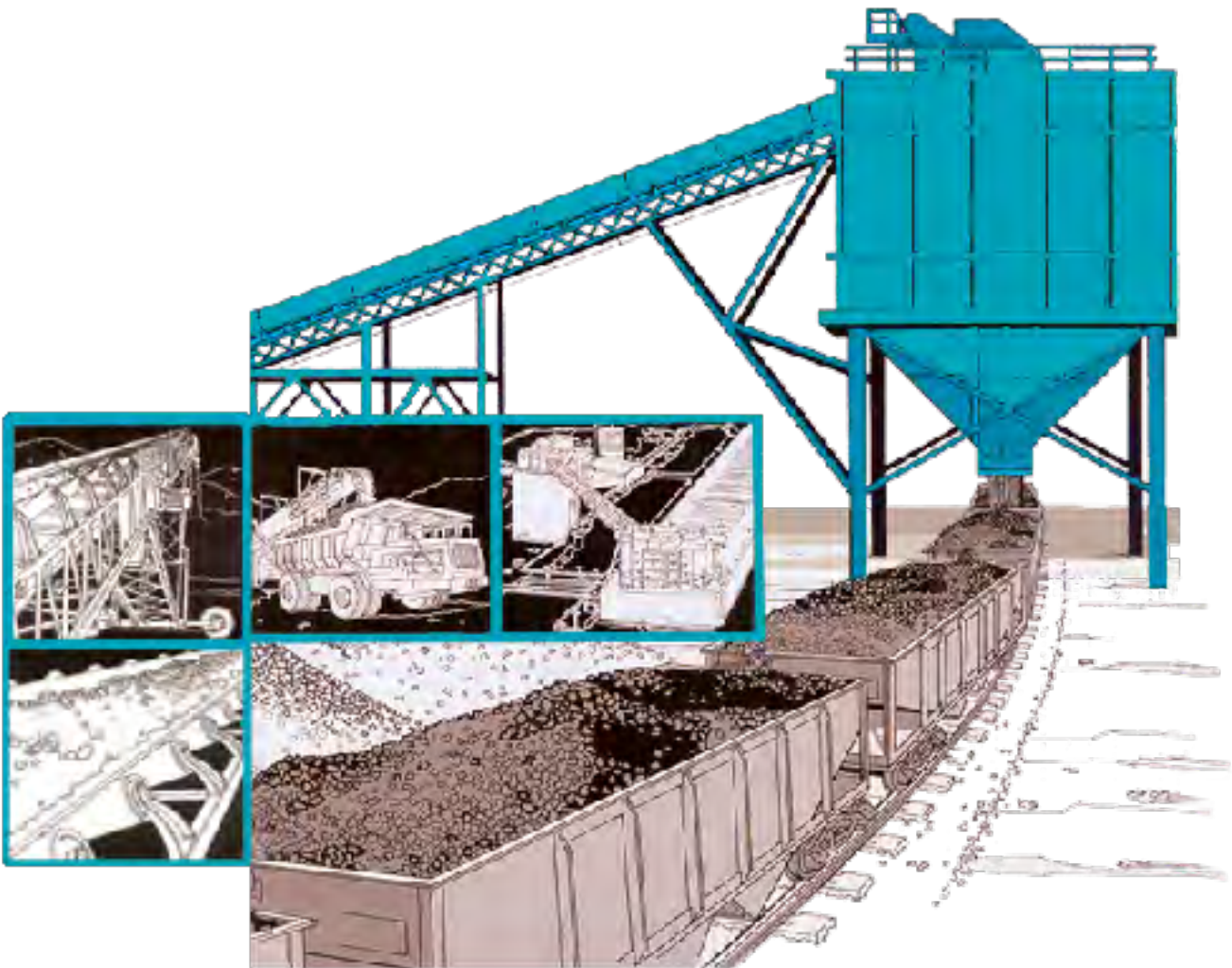


# THAYER SCALE BELT SCALE HANDBOOK Theory and Application

Achieving reliability and stability in severe environments  
using proven techniques



**THAYER**

INTELLIGENT  
**FMSS**  
TECHNOLOGY

## A MESSAGE FROM THE PRESIDENT OF THAYER SCALE

*You need more than a "belt scale" to weigh accurately on a conveyor.*

*The THAYER line of conveyor weighing equipment represents the outgrowth of our company's total commitment to provide industry with complete answers to continuous weighing problems. We emphasize the word "complete" because we firmly believe that we have been addressing ourselves to many of the problems that others continue to ignore.*

*Our organization and our facilities are unusually well suited to our endeavors and both represent the result of over 55 years of success in following a philosophy of focusing on the areas of business that our people know best.*

*Our typical equipment "package" consisting of scale suspension, load cell, belt speed transmitter, instrumentation and calibration equipment has evolved from following an integrated system approach to providing accurate and reliable weighing equipment. Many of our users express surprise when finding that our 4 and 6 idler scales require very little, if any, correction after material testing. Think of the importance of this in those installations where material testing cannot be accomplished in a practical manner.*

*We have prepared this material to be of use to you. We trust that you will find it both interesting and informative.*

Frank S. Hyer  
President



Frank S. Hyer is a graduate of Ripon College in 1956 with a B.A. degree in mathematics. He earned his B.S.M.E. at the University of Delaware in 1958 and his M.S.M.E. at the University of Wisconsin in 1968. His graduate thesis, which is entitled "A Scientific Approach to Conveyor Weighing", has been cited on numerous occasions as a reference in technical journals dealing with the subject of conveyor weighing. He is an active member of the American Society of Mechanical Engineers and the Instrument Society of America. He has served as past director of the Process Weighing Committee of ISA, and he helped to draft the committee's input to the National Bureau of Standards Handbook 44. In addition, he is an active patentee and contributor of technical articles in the fields of weighing and materials handling.

## WE HAVE THE COMPLETE ANSWER TO YOUR CONTINUOUS WEIGHING PROBLEMS. EXCELLENCE IN EVERY AREA IS THE KEY.

**THAYER performance...** the result of research, experience and dedication to our customers  
The precision performance of a THAYER belt scale is the result of an evolutionary process that began over four decades ago. Continuous research and development, and the commitment to advancing the state of the art through intelligent upgrading of designs, have assured our customers that equipment purchased TODAY will not be obsolete TOMORROW.

The impact of THAYER technology has been felt world-wide, and while often imitated, it has not been successfully duplicated. Every design improvement has been initiated only after the details for upgrading past designs have been worked out. To duplicate THAYER technology requires an allegiance to the past as well as to the future.

The purchase of a THAYER belt scale is the best insurance you can have toward years of satisfactory and maintenance free performance.

### **THAYER technology leads the way.**

Thayer Scale takes particular pride in its accomplishments in advancing the state of the art in continuous weighing. Beginning with the development and refinement of the theory of continuous weighing, significant improvements in levels of performance have been achieved by the introduction of innovative methods and designs to all key areas that contribute to the overall performance level of an installed weighing system.

### **THAYER theory leads the way.**

- Developed and published a useful mathematical model of the conveyor weighing system to analyze the effects of conveyor parameters on belt scale performance.
- Developed and published the method of "Force Alignment" to achieve greater insensitivity to belt tension factors.
- Developed and published a useful mathematical model for describing and evaluating the magnitude of error attributable to belting elasticity (stretch).
- Described the "K-Factor" as a composite of three separate terms, thereby leading to an explanation of observed performance characteristics of single vs. multiple idler suspension systems.

