Automated Precision Weighing

Automated Precision Weighing

Handbook

METTLER TOLEDO

Introduction

This handbook is intended as a guide for selecting and applying weigh modules for automated weighing applications. It provides scientific data and accepted guidelines needed to help you design an accurate, reliable weighing system.

This handbook is organized into the following chapters:

1. General Knowledge
2. Selection Criteria
3. Installation
4. Maintenance

Warning

This publication is provided solely as a guide for individuals who have received technical training and are familiar with the technical manuals of METTLER TOLEDO products.

This guide is not meant to replace the technical manual for various products.

Please review the specific technical manuals for detailed instructions and safety precautions before operating or servicing the various METTLER TOLEDO products.

METTLER TOLEDO reserves the right to make refinements or changes without notice.

Precautions

Save this handbook for future reference.

Do not allow untrained personnel to operate, clean, inspect, maintain, service, or tamper with equipment.

⚠ **WARNING**

PERMIT ONLY QUALIFIED PERSONNEL TO SERVICE EQUIPMENT. EXERCISE CARE WHEN MAKING CHECKS, TESTS, AND ADJUSTMENTS THAT MUST BE MADE WITH POWER ON. FAILING TO OBSERVE THESE PRECAUTIONS CAN RESULT IN BODILY HARM.
OBSERVE ALL APPROPRIATE SAFETY PROCEDURES WHEN INSTALLING AND SERVICING THE WEIGH MODULES.

Always disconnect equipment from the power source before cleaning or performing maintenance.

Call METTLER TOLEDO for parts, information, and service.

Contents

General Knowledge

The first chapter aims to give the reader basic knowledge about APW weigh modules. This basic knowledge can help the reader to better understand the subsequent chapters. Readers who know the basics can skip this chapter and can start reading from the second chapter. However, it should be kept in mind that the subsequent chapters are built upon the basics explained in the first chapter.

MFR Technology

Figure 1-1 shows an example of a load cell working with electromagnetic force restoration (EMFR) principle. If a sample is placed on the weighing pan, the lever tilts due to the weight force acting upon it. The displacement of the position vane that is registered by an electro-optical position sensor is passed on to an electronic controller that increases the compensation current flowing through the compensation coil until the lever has returned to its original equilibrium position.

Because the weight force is proportional to the compensation force, and this in turn is proportional to the compensation current, the compensation current is also proportional to the weight force and also to the load on the weigh module. Because the magnetic flux depends on the temperature, the latter is measured by a temperature sensor whose signal is also made available to the signal processor, which compensates for any drift of the measurement signal caused by temperature fluctuations. The measurement signal is linearized, translated into a mass unit, and finally indicated, or transmitted, over an interface.

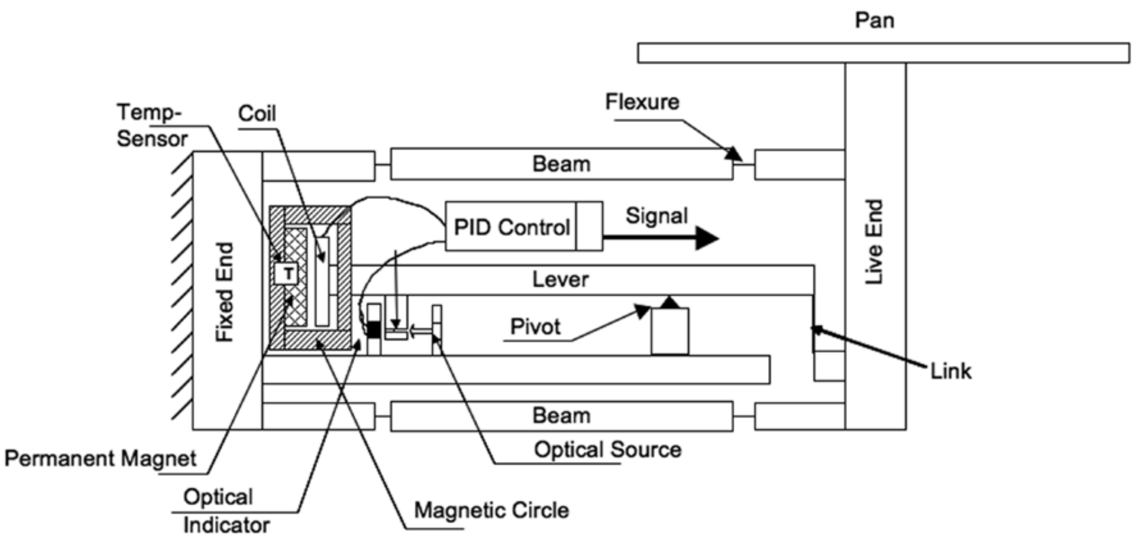

Figure 1-1: Principles of EMFR technology

Mechanical Interfaces

APW weigh modules have two different mechanical interfaces with which they can be integrated into a machine:
- Weighing interface
- Support interface

