Dispelling the common myths about conveyor belt scales

First patented in 1910 Conveyor Belt Scales have become ubiquitous in a wide range of applications, from mining, to aggregate conveying, to ship loading. David Hyer, Thayer Scale president, addresses the common misconceptions surrounding the technology.

FOR OVER 60 YEARS, my company Thayer Scale has engineered and manufactured a wide range of belt scales, from the single-idler Quarry King, to our 8-idler Approach Retreat Belt Scale designed to meet the accuracy requirements of NTEP, OIML and NMI weighing.

In the decades we have been actively producing high accuracy conveyor belt scales, we have encountered several misunderstandings and misconceptions about belt weighers. In this article, we will (again) attempt to dispel these myths, and provide a little humor along the "weigh".

Background:

In a recent article published by a technical journal, the following claims were made regarding belt scale performance:

1. Accuracy is +-1 per cent, susceptible to drift
2. Belt scales require frequent, extensive calibration
3. Conveyor belt scales must operate in a non-inclined section of the conveyor
4. Operating costs are high relative to other techniques (for example: radiation-based mass measurement)

This article will be the first of a series of articles addressing each of these misconceptions and will primarily deal with the issues of accuracy and drift. We will explain why in some cases these criticisms are actually quite valid – and what to do about these situations. Subsequent articles will cover calibration procedures, scale location and setup, and recommended methods to reduce operating costs.

Belt scale success is a complex problem to solve:

Belt scale suppliers have a difficult challenge in engineering a scale that can provide better-than 0.1 per cent accuracy of a commodity that is being conveyed at rates up to 10,000 tons/hr. To accomplish this, it must:

1. Reliably and accurately measure the speed of the conveyor belt which is moving at over six metres/second.
2. Precisely transfer the vertical forces due only to the material load to the load sensor while not transmitting extraneous forces which are being generated constantly due to variations in belting, off-centre belt loading, tensions changes, etc.
3. Operate in a wide-range of environmental conditions including significant temperature and humidity variation

How do these misconceptions arise?

If you study the marketing material of the leading Belt Scale providers, you will certainly not see any of these unflattering specifications. Accuracy is typically specified as 0.5-1.0 per cent for single-idler scales, and improves to 0.1 per cent for multiple-idler high accuracy, certified-for-trade systems. Calibration procedures are described as "routine", and "fast". Operating cost models are efficient and economical. So, where do these negative attributes arise?

To answer this question, it's important to start with the understanding that the success of a belt scale installation depends on a successful collaboration between the belt scale supplier and the conveyor engineering team. Often claims made by suppliers are made assuming ideal conditions exist at the scale location. The important attributes like belt-tension, belt stiffness, idler alignment, troughing angle, take-up type, and others must be considered to maximise belt scale performance of the belt scale. To do that effectively,

Figure 1: Thayer Scale Model RF Belt Scale operating reliably on an inclined conveyor

the parties must work together for a successful installation.

Unfortunately, often a belt scale is installed into an existing conveyor not originally engineered in anticipation of a belt scale installation. As a result, important considerations like belt-tension at the scale location, rigidity of the stringers, take-up device and many others are not factored into the engineering process, resulting in less-than-optimal performance.

Accuracy fact vs. fiction:

Let's start with the ever-important issue of accuracy. In the 1960s, Frank Hyer, (my father), in collaboration with Hendrik Colijn, developed mathematical models that describes how various conveyor parameters interact and affect a conveyor belt scale. These models have been further refined over several decades to account for a wide range of accuracy-related issues and have been validated in numerous real-world installations.

