Engineering White Paper

HOW TO SELECT A LOAD CELL
PENKO ENGINEERING B.V.

INTRODUCTION

This White Paper discusses the challenges, options and solutions for the industry when for the design of a weighing system one or more load cell(s) has/have to be selected. The definition of weighing is: “measuring of mass by means of gravity”. Many finished products are chemical or physical mixtures, of which the formula is based on the molecular mass, what means the mixing ratio is in gram molecules. So out of a chemical point of preparing mixtures or filling prepackages on weight is chemically correct, in a way you are counting molecules. Load cells are essential parts of a weighing system, they translate the load into a measuring signal.

PURPOSE OF WHITE PAPER

…- is to explain why it is important to select the right sensor. The selected type determines the way of construction, the accuracy of the weighing system and the suitability for the environmental circumstances.

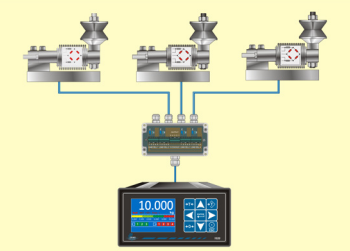

Figure 1. A basic weighing system

BACKGROUNG OF LOAD CELLS

Principally a modern mass measuring system realizes the conversion of a force, the load resting on the sensor(s), in an electrical signal, see figure 1. The industry requires a system that is accurate and also insensitive to contamination and moisture at the measuring point, so it is obvious to choose one that is completely static and also robust and small at the measurement point. The strain gauge load cell meets all these requirements.

If the weighing system in question is used for trade applications, then it must be entirely approved in accordance with the directives for non-automatic weighing instruments 2014/31/EU respectively, if it is an automatic operating system, for measuring instruments 2014/32/EU. Many load cells possess an evaluation certificate for these applications. The normative document for these certificates is OIML (International Organization for Legal Metrology) recommendation R60 dated 2017. The subdivision in accuracy classes with the corresponding number of load cell verification intervals d is laid down in table 1 of the recommendation:

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	Class A	Class B	Class C	Class D
Lower limit	**50 000**	**5 000**	**500**	**100**
Upper limit	**Unlimited**	**100 000**	**10 000**	**1 000**

Class C is intended for normal weighing, by example for industrial as well as for trade applications. The required accuracy is stated in table 4 of the recommendation:

MPE (+/-)	**Klasse A**	**Belasting Klasse B**	***m* Klasse C**	**Klasse D**
PLC x 0,5 *v*	**0 ≤ *m* ≤ 50 000 *v***	**0 ≤ *m* ≤ 5 000 *v***	**0 ≤ *m* ≤ 500 *v***	**0 ≤ *m* ≤ 50 *v***
PLC x 1 *v*	**50 000 *v* < *m* ≤ 200 000 *v***	**5 000 *v* < *m* ≤ 20 000 *v***	**500 *v* < *m* ≤ 2 000 *v***	**50 *v* < *m* ≤ 200 *v***
PLC x 1,5 *v*	**200 000 *v* < *m***	**20 000 *v* < *m* ≤ 100 000 *v***	**2 000 *v* < *m* ≤ 10 000 *v***	**200 *v* < *m* ≤ 1 000 *v***

In here:

MPE = maximum permissible error

v = verification interval

PLC = apportioning factor

m = the load applied

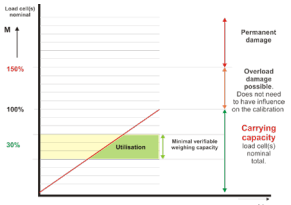

Figure 2. The relationship between carying capacity, weighing capacity and utilization

Important factors, laid down in the evaluation certificate, are furthermore the utilization, the maximum number of divisions (d) and the minimum verification interval (Vmin), see figure 2.

The relationship between them is the following. A weighing system has a carrying capacity, the product of the multiplication of the number of load cells with their capacity. A percentage of this product, mentioned in the utilization, determines the smallest permitted effective weighing range. The least useful division of the carrying capacity, divided by the maximum number of divisions (d), results in the minimum verification unit (Vmin).

The „industrial standard“ for load cells offers a number of 3 000 divisions (d), a utilization of 30% and a minimum verification unit (Vmin) of 1/10 000.