"Weighing pan" and "weighing platform" are other expressions used to describe the weighing interface. The weighing interface is usually situated at the top of the weigh module, but for some weigh modules, it is also possible to place the weighing interface under the weigh module. This kind of setup is called "weighing from below." You can find more information on this subject in Mechanical Requirements. If the standard weighing interface is not practical or usable for the application, a custom weighing interface can be built on the top of the standard weighing interface. Further hints for building a custom weighing interface,are given in Mechanical Design.

Support interface is the bottom plate of the weigh module with which the weigh module can be fastened on a machine. You can refer to Mechanical Design for tips on how to successfully integrate the weigh module on the support interface.

Figure 1-2 shows the mechanical interfaces of a weigh module as an example.

Figure 1-2: Mechanical interfaces of a weigh module

1: weighing interface
2: support interface

Connectivity with Control Systems

APW weigh modules have 2 types of integrated interfaces as default:

- RS232
- RS422

RS232 is a point-to-point communication interface, in which only one weigh module can be connected to the control system. The maximum permissible cable length for RS232 is defined as 15 m at 19,200 bits/second transmission speed.

With RS422, it is possible to build a network with up to 31 weigh modules and connect them via the same interface to the control system. It is possible to assign different addresses to the weigh modules in the network. The maximum permissible cable length is defined as 1200 m at 100 bits/second transmission speed.
As an option, it is also possible to add an Ethernet TCP/IP card to the weigh module and connect the weigh module to the control system via Ethernet interface. Communication speeds range from 10 to 100 Mega bits per second (Mbps). There is no limit to the permissible number of weigh modules in a network built with Ethernet TCP/IP interface (See figure 1-3).

Figure 1-3: Ethernet TCP/IP interface option

Finally, it is also possible to use external interface converters called fieldbus modules in order to convert from serial interfaces (RS232 and RS422) to the most popular automation interfaces, such as Profibus DP, Profinet IO, DeviceNet, Ethernet IP and CC-Link. Fieldbus modules are available as an accessory to connect weigh modules to these automation interfaces (See figure 1-4).

Figure 1-4: Fieldbus module which converts from serial interface to Profibus DP interface

Communication Protocols

APW weigh modules make use of 3 different kinds of protocols in order to communicate with control systems and computers:

- MT-SICS
- SAI
- Fieldbus protocols

MT-SICS is the abbreviation for **M**ettler-**T**oledo **S**tandard **I**nterface **C**ommand **S**et. MT-SICS is an ASCII-based communication protocol with string-type data format. In this command set, each command is defined with certain letters and digits. Each of these numbers or digits are assigned a string of bits, which is sent over the communication interface to the control system. Each string includes one start bit, 8 data bits representing the letter or digit, one parity bit and one stop bit. MT-SICS is a protocol defined by METTLER TOLEDO.

SAI stands for **S**tandard **A**utomation **I**nterface. This is a communication protocol based on binary data and is tailored for cyclic communication. The main advantage of this protocol is its reduced data package size and better communication speed. With SAI, it becomes possible to connect large networks to control systems without data loss or time delays in the protocol. SAI is a protocol defined by METTLER TOLEDO.

Finally, APW weigh modules can also communicate with the fieldbus protocols given in Connectivity with Control Systems. However, the weigh module has to be connected to an external fieldbus module in order to implement the protocol conversion from MT-SICS to the corresponding fieldbus protocol. The implementation of SAI rendered the usage of fieldbus modules obsolete.

Specifications

Various specifications are given in weigh module datasheets. The most widely used terms are given below:

- Capacity
- Readability
- Repeatability
- Linearity
- Eccentricity
- Sensitivity
- Minimum weight
- Settling time
- Interface update rate

This section aims to give a basic explanation for these terms.

Capacity: Capacity is the maximum value of the weighing range, which a weigh module can measure and display as a weight value. Weight values above the capacity are regarded as overload and are indicated with the "overload" message in a display or responded with a "+" sign when weight value is asked by the control system. Weighing range can sometimes also have a minimum limit. If this limit is gone below, "underload" message is displayed or "-" sign is transmitted when weight value is asked by the control system. This scenario can happen when the wrong or no weighing pan is mounted onto the weigh module.

