Engineering White Paper

HOW TO INSTALL LOAD CELLS
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 integrated in a construction. 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 preparing mixtures or filling prepackages on weight is chemically correct, in a way you are counting molecules. Properly installed load cells are essential parts of a weighing system, this way the accuracy is guaranteed.

PURPOSE OF THIS WHITE PAPER

…- is to explain why it is important to mount load cell(s) correctly and what criteria you have to respect during installation. When load cells are not mounted correctly this influences negatively the accuracy and even the lifetime.

BACKGROUND OF THE USE OF LOAD CELLS

Principally a modern mass measuring system realizes the conversion of a force, the load resting on the load cell(s), in an electrical signal, see figure 1.

The load cells themselves, the different types with their properties, measurement ranges and accuracy, can be found in the white paper „How to select a load cell“. When using these sensors you must bear in mind that it concerns measuring elements that you integrate into your construction. Of importance are the force introduction, the prevention against transverse forces and torsion, the foundation as well as friction between the weighing arrangement and the „fixed world“. A well-chosen and installed load cell offers you an optimal weighing result and has an almost eternal life.

The number and type of load cells in a weighing installation depend on the mounting, hanging or standing, the required carrying capacity and the shape or dimensions of the object to be weighed. For determining the carrying capacity we refer to the white paper „How do you select a load cell“. Please note the location of the center of gravity. With a symmetrical construction the center of gravity is in the middle

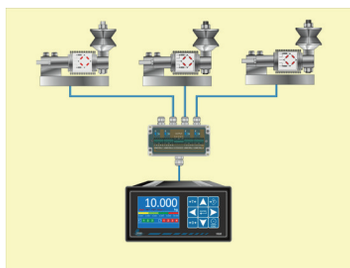

Figure 1. A basic weighing system.

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If this is not the case, it must be prevented that one or more load cells are overloaded while others hardly participate or are even negatively loaded. In particular with equipment with eccentric agitators, external drives and the like, the safe way is to calculate the load per support point separately, see figure 2.

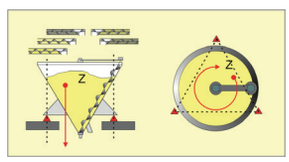

Figure 2. A conical mixer, mounted on load cells

When swinging cannot occur, it is easy to hang the weigher on one tension load cell. Tensile load cells are available up to a carrying capacity of 25 000 kg, so there hardly are limitations. However, you must bear in mind that this method might cause an extremely high point load on the supporting structure. Because of that, it is often advisable to distribute the load over several tension load cells, so more suspension points. Because of the stability and the load distribution, a structure with three sensors is preferred, see figure 3.

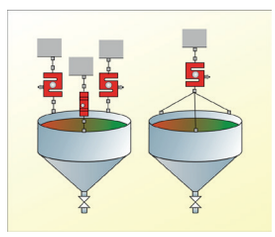

Figure 3. Examples of suspension constructions.

For higher carrying capacities, the construction with three load cells is preferred above four. Figure 4 shows a top view.
When the load cells are not mounted properly, it is conceivable that the loading of the load cells takes place via the diagonal B-D and the load cells A and C remain practically unloaded. The same bunker is shown, but resting on three load cell. The supporting surface is determined by three points, so every load cell is loaded.

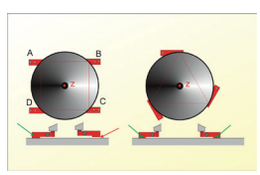

Figure 4. The selection out of three or four supports.

Another example is the weigh bunker shown in figure 5.
Such long weighing bunkers with extraction belts are common in the animal feed and concrete industry. The desired carrying capacity in combination with lengths up to 25 m requires the support on 4, 6 or even 8 load cells. These numbers of load cells prevent for reinforcement of the bunker and/or the foundation. Moreover, this way the load is spread over the surface. In general, it does not make sense to cut down the number of load cells for such large weighing equipment. The necessary reinforcements of the weighing equipment and construction are always more expensive.
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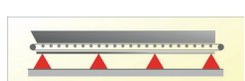

Figure 5. More than four load cells is a possibility too.