The Hyer model uses strain-energy methods, and mathematically treats the belt as a continuous beam. Without diving into the derivation of the model (or dealing with differing units of measure), the simplified model of the force on a horizontal (non-inclined) scale can be represented as:

$$P = (n * Q * L) + (2 * T * d / L) + (K1 * E * I * d) / L3$$

Where:

P = Force on the scale

n = number of conveyor-mounted idlers

Q = Belt Loading

L = Idler spacing

T = Tension in the belt at the scale location

d = Misalignment between the scale idlers and the adjacent idlers

K1 = Constant related to units selected

E = Modulus of elasticity of the belt

I = Moment of inertia of belt carcass

From this model, we can derive a set of equations that represent errors that will exist (not able to be calibrated out), due to belt tension variation, idler misalignment, and belt stretch as:

$$E\% = K1 * (d * (TR - TC)) / (n*Q*L2) - K2 * (TR - TC)) / (E * A) - K3 * ((TR - TC) * Wb)) / 100 * (E * A * Q)$$

Where (in addition to the terms above):

E% = % Error

K1, K2, and K3 represent constants related to units

TR = Belt Tension while conveyor is running

TC = Belt Tension while conveyor is in calibration

A = Cross sectional area of belt carcass

Wb = Weight / length of the belt itself

Although this appears to be complicated formula, we can simplify it as:

E% = (Error due to belt tension effect on misalignment) + (Speed measurement error) + (Belt Stretch Induced error)

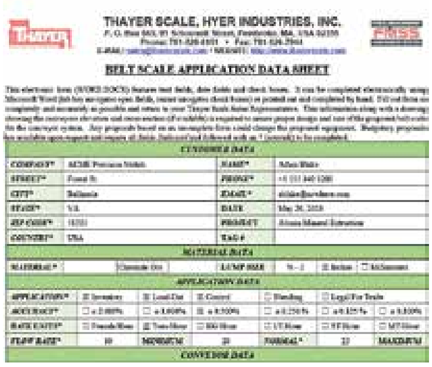
So, really the discussion about accuracy can be narrowed to a discussion about controlling belt tension, minimising the adverse effects of tension variability (especially the differences in tension that exist when the conveyor is running versus when it is being calibrated), minimising idler misalignment, reducing the sensitivity of the scale to idler misalignment, and finally establishing a calibration and material testing (K-factoring) process that enables frequent calibrations with minimal strain on personnel and equipment. With this in mind, let's look at the two primary tools at our disposal to impact these variables.

1. Conveyor design
2. Scale (weighbridge) design and installation

A detailed review of each of these issues is beyond the scope of this paper, but here are some general guidelines regarding each as it pertains to accuracy.

Conveyor design

As mentioned earlier, the success of a belt scale installation (in terms of accuracy) cannot be guaranteed without considering the environment in which the scale will operate. That environment is the conveyor itself. Thayer Scale, and other quality suppliers, perform a detailed analysis of the conveyor attributes prior to generating a proposal or quotation for a belt scale. Important aspects of the conveyor, material, and environment will be collected in an Application Data Sheet for review by the design engineer responsible for the belt scale. In many cases, during this process we will identify major obstacles that must be overcome to achieve success. Excellent guides are available online documenting all the key criteria for a belt scale installation.


THAYER SCALE, HYER INDUSTRIES, INC.

BELT SCALE APPLICATION DATA SHEET

Figure 2: Application Data Sheet - Thayer Scale

In terms of accuracy, the most important factors that need to be considered are:

– Scale location

The primary rule that applies to the scale location is to locate the scale in the area of lowest tension on the conveyor. Normally this location is near the tail pulley of the conveyor. As discussed above, high belt tension is a problem for belt scale accuracy. In addition, material needs time to settle on the conveyor prior to passing the scale, so the scale must be located sufficient distance from the end of the feed point. This can range from one metre to seven metres depending on belt speed.

– Take-up (tensioning device)

A vertical, gravity take-up is recommended for high accuracy installations. Screw take-ups are not advisable for use with belt scales as they lack the flexibility required to maintain consistent tension under varying loading conditions.

– Idlers / troughing angle

Flat single roll, or three-roll inline troughing idlers are required on the scale weigh bridge and two to three idlers on either side of the scale. Avoid the use of catenary or garland idlers. Scale idlers must be uniform and must meet CEMA (or equivalent) ratings for TIR. Use scale-quality idlers on the five idlers before and after the scale location.