### **THAYER application methods lead the way.**

Proprietary computer software developed to utilize THAYER theory is used to study customer applications thoroughly before a recommendation of a particular suspension configuration and its location within the conveyor is made. Numerous conveyor design parameters, as well as customer expectations and requirements as to accuracy, frequency of opportunity to calibrate, etc.; are dealt with to a degree never before possible. The net result of this advancement in application engineering is that important conveyor design deficiencies and improper suspension selection and location within the conveyor can be dealt with before costly mistakes are made.

### **THAYER belt travel measurement system leads the way.**

- Allows initial calibration measurement to take into account dynamic empty-belt stretch factor.
- Subsequent operation with material automatically compensates for higher stretch factors.
- Measurement wheel circumference machined to better than .05%.
- Self steering design eliminates side-slip errors.

**THAYER suspension systems lead the way**

- Depth of suspension members customized at 4, 6 or 8 inches to meet deflection criterion.
- Special pentagonal (5-sided) tubular stringers employed to meet combination needs of torsional/bending rigidity and low material build-up area.
- Patented rocking-flexure primary pivot is wearless and uniquely accommodates a distorting foundation (as is characteristic of typical conveyor structures).
- Isolation lever suspended by stainless steel prestressed aircraft cable protects load cell from extraneous horizontal forces that arise from distorting foundation and serves to provide means to optimize load cell utilization factor.
- Top-of-the-line 6 idler design configured for the most stringent commercial weighing applications.

**THAYER load cell leads the way.**

- Proprietary design and in-house manufacturing assure conformance to special specifications unique to the needs of continuous weighing.
- Signal level in the order of 100 times that of competitive designs.
- Range is changeable in the event of a future capacity change.
- Performance specifications relate to NET rather than GROSS weight. See section on Load Cell Utilization Factor.
- High performance in the usual precautionary environments. (temperature gradients, temperature transients, shock loading, motor and electromagnetic induced vibration).
- Considerably higher immunity to the effects of lightning (LVDT only).

**THAYER integrator leads the way.**

- Patented digital concepts provide immunity to effects of power source variations of both voltage and frequency.
- Patented concepts provide measurement accuracy on belt travel independent of speed, thereby assuring the same accuracy of actual measurement at low speeds as is attainable at full scale speed.
- Patented Scale Location Compensator provides for weight reading at head pulley discharge. It is also used to provide in-phase proportioning in a multi-scale system.

**THAYER calibration system leads the way.**

- Patented calibration method utilizing a controlled belt travel interval makes one-shot adjustment possible.
- Material totalization data is not affected by calibration runs.
- Unique test weight system eliminates need for test chains.
- AFE (as found error) data collection and evaluation program determines correct interval between calibrations.

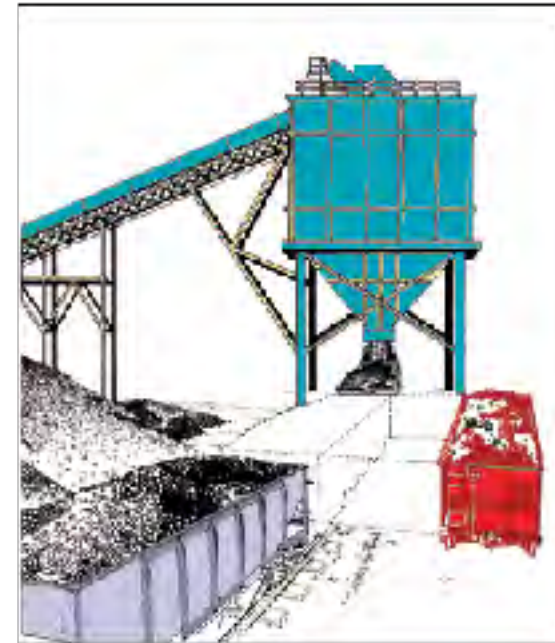
**THAYER scales lead the way in weighing bureau approval.**

In the past, in commercial applications where the belt scale was used for billing purposes, invoicing freight and custody transfer of goods and materials, approval was required by the weighing bureau which had jurisdiction for that particular geographical area. At that time blanket approval was not given to a particular model and each installation had to be certified by the specific bureau. It is important to note that the Model "RF" family of Belt Scales passed the certification requirements of the following weighing bureaus:

- Eastern Weighing & Inspection Bureau
- Western Weighing & Inspection Bureau
- Southern Weighing & Inspection Bureau

The Model "RF" Belt Scale was also submitted to the National Bureau of Standards, Office of Weights and Measures for prototype design approval and was granted OWM test # 51.

Today the "RF" Belt Scale family (NAR-4, NAR-6) is NTEP approved (NTEP CC 05-091) for use in commercial installations (see [www.NCWM.net/ntep](http://www.NCWM.net/ntep)).



**How important is accuracy and how much is it worth ?**

You can answer that question if you know how much your material is worth. You probably wouldn't be considering the purchase of Belt Scales if you weren't concerned about how much things cost. The information you receive from a Belt Scale tells you a lot about what is happening in your plant and, of course, one of the key bits of information is how much material has passed over the scale.

This weight information may be used for many purposes--Invoicing, Production, Inventory, Waste Measurement, Material Balance, Bonus Payments, Measuring Plant Efficiency, etc. At the end of a year of operation, the tonnage, and most importantly the dollars, can add up to a considerable amount. Have you ever tried to explain to a Vice President in charge of finance why \$2,000,000 worth of material disappeared?

JUST 1/4% ERROR CAN MAKE A BIG DIFFERENCE						
COST OF MATERIAL LOST BY SCALE INACCURACIES OF ONLY 1/4% FOR AN 8 HOUR SHIFT, 5 DAYS A WEEK, FOR 1 YEAR						
COST/TON	@ 200 TPH	@ 500 TPH	@ 1,000 TPH	@ 2,000 TPH	@ 5,000 TPH	@ 10,000 TPH
\$10	\$10,400	\$2,6000	\$52,000	\$104,000	\$260,000	\$520,000
\$20	\$20,800	\$52,000	\$104,000	\$208,000	\$520,000	\$1,040,000
\$30	\$31,200	\$78,000	\$156,000	\$312,000	\$780,000	\$1,560,000
\$40	\$41,600	\$104,000	\$208,000	\$416,000	\$1,040,000	\$2,080,000
\$50	\$52,000	\$130,000	\$260,000	\$520,000	\$1,300,000	\$2,600,000
\$60	\$62,400	\$156,000	\$312,000	\$624,000	\$1,560,000	\$3,120,000
\$70	\$72,800	\$182,000	\$364,000	\$728,000	\$1,820,000	\$3,640,000
\$80	\$83,200	\$208,000	\$416,000	\$832,000	\$2,080,000	\$4,160,000

## THAYER BELT SCALE THEORY PUT TO THE TEST-1977

It's one thing to analyze, field test and theorize on the ultimate in performance. It's another thing to put it to practice. Accepting the challenge has always been the THAYER motto.

The place: U.S. STEEL, CORBIN, KY

In 1977 Thayer Scale received and processed an order for four 2-idler belt scales to be installed in U.S. Steel's Corbin, KY, coal preparation plant. One of the scales was to be installed in the unit train loadout conveyor. It became apparent that this scale had to be certified by the Southern Weighing and Inspection Bureau to a tolerance of 0.25% (+/- 1/8%). We knew that a 2-idler scale was not capable of performing to this level of accuracy and decided that it was time to put all our experience and theory to the test.

What is perhaps the BEST CONVEYOR SCALE IN THE WORLD WAS BORN!

We put together a scale that included every conceivable improvement to our existing equipment we could think of:

- A 6-idler approach-retreat weighbridge.
- A new steerable speed pick-up wheel.
- A new simple two-board integrator using C-MOS circuitry.