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THE FORCE INTRODUCTION

Load cells are constructed in such a way that a force is converted into an electrical quantity, milliVolts per Volt power supply. That force must then be exerted correctly on the load cell, see figures 6 and 7.
As examples you see a bending beam and a shear beam load cell with the correct force introduction in green. If this does not take place perpendicular to the load cell, a transverse force is created as a result; if the load is introduced besides the center of the support point, the load cell is distorted, twisted. Both factors cause misconceptions, so you don't measure what you want.
With regard to torsion, the single point load cells or Centrecells are an exception. Within the specified limits these load cells are insensitive for torsion. This we will explain in a following chapter. With the right structural features, both disturbing effects can be prevented. To make it easy for you, you will find a summary of the available loading assemblies in this white paper. With these units both torsion and transverse forces can be largely eliminated.

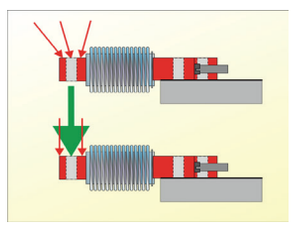

Figure 6. The force introduction of a bending beam load cell.

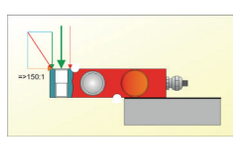

Figure 7. The force introduction of a shear beam load cell.

THE FOUNDATION

Characteristic for modern load cells is the compact design. This characteristic offers the advantage of an easy fit into existing constructions or, in new installations, little loss of construction height. Naturally, however, the entire load reaches the subsurface on a small area, see figure 8.
Frequently it will be necessary to mount the load cell on a hardened support plate. Such a plate must be machined to a surface roughness of $<10^{-6}$ m. Furthermore, the plate must be flat enough to make at least eighty percent of the soil supporting the sensor. Finally, the surface must be horizontal with as a maximum a fixed slope <0.5° or 10 mm/m.

Figure 8. Mounting a load cell on a beam.

When installing load cells, it is important to realize in the load cell a small deformation is converted into a measuring voltage. For every vertical deformation this is a very precise fact, any other than vertical deformation will negatively influence the precision. The location of the load cell also has an effect. This is especially true when mounting on steel profiles. If, for example, a shear beam load cell is mounted, as indicated in figure 8, the profile will certainly rotate and the load cell's position changes.

In such a case the reinforcement with sketch plates is recommended. Similar precautionary measures are also recommended for compression load cells for large carrying capacities and tension load cells, see figure 9. It is important to load the cell in the center line.
When a compression load cell is mounted on a column, it must be understood that as a result of the load the column starts to deform. This will have undesired influences on the measurement result. As a prevention the compression load cell can be mounted on a lattice structure, see figure 10.

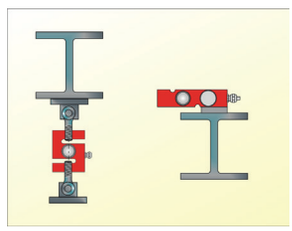

Figure 9. The prevention against the bending of the flange.

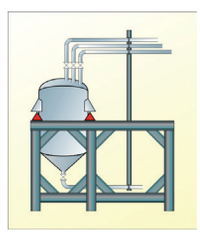

Figure 10. The reinforcement by means of lattice constructions.

When load cells are mounted directly by means of plates on a concrete floor, generally no problems are to be expected. Such a floor usually is sufficiently stable. This is different when mounted on or in a metal structure. Metal simply deflects proportionally with the load. As a general rule, a weighing arrangement may sag 10 mm, provided this is done vertically. A rotation ≤ 0.5° already causes a noticeable reduction in accuracy, see figures 11 and 12.
Symptoms, as shown in figure 12, particularly occur when several weighing systems are located on one floor or in one frame. Even when this floor serves for storage of other materials or when forklift trucks are present, such phenomena can be expected.

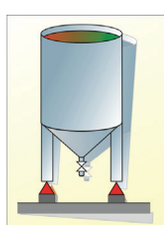

Figure 11. The distortion effect of a sagging floor.

When it concerns the design of a new installation, measures can be taken to prevent for this mutual influence. Each weighing installation is given its own, sufficiently solid, frame with the load cells mounted directly above the supporting beams. Moreover, when this frame is separate from the work floor and if it is reinforced where necessary, this is an ideal construction, see figure 13.
Moreover, this method prevents for vibrations, caused by for example mixers or transport means, reaching the weighing equipment.