– Conveyor inclination / concavity / convexity

Inclined conveyors must not exceed the angle at which material will slide backward on the conveyor. The inclination of the conveyor should be fixed at one angle. If curves are required, the scale should be installed so that the belt is always in contact with all the idler rollers. In general, the scale should be located at least 12 metres from the point of inflection for a concave curve, and at least four metres from the point of inflection of a convex curve.

- *Stacker / reclaimer*

Although variable incline stacker/reclaimer can accommodate a belt scale, the variation in incline, as well as the relative instability of the conveyor makes a stacker reclaimer a poor location for a high accuracy installation.

- *Material loading points*

Use a single feed point if high accuracy is a requirement. Multiple feed locations result in significant variation in tension, which as we know creates accuracy challenges.

Weighbridge design

Once the scale location, and conveyor design has been finalised, we can move on to a discussion about selecting a Weighbridge design to maximise accuracy. The topic of weighbridge design obviously encompasses other areas for discussion (like ease-of-installation, type and size of test weights used for calibration, ease-of-maintenance, etc.), but for this article we will narrow the discussion to issues related to accuracy only.

There are predominantly three classes of conveyor belt scale; full floating, pivoted, and approach/retreat (a special type of Pivoted). A full floating weighbridge consists of one or more idlers being fully supported by a scale platform that rests on two or more load cells. It can be classified as a force summing device since the vertical forces on the scale are summed by the load cells, and used to represent material load. The weight of the idlers and belt are present during load summing, so they must be subtracted (or tared) when calculating the net load.

In contrast, a pivoted weighbridge consists of one or more idlers supported on a weighbridge that is anchored on one end by a pivot or fulcrum. Each idler generates a moment around the pivot, so the weighbridge can be classified as a moment summing device. The sensitivity of each idler will vary in proportion to the distance from the pivot. The idler closest to the pivot is the least sensitive idler, which provides an accuracy benefit.

Finally, an approach/retreat weighbridge is a special class of a pivoted weighbridge consisting of two independent pivoted weigh sections, one with the fulcrum upstream of the load cell, and the second with the fulcrum downstream of the load cell. The moments on these two weighing sections are summed either mechanically or through multiple load cells. Regarding accuracy, this solution offers several distinct advantages over a full-floating or a standard pivoted weighbridge. First, the two weigh idlers closest to the fulcrums are the least sensitive idlers. One of the major contributors to belt scale inaccuracy is idler misalignment. Most often, the largest source of idler misalignment occurs between the last conveyor idler before the scale, and the first idler on the weighbridge. The relative insensitivity of this idler reduces the effect of this error. This also provides some immunity to tension variation. Second, an alignment error in the approach section of the weighbridge will be effectively cancelled by the corresponding alignment errors in the retreat section which will be of the opposite sign. Third, the pivots can be positioned in such a manner (coplanar with the centre of mass of the material flow channel), such that they eliminate, or significantly reduce the moment created by the tension pulling the material. And finally, the pivots provide a robust, stable mechanical anchor to fix the scale location when in an inclined conveyor. In contrast, a full-floating weighbridge must be held in place using check-rods or stay-