As a calculation example we use a single point load cell (centrecell) of 100 kg with the mentioned properties. With this load cell, a weighing range of 30 kg (30% of 100 kg) can thus be realized with the accuracy or division d of 0.01 kg (30 kg : 3 000 d). The mentioned 0.01 kg is also the minimum verification unit (Vmin). When using more than one load cells, the Vmin of the total may be divided by √n, where n is the number of load cells.

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THE SELECTION CRITERIA

The selection criteria are successively the construction method, the desired weighing capacity, the required accuracy, the material and the resistance to environmental influences such as moisture and chemicals.

The construction method you can select out of:

- a single point or multipoint support.
- hanging or standing constructions.

What the preferred one is, depends on the constructive possibilities. A wide range is available for every choice. The weighing capacity is determined by what you want to weigh, eventually inclusive the accompanying packaging. For industrial use, as mentioned, 3 000 d (0.03%) is more or less standard. Various types are also available with the accuracies of 1 000 d (0.1%) up to 6 000 d (0.017%). For the record, these accuracies apply to the entire weighing system. This is related to the apportioning factor mentioned in the previous chapter.

Depending on the environment, out of the following materials can be chosen:

1. Aluminum, usually anodised.

Advantages: less strong, so suitable for low carrying capacities.
good physical properties, such as linearity and creep.
affordable.

Disadvantages: less strong, so not suitable for high carrying capacities.
vibration sensitive.
sensitive for chemical pollution and corrosion.
sensitive to metal fatigue.

2. Steel, usually nickel plated.

Advantages: strong, so suitable for large carrying capacities.
good physical properties, such as linearity and creep.
less sensitive for metal fatigue.
affordable.

Disadvantages: strong, so not suitable for low carrying capacities.
sensitive for chemical pollution and corrosion.

3. Stainless steel, usually type 17-4 PH, AISI630 respectively (1.4548).

Advantages: strong, so suitable for large carrying capacities.
good physical properties, such as linearity and creep.
hardly sensitive for chemical pollution and corrosion.
less sensitive to metal fatigue.

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Disadvantages: strong, so not suitable for low carrying capacities.
more expensive.

The suitability for environmental influences is determined in the protection class, in accordance with standard IEC 60 529, chapter 3. So check the conditions in your production process and select the corresponding protection class.

Example of the indication of a protection class, by example IP43

Code letters
IP

First characteristic numeral		**Second characteristic numeral**	
4		**3**	
Protection of equipment against the ingress of foreign solid objects, first characteristic numeral		**Protection of equipment against the ingress of water with harmful effects, second characteristic numeral**	
X	**Not required**	**X**	**Not required**
0	**Non-protected**	**0**	**Non-protected**
1	**Protected against the ingress of solid foreign objects > 50 mm**	**1**	**Protected against vertical dripping**
2	**Protected against the ingress of solid foreign objects > 12 mm**	**2**	**Protected against dripping, 15° tilted**
3	**Protected against the ingress of solid foreign objects > 2,5 mm**	**3**	**Protected against spraying**
4	**Protected against the ingress of solid foreign objects > 1 mm**	**4**	**Protected against splashing**
5	**Protected against dust**	**5**	**Protection against jetting**
6	**Dust tight**	**6**	**Protection against powerful jetting**
		7	**Protection against temporary immersion**
		8	**Protection against continuous immersion**
		9K	**Protection against high pressure jetting/ steam jet cleaning**

Usually the protection classes for load cells are:

protected with a coating: IP65 and IP66.
hermetically sealed: IP68 and IP69K.

CALCULATION OF THE CARRYING CAPACITY

As a start you determine what you want to weigh and the minimum required accuracy. The weight you divide by the mentioned system accuracy, in a metric weight unit, 1.10^x, 2.10^x or 5.10^x. Here x can be both a positive or a negative number. Examples are 0.1, 0.2 or 0.5 kg, 10, 20 or 50 kg or 1, 2 or 5 t. The calculated value, the minimum desired number of divisions/intervals has to be rounded up to a usual number, for example 2 000 or 4 000 d. The rounded number you multiply with the desired accuracy/ division. The result forms the desired weighing capacity. You divide that capacity by the utilization factor. This way you will find the maximum carrying capacity matching with this weight and accuracy. This maximum carrying capacity can be divided by the number of load cells/supports. The maximum load capacity per sensor can be rounded off to a lower current value. When using multiple load cells, the Vmin of the total may be divided by √n, in which n is the number of load cells.