Final acceptance is based on running material tests which consist of three separate tests of ten railcars each. No adjustments to the scale are permitted once the testing has commenced. The tests were conducted on a track scale owned and operated by the L&N Railroad. The track scale had been previously tested and certified. Thayer Scale passes certification test on Sept. 30, 1977, without requiring "K-factoring".

Many said we were lucky and that the true test would be if the scale could maintain that accuracy for a year without "K-factoring".

After four years and several recertification tests the results have proven we were correct.

In July, 1979, a third recertification test was run and the result was an error of .08%. It was reported that we were the only scale to pass recertification tests for the year. All the competitors' scales had to have their "K-factors" readjusted for new values. This means that if a THAYER 6-idler belt scale is properly applied to the conveyor an accuracy to +/- 0.125% can be achieved. Proper conveyor application is the only solution. You cannot depend on material tests alone to solve the problem of large bias errors.

FINDINGS	TEST #1	TEST #2	TEST #3
THAYER "RF"	973.300 Tons	971.200 Tons	980.200 Tons
L & N Track Scale	973.105 Tons	971.895 Tons	979.825 Tons
Scale Difference	+0.195 Tons	+0.305 Tons	+0.375 Tons
% Error	+0.020%	+0.031%	+0.038%

## (CORBIN) INSTALLATION SPECIFICATIONS:

USER: U.S. STEEL CORPORATION  
 LOCATION: Corbin, Kentucky  
 THAYER S.O.#: 3430A  
 MODEL #: 6RF-4-72  
 SERIAL #: 1200-885

### CONVEYOR DESIGN:

Capacity: Maximum: 4000 STPH  
 Normal: 3000 STPH  
 Material: Coal  
 Density: 50 lb/ft<sup>3</sup>  
 Size: 3" x 0"  
 Belt Width: 72"  
 Belt Speed: 550 FPM  
 Idler Spacing: 4'-0"  
 Idler Troughing Angle: 35°  
 Conveyor Configuration: Straight incline 18°  
 Conveyor Length: 262 Feet--Pulley centers  
 Conveyor Stringer: 8" Channel  
 No. of Feed Points: One  
 Scale Location: 38 Feet from tail pulley  
 Type of Take-up: Vertical gravity  
 No. of Belt Splices: One-Vulcanized

### SCALE DESIGN:

Model: THAYER 72" Model 6RF-4-72  
 Weigh bridge: 6-idler approach-retreat configuration with secondary lever and mass counterbalancing of the dead load.  
 Weight Transducer: Custom built super precision LVDT type applied in tension.  
 Speed Pick-up: Precision 2'-0" circumference wheel--spring loaded against the underside of the load carrying strand of the belt.  
 Speed Transmitter: High resolution, digital pulse tachometer with a resolution of 1/200 of a foot.  
 Integrator: THAYER Model I-133 two board Integrator with patented, built-in calibration feature housed in NEMA-4 wall mount housing.

### TEST EQUIPMENT:

Test Weight: 64.269 lbs..  
 Test Chain: 6973.875 lbs. X 38.79 ft long.

ACCESSORIES: 12" circular chart recorder with Hi/Low Alarms. Ticket Printer.

## THAYER BELT SCALE THEORY REAFFIRMED - 2005

The place: Duke Energy's Buck Steam Station, Salisbury, North Carolina

The coal unloading scale at Buck Steam Station was used for Thayer Scale's \*NTEP field certification site test.

In November of 2004 after successful completion of the laboratory portion of the NTEP compliance testing, Thayer Scale's newest Integrator, the Series 5200 was ready for its field trial. It was installed on an existing belt scale that had been certified according to Handbook-44 since 1999.

On November 16, 2004 the six month field compliance test began with 3, seven car unit trains used in the material testing. Testing was in compliance with HB-44 and NTEP procedures (see below for material test results).

In May of 2005, after running for six months according to the specifications and tolerances set in Handbook 44 and the restrictions set by NTEP, and without any adjustment to the scale, the second phase of the field test was completed. The belt scale was again tested using 3, seven car unit trains. Testing was in compliance with the Handbook and NTEP (see below for results).

Also, in November 2005, 6 months following the completion of the field test and 12 months following startup, the scale again passed its routine recertification test without requiring adjustments of any kind. The inherent advantages of the THAYER Approach-Retreat suspension system and the reliability of its built-in Test Weight Calibration Method, permitted these tests to be completed at minimal cost in terms of both labor and material. Each test was successfully concluded after running only the minimum series of material tests required. Since adjustments of any kind were not required, the need for costly follow-up testing was eliminated.

\* The "NATIONAL TYPE EVALUATION PROGRAM" (NTEP) is a program of cooperation between the NATIONAL CONFERENCE ON WEIGHTS & MEASURES (NCWM), the NATIONAL INSTITUTE FOR STANDARDS AND TECHNOLOGY (NIST), State Weights & Measures Officials, and the private sector for determining conformance of weighing equipment with the provisions of Handbook 44. NTEP provides the testing procedures for each type of device, oversees its testing, and issues a Certificate of Conformance (CC) upon acceptance. The range of operating parameters that a family of devices covered by a single CC can have is restricted and noted on the certificate.

FINDINGS:	TEST #1	TEST #2
THAYER "NAR"	751.4 tons, 715.2 tons, 737.2 tons	813.6 tons, 822 tons, 821.7 tons
* On-Site RR Track Scale	750.25 tons, 714.64 tons, 736.54 tons	814.22 tons, 821.71 tons, 820.97 tons
Scale Difference	1.15 tons, 0.56 tons, 0.66 tons	-0.62 tons, 0.29 tons, 0.73 tons
% Error	0.153%, 0.078%, 0.090%	-0.076%, 0.035%, 0.089%

\* Certified by Norfolk-Southern Corporation

## (Duke Power) INSTALLATION SPECIFICATION:

USER: DUKE POWER  
 LOCATION: Salisbury, North Carolina  
 THAYER S.O.#: 7883  
 MODEL #: NAR-6-72-48  
 SERIAL #: 1200-5913

### CONVEYOR DESIGN:

Capacity: Maximum: 4800 STPH  
 Minimum: 1680 STPH  
 Material: Coal  
 Density: 50 lb/ft<sup>3</sup>  
 Size: 3" x 0"  
 Belt Width: 72"  
 Belt Speed: 701 FPM  
 Idler Spacing: 4'-0"  
 Idler Troughing Angle: 35°  
 Conveyor Configuration: Straight incline 15°  
 Conveyor Length: 240 Feet--Pulley centers  
 Conveyor Stringer: 8" Channel  
 No. of Feed Points: One  
 Scale Location: 107 Feet from tail pulley  
 Type of Take-up: Vertical gravity  
 No. of Belt Splices: One-Vulcanized

### SCALE DESIGN:

Model: THAYER 72" Model NAR-6-72-48 weigh bridge  
 (NTEP CC 05-091): 6-idler approach-retreat configuration with secondary lever and mass counterbalancing of the dead load.  
 Weight Transducer: Totalcomp, Inc Model TS-150 (NTEP CC 93-028)  
 Speed Pick-up: Precision 2'-0" circumference wheel--spring loaded against the underside of the load carrying strand of the belt.  
 Speed Transmitter: High resolution, digital pulse tachometer with a resolution of 1/200 of a foot.  
 Integrator: THAYER Model Series 5200 Integrator with patented, built-in calibration feature housed in NEMA-4 wall mount housing.

TEST EQUIPMENT: Test Weight: 54.870 lbs equivalent to 186.713 #/ft Belt Loading

ACCESSORIES: 10" circular chart recorder with Hi/Low Alarms. Ticket Printer.

