PROCESS INSTRUMENTATION

# Four key criteria for choosing a conveyor belt scale for critical mining applications

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## Easy installation, low maintenance, fast response, and high accuracy are top factors in selecting a conveyor belt scale for mining operations. By choosing well, engineers can avoid profits lost to inaccurate measurements while improving availability and operational safety.

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The mining industry worldwide uses conveyor belt scales in a variety of locations and applications in their operations. Examples include monitoring the primary crusher throughput, controlling the milling process, optimizing the leaching process, and maintaining ore inventory. When properly installed and maintained, belt scales can achieve accuracies as precise as 0.5% with the accuracy of some belt scale designs attaining accuracies as low as 0.125%.

Of course, the catch is "when properly installed and maintained." Few industries are as rough on equipment as mining, especially equipment used to move mined material. Conveying heavy ore-bearing rocks of different shapes and weights, plus associated dust and dirt, push the durability of conveyors and their mechanisms to their limits.

## High costs of downtime, unsafe operations, and weighing inaccuracies

Conveyor and belt-scale downtime can be costly and because mines are usually in remote locations, reliability is critical. If a key conveyor system goes down, production can stop for days depending on how serious the problem is. That's why minimizing the number of moving parts and regular maintenance are both key to a conveyor system's availability for continuous throughput. Safety is an important consideration, too.

While the cost of human injury cannot be priced, a single injury is one too many. A safety incident can halt production, while its causes are determined and remedied. That's not to mention prompt disruptive and costly regulatory investigations plus potentially huge fines. Downtime by itself can be expensive, depending on the materials being mined. Probably the most expensive example would be gold ore, where an Alaskan operation estimated the cost of its production shutdown to be $240,000 an hour.

Weighing inaccuracies, even small ones, can generate huge costs that could be hidden without regular calibration. That's because a mining conveyor belt will typically operate for extended periods of time, so small errors will accumulate and become significant. Let's consider the use of a belt scale in a conveyor application that moves 200 tons of ore per hour. If the conveyor operates 16 hours per day, 300 days a year, the conveyor will transfer 960,000 tons of ore a year, or 3,200 tons per day. If the ore's extraction cost is $20 per ton, that works out to approximately $19.2 million per year, or $64,000 per day.

As Table 1 shows, if a mine's belt-scale accuracy were allowed to degrade by 5%, the cost of its weighing inaccuracy would be $960,000 a year. So, improving the scale's accuracy to 1% could yield as much as $768,000 in savings. Also as shown, the savings only grow with as belt-scale accuracy improves. With proper scale selection, installation, and maintenance, accuracies of 0.5% are common, even in mining's harsh operating conditions.

Table 1 Cost impacts of weighing inaccuracies

| | Material Error | | Cost of Error | | |
|---|---|---|---|---|---|
| % of error | Daily | Annually | Daily | Annually | Annual Savings |
| 5.00% | 160 | 48000 | $3,200 | $960,000 | |
| 1.00% | 32 | 9600 | $640 | $192,000 | $768,000 |
| 0.50% | 16 | 4800 | $320 | $96,000 | $864,000 |
| 0.25% | 8 | 2400 | $160 | $48,000 | $912,000 |

## Conveyor belt scales, principles of operation

In discussing criteria for selecting a conveyor belt scale for a particular mining application, a brief review of the technology's principles of operation can be helpful. Belt scales have been available and used in the mining industry for decades, but in that time, they have integrated digital processing with much faster sampling times for greater accuracy and also a wider range of connectivity protocols to help them contribute to greater visibility of material movements and rates of throughput.

Figure 1 shows a side view of a typical belt conveyor with a detailed inset view of a belt scale system that shows the belt scale's key functional components:

(1) **A weighbridge with strain gauge load cells.** The strain gauge assembly resides inside the load cell frame, as shown in Figure 2. It's made of structural, specially tempered stainless steel and converts the downward force of the load acting on them into electrical signals. The weight on the load cell is measured by the voltage fluctuation caused in the strain gauge when it undergoes deformation. Sampling is done at 32,000 times per second (i.e., 32 kHz).

(2) **A speed sensor.** This sensor is typically mounted to a bend pulley or the tail pulley to measure the speed of the belt. A speed sensor is needed to determine an accurate belt speed. Environmental factors and load variations will cause small changes in belt speed that must be accounted for to allow a belt scale to read accurately. Without a speed sensor, load weights will be inaccurate to the extent of these variations.