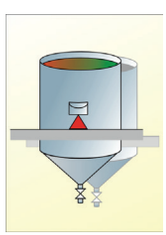

Figure 12. The effect in height of a sagging floor.

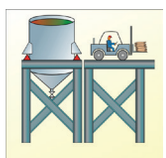

Figure 13. The effect in height of a sagging floor.

PREVENTION FOR FRICTION

Well-designed and installed industrial electronic weighing equipment, without a supply and discharge system, nowadays achieves accuracies better than 3 000 or 6 000 d, ie 0,03 or even 0,015%. Supply and discharge systems obviously don't improve these values. In fact, the damage can only be limited. Where possible, it is advisable to pass the supply pipes through large holes in the cover of the weigher or to omit the cover. In many cases this is not possible, for example for the prevention of the spread of dust or the release of fumes.

The maximum permissible vertical force, applied by supply and discharge systems to the weigher, is laid down in the formula:

$$F < 3.M.cl$$

Herein is:

M = weighing capacity (kg);

cl = accuracy class as a percentage;

F = maximum permissible vertical force in Newtons.

Example: on a weighing system for 1 000 kg, class 0.03, a force F with a maximum of 3 x 1 000 x 0,03 = 90 N can be exercised. This force represents the effect of the sum of four material deformations, namely:

*deformation of the supporting structure of the weigher;

*distortion of the piping system, close to the weigher;

*vertical thermal shrinkage/expansion of the weigher;

*vertical thermal shrinkage/expansion of the supply/discharge systems.

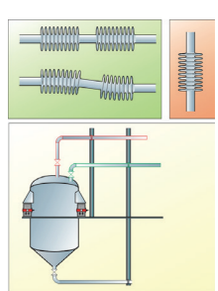

Figure 14. The connection of supply and discharge systems.

It is clear the first two factors are largely limited by fastening the supply/discharge on the same floor as the weighers, see figure 14.

A generally accepted rule is the minimum vertical freedom of movement per pipe must be ten times the compression of the load cells. Since most modern load cells deflect between zero and full load 0,5 mm, this amounts up to 5 mm. This naturally only applies if weigher and pipes are fastened to the same shop floor. If the latter is not the case, the sum of the four deformations has to be inside the aforementioned 5 mm. In most cases, the required freedom can be created by self-supporting, over a certain length, supply and discharge pipes to or from the weighing vessel.

.Because no further provisions are required then, this method is preferred. If this cannot be met, the required freedom of movement must be obtained in another way. Depending on the media to be transported, bellows or compensators are recommended for this purpose. These are available in various types of steel, stainless steel, rubber, plastic and synthetic rubber. If a choice has to be made, the compensators will have to comply with the above. Furthermore, for installation in vertical sections one compensator, and in horizontal sections two compensators, must be provided, see also figure 14.

SPECIAL PROVISIONS

Because the most accurate adjustment of weighing systems is by means of mass pieces, provisions for placing these weights must be available. Such facilities prevent dangerous situations during commissioning, checks and adjustments. In order to adequately check the construction, it is desirable to place 10% of the weight in mass pieces in the center line of each load cell.

For small weighing capacities, it is advisable to install overload protections. For larger structures, it is useful to provide working points for lifting or screw jacks. These measures facilitate the installation and, at a later stage, eventual replacement of the load cell(s). Moreover, it must be kept in mind that a load cell is a measuring element. The load cell indeed is a part of the structure, but, especially in hanging structures, it does no harm to install a safety device parallel to the load cell(s). Such a protection for example can be a cable or chain. During assembly this device offers a lifting option.

In an industrial environment protection against ground and welding currents is another requirement. Currents select the easiest way, with the lowest resistance, to earth. If, for example, a welding current or a derivative thereof, passes through the load cell, it immediately destroys the measuring bridge, see figure 15.

Finally, it is necessary to protect load cells against temperature shocks. This is the case when weighing systems are used for boilers, but also the influence of direct sunlight, radiation of heating coils and so on. Unilateral heating causes unbalance of the measuring bridge, so significant errors.