## How accurate are belt scales?

### An Example:

A 400 TPH single idler scale, operating at 350 FPM is supplied with a test load (weight or chain) representing 30 pounds per foot loading (78.75% F.S.). The instruction manual indicates that the calibration run should consist of 2 belt circuits which in this example is 620 feet. The integrator display resolution is 0.01 tons.

1. After zeroing the system, the integrator should advance exactly 18,600 lbs (30 x 620) during a calibration run. If it doesn't the "span" is to be adjusted accordingly.

2. After 30 days of operation the plant records show a discrepancy between the belt scale readings and the readings of their accepted check scale.

Material checked by static scale = 102,501 tons  
Belt scale totalization = 97,325 tons  
Difference = 5,176 tons = -5.05%

3. After reporting the results to the scale supplier the user is provided with instructions to change the existing K-Factor in the scale instrumentation's menu. The new K-Factor is determined by the formula: actual weight / weight on totalizer X existing K-Factor. In this case the K-Factor would be 102,501 / 97,325 X 1.0 = 1.05318.

PRESTO! This scale has been "K-Factored" It is also assumed that once factored all is well. Experience may prove otherwise.

If you investigate the various belt scales available on today's market, you will find that accuracy claims vary anywhere from 1/2% to 1/4% based on either full scale or on a range of operation that extends from as narrow as 3:1 to as wide as 15:1 (10% to 150%).

This might lead you to conclude that if you install and calibrate the scale per the manufacturer's instructions it will weigh your material to within the accuracy claimed. NOT NECESSARILY SO. Better re-read those accuracy claims. That is not what they say. It is left to you to determine whether or not you are achieving the expected level of performance or not. One of the ways you can do this is to run some form of a comparison test which is usually achieved by statically weighing the material that has been run across your belt scale on some other reference scale. If you do find a discrepancy in the results it is suggested that you adjust your standard calibration procedure accordingly. This is normally done by factoring the simulated loading value of the Test Weight or Chain that has been provided with the scale. Once this is done, the scale is said to have been "K-Factored". Unfortunately in the majority of installations it is extremely difficult, if not impossible, to conduct such a comparison test.

One major misunderstanding about "K-Factoring" is that it is assumed that once done, there is no need for further concern. The following will describe the "K-Factor" in greater detail and clarify why suspension design is important irrespective of the scale's end use.

## Breaking the K-Factor into three components

- K1 (Conveyor Influences)
- K2 (Test Load)
- +K3 (Speed)

### K-Factor

K1 factor: Low belt tension, heavy loading, long idler spacing in weighing region, many weigh idlers, excellent alignment, low troughing angle, constant tension take-up, flexible belting, horizontal conveyor, good belt tracking.

K2 factor: A Test Load of specified loading value which when applied to the installed scale suspension, produces a weight signal from the load cell that is identical to the signal that is generated by an idealized normal loading pattern of same specified loading value acting through the belt-to-weigh idler interfaces. In practice, this requires extraordinary attention to details in the manufacture and testing of hardware prior to shipment of the scale. Substitution weighing equipment of special design is required of the manufacturer. Suspension details must provide for ability to knock down for shipment and re-assemble for installation in such a way as to not invalidate the established calibration constants.

K3 factor: Locate the belt measurement interface on the load carrying section of the belt adjacent to the scale but far enough away as to not interact with load measurement. Provide attention to details in arriving at linear-to-rotation transfer function.

Let's look at the "K-Factor" as the sum of 3 separate factors:

$$K = K1 + K2 + K3$$

K1= The correction constant that needs to be applied to the simulated loading value of the Test Load (weight or chain) to compensate for the magnitude and direction of the extraneous forces that arise from friction and the effects of belt tension and stiffness acting on the suspension system owing to its configuration and overall condition of the alignment of idlers throughout the weighing region of the conveyor.

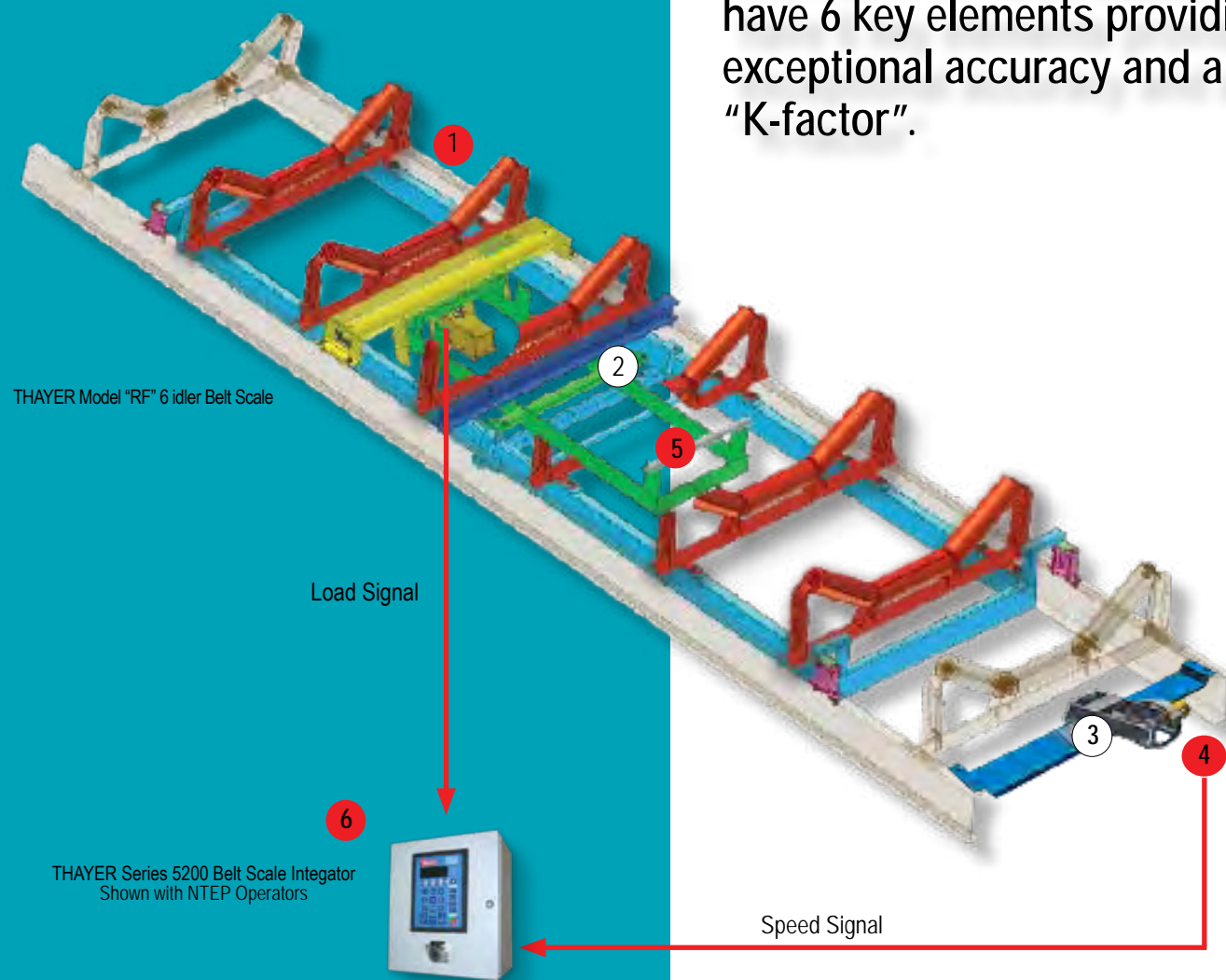
K2= The correction constant that needs to be applied to the simulated loading value of the Test Load to compensate for the fact that when applied to the suspension it may produce a force at the load cell which is not exactly the same as the force produced by the actual conveyed material, exclusive of all conveyor influences.