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Example 1.

Technical data:

- Weighing roller conveyor
- To be checked: ≤ 48 kg.
- Required accuracy: 20 g.
- Sizes: 450 x 600 mm.
- Dead weight: ≤ 12 kg.

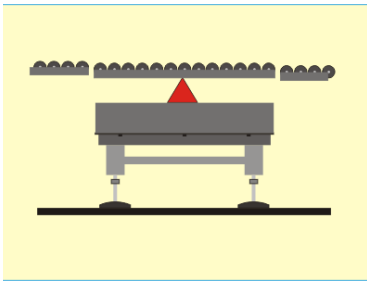

Figure 3. A weighing roller conveyor.

How to proceed:

- Suitable for a single point load cell (Centrecell)
- 48 : 0,02 = 2 400 d (rounded off ↑ to 3 000 d)
- 0,02 x 3 000 = 60 kg (weighing capacity)
- 60 : 0,3 = 200 kg (carrying capacity)
- 200 – 60 = 140 kg, sufficient for the dead weight

Example 2.

Technical data:

- Mobile bunker for loading trucks.
- To be loaded: ≤ 1 100 kg per (partial) load.
- Required accuracy: ≤ 0.5 kg.
- Sizes: 2 000 x 2 000 x 1 600 mm (l x w x h).
- Dead weight: ≤ 250 kg.

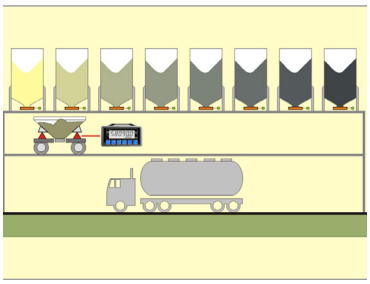

Figure 4. A loading system for bulk material.

How to proceed:

- Construction matches with a four point support
- 1 100 : 0,5 = 2 200 d (rounded off ↑ to 3 000 d)
- 0,5 x 3 000 = 1 500 kg (weighing capacity)
- 1 500 : 0,3 = 5 000 kg (max. carrying capacity)
- 5 000 : 4 = 1 250 kg, rounded off ↓ to 1 000 kg per load cell
- (4 x 1 000) – 1 500 = 2 500 kg, sufficient for the dead weight

How to proceed, alternatively with improved accuracy:

- 1 100 : 0,2 = 5 500 d (rounded off ↑ to 6 000 d)
- 0,2 x 6 000 = 1 200 kg (weighing capacity)
- 1 200 : 0,3 = 4 000 kg (max. carrying capacity)
- 4 000 : 4 = 1 000 kg, a standard load cell capacity
- (4 x 1 000) – 1 200 = 2 800 kg, sufficient for the dead weight

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Example 3.

Technical data:

- Conical mixer
- To be dosed: ≤ 900 kg.
- Required accuracy: 0.5 kg.
- Sizes: 1 500 x 1300 mm (
- Dead weight: ≤ 3 200 kg.

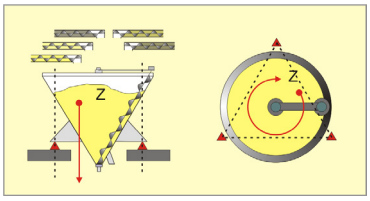

Figure 5. A conical mixer

How to proceed:

- Construction matches with a three or four point support, preferably 3
- 900 : 0,5 = 1 800 d (rounded off ↑ to 2 000 d)
- 0,5 x 2 000 = 1 000 kg (weighing capacity)
- 1 000 : 0,3 = 3 333kg (carrying capacity)
- 3 333 < (900 + 3 200) kg, must be including reserve (10%) 4 500 kg necessary
- 4 500 : 3 = 1 500 kg, rounded off ↑ to 2 000 kg per load cell
- With C3 load cells, accuracy (3 x 2 000 x 0,3) : 3 000 : √3 = 0,35 kg, rounded off ↑ 0,5 kg