Readability: Readability is the smallest difference in mass that can be read by a weigh module. It is also defined as the smallest unit displayed after the decimal point. Readability doesn`t imply the same concept as accuracy. With a software command, it is possible to set the readability of the weigh module to any desired value, but accuracy of the weigh module always stays constant. For more details on accuracy, you can refer to Weighing Requirements. Some weigh modules also have a so-called "dual range," which is a limited weighing range mostly at the lower end of the full weighing range where the readability of the weigh module is 10 times higher than the default value. This is mostly done to display lower weight values with a higher precision.

Repeatability: Repeatability is the ability of a weigh module to display identical measurement values for repeated weighing of the same or similar objects under the same conditions, such as the same measurement procedure, same operator, same measuring system, same operating conditions and same location over a short period of time. Repeatability is expressed as the standard deviation of multiple weighing operations. Repeatability is calculated according to the following formula:

$$s = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}(x_j - \bar{x})^2}$$

n = number of weighing trials
x_j = measured weight value at j-th trial
$\bar{x}$ = average value of the weighing trials

Repeatability in datasheets is generally taken as equal to the standard deviation. However, the factor of the standard deviation can also be taken as 2 or 3 if the accuracy requirements are more strict. Repeatability is directly proportional to the concept of accuracy. You can refer to Weighing Requirements for more details on accuracy.

Linearity: Linearity is defined as the ability of a weigh module to follow the linear relationship between a load m and the indicated value W. Non-linearity, on the other hand, defines the deviation of the characteristic curve from the straight line between the zero load and nominal load that is defined by the sensitivity. By definition, the linearity deviation of the starting and finishing point of this straight line is zero, and a possible deviation of the sensitivity (slope of the straight line) does not count as linearity deviation. Non-linearity is usually expressed as a ± limit value in mass units, e.g. [g].

Non-linearity becomes a critical error source when a filling or dosing process is done with the weigh module where the entire or most of the weighing range is used during the application. It becomes less critical when the application is control weighing, in whch a small range is used during the weighing process.

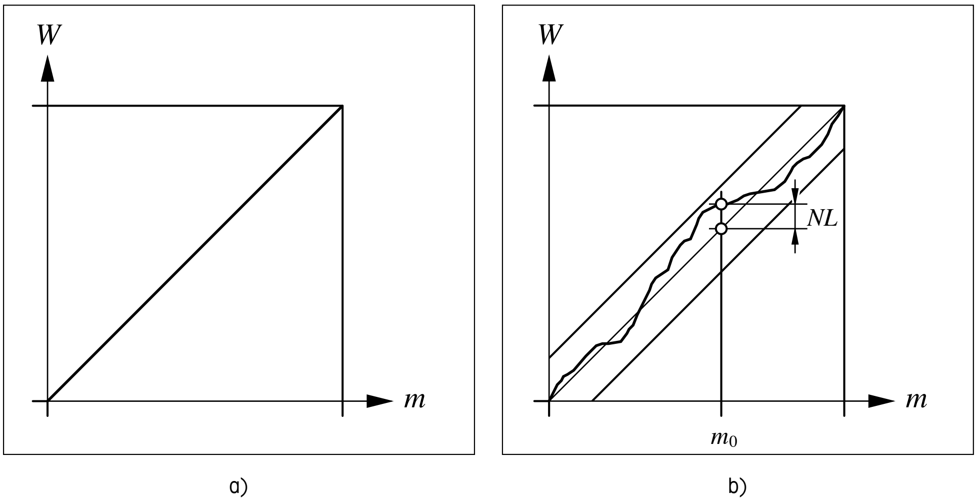

Figure 1-5: a) Linear characteristic curve of a weigh module between load m and weighing value W
b) Linearity deviation (exaggerated) between load m and weighing value W. A possible deviation of the sensitivty (slope of the straight line) does not count as linearity deviation

Eccentricity: Eccentricity is defined as the deviation in the measurement value caused by eccentric loading; that is, in other words, asymmetrical placement of center of gravity of the load relative to the load receptor. The eccentric load increases with increasing load and distance from the center of the load receptor. Eccentricity describes the change of the displayed value when the load is placed on different positions of the weighing platform.

Eccentricity can become an important source of error when the weighed object is placed manually on the weighing platform and the position changes each time due to human error. In automated applications where APW weigh modules are used, this is not a problem because the positioning on the weighing platform is managed automatically by robotic arms and hence the error possibility is removed.

