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X-ray Weighing Technology

Exploding The Checkweigher Accuracy Myth

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Preamble

At the time of this writing, it has been apparent for several years that there is a fundamental misunderstanding about the viability of an X-ray Inspection system to be used as a checkweighing device. The goal of this paper is to examine the reality and lay forth the facts surrounding this technology. The intent is to enable a sensible judgment to be made in determining if and when the inherent secondary ability of X-ray systems to checkweigh can and should be used versus using a conventional gravimetric electro-mechanical checkweigher (hereafter herein termed a "checkweigher").

What is hypothesized, and herein substantiated, is that:

- In most cases, an X-ray System can do a fully adequate job of checkweighing, and
- Sometimes, an X-ray system can do a better weighing job than a checkweigher, and
- The reliability and multiple functionality of X-ray systems provide better value.

The approach of this paper will be to examine the issues, with particular attention to:

- The issues behind the common misperception that a conventional checkweigher is always more accurate in checkweighing than an X-ray system, and
- Why and how an X-ray system can and does avoid pitfalls inherent to checkweighers.

Why Checkweigh?

There are two prime reasons to checkweigh a product sold by weight or count. These are:

1. **LEGAL/ECONOMICAL** – Most modern countries have packaging requirements that make it an offense to sell underweight packages of product. There is a fairly standard approach that states for a common category of product that:
   - The average contents of a group or batch of packages must not be less than the declared net weight,
   - The batch must not exceed more than some small percentage (ie.2.5%) of tolerably underweight packages (this value varies by product, country, etc.), and

- The batch must not contain any intolerably underweight packages (example could be those which are deficient by more than twice the tolerable underweight value). (For more on this subject, refer to the Department of Commerce National Institute of Standards and Technology's (NIST) Handbook 133.)

  While this is a grossly simplified explanation of regulatory requirements, it fairly well describes the driving consideration. As such, the prime goal of the producer is to stay on the legal side of this requirement, while not "giving away the store".

2. **MARKET SHARE** – Whose ramifications are less well understood. This is especially true as regards the magnitude of loss indicated by customer complaints. While this subject is the topic of a whole second paper, very few will argue that to flagrantly ship underweight product would have a negative effect on the consumer and retailer. Unhappy customers vote with their feet.

DON'T ASSUME – Just because you have apparently addressed a problem in terms of conventional wisdom (i.e. you have installed a checkweigher and metal detector), don't just assume that there is nothing more you can do. For example, if you examine the customer complaints at many companies who have quality checkweighers installed on every line, you find there are still product shortfall complaints. This is due to some inherent shortcomings of the conventional electro-mechanical checkweighers.

This paradox of having online a system that conventional wisdom would indicate is the best weight monitoring solution, and still having adequacy of contents complaints illustrates once again the old axiom that "the devil is in the details".

The Details

Typically, both X-ray systems and check-weigher systems tend to share a lot of common points:

1. They both can monitor an average over either time or a preset amount.
2. They both display the product weight in (typically) grams, and weight histogram.
3. They both can reject product exceeding underweight and overweight set points.
4. They both can keep electronic records. (Valuable for 21 CFR Part 11 compliance) and can be accessed remotely.

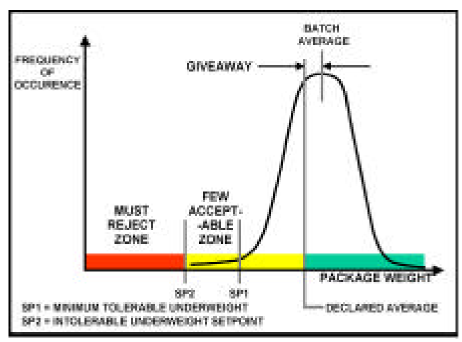

Fig.#1 Typical Product Weight Histogram

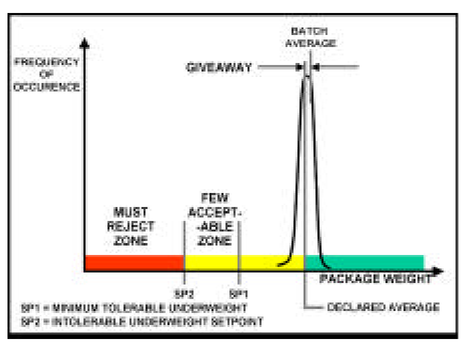

Fig.#2 Near Perfect Product Weight

In this day and age of computer power, once the fundamental values are measured, it would be more astonishing if the systems couldn't do this than the fact that most do. Number crunching at high speed is no longer the challenge it once was.

Figure #1 and #2 explain the job that the product weight-monitoring device must perform. In order to minimize the giveaway amount, the width of the distribution bell curve must be kept as tight as possible. To do so requires having very accurate and repeatable package filling machines and also the accuracy of the value from the weighing device will affect this.