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COMPETITIVE ADVANTAGE

The lack of moving parts avoids for wear and so aging. The compact design in combination with utilizations of up to 20% makes it possible to integrate the load cell into almost any construction; in spite of high dead weights an accurate measurement remains possible. This way the strain gauge load cell forms the ideal link between the mechanical construction and the control system. Thanks to the protection classes up to and including IP69K and the stainless steel version, use is possible in almost all industrial environments. Even hazardous areas are no obstacle, certifications such as Ex II I GD Ex ia, EX II 3G Ex nA and Ex II 3 D Ex tc offer plenty of possibilities.

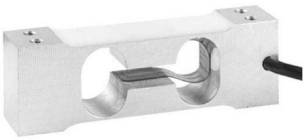

Photo 1. Single point load cell type 1006

PRODUCT SOLUTION

Single point load cells (centrecells) out of aluminum, steel and stainless steel.

These sensors are specially designed for installation in small weighing platforms, see figure 6. Due to the construction method, the sensors are insensitive for torsion, what makes one sensor, mounted in the center of the platform, sufficient. Transverse forces disrupt the measurement.

Specifications are:

protection classes:	IP65 up to IP69K.
carrying capacities:	0.3 up to 5 000 kg.
accuracy classes:	up to 6 000 d.
platform dimensions:	up to 1 400 x 1 400 mm.

Complete platforms including single point load cells are also available.

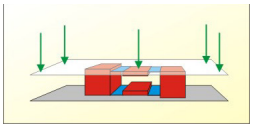

Figure 6. The load on a single point load cell (centrecell).

Damped single point load cells (centrecells) out of steel and stainless steel.

These sensors are also specially designed for installation in small weighing installations. They consist of a single-point load cell mounted between frictionplates in a housing filled with a damping fluid. In addition to the single point features, this damping suppresses the dynamic effects, allowing as an example moving objects to be properly controlled.

Specifications are:

protection classes:	IP65 up to IP68.
carrying capacities:	2 up to 200 kg.
accuracy classes:	up to 3 000 d.
platform dimensions:	from 150 x 150 up to 400 x 400 mm, depending of the capacity.

Photo 2. Damped single point load cell type 260.

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Bending beam load cells out of stainless steel.

A universal load cell for medium-sized industrial applications, see figure 7, which measures the deflection. The compact construction makes the assembly easy. Transverse forces and torsion disturb the measurement result.

Specifications are:

protection classes:	IP68 and IP69K.
carrying capacities:	5 up to 1 500 kg.
accuracy classes:	up to 6 000 d.

Complete platforms including these load cells are available, weighing platforms.

Photo 3. Bending beam load cell type 300.

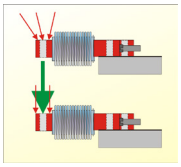

Figure 7. The force introduction on a bending beam load cell.

Shearbeam load cells made out of steel and stainless steel.

A universal load cell for the larger industrial applications, see figures 8 and 9. It can be seen that not the deflection but the shear force is measured in the neutral line of the sensor. This makes these sensors fairly insensitive to transverse forces, but torsion distorts the measurement result. The compact construction makes the assembly easy.

Specifications are:

protection classes:	IP66 up to IP69K.
carrying capacities:	200 up to 45 360 kg.
accuracy classes:	up to 6 000 d.

Complete platforms including these load cells are available.

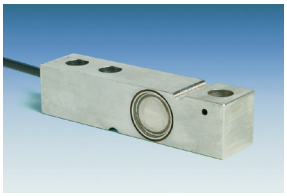

Photo 4. Shearbeam load cell type 350

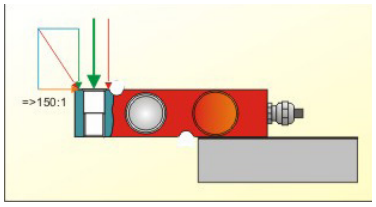

Figure 8. The force introduction on a shearbeam load cell.

