Figure 1. Conveyor belts are often used to move materials in mining and other applications, and a measurement of the amount of material conveyed is a key control parameter.

Smart Moves:

A comparison of the two main ways to measure mass flow of bulk solids on conveyors

Mass flow measurements are common and necessary across many varying industries. From mines to paper mills to power plants, operators move material on conveyor belts and on screw and chain conveyors (Figure 1). Conveyors are also a popular means of loading and unloading trucks, barges, and rail cars at plants. Mass flow measurements of these bulk solids are required for two main reasons: control and material transfer.

The amount of material fed to a downstream process is regulated in control applications. Mass flow, for example, is measured and sent to an automation system, which can then change a conveyor's speed to control the amount of material being delivered to a downstream process, such as ore into a crusher at a mine or wood chips into a digester at a paper mill. The same technology can be used as a set point to control other processes, such as the feed of a secondary material in a blending system.

In material transfer applications, mass flow is used to monitor the amount of material being transferred from one place to another, such as from a process plant to a truck or from a coal bin to a kiln.

Consensus across multiple industries is that accurate mass flow measurement is of the utmost importance. Opinions are split, however, when it comes to the best means of mass flow measurement. Some operators prefer radiometric measurement, while others are entrenched in the belt conveyor load cells camp. This paper will compare how these two technologies operate and contrast their performance in practical application. A Table at the end of this paper will summarize their similarities and differences.

Principle of Operation, Radiometric

A radiometric sensor consists of a sealed radioactive source in a source holder and a scintillation detector. The source and detector are mounted on opposite sides of the conveyor (belt, screw, drag chain, or vibrating). In some applications, the source is mounted above and the detector is mounted below, while in other applications the detector is mounted above and the source below.

In either case, a fan-shaped collimated beam of radiation is transmitted from the source through the process material and the conveyor to the detector (Figure 2).

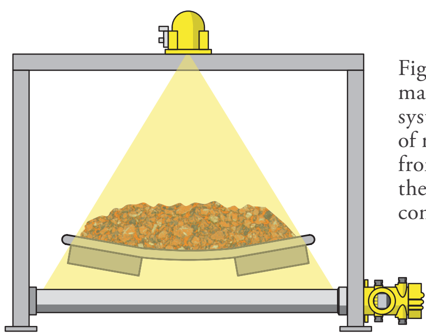

Figure 2. With a radiometric material measurement system, a fan-shaped beam of radiation is transmitted from the source through the process material and the conveyor to the detector.

As radiation passes through matter, its field strength weakens. As the total mass per square foot on the belt or screw conveyor changes, the amount of radiation reaching the detector changes inversely. The greater the loading or mass on the belt, the lower the radiation field at the detector. Conversely, the lower the loading or mass on the belt, the higher the radiation field at the detector. The amount of radiation seen at the detector is thus proportional to the amount of material on the conveyor, and is translated into an output signal from the detector.

Practical Application, Radiometric

Radiometric weight measurement works best with consistent medium to heavy loads and can lose accuracy with very light loading and thin layers of material, due to the randomness of gamma ray emission. Conveyor widths from about .5 to 3.0 meters can be accommodated, with wider belts better suited to measurement with load cells.

Radiometric detector electronics typically include a discrete or an analog input for input of a tachometer signal, which is required to determine the speed of the material being conveyed on variable speed belts. This signal allows the electronics to make an accurate measurement of total tonnage that has passed the scale. The discrete input typically accepts a frequency output from the tachometer. Alternately, the analog input can accept a 4 … 20 mA current signal from the tachometer.

Radiometric mass flow measurement has proven very reliable, even in extreme process conditions. The non-contact measuring principle makes it nearly invulnerable to the vibration common to conveying applications, and radiometric measurement is unaffected by temperatures up to 140° F (60° C). Electronics are typically built into the instrument to compensate for additional variables such as belt or screw speed, and to use these factors to convert the measurement into a total weight or a weight-per-time period output.

This method of measurement is more expensive up front, but provides an extremely stable solution with little required maintenance. Measurement precision is about ±1%, and is independent of process material effects such as dust, corrosion, and spillage.

Installation is relatively simple as the instrument is usually supplied with a frame, which mounts directly to the conveyor. The instrument can be relocated with minimal effort, and can be mounted on inclined conveyors without affecting measurement.

Startup requires empty and loaded belt sampling runs in order to calibrate the device. This calibration can be accomplished with a HART handheld device connected to the electronics, an onboard display/configuration module, or a device type manager (DTM) setup routine. DTM is a standard communications interface protocol often used in the industrial automation industry. The DTM setup is accomplished through a Windows-based software package available from the scale manufacturer, and is generally the most intuitive setup option due to its graphical user interface.

Most radiometric instruments feature a variety of outputs suitable for direct connection to plant automation systems. Typical output options include 4 … 20 mA with or without HART, Profibus PA, or Foundation Fieldbus.

By and large, users can set it and forget it when it comes to radiometric systems. The non-mechanical devices provide a solid state measurement, greatly reducing required maintenance. This is their chief advantage over belt conveyor load cells.