(3) **A belt scale integrator.** This device uses the signals from the weighbridge and the speed sensor to calculate the rate of material flow using the formula Rate = Load x Speed. The belt scale integrator will then convert the calculation to a usable measurement in the form of a displayed value, analog signal, or digital output.

Basically, two forces are acting on a conveyor belt scale at the same time: (1) a vertical force due to the weight of material (i.e., the load being measured); and (2) a horizontal force of the belt being pulled across the scale idler. The latter must be mechanically eliminated to provide a high accuracy reading of the material weight.

There are two ways to eliminate the horizontal force, depending on the type of belt scale. One uses a specially designed parallelogram-style load cell, such as the one used by the Siemens MSI belt scale pictured in Figure 1.

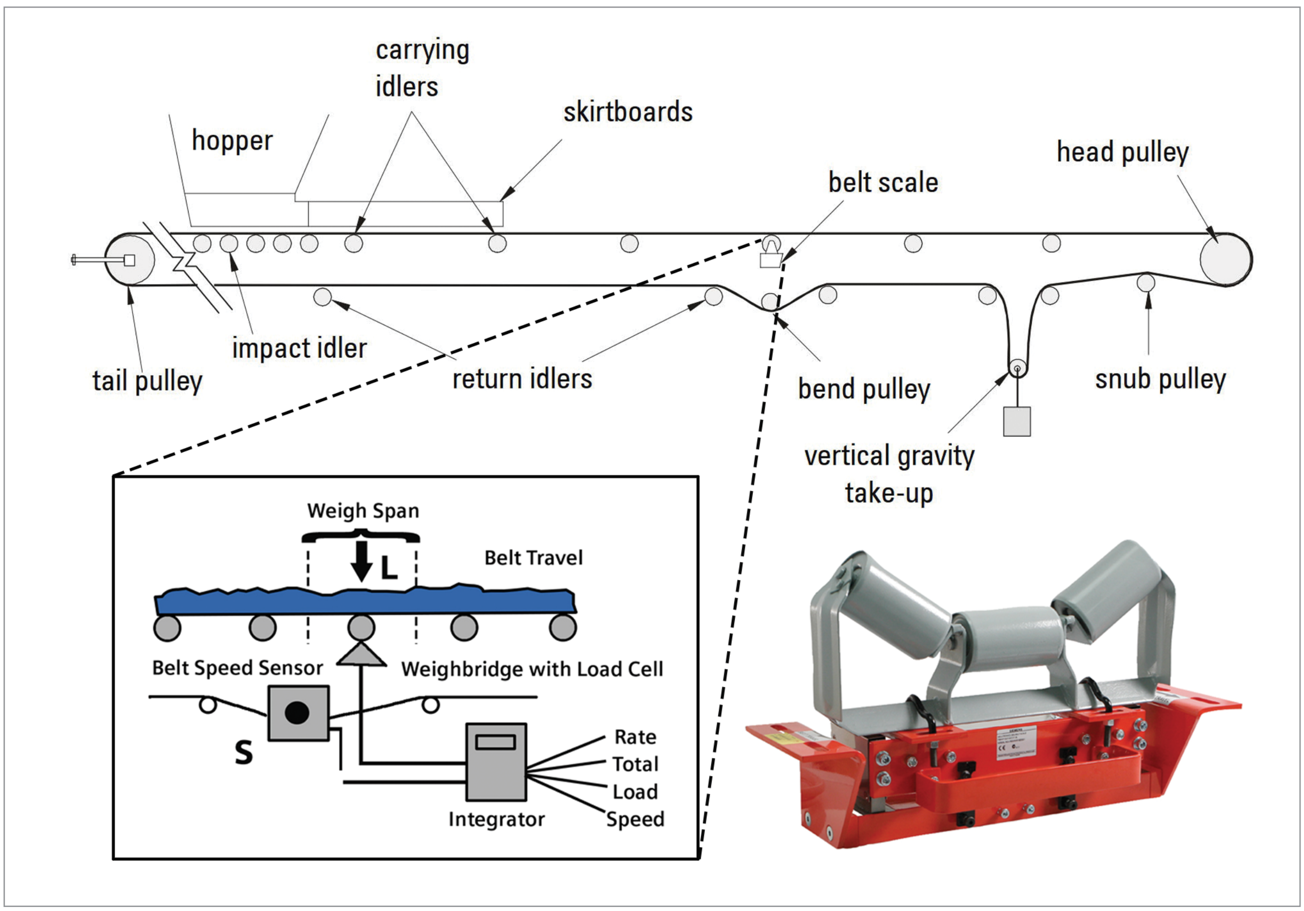


Figure 1 Belt conveyor side view with inset view of belt-scale components and functional detail. Photo is of a Siemens MSI heavy-duty, high-accuracy, full-frame single-idler belt-scale.