This is where the dynamic accuracy of a checkweigher comes into play in a significant way.

In a perfect world, if you had a quantity of products that weighed exactly the same (i.e. perfect product) and ran them in a perfect cadence, on a perfectly engineered line, the theoretical perfect result would be a very tight bell curve, and in fact the only factor that would create any width to the bell would be the precision of the checkweigher.

As you can see in Figure #2, in this optimum instance, the giveaway is much lower and there are none in the "few acceptable" zone as well.

Indeed, in this extreme (and unlikely) case of perfect product on a near-perfect checkweigher, the "giveaway" could be reduced to virtually zero without having too much in the "few acceptable" or "must reject" zones.

So why do we say "unlikely case"? The answer is because product weight varies naturally due to filling machine variability, etc., but even more importantly so does the quality (i.e. dynamic accuracy) of the instantaneous weight values coming from a checkweighing device. This variability in the weight value due to the checkweigher is due to inherent system errors.

It is important to remember that in this second case the low-to-no "giveaway" would only be possible with if one were using a perfect checkweigher and on the perfectly installed line. This leads nicely to the next and key issue in this discussion. For practical purposes, we will assume that the reader has made every effort to optimize his filling machines and now is focused on the checkweigher.

Checkweigher Myths Versus Reality

Some common misunderstandings are that:

1. ***"Conventional checkweighers are both very accurate and very precise, -- much more so than X-ray weighing systems."*** – While this is generally true in both the static (normally useless mode) and in the optimum weighing conditions mode (hard to maintain), the reality is that in actual production situations this is not normally the case. Very often X-ray systems will actually perform better. Under optimum conditions, the conventional checkweigher can and do give amazingly good accuracy, but under more pragmatically typical conditions they degrade rather rapidly. On the other hand, the X-ray system retains its accuracy under a wide range of conditions. Typically, the more intense the production, the worse the checkweigher degradation is, while the X-ray system remains relatively unaffected.
2. ***"X-ray systems can't be used because they don't meet "Weights and Measures Standards whereas checkweighers do".*** – This is also a myth. The on-line checking systems normally don't fall under the weights and measures act of most countries. As such, this is a common denominator for both systems.
3. ***"Certainly a checkweigher will ensure that no gross under-fills escape my factory."*** – Again, this has often proven to be a myth. An examination of customer complaints shows short-fill complaints that are not about 5% or 15% missing, but rather gross amounts like 50% or more. Conventional wisdom frequently dismisses these as fabricated stories, but experience has shown that once an X-ray weight-monitoring system was implemented the complaints go down to virtually zero. This fact demonstrates that the customers' complaints are valid. This seemingly impossible situation (given a good gravimetric checkweigher was on-line) is more easily understood when one examines all the issues that affect these conventional checkweighers.
4. ***"Yes, but an X-ray machine is not really weighing whereas a checkweigher is."*** – This is endlessly debatable, but consider the following. The final objective is to ensure that the correct amount of product is in the bag/box/carton. This is a measurement of quantity or

mass. The easiest way (at least for the past few centuries) to measure mass has been by gravimetric "pull". A given mass, in a standard terrestrial gravity field will exert a specific downward force due to the attraction of gravity. In a gravimetric checkweigher, this force is then converted by some form of mechanical-to-electrical device (e.g. a load cell, etc.) to an electrical signal, and then displayed. An X-ray system beams X-rays through the body of the substance, and converts the cross sectional absorption of these rays into a mass proportional signal. In both cases, the mass is being measured by the use of a secondary phenomenon.

The point is that you must bear in mind what you set out to do; -- namely ensure that the package has the correct amount of substance therein. There is nothing "sacred" about gravimetric measurement of weight. Even though this has been the conventional method for the industry, how you ensure that the fill is correct is immaterial as long as it works. Ensuring the correct amount of mass via absorption is just as valid as gravitational pull, and even better if it results in a more reliable rendering of satisfactory product.

5. ***"But the gravimetric checkweighers quote excellent accuracy specifications"*** – It is not uncommon to see accuracy and precision specifications for checkweighers that are quoting numbers like 1 tenth and even 1 one-hundredth of a percent accuracy. In practical terms, these are unrealistic in terms of their routine attainability on a production line. **The reality is that for many (perhaps most) products, the achieved accuracy is on the order of +/- 0.8 % to +/- 3.0% and not the fractions of a percent stated.** This is easy to substantiate for yourself. Just go to a high production rate line, and repeatedly reweigh one product by noting it's reported weight as it passes over the checkweigher, then reweigh it by manually reinserting it on the line upstream of the weigher and repeating the process 10 or more times. The successive values of that one product will likely vary considerably more than the standard specification for the checkweigher, even in representative "normal" conditions on the line.
6. ***"How can checkweighers be so bad when their specifications and even the general perception of users is that they are so much better? Are these manufacturers exaggerating? "*** – No, but there is an "old saw" that says that *"if you torture figures long enough you can get them to say whatever you want."* Perhaps a kinder explanation would be to say that it is harder to define a non-optimum condition than an optimum one, so the latter is chosen for specification purposes even though the likelihood of achieving this in process is very small.