K3= The correction constant that needs to be applied to the simulated loading value of the Test Load (even though the effect is primarily sensed at the belt speed measurement interface) to compensate for an error in measuring belt speed due to belt stretch factors and/or incorrect measurement/calculation of initial calibration constants related to the measurement of belt speed (i.e. an error in the assumed "belt travel pulses per lineal foot") or to changes in circumference of the measuring wheel owing to wear or material build-up.

By looking at the "K-Factor" as a composite of three separate factors, we are better able to discuss accuracy in more meaningful ways. Running material tests allows us the opportunity to establish a "K-Factor" for a given set of conditions. However, adequacy of a particular "K-Factor" selection for an extended period of operating time (i.e. months) is dependent on the stability of the K1 factor and relatively independent of the K2 and K3 factors.

If operating requirements and/or equipment layout rule out the possibility for material testing, It is imperative that the scale purchaser face up to the need for a total solution to his weighing problem. This requires that no compromises be made in any of the areas that are of key importance in providing low "K-Factor" weighing equipment. If, on the other hand, material testing can be accomplished, less attention can be directed to the K2 and K3 factors since these remain relatively constant. This means that a relaxation in the care of determining a loading value for the Test Load and in determining the belt speed factors may be acceptable. Attention to the K1 factor may also be relaxed somewhat if reproducibility over very short periods of time are all that matters. This suggests the use of the least expensive model of any particular manufacturer. However, if reproducible results are important over reasonably long periods of time (i.e. weeks and months) consideration should be given to upgrading the suspension system to a longer weigh span design to assure that a low and stable K1 factor is realized.

## THAYER "RF" Belt Scales have 6 key elements providing exceptional accuracy and a low "K-factor".



Those numbers that are bold **1** denote elements that are selected by the THAYER Applications Program. The computer essentially tailors each component to maximize the performance of the complete system based on the specific requirements of the application.

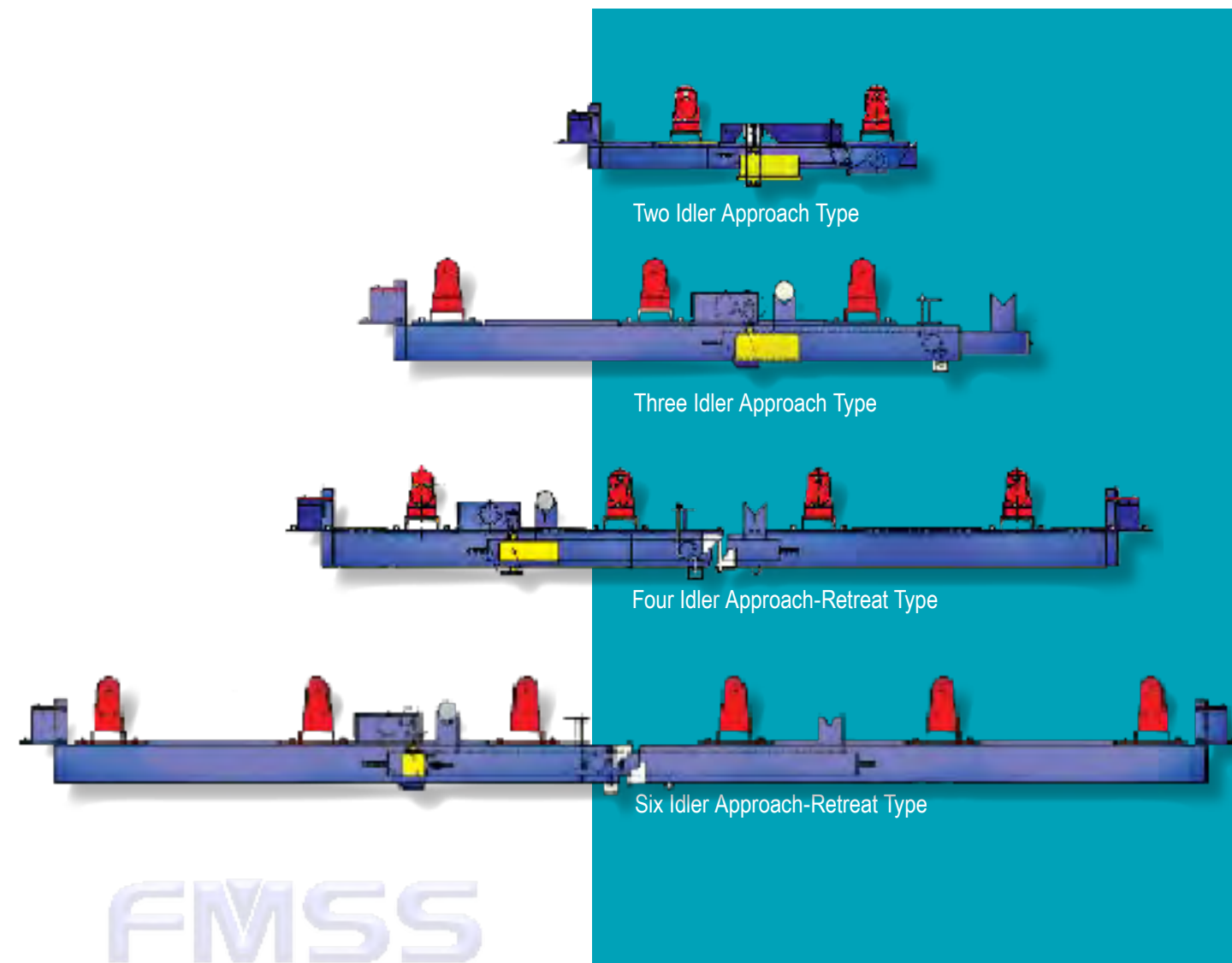
- 1** Configuration of suspension is selected to assure immunity to existing conveyor parameters. Assures low K1 factor.
- 2** Isolation lever and mass counterbalancing provide for high Load Cell Utilization Factor resulting in maximum sensitivity and long term stability.
- 3** Belt speed measurement takes place beneath the load carrying strand of the belt assuring immunity to belt stretch errors. Assures low K3 factor.

- 4** Rotary pulse generator provides errorless mechanical-to-electrical conversion of speed signal.
- 5** Test Weight is sized and evaluated as to its corresponding loading value using a factory controlled testing procedure employing substitution weighing techniques. Assures low K2 factor.
- 6** Integrator offers patented features to provide exceptional accuracy and stability, simplified calibration and (available) Scale Location Compensation.



## 1 WEIGHBRIDGE CONFIGURATION

- There are two basic weighbridge configurations - approach and approach-retreat. The selection depends on a number of factors. Among them are space available, belt loading, idler spacing, belt tension, required accuracy and frequency of calibration.
- **APPROACH TYPE:** An approach weigh bridge is suitable for most applications requiring an accuracy of 1/4% to 1% of full scale. It is available in one, two and three-idler designs.
- **APPROACH-RETREAT TYPE:** The approach-retreat weighbridge is designed principally for high accuracy applications-normally requiring certification for commercial weighing and accuracy as low as 1/10%...available in four and six idler designs.