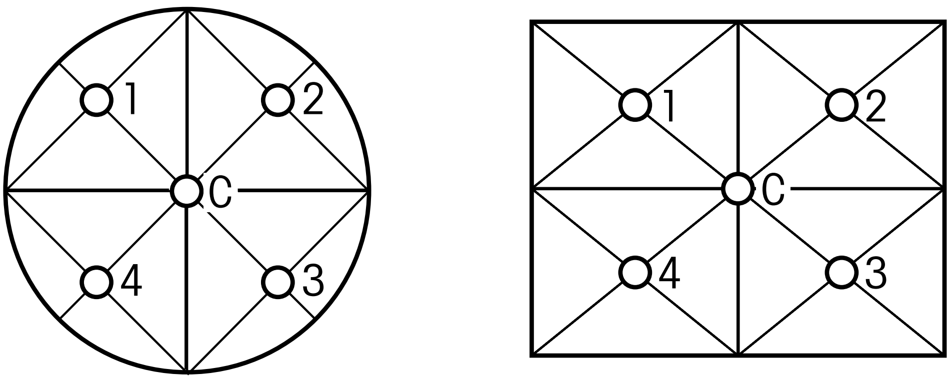

Figure 1-6:
Positions on the load receptor to test the eccentric load
C: central load
1...4: eccentric loadings

Sensitivity: The Sensitivity **S** of a weigh module is defined to be the change in the weighing value **ΔW** divided by the change in load **Δm.**

$$S = \frac{\Delta W}{\Delta m}$$

The sensitivity of a weighing instrument is a quantity without dimension if the change in the measurement value is expressed in mass units. The correct value is 1.
Sensitivity belongs to the most important specifications of weigh modules and relates usually to its slope (global sensitivity) measured over the nominal range.

$$S = \frac{\Delta\ W\ nom}{\Delta\ m\ nom}$$

Linearity deviation specifies the deviation of the characteristic curve from the global sensitivity.
The sensitivity of weigh modules, which use weight force as the physical weighing principle, is proportional to local gravity.

Sensitivity adjustment at the place of use is necessary due to the local gravity, depending on the number of scale intervals (resolution).

Deviation of sensitivity (sensitivity drift by environmental influences) can be caused by changes in temperature, air pressure fluctuations and/or time going by (long-term stability).

Deviation of sensitivity from the correct value (S = 1) causes positive or negative deviations of weighing values, which typically grow with the mass (true value) of the weight.

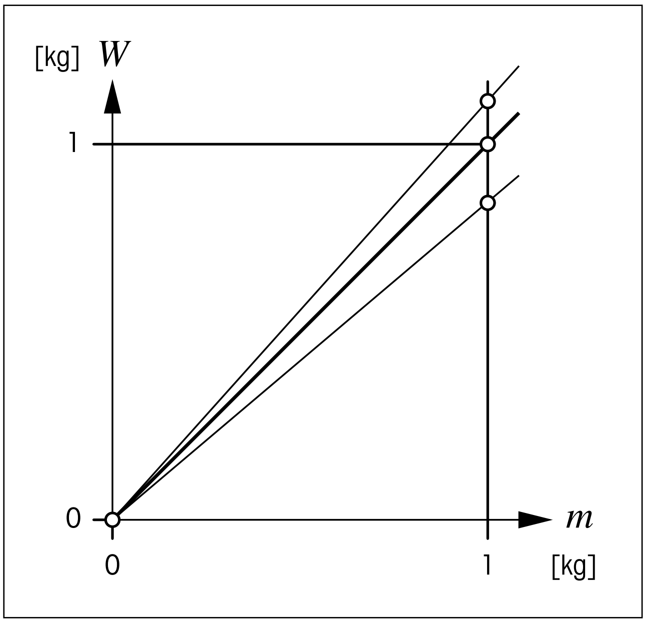

Figure 1-7: Sensitivity between weighing value W and load m, on the example of a weigh module with a nominal range of 1 kg. The middle line shows the characteristic curve of a weigh module with correct sensitivity (slope). The upper characteristic curve is too steep (sensitivity too high, exaggerated for reasons of illustration), while the lower curve is not steep enough (too little sensitivity).

