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

Many industrial operations need to make mass flow measurements of dry bulk solid materials on conveyor belts, and on screw and chain conveyors (Figure 1). Typical industrial applications include moving materials at mine sites, paper mills, and power plants—as well as bulk material blending. Loading and unloading of trucks, barges, and railcars to and from plants are also popular applications. Mass flow measurements of these bulk solids are required for two main reasons, control and material transfer.

In control applications, the amount of material fed to a downstream process is regulated. Mass flow is measured and sent to an automation system, which can then speed up or slow down the conveyor 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. Alternately, the measurement 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, the mass flow must be measured to ascertain 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.

Two common ways of making these mass flow measurements are:

- Radiation-based instrument
- Belt conveyor load cells

The Table compares these two technologies, and the text below describes each in detail.
Radiation-based, Principle of Operation

A radiation-based 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).

As radiation passes through matter its field strength weakens. As the loading of the material, or total mass per square foot, on the belt or screw conveyor changes, the amount of radiation reaching the detector changes. 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.

Radiation-based, Application Advice

A Cesium-137 or Cobalt-60 isotope emits gamma rays, which are focused by a source holder, and then attenuated when penetrating the material and the conveyor belt. A polyvinyl toluene or other type of scintillator detector mounted on the other side of the conveyor belt receives the radiation, the strength of which is proportional to the amount of material on the belt.

Radiation from the source holder is a random emission of gamma rays produced as the isotope decays to a stable state. Radiation-based weight measurement works best with consistent medium to heavy loads, but can lose accuracy with very light loading and thin layers of material due to the randomness of the 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.

It’s typical for radiation-based detector electronics to 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.

This measuring principle has proven to be very reliable in even the most extreme process conditions because it performs non-contact measurement through the conveyor belt. As noted, integrated 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.
As shown in the Table, this method of measurement is more expensive up front, but provides an extremely stable measurement with very little required maintenance. Radiation-based measurement is not affected by the levels of vibration typically found in conveying applications, or by high temperatures up to 60°C. 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 if required 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 radiation-based 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.

Radiation-based systems provide a non-mechanical and solid state measurement, greatly reducing required maintenance, which is their chief advantage over belt conveyor load cells.

**Belt Conveyor Load Cells, Principle of Operation**

A belt conveyor load cell system replaces a short section of the support mechanism of the belt, often 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).

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.

Figure 3
**Belt Conveyor Load Cells, Application Advice**

Although this method of measurement is less expensive than a radiation-based instrument, it costs much more to install and maintain. However, it can accommodate a very wide range of weight, and very wide conveyor belts.

Because a section of conveyor belt support must be replaced with the belt conveyor scale, it is difficult to relocate these systems once installed. A significant straight run of level belt is also required.

Due to the variability of belt tension and the effects of vibration on the weighing system, frequent calibration checks must be performed, 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 radiation-based systems at around ±1% when first installed, significant drift often occurs in short order. As compared to radiation-based 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, Profield PA, and Foundation Fieldbus often supported.

**Application Comparing the Two Methods**

A limestone mine conveyed much of its product on belt conveyors, with several thousand feet of conveyors on site. Optimization of ore processing 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 began to research alternate technologies for making mass flow measurements of material moved by their conveyor belts. The low operational maintenance cost of a radiation-based solution drew the interest of the mine, and a ROI study revealed that a radiation-based system would pay for itself in less than a year due to lower operating expenses.

The next step was to address the concerns associated with the radioactive material in the source holder. Radiation-based weighing systems use a low level radioactive source. The source holder shields the radiation around the scale to a level that is at or slightly above background radiation. The radiation stray fields around the scale were modeled by the scale supplier based on the source activity required for the application, and the results were presented to the mine’s management team and the employees in the context of background radiation and a typical chest X-ray.
After considering the cost benefit versus the requirement of a radioactive source, the decision was made to move to the radiation-based technology (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 radiation-based system has been in use for nearly three years, and results have been as expected with payback on the investment within eight months. As of September 2015, the mine has taken ownership of seven radiation-based scales and expects to purchase additional units in the future. Operational maintenance requirements have been dramatically reduced, with consequent cost savings.
Conclusion

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

The radiation-based system has a higher upfront purchase price, but 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.

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

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