximum glass level operating condition, and the minimum glass level operating condition. Calibration points are taken with glass flow remaining steady at the designed furnace glass level. A precise method to raise and lower the source shield and detector in lockstep to each calibration point can be achieved using a detector/shield mount that incorporates precision adjustable linear slide rails. With this calibration procedure, an effective calibration curve is built and can be verified via manual dip checks. With accurate cold alignment and proper calibration procedure, Co-60 nuclear glass level measurement systems have resolution of down to 0.05 mm / 0.002 in. This robust resolution and repeatability provide reliable process measurement and control for the end user resulting in increased throughput and reduction in maintenance as well as in downtimes.



Summary

Glass melt furnaces offer one of the most challenging environments for any type of industrial process measurement and control. Efficient and quality glass production requires a reliable and safe glass level measurement just after the glass leaves the main feeder channel. The extreme temperatures and dense refractory call for a robust, yet repeatable and accurate level measurement. Nuclear level measurement systems with the use of Co-60 isotope, proper alignment, and an effective calibration procedure offer best in class measurement results for the glass industry to maximize safety, reliability, and throughput.

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