Minimum weight: Minimum weight is defined as the smallest weighed-in quantity required for a weighment to just achieve a specified relative accuracy of weighing. Provided that systematic errors have already been corrected, the minimum weight m_{min} can be determined from the process uncertainty (tolerance) U and the repeatability of the weighing s_{RP}.
m min = (k/U) * s_{RP}
k → expansion factor
Corresponding requirements are described, for instance, in guidelines such as pharmacopeias
(e.g. → USP U = 0.1 %, k = 3 [USP<41>]), or may be defined in the user's process specifications.

Settling time: Settling time is the time between placing the weighed object on the weigh module and indication of a stabilized weighing value under optimal environmental conditions.

Settling time is usually stated as a typical value taking into account also the influence of environmental conditions, configuration of the weigh module and the weighed object. When these factors are considered, settling time is expressed also as the weighing time.

The user of the weigh module has an influence on the settling time when defining the stabilization criteria and the strength of the filtering. Strict stabilization criteria and very strong filtering can lead to a higher settling time. Settling time also depends on the influence from the environment, such as mechanical vibrations and air pressure changes. These external factors can also increase the settling time and in the worst case make it even impossible for the weighing device to settle to a final stable value. Settling time is a metric for the weighing speed.

Update rate: For weighing applications, such as dispensing to a specified target weight, the dispensing system must record the weight change continuously so as to regulate the dispensing process. In this case, you can define the number of weight values to be transmitted per second via the interface in what is known as *send continuous" mode.

Update rate is measured in Hz or weight values per second.

Update rate of the weigh module for continuous weight transmission can be adjusted with the MT-SICS command "UPD". For more details on this command, you can refer to the MT-SICS user manual.

Please note that baudrate should also be adjusted in order to enable a high update rate. Max. possible update rates are given in the table 1-1.

Internal conversion rate is not the same as the update rate. It is about the internal sampling rate of the DSP. 3 or 4 signal values are used to build one output value. Therefore maximum update rate can be 1/3 or 1/4 of the highest internal conversion rate.

APW weigh modules can have update rates of up to 92 values per second.

Update rate is not a metric of weighing speed. It can be set to high rates with a software command, but at the cost of weighing accuracy.

Required Baudrate	**Max. Update Rate**
2400	5
4800	10
9600	20
19200 ≤	92

Table 1-1: The relationship between the required baud rates and the maximum possible update rates

Approvals

APW weigh modules are subject to the following approvals:
- Legal for Trade
- EMC
- Hazardous area
- RoHS

Following approvals are not attained by APW weigh modules:
- MID
- Hygienic design

This section aims to briefly explain these approvals and their relevance to APW weigh modules. Each APW weigh module is delivered together with a "declaration of conformity" document, which shows the approvals or standards complied by the weigh module.

Legal for Trade: Legal-for-trade (often also called "Approved") applications are legally required and commonly occur where products are sold directly to the public based on weight and sometimes count. The weigh module model has to be tested and certified/approved by a testing lab and then the actual weigh module used is calibrated, tested and sealed by a government agency.This approval concerns the accuracy of the weigh module. There are several standards for the accuracy of weigh modules. In USA, NTEP is such a standard, and in Europe, OIML is an example. Both standards define the maximum permissible weighing error of the weigh module as the number of divisions. Maximum permissible error is dependent on the weight of the object placed on the weigh module. Figure 1-8 shows an example for OIML class III acceptance tolerance. The divisions on the vertical axis represent permissible error (the specified limits). The horizontal axis shows the number of divisions that corresponds to the actual weight on the weigh module.