Having said this, let's take a hard look at what some checkweigher companies are actually stating if you look carefully at their figures.

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Some Examples Of Specifications

Figure #3 following, is a fairly typical specification from a quality vendor's brochure. The model numbers have been hidden to maintain the anonymity of the vendor.

Our example chosen, others similar.

Standard specifications

Model						
Range		1~100g	2~200g	10~1000g	20~2000g	5~500g
Accuracy		±0.1g	±0.2g	±0.4g	±1.0g	±1.0g
Speed (Max.)		120packs/min.	150packs/min.	120(150)packs/min.	120packs/min.	220packs/min.
Increment		0.05g	0.1g	0.2g	0.5g	0.5g
Rated Selectivity Range		0~±9.95g	0~±99.9g	0~±99.8g	0~±99.5g	0~±99.5g
Products	Length	Max.150mm	Max.180mm	Max.250mm	Max.300mm	Max.150mm
	Width	Max.100mm	Max.120mm	Max.220mm	Max.220mm	Max.220mm
	Height	Min.5mm	Min.5mm	Min.5mm	Min.5mm	Min.5mm
Power consumption		150VA	150VA	250VA	250VA	200VA
Power supply		AC230V +/-10%, 50/60Hz, single phase, 450VA				
Air supply		0.5MPaG(5kg/cm²G) 0.1Nm³/min(for rejector)				

The accuracy and the speed are subject to change by the shape and the contents of the checked products.

Figure #3. Checkweigher Specs from a major manufacturer

Let's look at this typical system giving a range of 20 to 2000gram capacity. Note that the "Accuracy" is given as +/- 1.0g, which one would say, *"Fine, at a weight of 2000g this is an accuracy of 0.05% which is great".* You would be forgiven if you thought that every package that went over this unit would be weighed to this kind of accuracy, but this is nearly always not the case. One must examine the details a bit more.

If you examine this same brochure a bit more, you will also see some interesting accuracy diagrams given for each model. Look at their diagram (Fig.#4) for this same unit, and use the 1500-gram weight example.

- Notice that as the package length gets longer, the accuracy specification goes down due to the need to run the conveyor faster, resulting in more table bounce and less settling time.
- Notice also, that for over 1500 grams that the specification is reduced to 80 packs per minute.

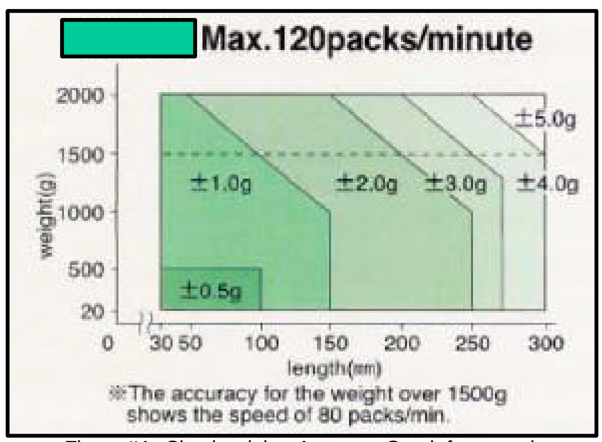

Figure #4. Checkweigher Accuracy Graph from vendor

So, for example if you have a product (such as a carton of cereal) that weighs around 500 grams, and the carton in the direction of travel is 254mm (10 inches) that the accuracy is now given as having degraded to +/- 3.0 grams or in other words 3 grams on 500 grams or +/- 0.6% and this is at optimum conditions. Non-optimum conditions can degrade performance even further.

Still, not so bad you say? There is another matter to consider. That is, what does the word <u>accuracy</u> mean? This criteria is far from standardized in the industry as yet, -- but in qualitative terms it means the following:

> ***"Checkweigher accuracy is defined as the standard deviation of the weighments of a single item weighed on the checkweigher several times. It is the variability, or uncertainty, of the checkweigher."***

Standard Deviation

So what does this invocation of the revered term "***standard deviation***" imply? Without stating how many Standard Deviations (SD) that are used in the expression of accuracy, you really can't tell much at all. This term is needed to really understand what the term accuracy means. For example, figure #5 below explains the relationship of the SD term.

This figure represents the same product dynamically weighed repeatedly and the values plotted. The mean value is correct for the weight, but as you can see, the same product is reported higher and lower than the actual value with some frequency.

You can see that 68% of the time the reading is "*nearly bang-on* " or very close to the mean (and true) weight. Also, 95% of the time it is "*fairly close*", and 99.7 percent of the time it is "*not too bad* " as shown.