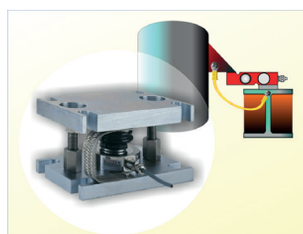

Figure 15. The protection against welding and stray currents.

OUTDOOR APPLICATIONS

Thanks to their protection class and temperature compensation, all strain gauge load cells are suitable for outdoor installation. The protection class namely is IP66 or better and the temperature compensation has a range of -10 up to +40 °C. Finally, the load cells and the loading assemblies are treated corrosion-resistant. Attention should however be paid to direct sun radiation and the wind load.

Sunlight.

The temperature compensation works perfectly, as long as the differences in temperature occur evenly and the load cell has the opportunity to stabilize. This is not the case with direct radiation of sunlight. The load cell has an „exposed“ and a „shadow” side, with as a result unbalance of the Wheatstone measuring bridge, and not by weight difference. That’s why a shielding is a requirement.

Wind load.

The pressure of the wind causes three kinds of errors in the weighing system, namely

- a transverse force.
- a moment; one side is lifted, the other side pressed down.
- lift or negative lift, so a positiveor negative error.

The wind pressures in the Netherlands are:

Hoogte H boven het maaiveld	aan de Noordzeekust	in het binnenland
in m	in N/m^2	in N/m^2
≤ 7	970	710
8	990	730
9	1010	750
10	1020	770
15	1070	830
20	1120	880
25	1150	930
30	1190	970
35	1220	1010
40	1250	1040
45	1270	1070
0	1300	1100
55	1320	1120
60	1330	1140
65	1350	1160
70	1360	1180
75	1380	1200
80	1390	1220
85	1400	1230
90	1410	1250
95	1420	1260
100	1430	1280
110	1450	1300
120	1460	1320
130	1480	1340
140	1490	1360
150	1500	1380
160	1510	1400
170	1520	1410
180	1530	1430
190	1540	1440
200	1550	1450
250	1570	1510
300	1600	1560

Example, see figure 16, round silos with a height of 11.5 m and Ø 3 m, mounted on 3 load cells near the coast.
The wind thus acts on a 34,5 m² surface per silo, because of the round shape with a reduction of √2 can be calculated. The pressure, see table, is approximately 1 020 N/m², so the transverse force is: 1 020 x 34,5: √2 = 24 883 N. This means a transverse force of 8,3 kN per load cell. This force acts at half the height, so a moment of 5,75 x 24 883 = 143 077 Nm acts on the support structure. In the situation described, the sensor on the windward side will have to take the calculated torque, 143 077: ½ Ø or 1.5 m, ie 95 385 N of tension. Worst case the two sensors on the lee side both receive an additional load of 143 077: 1/6 Ø, 0.5 m, ie 286 154 N together or 143 077 N each. The lift influences are difficult to predict, they depend on the shape of the silo, buildings in the environment and so on. The lift effect of strong winds usually is limited to disquiet measurement data.

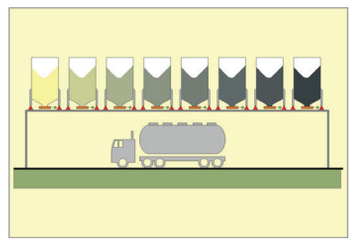

Figure 16. A bulk loading station.

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POINTS FOR ATTENTION WHEN USING SINGLE POINT LOAD CELLS

When using these load cells, it is important that extra care is taken to protect against overload and, if the hermetically sealed stainless steel version is not chosen, protection against external influences. Especially in the low measuring ranges, human beings are the main threat. The load cell can already be overloaded during mounting. But even in operation, without protection a load cell can easily be damaged, for example by bending it too far in the vertical direction, up as well as down. Additionally, protection against transverse forces is recommended. Protection can take place in two ways: directly and indirectly.

Direct protection.

Simple and safe protection offers the installation of adjustable stops on site. Most Centrecells usually posses a kind of built-in overload protection, but this only prevents overloading in the center of the scale. The load cell twists from the four corners of the platform or the weighing arrangement, what cannot be protected internally in the load cell. So the corners of a platform must be provided with stops, as directly as possible above the legs or the supporting structure, see figure 17.