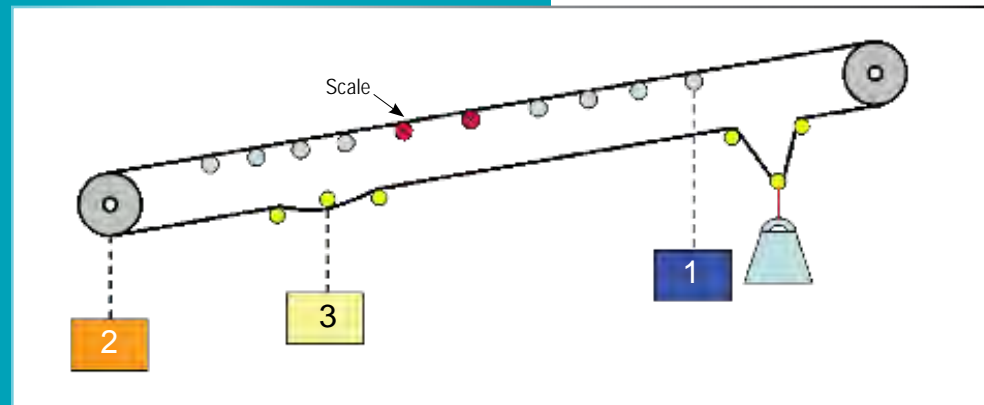
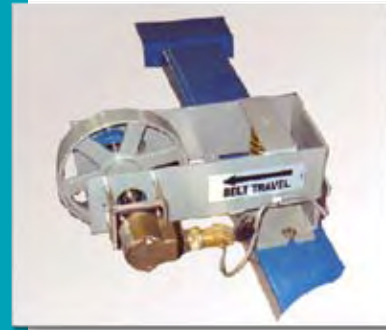
## 2 ISOLATION LEVER AND MASS COUNTERBALANCE

The scale provides for complete mass counterbalancing of the dead load (idlers and belt) of the conveyor permitting the load sensor to react only to the net material load. This unique system is not affected by dirt, shocks or vibration, and can withstand overloads in excess of 1,000 pounds without causing damage or affecting calibration. The highly advanced and extremely robust sensing technology is based on the marriage of the weight transducer, embedded temperature sensing and proprietary linearizing and temperature compensating algorithms.

### LOAD CELL UTILIZATION FACTOR

The performance of a load cell and its instrumentation is specified on the basis of the load cell's rated output. If the load cell is supporting a quantity of dead-weight (i.e. idlers, belting, suspension system) and has been further oversized to accommodate problems of overloads, off-center conveying, shock and vibration and negative integration, then the amount of range left to do the job of weighing is only a fraction of the cell's rated output. The percentage of the load cell's rated output reserved for the actual job of weighing material is called the LOAD CELL UTILIZATION FACTOR. THAYER "RF" Belt Scales with "FMSS" Force Measurement Suspension System mass counter balance technology assures better than 80% Load Cell Utilization.

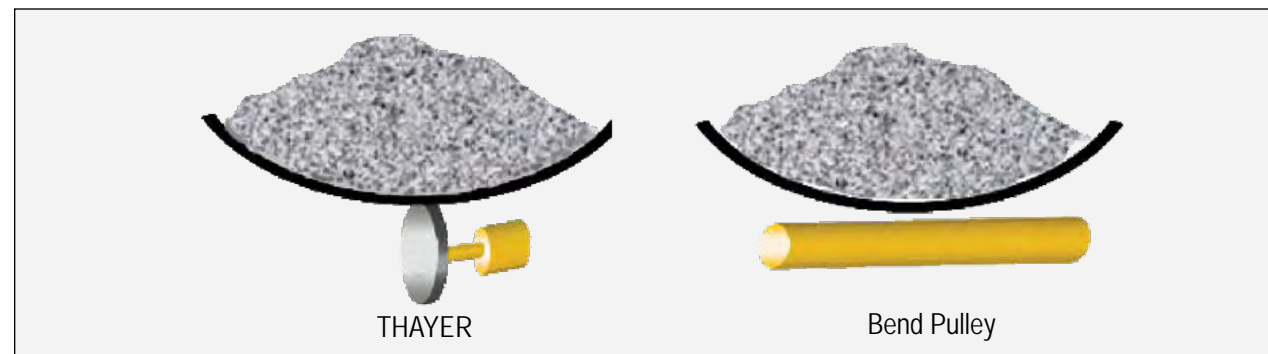
#### 4 BELT SPEED MEASUREMENT



A very important consideration in achieving high accuracy with a minimum bias error is the measurement of the conveyor belt speed. Thayer Scale was the first company to recognize the fact that measuring the slack side speed introduced a measurement error due to the fact that the conveyor belt stretches under load and therefore increases its length. Measurements at locations 2 and 3 are subject to belt stretch error and build-up of material which can result in large speed signal errors. Also, at these locations the belt is wrapped around a pulley, thereby introducing an uncertainty as to the actual pulley diameter.

$$\text{BELT stretch error} = -100 \frac{(T_R - T_C)}{EA}$$

Where TR = Tension (lbs.) under running conditions  
 TC = Tension (lbs.) under calibration conditions (empty belt)  
 E = Modulus of elasticity of belt carcass in lbs./inch<sup>2</sup>  
 A = Cross sectional area of carcass in inches<sup>2</sup>



\* Bend pulley subject to build-up. Example: 4" dia. pulley with material build-up of .062" = 3% speed measurement error.

#### 4 SPEED TRANSMITTER

The speed transmitter is a high resolution, optical pulse generator. The transmitter is equipped with special seals designed for operation in an environment laden with abrasive dust such as iron ore taconite or coal. The pulse frequency is directly proportional to the speed of the conveyor belt and each pulse represents a specific increment of belt travel.

#### 5 METHODS OF CALIBRATION

A belt scale should be thought of as a precision instrument and its performance should be quickly and easily checked. Accuracy and the method and frequency of calibration are directly related. It is a well known fact that the only positive way of verifying scale accuracy is to conduct a material test using a static scale to check the weight of material passed over the scale. The results of the material test are used to factor the simulated test device which is either a test chain or calibrating weight.

Thayer Scale is the only manufacturer that can provide an accurate reliable calibration using a calibration weight instead of test chains for all scale capacities. As a result other manufacturers have had to resort to dummy signals which (while providing a stable signal to calibrate the integrator) result in very large scale calibration errors and a false sense of security due to the fact that the scale's mechanical components are not exercised during the span portion of the calibration.

Thayer Scale developed and patented the first automatic calibration system in 1971. Although there have been attempts to develop non-infringing systems none of them have achieved the simplicity or accuracy of the THAYER method.

#### TEST WEIGHT CALIBRATION

Past experience with test weights has been generally poor because none of the scale manufacturers were able to correlate the value of weight with respect to the pounds per foot loading it represented on the conveyor belt. Consequently all sorts of false theories were generated about test chains best simulating actual material on the conveyor belt.

Another problem relating to test weights is that on large capacity scales such as those employing a full floating weigh bridge, it is virtually impossible for most scale manufacturers to use test weights because the size of the weight required prohibits their use.

Thayer Scale pioneered the successful use of the test weight calibration technique by a careful and thorough analysis of the factors that relate to the methods of simulated testing. Additionally, such large weights pose a potential safety problem for plant personnel.

#### DEAD WEIGHT TEST

The only exact method of determining the value of the test weight is by dead load testing the scale. This is done by completely assembling the weighbridge and scale and placing test weights on the idler mounting pads to duplicate the idler belt and material weight. The counterbalance weights are then adjusted to empty balance the scale. After the scale has been calibrated and zeroed to the dead weight, the value of the calibration weight is determined by the substitution method. Very few manufacturers dead load test the complete scale. Consequently, it is difficult to predict how large an error may exist between actual material weight and the simulated load. The use of a test weight is the only assurance the user has against gross weighing errors.