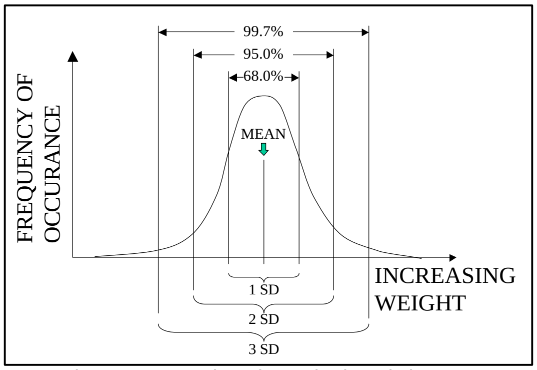

Figure #5. Meaning of Standard Deviations

You can see that the accuracy that you could claim at 1 SD is better than 2 SD and so on. Normally, good practice would indicate using 3 SD to indicate that the value will be as accurate as stated at least (99.7%) of the time.

Susceptibility to "Bursts"

Quite possibly, even this achieved performance for a given product would be acceptable <u>if it was reliable</u>. However, there is <u>another issue</u> that can further <u>degrade</u> the <u>dynamic performance</u> considerably. This issue is rather likely to occur in normal plant environments, and it tends to be exacerbated at precisely the time when a checkweigher is most needed, during times of heavy production.

It occurs when the filling machine has temporarily developed a repetitive "glitch" in its operation. Experience has shown that it is not uncommon for filling machines to sporadically "glitch" thus producing a series (or train) of packages that are off-weight rather than just a sporadic off-weight package. A sticking bucket in a multi-head weigher could cause this for example, or clumping product feed that renders the multi-head weigher incapable of finding a combination that equals the declared weight. For these, and several other reasons, filling machines can go "off their game" and produce a series of off-weight packages. This is the worst-case condition for conventional checkweighers. In addition, the product pacing can change both in terms of cadence as the production rate changes and also in orientation and spacing. These will have serious negative effects on a checkweigher for the reasons that follow.

The point here is that it is important to know several things to really specify a checkweighers' accuracy:

1. First of all, you must know what confidence it is based on, that is to say how many SD. Often the confidence value (SD) is not given, thereby rendering the accuracy value given as essentially not meaningful. In the curve above, +/-0.6% at 1-SD is +/- 1.8% when stated at 3-SD.
2. Second of all, the specific conditions must be known for the checkweigher accuracy. As you will recall from the brochure specification (Fig. # 4, page 6), the accuracy depends on the package frequency, weight, and shape. So, the +/- 0.6% given in the prior example may very well be stated as an impractical/idealized situation, and the practical in-situ value achieved on typical production is likely to be on the order of +/- 1.5% at 1-

SD in real terms. Any floor or other transmitted vibration, as well as air currents (fans, etc.), and any package drag/touching of side rails can further degrade the performance.

How A Gravimetric Checkweigher Works

Generally, a gravimetric checkweigher is comprised of a series of small conveyors in series with the final one being mounted on a moveable force-to-electrical signal transducer. These transducers are typically:

- A piezo-electric crystal load cell, that produces a signal when the crystal is twisted, and this signal is measured as proportional to the weight, or
- It may be a displacement cell that when deflected applies a return force to return to the original position (minus some infinitesimal error amount) and this signal is measured as proportional to weight.

In both cases, the mass traveling over the weigh table is acted upon by gravity, and the transducers measure the resultant downward force. The resultant signal may not be linear and will often need linearization, but this is simple in this day of high speed computing.

As may be seen from Figure #6 at right, a good conventional checkweigher installation will include the necessary components to orient and pace the product. This is an example of a typical system, which relies upon the "slow-then-fast" conveyor pair for this function. If a product comes down the feed conveyor skewed but not closely followed, there will be no "rear-ending effect" to correct the orientation. The speed and timing of the orientation and spacing belts are critical, and assume a certain mean pitch from the approaching product. Needless to say, if the feed rate (products/minute) varies widely (as they could if this line had more than one filler feeding it) this scheme is not always successful.

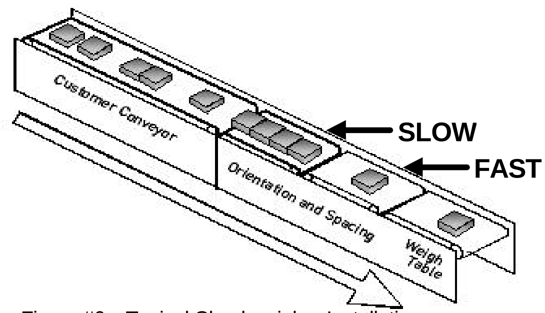

Figure #6 – Typical Checkweigher Installation

Checkweighers' Weakness Points

When you stop and think about what a conventional checkweigher must do, it is often amazing that they do as well as they do. Imagine having a football team run across a bathroom type scale at full speed one behind the other and you are supposed to record accurately the weight of each player. The needle would be bouncing around and you would have to just take an educated guess as to which point on the scale was the stable accurate reading. This is very much akin to the job the checkweigher electronics must do.