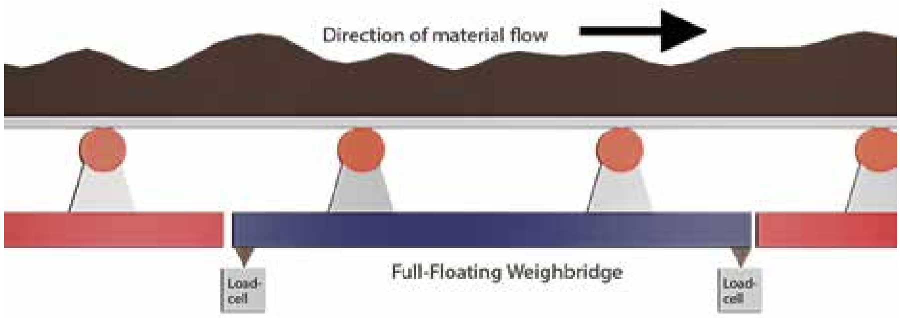


Figure 3: A full-floating two-idler weighbridge

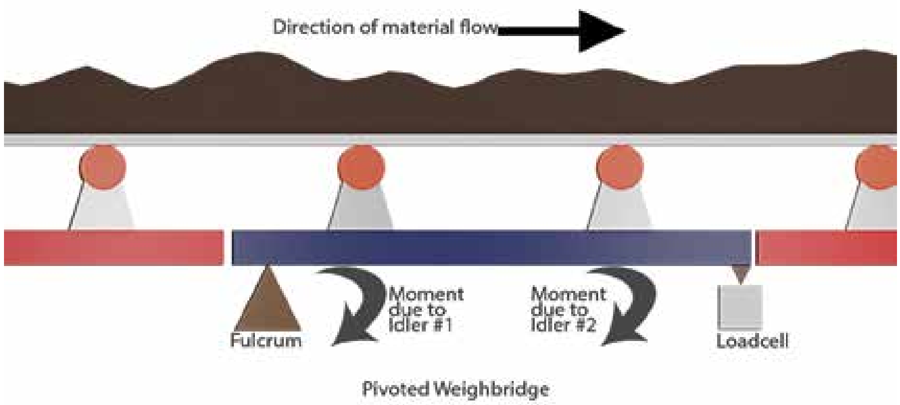


Figure 4: A pivoted two-idler weighbridge

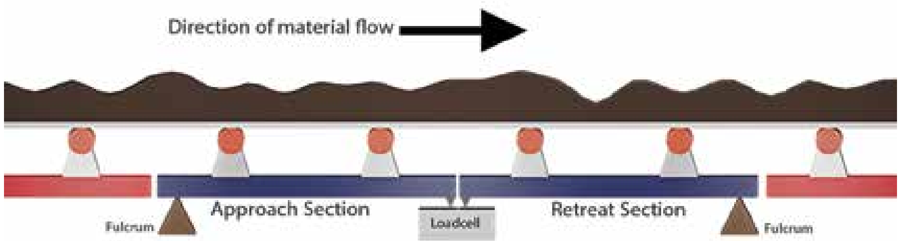


Figure 5: Approach retreat four-idler weighbridge

rods. Check rods will generate a force/ moment couple during operation which will different significantly from that generated during calibration.

On shorter weighbridges, the relative simplicity of the full-floating weighbridge may dictate that it is worth paying the small accuracy price to gain the benefits of a generally simpler design. Although it is more susceptible to errors generated by misaligned idlers, it is usually simpler and faster to install.

Number of weighed idlers

When expressed as a percentage of the total load on the scale, the fixed errors due to belting effects become smaller as the weighbridge get larger. In addition, a longer weighbridge will permit material to reside on the scale for a longer period (residence time). This has the advantage of damping any dramatic loading variations that might exist if the conveyor is not evenly loaded. Sharp changes in loading can often be missed by the integrating instrumentation. Therefore, it is generally the case that the highest accuracy scales will include multiple-idler weigh sections. At Thayer Scale, our eight-idler certified-for-trade scale delivers +-0.125 per cent accuracy across a three to one turndown range.

One caveat to the "more idlers is better" argument is this. Some suppliers will chain together multiple single idler scales and claim that this provides the same benefits that a true multi-idler scale weighbridge provides. Unfortunately, that is not the case as the residence time on each individual scale is quite short. Summing these independent scale signals in the integrator will not overcome this problem.

Drift

Accuracy is important, but if a belt scale drifts over time that is a problem. Drift can be innocuous, and readily overcome. It could also be sinister, resulting in incorrect totalised numbers, perhaps impacting the certification-status of the certified-for-trade installation.