As shown, a vertical load will cause a deflection of the load cells front post. A horizontal force will transfer through the horizontal beams into the back post which is rigid and will not allow deflection. As a result, the load cell will not allow any deflection as a result of a horizontal force. The advantages are simplicity and, because there are no moving parts, no maintenance is required, just periodic calibration of the scale.

Figure 2 shows the MSI belt scale's parallelogram-style load cell, which uses 4 strain gauges that are potted to protect them from dust, dirt, and moisture. It is composed of solid stainless steel, tempered using a technology adapted from the manufacture of gun barrels by one of the foremost firearms makers in the world.

Other commonly used belt scales use a pivot-lever system. In these systems, a lever is suspended on one end of the load cell and a pivot on the other end. The idler is mounted to the top of the lever. This way, any horizontal force will pull against the pivot and vertical force will transfer down through the level to the load cell for weighing. This is a more complicated system and, with more moving parts subject to dust and dirt buildup, it can require more maintenance in addition to periodic calibration.

Compared to pivot-lever systems, the response time of the parallelogram-style load cell is twice as fast, which facilitates a nearly instant response to changes in product loading. The former's slower response time is the result of the time the pivot-lever mechanism requires to transfer the load's weight to its load cell for measurement. Figure 3 shows how the pivot-lever system works and compares its response time with that of a parallelogram-style load cell.

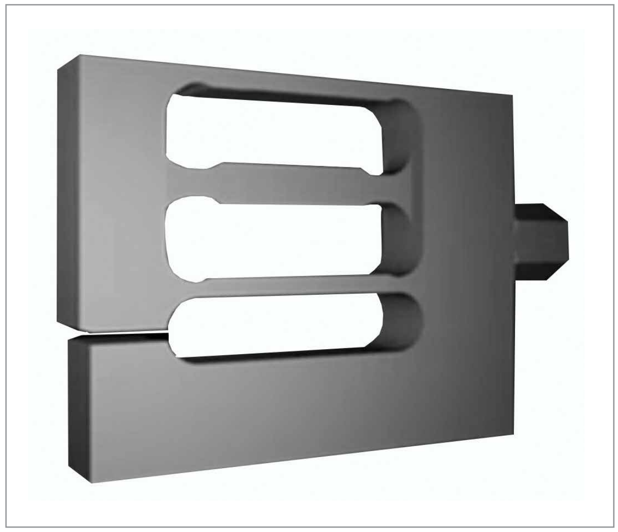

Figure 2 Solid stainless-steel parallelogram-style load cell for weighing material converts the downward force of the load acting on it into electrical signals. The weight on the load cell is measured by the voltage fluctuation caused in the strain gauge when it undergoes deformation of less than a millimeter. Sampling is done at 32,000 times per second (i.e., 32 kHz).

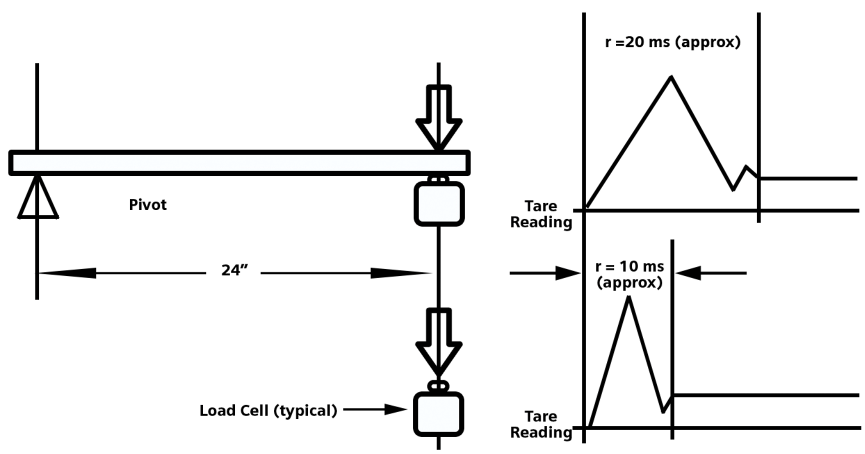


Figure 3 Top diagram shows a weight applied to a load cell through a pivot system, which approximately doubles its response time versus the load being applied directly to a load cell.