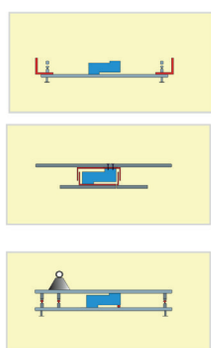

Figure 17. The protection of single point load cells.

A stop with a fine thread facilitates accurate adjustment. You secure this bolt with nuts or Loctite. A further problem during assembly may be that the built-in overload protection cannot be used. Then the best solution is to provide an external protection in the form of an adjusting bolt or an adjustable plate under the front end of the load cell. Of importance in any case is that the load cell is mounted on a firm, flat base that does not even bend under full load. Another important aspect is that the suggested tightening torque for the mounting bolts of the load cell must not be exceeded. This especially applies for load cells with low carrying capacities. Wringing always means permanent damage!r

Adjustment of the protection

A main rule is that the load cell should not perform abnormal movements. Practical values for setting the overload stops when using the platform dimensions as recommended by the factory are:

100 % of the weighing range in the center of the load cell:

60 % up to 80 % of the weighing range for the overload stops on the corners.

Do not forget that the platform's dead weight plus the required capacity must be covered by the capacity of the load cell! Each scale or load cell must be adjusted individually. The overload protection in the center, for example, does not work when the load is applied between the edge of the platform and the rear end of the load cell. This causes a slight lift of the load cells front end. In such a case, a sixth overload stop halfway between the rear of the load cell and the edge of the platform offers safety. The overload protections as described protect the load cell in one direction only. In the low weighing capacities, up to 15 kg, the load cell can easily be overloaded negatively. The preferred solution then is to apply an under- and overload protection. As a scale normally is used in a positive way, the stop can be set to a negative value of 20% to 40% of the weighing range.

Indirect protection.

Rough environmental operating conditions require an extra protection against transverse forces. The single-point load cells are rigid in the horizontal plane, as a result of which the usual stops are hardly sufficient. A solution forms the provision of an external protective edge, connected to the support structure, as showed in figure 17. The resistance, caused by penetrating dirt, can be avoided by maintaining a safe distance between this edge and the weighing platform.

Additional protection

Counter and letter balances in general are used in a clean environment. In contrast with this, for example, the fish processing industry uses water, salt and acid. All three are “threatening” the sensor. Most so-called “open” or coated sensors are made of aluminum and have a protection against moisture. If the working conditions do not allow a compromise, use the stainless steel, hermetically sealed versions. These have a protection class of IP68 or IP69K and are also suitable for commercial purposes.

COMPETITIVE ADVANTAGE

Well-selected and installed load cells offer a reliable, accurate solution for every industrial weighing system. Thanks to the extensive choice of load cells and accessories, a solution can be found for every installation. The absence of moving parts at the measuring point means that there can be no wear, what improves the operational life time. A weighing system with these components is a good and reliable investment.

PRODUCT SOLUTIONS

Machine feet type T-end

These accessories possess an integrated vibration damper and can be mounted between the load cell and the weighing frame or between the load cell and the foundation. It is advised to attach the load cell to the more stable of the two, what prevents the load cell against disturbing influences such as torsion, causing tilting. The spherical head of the machine foot allows a slight twist. Thanks to the isolation the T-end feet protect against stray currents. There are several versions, with and without flange plates as well as, especially for mounting under platform weighers, height adjustable ones. T-end feet are available for the shear beam load cells for carrying capacities from 300 up to and including 5 000 kg.

Photo 1. A T-end foot with flange.

Photo 1.

Vibration absorbers

The vibration absorbers can be mounted between the load cell and the weighing frame or between the load cell and the foundation. It is advised to attach the load cell to the more stable of the two what prevents the load cell against tilting, which cause disturbing influences such as torsion. The flexibility of the attachment allows a slight twist. Thanks to the isolation the absorber protects against stray currents. Multiple versions are available for bending beams, shear beams and torsion ring load cells with carrying capacities from 5 up to and including 50 000 kg.

Photo 2. A vibration absorber.