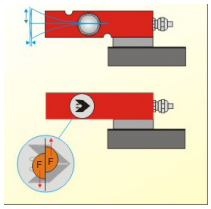

Figure 9. The measurement of the shear

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Tension load cells made out of aluminum, steel and stainless steel

A universal load cell for small and large industrial applications with hanging constructions, see figure 10. The principle is a measuring element in which the deflection or shear, depending on the type and carrying capacity, are measured. Around the measuring element is an S-shaped body with coupling points for the suspension. As always shackles or rod ends with swivel bearings are used, the combination is self-aligning to the load, so transverse forces and torsion are avoided. Moreover, mounting is simple this way.

Specifications are:

protection classes:	IP66, IP67, IP68 and IP69K.
carrying capacities:	50 up to 25 000 kg.
accuracy classes:	up to 3 000 d.

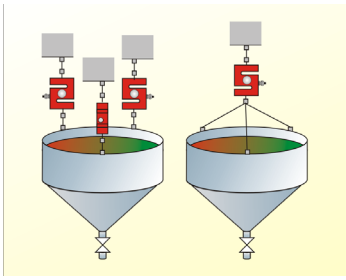

Figure 10. Hanging constructions with one or three load cell(s)

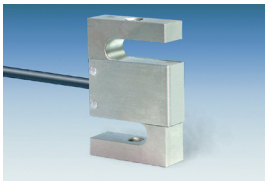

Photo 5. Load cell for tension type 610.

Double-ended shearbeam load cell made out of steel and stainless steel.

A universal load cell for big industrial applications, see picture. Visible is not the deflection but the shear force is measured at two points, almost in the neutral line of the force sensor. This makes these sensors fairly insensitive to transverse forces, but torsion distorts the measurement. The compact construction makes the assembly easy.

Specifications are:

protection classes:	IP67 and IP68.
carrying capacity:	5 000 to 200 000 kg.
accuracy classes:	up to 3 000 d.

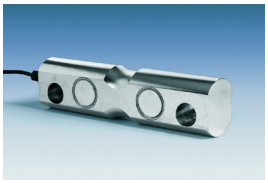

Photo 6. Double ended shearbeam type 460

Torsion ring load cells made out of stainless steel.

A universal load cell for major industrial applications, see picture. Visible is the deflection forces an inner ring to tilt, causing the semi-circular strain gages to deform mutually reversed. This results in a low, flat force sensor which is reasonably insensitive to transverse forces and torsion. The compact construction makes the assembly easy.

Specifications are:

protection class:	IP68.
carrying capacity:	500 up to 50 000 kg.
accuracy classes:	up to 6 000 d.

Photo 7. Torsion ring load cell type 220.

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Canister load cells out of stainless steel.

A universal heavy duty load cell, see picture. Visible is the deflection of a rod, the measuring element, is determined. Because the measuring element has a spherical end at the bottom and the top, the sensor is self-aligning. The radii of both support surfaces are chosen in such a way the load is lifted when tilted. Because of the combination of load and gravity, the combination remains in position. The accompanying mounting accessories make the assembly easy.

Photo 8. Cannister load cell type RC3.

Specifications are:

protection classes:	IP68 and IP69K.
carrying capacities:	7 500 up to 600 000 kg.
accuracy classes:	up to 4000 d.

CONCLUSION

If properly chosen and installed, the strain gauge load cell provides a reliable, accurate, basis for every industrial weighing system.

Determining the weight to monitor, regulate or track the processes within strict accuracy requirements remains a challenge throughout the processing industry and will vary from one manufacturer to another. Consideration should not only be paid to the risk of over/under filling challenges, preparation of erroneous mixtures or too high or too low material flows, but each product - particularly natural products - has its own intrinsic weight and volume that influences the control process.

For the selection of the ideal sensor per industrial application, per product or per manufacturer, there is no “one-size-fits-all” solution. Engineers at PENKO work out the best and most effective way this can be done.

Following White Paper will discuss the installation of Load Cells, Non Automatic Weighing Systems, Check Weighing Systems, Filling Systems, continuous totalizing with Belt Weighing, continuous totalizing with Loss-in-Weight, discontinuous totalizing with Hopper Weighers, Grading Systems by means of Weight and Batch Control on Weight for Mixing Plants.

For more information: www.penko.com

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