## Proper conveyor belt scale installation

In selecting a scale, mine engineers should consider the needed accuracy for an application. For example, applications used to control a material's feed rate into a process may not require as much accuracy as a scale being used for custody transfer where the cost of an error is related to a direct loss of finished product.

Before installing a conveyor belt scale, engineers must first consider the type of conveyor and its suitability for a belt scale. Proper operation requires the conveyor be of sufficiently rigid construction to prevent any deflection of the conveyor. Conveyor components such as idlers, take-up systems, belt plows and scrapers should all be in good working order. The belting should be in good condition and pliable so that it will lay into the idler making good contact will all the idler rollers.

**Location. Location. Location.** Two factors required for proper performance of a conveyor belt scale are the smooth movement of the belt across the weigh idler and appropriate, consistent belt tension. Because these factors are affected by the scale's location on the conveyor, they must be considered when selecting a belt scale location. Selecting the most appropriate location for the scale and performing a proper idler alignment will assure these factors do not affect the performance of the scale. Our recommendations follow:

- **Belt tension.** This varies in relation to material tonnage, belt speed, conveyor length and the height that the material must be raised. The larger these values, the greater the tension and its effect on the belt scale's performance and accuracy. We recommend that the scale be installed close to the tail section of a conveyor where tension and tension variations from no load to full load are minimal.

  A variety of conveyor belt take-ups can control conveyor belt tension. Of the two basic types — screw and gravity — the gravity take-up is the most reliable because it can react to changes in belt tension and maintain relatively uniform tension. Using a vertical gravity take-up greatly reduces the influence of belt tension on the scale and improves accuracy. For the best accuracy, use a gravity take-up. The use of the screw type take-up should be limited to conveyors with pulley centers of less than 60 feet (18 meters).

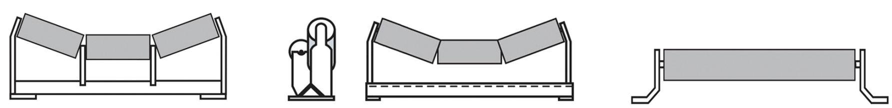

Figure 4 Three types of idlers well-suited for conveyor belt scales.

- **Material turbulence.** Material leaving the area of the feed point and associated skirtboards will be turbulent and require some belt distance to settle. Material should settle completely before being weighed. Locating the scale also depends on the conveyor belt speed and the characteristics of the material, so locate the scale no less than one idler space beyond where turbulence stops. If that cannot be determined, refer to the following chart:

| Belt Speeds | Scale distance from where material settles |
|---|---|
| Up to 300 ft/min (1.5 m/sec) | 6 ft (2 m) |
| Up to 500 ft/min (2.5 m/sec) | 10 ft (3 m) |
| More than 500 ft/min (2.5 m/sec) | 15 ft (5 m) |

- **Curved conveyor challenges.** Vertical curvature in the conveyor design can create difficulties with belt scales. Both concave and convex curvatures will disturb the belts ability to make consistent contact with the scale idler if the belt scale is installed in the area of the curve. The concave curvature is more difficult to manage because it may lift an empty belt off the idlers around the curve, preventing a good empty belt zero balance for the scale. The diagrams below illustrate the minimum distance the belt scale should be from the curvature to obtain accurate results.

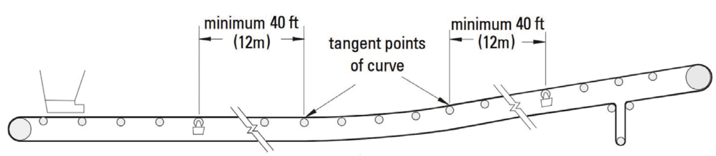


Figure 5 Concave belt-scale placement.