Principle of Operation, Belt Conveyor Load Cells

A belt conveyor load cell system replaces a short section of the support mechanism of an existing belt, often with one or more sets of idler rollers. This support roller is mounted on load cells, so the weight of the dry bulk material on the belt is measured (Figure 3).

Figure 3. Load cells can be used to measure a very wide range of material weights on belt conveyors, with no practical restriction on belt width.

This load cell weight measurement is then integrated with the belt speed to compute the mass flow of material moving on the belt after deducting the mass of the belt itself. Belt conveyor load cell systems generally include the electronics to perform this calculation in the form of a weight instrument.

A belt conveyor load cell system is normally mounted in a well-supported straight section of belt, with no vertical or sideways curvature permitted, and as close to level as is practical. The weighed support must be aligned vertically and horizontally with the adjacent supports to avoid tensile forces in the belt, as these can skew the measurement.

Practical Application, Belt Conveyor Load Cells,

Although the upfront costs of this method of measurement are less expensive a radiometric instrument, it costs much more to install and maintain long-term. However, it can accommodate a very wide range of weight, and very wide conveyor belts.

A significant straight run of level belt is necessary for installation, and once installed load cells are difficult to relocate because they replace a section of conveyor belt support. Once they're in, they're in.

Due to the variability of belt tension and the effects of vibration on the weighing system, operators must perform frequent calibration checks, often requiring check weights and significant downtime. Calibration is required more frequently on applications where the conveyor loading is light due to the small amount of weight which must be measured.

Although accuracy is comparable to radiometric systems at around ±1% when first installed, significant drift often occurs in short order. Compared to radiometric instruments, load cell systems are not as rugged, and are thus more affected by environmental issues such as temperature and vibration.

Outputs from belt conveyor load cell system weight instruments are typically an analog 4 … 20 mA signal proportional to the flow rate, with popular communication protocols such as HART, Profibus PA, and Foundation Fieldbus often supported.

Comparing the Two Methods in Application

A limestone mine moved much of its product on belt conveyors, with several thousand feet of conveyors on site. Ore processing optimization requires precise and repeatable measurement of the quantity of material conveyed from one operation to the next, and a load cell based system was being utilized for this measurement.

The mine identified a large operational expense related to the maintenance of the load cells, and researched alternate technologies for measuring the mass flow of material moved by their conveyor belts. The low operational maintenance cost of a radiometric solution from VEGA drew the mine's interest, and a ROI study revealed that this solution would pay for itself in less than a year due to lower operating expenses.

Our next step was to alleviate the mine operator's concerns about using radioactive material. We explained that radiometric weighing systems use a low level radioactive source, and the source holder shields the radiation around the scale to a level that is at or slightly above background radiation. We then modeled the radiation stray fields around the scale based on the source activity required for the application, and presented the results to the mine's management team and employees in the context of background radiation and a typical chest X-ray.

After considering the cost benefit versus the requirements of using a radioactive source, the mine moved to VEGA's radiometric method of mass flow measurement (Figure 4). Installation and calibration of the system was completed in four hours using the DTM methodology and the manufacturer's software. Calibration was based on physical weights, a very accurate and intuitive method.

The radiometric system has been in use for nearly three years, and results have been better than expected with payback on the initial investment within eight months. As of September 2015, the mine has taken ownership of seven radiometric scales and expects to purchase additional units in the future. Operational maintenance requirements have been dramatically reduced, with consequent cost savings.

Figure 4. A mine replaced a load cell system with this radiometric material measurement system, resulting in a payback of eight months due to reduced required maintenance.

Conclusion

The two main technologies for mass flow measurement of bulk solids are a radiometric and load cell systems. The upfront purchase price is less for the load cell system, and it's a better fit for belt widths of three meters and larger, and for belts with very light or greatly varying material weights.

The radiometric system has a higher upfront purchase price, but it pays for itself quickly in many applications due to dramatically reduced maintenance expenses. Many users opt for this method of measurement due to these savings.

Deciding which technology is best requires a look at the details of each application as each method of measurement has its place. You can learn more about VEGA's radiometric mass flow instruments by visiting www.vega.com.

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Table: Comparison of the Two Main Ways to Measure Dry Material Flow on a Conveyor Belt

Characteristics	Radiometric	Belt Conveyor Scale
Measurement range	Medium to high weights	Widest range, low to high weights
Upfront cost	High	Medium
Operating cost	Low	High
Life span	Long with minimal maintenance	Long, but requires substantial ongoing maintenance
Installation effort	Minimal, bolts to conveyor frame	Requires replacement of conveyor section
Startup effort	Minimal	More extensive
Required maintenance	Minimal	Extensive, requires frequent calibration
Measurement precision	Plus or minus 1%, stable	Plus or minus 1%, susceptible to drift
Independence from environmental effects such as high temperature and vibration	Excellent, -40 to +60°C. Highly resistant to vibration.	Wide temperature range, but requires compensation. Load cells susceptible to vibration.
Independence from process material effects such as dust, corrosion, and spillage	Excellent	Fair
Required space	Least, 12" span of belt	Needs straight span through five idlers on conveyor
Maximum conveyor width	3 meters	No set limit
Easy to relocate	Yes	No
Can use on inclined belts	Yes	No