If you plot the signal coming off the weight transducer (be it load cell, or displacement cell) you will see this same effect. When the weight first arrives on the cell, there is a short temporary overshoot due primarily to the inertial effect of the mass, and then given sufficient time there will be a period of stability, followed by an undershoot as the weight departs the weigh-table, and perhaps some "ringing" due to table bounce and external vibration. Then, as the next product arrives the process is repeated.   When the stabilization period is sufficiently long, this weight value will be very good, potentially as good as the static weighing ability of the checkweigher itself. In these situations these electromechanical systems will give very good gross package weights.

However, the situation is often not optimum. For example, when you run a Form/Fill/Seal machine at a rate of 120 packages per minute, there will be a package arriving to be weighed every 500 milliseconds. If you noticed in the example of a vendor specification given in figure

#4 (p.5), there was a reduction in accuracy when the package frequency became 80 packages per minute. This is simply because the time required for the product to "get aboard" the weigh platform, then stabilize, and then get back to zero as it departs is beginning to equal this 500 millisecond time. When this begins to happen, in effect the weight mechanism has not fully recovered from the last product by the time the next one arrives. This problem has been dealt with to a certain extent by developing "predictive" software routines that look at the weight cell signal through an Analog-to-Digital converter and then apply mathematical predictive algorithms to the signal to extrapolate what the weight stability plateau would have been if it had had time to stabilize. All things being equal, this methodology is of value, but the caveat is the "all things being equal" phrase. Unfortunately in the packaging industry, it is frequently difficult to maintain "all things being equal", and when things are not equal, that is to say the cause and the duration of the product-to-product interference are varying, then the assumptions of the predictive algorithm are not met and the algorithm will make erroneous predictions as would be expected. These errors created by the corrective software can range from insignificant to truly major errors.

The traces in Figure #7 below represent an example of the signal that comes from the weight transducer.

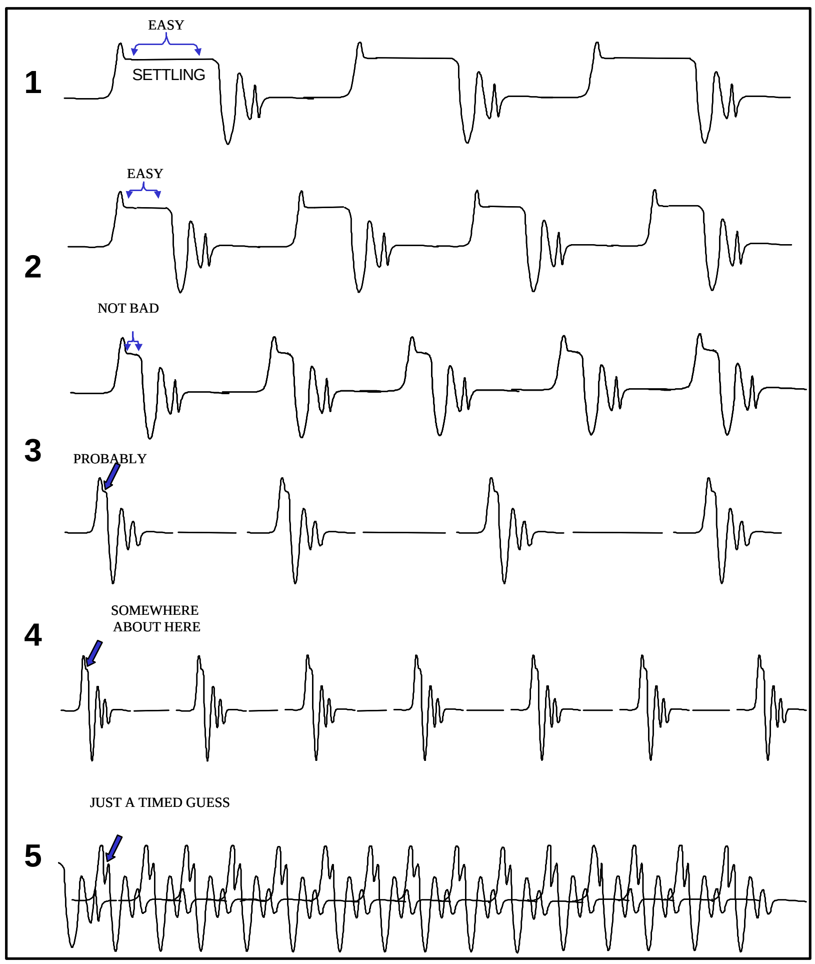

Figure #7. Effect of speeding up conveyor and product appearance frequency.