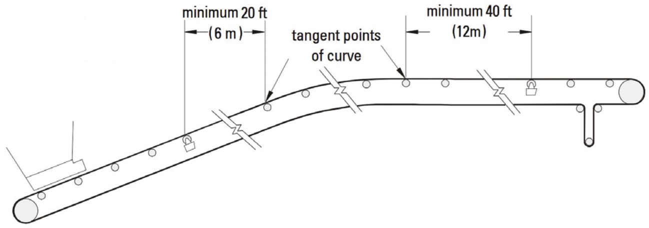


Figure 6 Convex belt-scale placement.

- **Appropriate conveyor belting.** During zero calibration, most belt scales average the weight of the belt over one complete circuit of it. However, variations in the number of belt plies, the cover thickness and the type and quantity of splices in a given conveyor belt causes considerable variation in the weight per length of that belt. The amount of deviation (+ or -) from that average, if great enough, can make it hard to obtain a good zero reference and subsequent scale accuracy.

  One common issue is belt stiffness. For example, a belt that is over-rated for its intended use may be so stiff that it cannot flex enough to properly trough in the idlers. When this happens — especially in 35° and 45° idlers — the belt arches across the idler, as shown in Figure 7, and neither a good zero of the belt nor a good span calibration can be obtained. So, when replacing worn sections of belting, ensure that it is the same as the existing belting. When choosing a new belt, select one that suits the application. Avoid selecting an over-rated belt, which will make calibrations difficult as well as cause weighing inaccuracies.

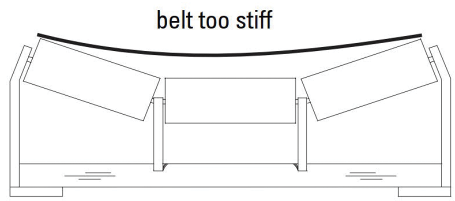


Figure 7 When belts are too stiff, left, they cannot flex enough to properly trough in the idlers, right.

- **Proper idler alignment.** The proper alignment of idlers in the scale area is critical for belt scale function and accuracy. Properly align the scale idlers and position at least two idlers on each side of the scale. Figure 8 shows an example of correct idler alignment. Most belt scales, including pivot-lever ones, require three idlers while belt scales using a parallelogram-style load cell may only need two idlers, which helps simplify installation and maintenance.

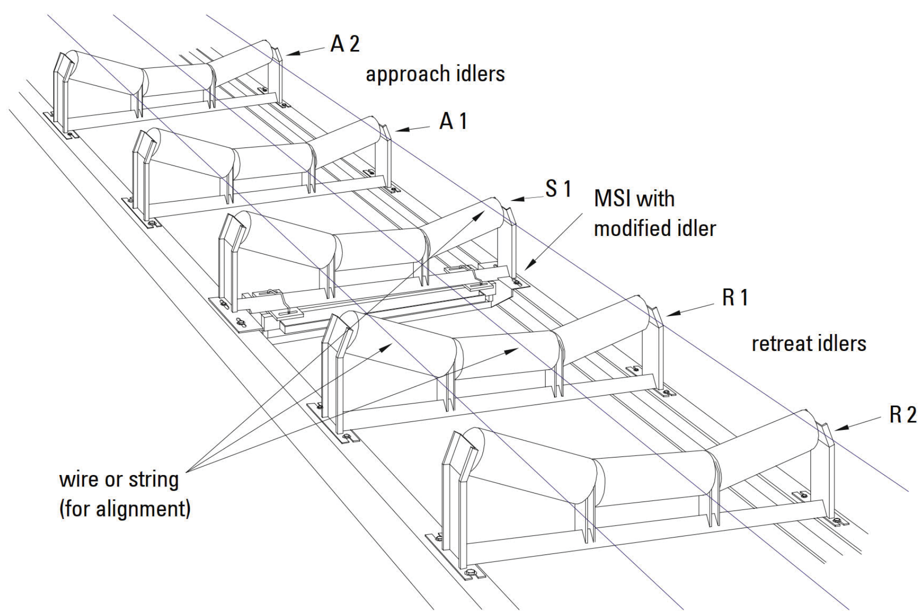


Figure 8 Idler detail showing the proper alignment of idlers on each side of a belt scale, which is critical for belt scale function and accuracy.