Complete loading assemblies with base plate and support plate including vibration absorber

This loading assembly offers an ideal solution for large dynamic applications such as mixing and stirring tanks, reactors and the like. The base and top plate offer stable mounting options, the vibration absorber offers flexibility and protection of the load cell. Thanks to the isolation the absorber protects against stray currents. Versions are available for torsion ring load cells with carrying capacities from 5 000 up to and including 50 000 kg.

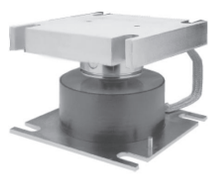

Photo 3. A torsion ring type load cell with vibration absorber and mounting flanges.

Complete loading assemblies with base plate and support plate including vibration absorber and lift off protection

This loading assembly offers an ideal solution for dynamic applications such as mixing and stirring tanks, transport systems and the like. The base plate provides a stable surface, the vibration absorber offers flexibility and protection of the load cell. Thanks to the isolation the absorber protects against stray currents. Multiple versions are available for bending beams and shear beams with carrying capacities from 5 up to and including 5 000 kg

Photo 4. A complete set of accessories with vibration absorber, mounting flanges and lift off protection.

Complete loading assemblies with base plate and support plate including ball and cup arrangement and lift off protection

With this loading assembly you have under all circumstances a reliable introduction of the force, the start for accurate weighing. The foot plate offers a stable surface, the ball and cup prevent influence of the measurement by transverse forces and/or torsion. Multiple versions are available for bending beams, shear beams and torsion ring load cells with carrying capacities from 5 up to and including 30 000 kg.

Photo 5. A complete set of accessories with ball and cup, mounting flanges and lift off protection.

Complete loading assemblies with base plate and support plate including cardan bearing support and lift off protection

This loading assembly, specially developed for heavy applications, offers you a reliable force introduction under all circumstances, the start of accurate weighing. The base plate provides a stable surface, the cardan bearing support prevents the measurement against transverse forces and/or torsion caused by the weighing vessel. This type is suitable for double-sided shear beam load cells with carrying capacities from 5 t up to and including 100 t

Photo 6. A double sided shear beam load cell with cardan bearing support and mounting flanges

Complete loading assemblies with base plate and support plate, suitable for self-aligning load cells, including lift off protection

This loading assembly, specially developed for applications such as the weighing of large silos and tanks, provides a reliable force introduction under all circumstances, the start of accurate weighing. The base and support plate offer stable mounting options, the self-aligning properties of the load cell prevent for effects of the measurement by transverse forces and/or torsion. This type is available for canister type load cells with carrying capacities from 7,5 t up to and including 600 t.

Photo 7. The accessories for a self-aligning canister type load cell.

Self-aligning rod end bearings, with or without forks, for suspended constructions

Rod ends bearing, thanks to the external thread suitable for most tension load cells, always offer a perfect force introduction, contributing to an accurate weighing. These accessories are available with threads from M8 up to and including M25, so suitable for tension load cells from 50 up to and including 10 000 kg

Photo 8. The accessories for a tension load cell, rod end bearings and forks.

Self-aligning suspension eyes, shackles, links and, also rotatable, load hooks for suspended constructions

In combination with the tension load cells, you can use these accessories for suspended structures with weights from 2 up to and including 25 tonnes. The self-aligning properties guarantee a perfect force introduction, so good weighing properties.

Conclusion

Today's strain gauge load cells and associated loading assemblies considerably simplify the manufacture of weighing arrangements. This, among other things, because protection against transverse forces usually is no longer necessary or integrated into the loading assembly, just as, for outdoor installations, additional lift off protections against wind effects. However, attention is required when preparing the supporting structure, taking care of the surface for the load cells and designing the supply and discharge systems. Again you can see a summary in figure 18.
When sufficient attention is paid to all these factors, industrial weighers are created with a very high measurement accuracy and excellent operational reliability.

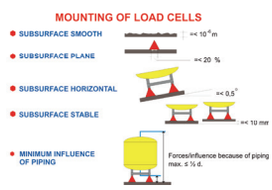

Figure 18. A summary of the requirements for the foundation

For the selection of the ideal sensor with accessories 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 Papers will discuss the selection 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.

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