As may be seen in trace #1, it is easy to see when the weight arrived on the cell, the initial inertial overshoot, and the subsequent cell value settled. Thus, taking a reading is very easy and it will be very good. There is also plenty of time to recover zero before the next product arrives.

Now, as you speed up the conveyor, the product does not stay on the weight table very long, so the settling time gets smaller and smaller. You see that by trace #4 that the settle time is getting very small. Thankfully, though the product is running on a fast conveyor, the repetition rate is still low, so there is lots of zeroing time between packages. As the production rate of packages per minute gets faster, not only does the settling time begin to disappear, but also the time to zero between packages is vanishing. Now, it becomes necessary to take a timed reading. This is done with a leading-edge trigger from a photo-eye followed by a time delay. When the system is really running fast, there is insufficient time for the table to really stabilize, and the resultant signal series is shown in trace #5.

Here, the bounce of the prior product begins to overlap the current one. When this effect begins, even with excellent photo-eye timing the weight can be seriously affected as the degree of overlap and the exact nature of the bounce period will be affected by very small cadence (pacing) and package orientation (rotation on belt) variations. Thus, truly compensating for this becomes virtually impossible.

When the product is "behaving" very well on the conveyor, as is shown in Figure #8, the plateau of settling time is reasonably good and predictable in terms of bounce correction, and the checkweigher will give very good answers. However, this is rather idealistic and the reality is that the product pacing can vary for a host of reasons. In addition, the product orientation can be affected for a host of reasons.

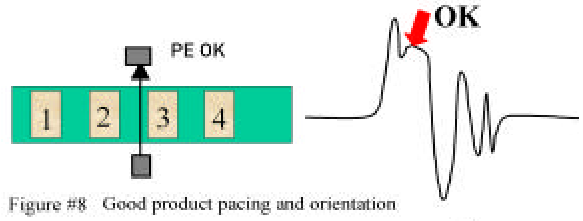

Figure #8 Good product pacing and orientation

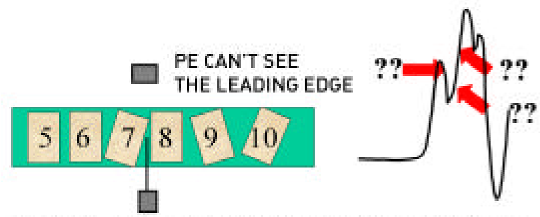

Figure #9 Poor/close product pacing and variable orientation

When the product begins to behave as shown in Figure #9 the effect on the weigh table is very different. For example, there is no gap between product 7 and product 8, so the photo-eye gets confused and also the weigh table bounce is radically different than it was in the Figure #8 example.

Finding the true point on the weight signal waveform-by-waveform analysis is next to impossible in this situation, since there is no reliable leading-edge trigger. Much effort has gone into developing ostensibly intelligent curve deconvolution algorithms that will extrapolate where the weight settle point is independent of a photo-eye start signal, but the reality is much the same as the old adage, *"garbage in equals garbage out".* A not infrequent sequence of events is that the package filling machine "runs amuck", and a whole train of product is produced that is out of spec and frequently is disrupted in cadence. This is the very time is when the "policing" effect of a good on line checkweigher is most needed, and this is the very time that the electro-mechanical one is at its poorest (product coming rapidly and inter-product bounce is atypical).

It is obvious therefore, that keeping the product cadence and orientation constant is critical to the good operation of a high-speed conventional checkweigher, but this is easier said than done. At this point, one is in the undesirable position of trying to make the product accommodate the checkweigher when the opposite should be true of a well-designed process machine. Furthermore, it is often tantamount to impossible to prevent all "hiccups" in the weigh/fill devices. They can be affected by feed issues, the product clumping or sticking, hoppers that won't empty - thus precluding a correct weight, and so on. While the frequency of this happening is generally considered low enough to be tolerable in a well-engineered filling system, it still does happen in bursts. Experience has shown that this is the real domain where the X-ray weight checking system excels.

Adding to the difficulty experienced by an electromechanical checkweigher, the following issues also degrade the performance:

- Air currents can blow on the weigh table and add or subtract from the true weight.
- Spillage on the table can affect the tare value of the table.
- Floor vibrations from other machinery or forklifts can affect the weight table.
- Static electricity can create an electrostatic attraction that can alter the apparent weight.

So How Does X-ray Checkweighing Avoid These Problems?

Since X-ray checkweighing is totally non-dependant on any physical movement of a weight-table, most of these issues are avoided. The following is an explanation of how the weighing is achieved.