**Ease of installation.** Belt scales can widely differ in the degree of installation difficulty, which can determine the extent of production disruption. For example, belt scales that use a parallelogram-style load cell can be installed with just two people placing and mounting one in the appropriate location with a sufficient number of idlers (typically two) on either side. Installation can take just a few hours, and with calibration and testing, the belt scales can be operating in less than a day. In retrofits, the conveyor belt does not need to be cut. This minimizes production downtime considerably.

Pivot-lever belt scales can be more complicated and costly to install thereby requiring more time and production disruption. That's because they can weigh considerably more, often needing heavy lifting equipment, to lift and position them. And because of their typically larger size, the conveyor belt may need to be cut and then splice the belt back together, adding additional time to the installation. Once installed, they also will require calibration and testing.

"Belt scales using a direct suspension system with parallelogram load cells are much easier to install than the large pivot belt scales. Large pivot belt scales take noticeably longer to install because you have to cut the belt, use heavy lifting equipment to set the belt scale module in place, and then splice the belt ends back together. Two men can easily set a direct suspension system with parallelogram load cells in place and install it."

— Herb SteindlerResearch Engineer
Industrial Instrument Solutions

**Calibration and testing.** To calibrate a newly installed conveyor belt scale, initial zero calibration should be done with the belt running empty. After the initial zero calibration is done, a span calibration should be done using a simulated load calibration to establish a reference point for the calibration. Simulated load calibration compares a simulated load on the scale to a reference value called the Test Load, which is programmed into the conveyor belt scale integrator.

There are three commonly used types of simulated load calibration for conveyor belt scales, static weights, test chains, and electronic. Electronic calibration, also known as E-Cal, is the least accurate method of calibrating a scale because there is no load applied to the load cells.

As soon as the scale has been calibrated, mine engineers should perform a material test. This consists of transferring a material sample that has a known weight or can be weighed on a static scale that is known to read accurately immediately after being transferred across the conveyor belt scale. The amount of material totalized on the conveyor belt scale is then compared to the measurement from the static scale. This process is repeated two or more times to establish repeatability. If a repeatable error is identified, a factor can be entered into the integrator to adjust the belt scale's calibration.

## Maintenance

Proper and consistent maintenance on the conveyor and belt scale is needed for reliable operation and accuracy. The scale should be routinely calibrated per the manufacturer's recommendations with consideration given to the nature of the application and desired accuracy. Generally, the duration between calibration checks can be extended after the scale has proved reliable for a reasonable period of time. At a minimum, a conveyor belt scale should be calibrated seasonally, and any time maintenance is done to the conveyor.

Calibration records should be maintained for periodic review to discover hidden problems, especially any degradation in scale accuracy. If undetected, inaccuracies can cause costs to accrue over time yet conceal them from mine operators until discovered.

When the scale is calibrated, inspections should be made of the scale area idlers, take-up system, belt, speed sensor, and scale to make certain they are in proper working order and that material build-up is not hindering operation. Experience shows the majority of conveyor belt scale accuracy problems are the result of mechanical issues with the conveyor. Any issues with the conveyor or the scale should be corrected prior to calibration of the scale.

## Conclusion

Proper installation is essential to achieving accurate reading from a conveyor belt scale. The first step of installation, and perhaps the most important, is determining the proper location for the scale. To select the optimum location for the scale consideration should be given to conveyor curves, idler type, and belt tension. After the scale location has been selected, the scale should be installed and aligned with the idlers on each side of the scale.

To assure the long-term accuracy of a conveyor belt scale, a routine maintenance schedule should be established. This maintenance schedule can vary with scale design and application, consult your belt scale manufacturer to determine the maintenance requirements of your belt scale and application. With proper installation and maintenance conveyor belt scales are capable of providing many years of reliable, accurate measurements.

## Author Biographies

**John Dronette** is currently a Product Manager for Siemens Industry, Process Instrumentation Business. In his current role he is responsible for sales support and marketing of the Weighing Technology and Process Protection products. He has been with Siemens and Milltronics for 32 years. He began his career servicing belt scales as a Field Service Engineer and spent 10 years as the Service Manager for the companies' level and weighing products.

**Tom Pendergras** is currently an Application Engineer with focus on belt scales for Siemens Industry, Process Instrumentation Business. In his current role he is responsible review customer applications and offering assistance in equipment selection and providing application guidance. Tom has been with Siemens for 21 years. Prior to Siemens, Tom was a designer for a major conveyor builder in the U.S.

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