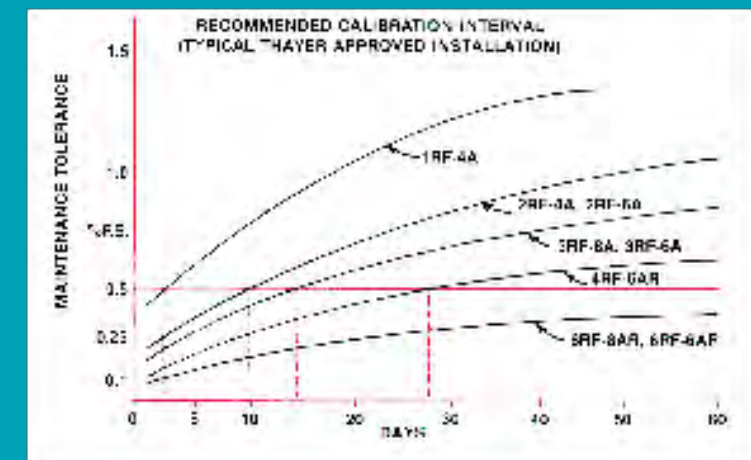
#### FREQUENCY OF CALIBRATION

There is a correlation between frequency of calibration, number of idlers on the scale weighbridge and the accuracy required. While it may be possible to achieve a reasonably high degree of accuracy for a short time with a single idler scale in a good installation it is obvious that the single idler scale is more susceptible to belt effects and changes in alignment and therefore the calibration should be checked more frequently. Likewise, a multiple idler weighbridge will not have to be checked frequently if 1% accuracy is all that is required.

A common mistake made in the selection of belt scales is choosing a single idler scale or short weighbridge because the accuracy required is only 1%. It may be possible to achieve 1% but it might require calibrating once a day.

#### HOW OFTEN SHOULD CALIBRATION BE CHECKED?

The frequency of calibration is best determined from actual operating experience. Initially the tests should be performed more frequently (once a week) to establish a confidence level based on accuracy required and the number of times an adjustment had to be made. The tests should be based on the As-Found-Error (AFE).



#### AS-FOUND-ERROR (AFE) CALIBRATION CHECK

The As-Found-Error calibration check (Cal "B" Mode) is based on applying the test weight and running a span calibration without adjusting the "zero". This provides a method of determining the combined "zero" and "span" error so that the scale performance can be verified and the scale readings validated for the time period between calibration checks.

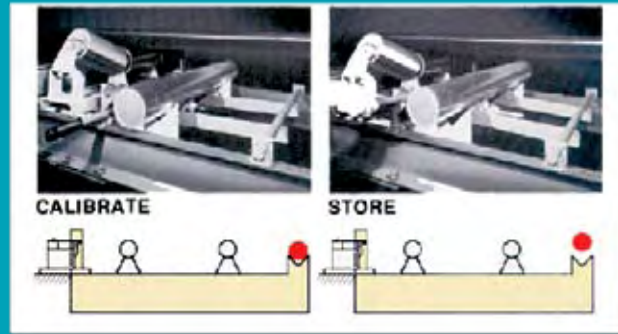
#### CAL "B" MODE

Thayer's Series 5200 offers users the ability to check and adjust only the AFE on all types of Belt Scales with the exception of Certified Scales. On Certified Scales the AFE is displayed at the completion of a span check and the information can be recorded, but not adjusted.

## THAYER TEST WEIGHT LIFT AND STORAGE ASSEMBLY

(Applications where belt loading is less than 300 lbs. per idler)

The test weight lift and storage assembly was developed by Thayer Scale in 1967 to provide a safe and convenient method of accurately applying the calibration weight. It provides a repeatable result and eliminates one of the problems associated with test weights which were related to the inconsistent placement of the test weights.



The test weight lift and storage assembly provides a safe, convenient method of placing the calibration weight on the scale weighbridge accurately -- test after test. It also provides a convenient storage area that prevents loss or damage to the test standard.

Provides these advantages:

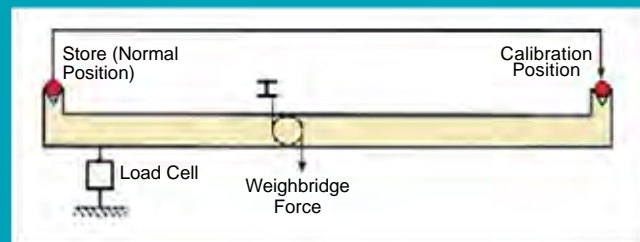
- Safe -- Eliminates need to go between belt strands.
- Easy -- Permits one man to operate.
- Convenient Storage -- Prevents loss or damage.
- Repeatability -- Weight is always positioned in the same location test after test.

## THAYER TEST WEIGHT USING "SEE-SAW" SECONDARY LEVER

(Applications where belt loading exceeds 300 lbs. per idler)

On high capacity scales where it is impractical to apply the test weight directly to the end of the weighbridge because of the physical size of the test weight, a special arrangement of the secondary lever is used.

In this configuration, the test weight provides tare mass counter-balance in its "storage" position on the secondary lever and a test load of known value in its "calibrate" position. By taking advantage of ratios in the secondary lever, smaller, easily manageable test weight(s) can be used to produce significantly higher loading values. This method of applying the test weight does not introduce error on inclined conveyors. Since the test weight is on the scale at all times, its moments due to the sine component remains constant regardless of the test weight's position on the lever.



## 6 THAYER SERIES 5200 INTEGRATOR

The simplest high precision Belt Scale Integrator in industry today, the SERIES 5200 is the product of a careful, well thought-out program to eliminate the fears of many scale users that electronic instruments are too complex for the average plant maintenance man.

- The SERIES 5200, Thayer Scale's new generation of operator interface for control and monitoring of any process weighing and flow control equipment.
- For use with any Strain Gauge or LVDT type load cell.
- Powerful internal 24 bit (1 part in 4,000,000) load resolution produces unparalleled system accuracy.
- Minimal customer wiring. The Scale Unit (SU-5200) mounted at the conveyor gathers load, speed and temperature data and communicates this information to the central processor (CPU) through a 2-wire RS422/485 connection.



### OPERATOR INTERFACE

This is the human interface of the control system. It is responsible for providing the operator with a means of easily interfacing with the process weighing equipment. It includes 24 graphic keypad controls, a 4 x 20 vacuum fluorescent dot matrix display and audio beeper that combined, provide visual as well as the tactile feedback needed to program, operate, maintain, diagnose, and troubleshoot the entire control system.

Each belt scale application can contain up to three Operator Interfaces. One unit is typically mounted in the door of the instrument (CPU) and the others (if applicable) are shipped loose for remote mounting. Remote mounted units are available in industrial rated enclosures or as open chassis and are supplied if additional operator interfaces or remote stations are required. Each unit, regardless of its location in the system, receives its information to and from the instrument controls via a communications link. A minimum of one operator interface unit is required for system operation.



## SCALE UNIT (SU-5200)

This is the heart of the control system. It is responsible for continuously monitoring the major sensor signals of the process weighing equipment and digitally communicating their status back to the CPU for further processing. The Scale Unit consists of a motherboard that accepts several optional plug-in boards. These allow it to be easily configured for a variety of process weighing or flow equipment sensors. The mother board is also equipped with digital Input/Output terminals that can monitor and/or control specific weighing equipment signals such as; Automated Calibration Devices, Belt Tracking Limit Switches and other similar devices. It is located within ten feet (three meters) of the load sensor.