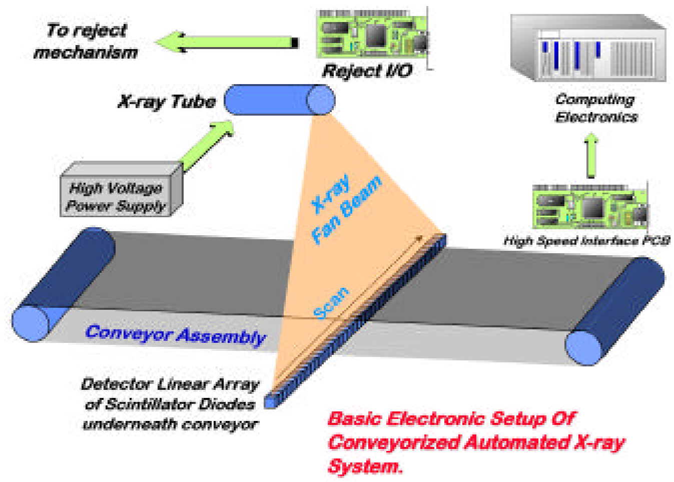

Figure #10 X-ray System basic component layout.

Figure #10 at right shows the basic system. The product is conveyed through the fan shaped beam, and the many diodes under the belt are sequentially scanned for X-ray intensity value. As the product moves through the beam, it creates a diminution of the beam and this diminished intensity is recorded on a point-by-point basis across the belt. This is repeated many times per second while the product is moved forward as well. The net effect of this is to "slice" the product into many very narrow slices and each of these slices is divided up into hundreds of individual points. There will be as many points of data as there are detector diodes in the Linear Array under the belt (typically 640 or more). Correlating successive "slices" then creates an image made up of many thousands of small "area views", each of which has a respective intensity value. Perhaps the easiest way to think of this image is as if the system has made a very fine grid of the product with a density (area density) value for each point in the grid. This "grid" is on the order of 0.8mm by 0.8mm in dimension, so the product is divided into hundreds of thousands of individual cross sectional density values.

Since each single grid point density (area weight) value is proportional to the cross section of the product at that point, (i.e. the thicker the product, the more shielding effect) the point value is representative of the area weight assuming a substance that is essentially homogenous in material terms. This is normally the case for most foodstuffs and pharmaceuticals, etc. so one may then sum the individual grid point area weights and create a value proportional to the overall density of the product. This summation will be proportional to the product mass, hence the weight. Figure #11 helps to illustrate this point.

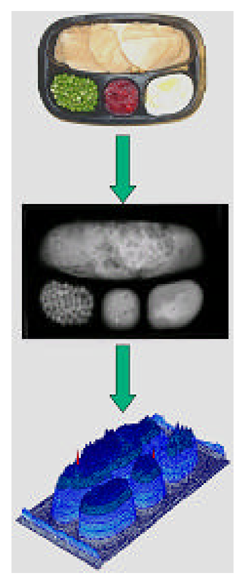

Figure #11

Figure #11 shows the top a four-part Home Replacement Meal (HMR, or so-called "TV Dinner"). The carton has been removed to photograph the contents, but it was X-ray weighed inside the carton. This may be seen in the central gray-scale image (you can faintly see the carton). The parts of the meal are Turkey meat, peas, cranberry sauce, and potatoes. As can be seen in the middle portion of this diagram, the X-ray picture provides a gray-scale image wherein the "gray-ness" of the image is proportional to the area density (grams/cm2) at each point in the meal. If all the adjacent grid point density values (area weights) are added then one has the weight for that respective portion of the entire meal. These area weights can be displayed as a 3 dimensional vertical bar graph for visualization purposes, and this is shown in the bottom third portion of this figure.

The important issues to focus on here are that:

- The image will remain the same regardless of rotation.
- There is no inertial effect so weigh-table "bounce" is not an issue.
- Packages touching each other have no negative effect (more on this below).
- Air currents have no effect.
- Vibration has no effect, as there are no moving parts (other than conveyor).

An Important Additional Benefit – Selective Area Weighing

One more distinct advantages of X-ray weighing is the ability to independently weigh selected areas within a package. This adds the benefits of the ability to tolerate touching packages, and the ability to segregate the weights internal to the package and weigh them independently of each other.

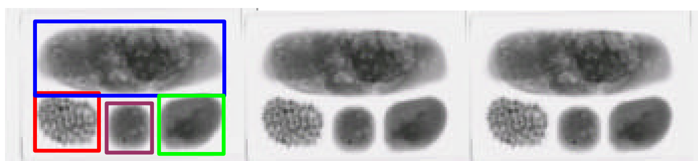

Figure #12 Product packages touching.

As you may see in figure #12, even when the products are touching at the package edges, the contents are still normally clearly separable, not only as packages (due to their grouping) but from each other.

By identifying each distinct areas of mass within each package, each individual component of the package may be selectively and independently weighed. In the product at the left of figure #12, you can see that each area of the "TV Dinner" is independently identified. If there is one component that is critical in terms of adequacy (i.e. the Turkey meat in the blue rectangle), then this item can be weighed and compared against its own weight standard and is not "lumped in" with the rest of the meal components.