So, what causes drift? And what can be done about it?

The three primary causes of drift are:

1. Material build-up on weighed sections of the weighbridge, belting, and scale idlers
2. Belt-stretch induced drift due to temperature variation
3. Instrumentation-related drift (commonly associated with older instruments)

Material buildup

Over time, many bulk solids will tend to adhere to surfaces of the conveyor, belt, and idlers of a conveyor. Special care needs to be paid to this build-up of material, especially in the weighing section of the conveyor. Material buildup on scale components will add load to the scale, resulting in increased totalisation numbers. Material that adheres to rollers will alter the speed calculations used by shaft-mounted speed sensors. These sources of inaccuracy will tend to grow over time, requiring frequent calibrations.

Well-designed belt scales will include carefully engineered surfaces to minimise material build up on weighed components. Figure 1 shows the main weigh section of the Thayer Scale Quarry King, as an example. The surfaces have been designed to minimise cross-sectional area reducing the possibility of material buildup. In addition, the lever arm has been engineered to avoid the possibility that material will jam between the lever-arm and the belt.

Another important feature provided by most modern belt-scales is the ability to sense when the belt is running empty, and initiate a zero-calibration during these times. An accurate zero calibration is critical for belt scale accuracy, as the zero number is constantly integrated while the belt is running. So be sure to enable automatic-zero calibrations if it is available in the belt-scale instrumentation.

Finally, another feature of many belt scale instruments is the ability to complete a calibration calculation to determine the "As Found Error" as an aggregate number. Under normal calibrations, zero and span are separately calculated, and the values are stored in the instrument for future integration. However, if the scale has operated without calibration for a period of time, performing an "As Found Error" check enables plant personnel to calculate the likely error that existed during previous operations. This error can then be used to reduce or increase the totalisation value after the fact.

Temperature variation

Significant temperature variation is a frequent operating condition for many belt scales operating in uncontrolled outside environments. Wide variation in temperature will affect different components of the conveyor, and will result in the possibility of significantly different load and speed measurements due to stretching or contracting of critical elements. Back in the 70s, belt scale instrumentation was often responsible for significant drift as much of the analogue circuitry used to load cell excitation and speed monitoring was highly susceptible to drift. Fortunately advances in belt scale instrumentation has effectively solved that problem, but perhaps the misconception has lingered to this day.

The most significant contributor to temperature-induced variation is the stretching that occurs in belt material. In severe environments where the belt will be subject to extreme temperature due to hot materials being conveyed, a heat-resistant, or high temperature belt should be used. This will limit belt stretch, and provide structural stability.

To handle environmental temperature variation, high accuracy belt scales and instrumentation must incorporate a temperature sensor circuit at the scale location. This temperature sensor will provide live temperature data to the instrument enabling compensation of load and speed information as needed. To properly compensate for temperature, it is critical that the belt scale supplier perform factory temperature testing utilising an environment test chamber. In addition, since the expansion of metal in the weigh section, and in any compensating structures (stay rods for example) will affect weighing accuracy, the factory temperature testing should include these elements in addition to the load cell and speed sensor.

A few useful rules-of-thumb regarding accuracy and drift

As we have shown, there is no simple formula for determining the likely accuracy of a belt scale installation, instead as stated above, a successful belt-scale installations requires a partnership approach between the belt-scale supplier, and the consumer. Fortunately, the long, successful history of the belt scale has enabled the industry to understand accuracy and drift issues in great detail, and this understanding has led to significantly better products, better instrumentation, and better support infrastructure. When evaluating the installation of a belt scale for high accuracy installations, keep in mind the following key points:

Rule of thumb #1 – For high accuracy installations, specify a belt scale that includes a 4-idler or larger weigh span.

Rule of thumb #2 – Pay very close attention to idler alignment at the weighbridge, and at 3-5 idlers on either side of the scale. Any misalignment will result in errors on the scale. Choose a scale design that minimises the effects of idler misalignments on the weighbridge.