The Scale Unit receives its power from the main instrument dedicated DC power supply and digitally transmits its information back to the instrument via RS-485 communication link. Both of these cables run back to the instrument in a single dedicated conduit run.



SU-5200 SCALE UNIT

### SOFTWARE

The Embedded PC (EPC) executes proprietary software based on real time operating system firmware. Both the software and firmware are stored in a nonvolatile memory format (compact FLASH card). The EPC directly boots from this FLASH card each time the instrument power is cycled. This makes it easily reconfigurable to manage a variety of open and closed loop software applications.

At the initial boot up the EPC retrieves all vital information regarding the application software it is to execute from the FLASH card. This software must then be programmed and set-up for the actual piece of process equipment it will manage. During this process all of the application specific information is stored on the FLASH card so that all successive boots require no further action to be taken other than the normal operational commands

### SYSTEM INTEGRATION/COMMUNICATIONS

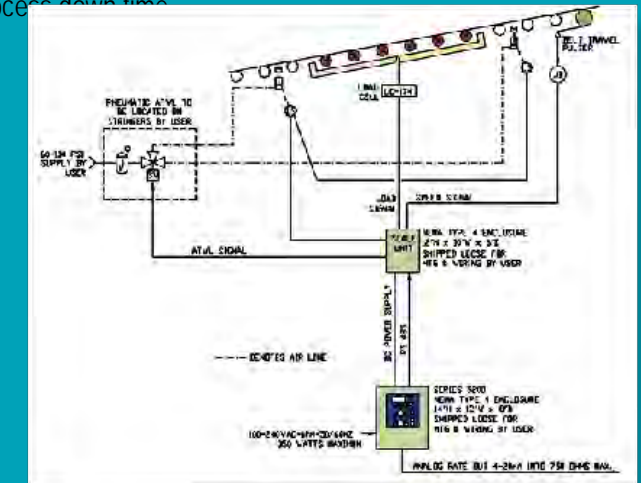
Thayer Scale provides a wide variety of interface options, including standard bi-directional analog and serial communications and device level field buses including:

- Serial DF1 Allen Bradley Interface.
- Serial RTU Modbus Interface.
- Fieldbus DeviceNet Interface.
- Fieldbus Profibus Interface.
- Ethernet/IP - Modbus/TCP Interface.

## Automated Test Weight Lifter (ATWL)

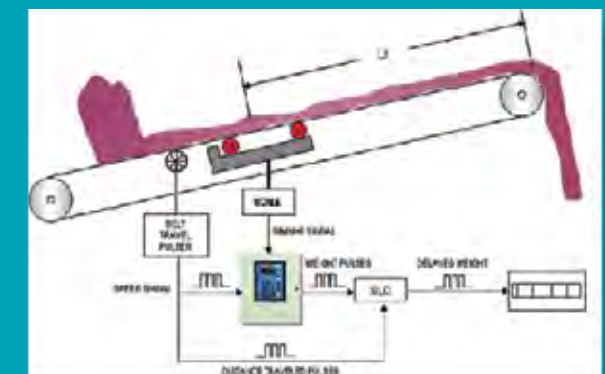
Many plants have instituted safety procedures that prohibit operations personnel from being in close physical proximity to moving conveyors. Consequently, routine calibrations can become tedious as lock-out/tag-out procedures must be followed before test weights can be manually re-positioned. As most large conveyor belt drive systems allow for only so many re-starts in a given time frame, the calibration process can become time consuming, requiring extended process down time.

Recognizing that routine calibrations are more likely to be performed on a regular basis if they are easy to accomplish, Thayer Scale offers an automated test weight placement system that automatically re-positions test weights at the proper time during the calibration routine, eliminating the need to stop and re-start the conveyor as well as eliminating the need for operators to be in close physical proximity to high speed conveyors. THAYER's Automated Test Weight Lift (ATWL) and Storage System provides quick, repeatable, and traceable calibration results without the need for operator intervention and with minimal process down time.



## THAYER SCALE LOCATION COMPENSATOR (SLC)

One of the basic problems associated with the application and use of belt conveyor scales is the problem of the scale location. Accuracy dictates that the scale be located toward the tail end of the conveyor in the area of least tension; however, the process requirement may necessitate knowing the amount of material that is discharged from the head pulley of conveyor for batch out applications. The SLC accurately provides this solution by accurately shifting the point of measurement to the head pulley to keep track of material that has been weighed but not yet delivered from the head pulley. This is particularly important in load out applications.



## Thayer Scale Belt Scale and Weigh Belt Environmental Test Chamber

For weigh belt feeders and conveyor belt scales installed outdoors, extreme temperature swings can adversely affect their performance. The operating temperature limits of a weigh sensor can only be accurately determined and compensated for, by applying it to a simulated installation and subjecting it to varying temperature ranges.

In order to better assure customers of a successful installation of our products, an Environmental Test Chamber, located within the Thayer Scale manufacturing facility, provides a means for temperature testing of load cells, scale suspension systems, instrumentation and entire weighing and feeding machines.

This test chamber is equipped with special suspension loading "aids" (for precise positioning of static weights on the pivoted suspension members), for use in the manufacturing process of the RF Belt Scale and MD and MDL Weigh Belts.

The chamber finds use in Mechanical and Electrical Research and Development work, as well as in Production as a Quality Assurance tool where particularly stringent temperature specification are called for. A distinguishing feature of these confirmation tests is that they also include the effects of the lateral and longitudinal restraining elements required to hold the suspension in place on inclined conveyors.

A quality control procedure using the test chamber assures that the particular equipment being tested either meets or exceeds Thayer's requirements for stable load cell output but in the case of commercial belt scales exceeds the stringent temperature requirements dictated by the NTEP phase 1 test procedures. The chamber tests also go beyond the scope of the present NTEP tests in that all active suspension elements, including those that are used to restrain the lateral motion of the scale on inclined conveyors, are tested for their combined effects.



## Belt Scale Suspension Testing Conveyor

To aid in scale and conveyor design Thayer maintains a Belt Scale Suspension Testing Conveyor at its corporate headquarter in Pembroke, MA. This test conveyor was originally designed to study the effects of changing conveyor parameters on the accuracy of a particular scale's loading signal as well as to compare the long term stability and reliability of speed measurements made at various locations within the conveyor. Currently it is used as an evolutionary development tool, where proposed design recommendations are simultaneously tested under identical conditions against existing configurations.

This test conveyor is 24" wide, 50 ft long, and can be equipped with 20 or 35 degree troughed idlers at variable spacing. It can operate under controlled belt tension from 500 to 1500 pounds, and belt speeds from 10 to 400 fpm. The conveyor is located outdoors to best simulate a customer's installation and the effects of the environment (temperature swings of  $-15^{\circ}$  F to  $+90^{\circ}$  F) on scale performance.

The conveyor is equipped with a Thayer single idler Model "Quarry King" and 4 idler Model RF, Rocking Flexure Belt Scale. Both scales are outfitted with Thayer's various instrumentation packages.



The potential performance level of a conveyor belt scale installation is dependent on things other than the belt scale itself. Major factors include: conveyor design, scale suspension design, location of load and speed sensors in relation to both conveyor terminal equipment and loading points, installed alignment conditions, duration and consistency of loading cycle, condition of rolling conveyor elements, the uniformity and stiffness of the belting itself, condition and size of take-up apparatus, the precision to which the system can be routinely calibrated, adherence to calibration schedule, and operating environment.

While the Belt Scale Suspension Testing Conveyor can not simulate all the factors that directly effect a belt scale's performance, it does provide many of the crucial variations in order to assure that a THAYER Belt Scale is designed for optimal accuracy and performance.



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