Furthermore, as may be seen above, the fact that the products are touching at the packaging edges does not preclude this ability. Both this ability to weigh subcomponents of the package, and the ability to tolerate touching packages are not tolerated by electro-mechanical checkweighers.

How Then Can I Decide When To Use Which Technology?

The easiest answer is to say that you ought to use X-ray whenever it can meet your tolerance needs. This is for two main reasons:

1. It is likely to be consistently more accurate in true production situations.
2. It can simultaneously provide many other monitoring functions.

The graph in Figure #13 perhaps explains the concept best. As stated, an electromechanical checkweigher will almost always be more accurate than an X-ray weighing system at low packs/min. rates. In fact, there is no such thing as a "static mode" in a conventional X-ray weighing system, as the only way these systems can weigh is dynamic.

However, the advantage they have is that their accuracy does not deteriorate with product speed and repetition-rate, as is the case with the electro-mechanical weigher.

As you may easily see on this graph, once the package per minute rate goes up, and normal issues of package orientation, pacing, and normal production environment issues pertain; the X-ray checkweighing system is a clear leader.

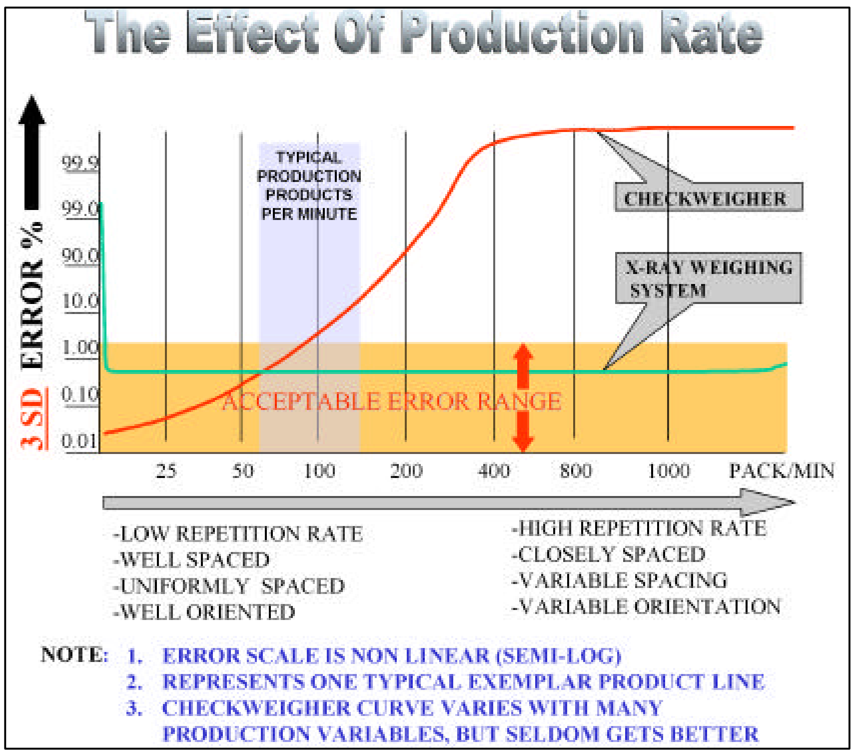

Figure #13 – Effect of production rate on the system at 3 SD error.

In Summary (Good Enough All The Time Is Better Than Excellent Some Of The Time)

For years the expectations and understanding of the accuracy of the values from most electromechanical checkweighers have been based upon unrealistic performance. This has been fostered by the practice of omitting from the accuracy specification the term and quantity of Standard Deviation which defines the uncertainty under operational conditions. Additionally, the non-representative test methods promulgated by many manufacturers have led to a widespread misunderstanding of what checkweigher accuracy really is.

The commonly verbalized accuracies bandied around have been on the order of tenths or even hundredths of a percent, while the in-situ reality was more often on the order of 1 to 3 percent. This has been primarily due to the multiplicity of factors affecting an electromechanical checkweigher system in a typical production situation, the non-representative conditions of the stated accuracies, and the specification issues mentioned above.

There is no circumstance, or situational "sweet spot", whereby an X-ray checkweighing system can reach a similar high accuracy as the tenths or hundredths of a percent mentioned, but on the other hand the practical 3-SD accuracy of (for example) +/- 1% will be solid and hold over a very wide range of conditions. This latter attribute makes the X-ray system a very worthwhile inspection technique for a production line.

Add to this, the ability to weigh independent of the packaging, selective areas within the package, while simultaneously detecting a wide range of other potential product defects as well, and you have a system of unparalleled value.

All this is achieved with far fewer moving parts, better reliability, less line space, and less overall capital cost than would be required for a quality electromechanical checkweigher and a metal detector combination.

X-ray Technology truly does currently approach the closest you will come to the ultimate end-of-line inspection system.