Rule of thumb #3 – Select a supplier that will analyse your conveyor in detail and provide a comprehensive analysis of the proper installation location, take-up recommendations and other site-specific details.

Rule of thumb #4 – Take advantage of advanced features in your belt scale integrator. For example, utilise automatic zero calibrations whenever the scale is idle. Use feature that enable temperature compensation. B

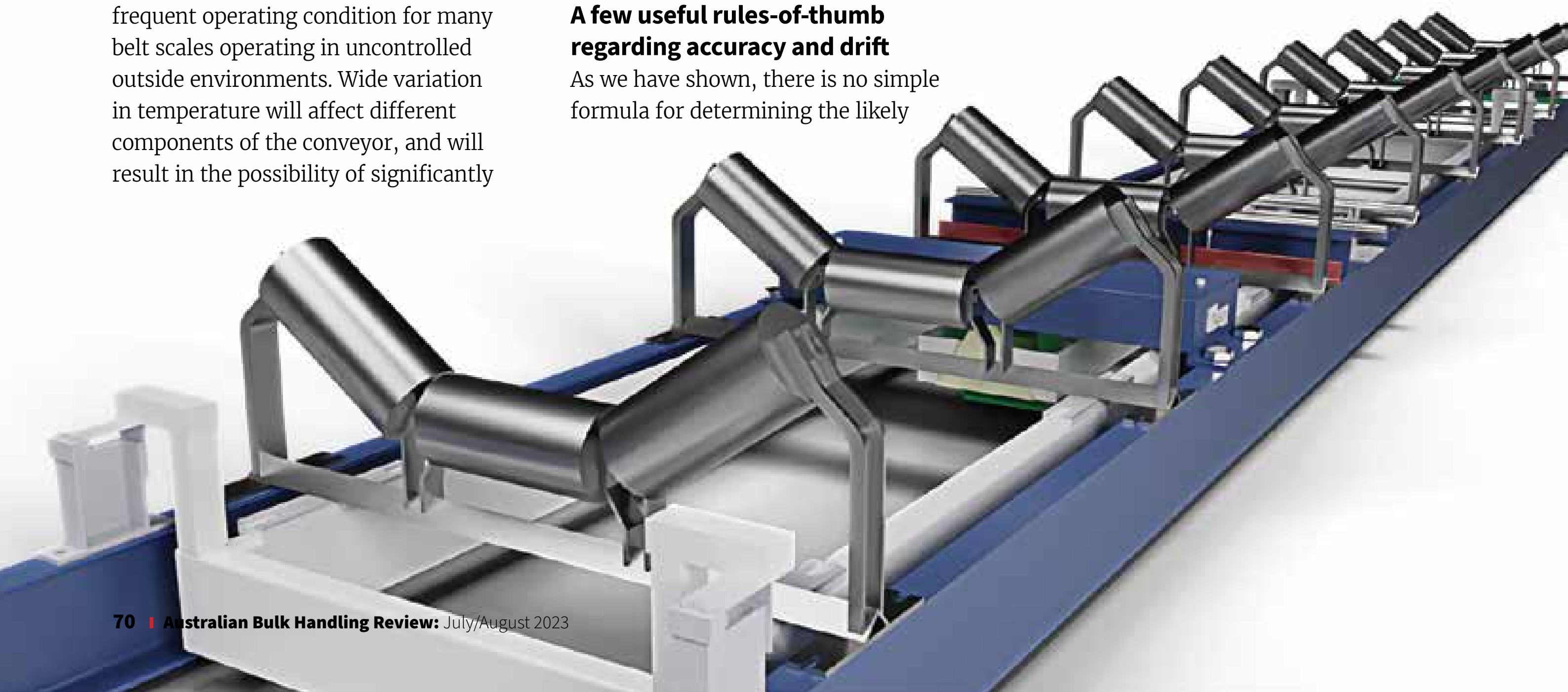


Figure 6: A Thayer Scale model 6RF Approach / Retreat Weighbridge