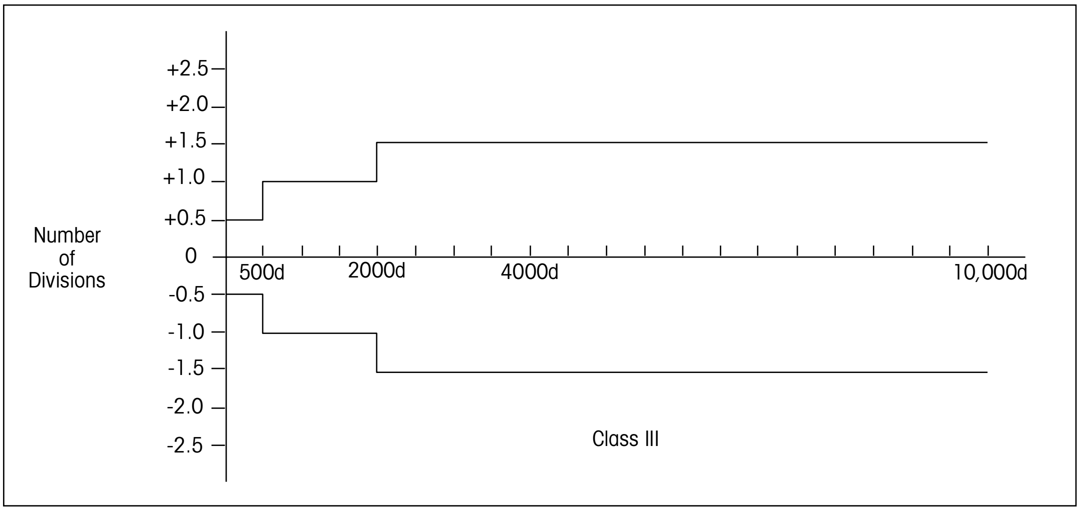

Figure 1-8: OIML class III (medium accuracy) acceptance tolerances:

Weigh modules with legal-for-trade approval have the following characteristics:
- Always include an indicator/display
- Specific start-up dead-load range
- Weighing below is not allowed
- The load cell and its external electronic unit can not be replaced independently. It is mandatory to keep the original pair. Therefore, load cells and electronic units are not available as individual spare parts.
- After power-up, the available zero setting range is about 10% of the weighing capacity.

Most APW weigh modules don`t have this approval because they are not used in applications where the weight of finished packaging is measured. In other types of applications, the process tolerances defined by the customers are used instead of the accuracy requirements from this approval.

EMC: EMC stands for "electromagnetic compatibility." EMC aims to ensure that equipment items or systems will not interfere with or prevent each other's correct operation through spurious emission and absorption of electromagnetic interference.

An EC type-examination certificate is a document in which a notified body certifies that the type of equipment examined complies with the provisions of the directive which concern it. Figure 1-9 below shows the "EC- Declaration of Conformity" document of a weigh module as an example.

EC - DECLARATION OF CONFORMITY
EG-Konformitätserklärung
KD-Nr.: 30060452 **Doku-Nr.: 20120007**

The undersigned, representing the following manufacturer
Die Unterzeichnenden vertreten das folgende Unternehmen
Mettler-Toledo AG (MTLabTec)
Im Langacher 44
CH-8606 Greifensee, Switzerland

CE
1258
Electrosuisse
Luppmenstrasse 1
CH-8320 Fehraltorf

herewith declares that the product
hiermit deklarieren wir, dass das Produkt
Weighing cell
WMSxyC-LX/z (WMSxyC-LX/z series)
For additional types, see page type code

certified model: --
Modell für Eichprüfung

is in conformity with the provisions of the following EC directives (incl. all applicable amendments)
mit den folgenden EG-Richtlinien (Inkl. Änderungen) übereinstimmt

94/9/EC	Equipment explosive atmospheres (ATEX)
2004/108/EC	Electromagnetic compatibility (EMC)

and that the standards have been applied.
und die Normen zur Anwendung gelangten.

Last two digits of the year in which the CE marking was affixed: **12**
Die letzten zwei Zahlen des Jahres der Erst-CE-kennzeichnung des Produkts mit dem CE Zeichen.

CH-8606 Greifensee
06.08.2012

Dr. René Lenggenhager
General Manager LabTec

Hanspeter Kunz
Head Business Area Weighing Components

References of standards for this declaration of conformity, or parts thereof:
Harmonized standards of Europe and Switzerland:

Notified Body for production:
DEKRA Certification B.V.
Utrechtseweg 310
NL-6812 AR Arnhem

Safety standards:
EN60079-0:2009
EN60079-15:2010, SEV 12 ATEX 0134 X

EMC standards (* Emission; ** Immunity):
IEC61326-1:2005 / EN61326-1:2006 (class B *)
IEC61326-1:2005 / EN61326-1:2006 (Industrial requirements **)

Metrological standards:
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IP standards:
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Standards for Canada, USA and Australia:

released:5.06.2012 / CR Seite 1 von 2 printed: Aug. 2012

Figure 1-9: EC – Declaration of Conformity document issued for a weigh module.
Red rectangles show the parts related to EMC.

Hazardous Area: In some applications, there is the hazard of explosion. APW portfolio includes weigh modules, which can be used in hazardous areas. There are many guidelines and standards in the world, which specify the rules for hazardous areas. Figure 1-10 below shows the world map, which depicts the valid standards in different regions.

Guidelines	Standard
CENELEC (Europe)	ATEX
CEC (Canada)	CSA
NEC (USA)	FM
NEC (USA)	UL
GOST R (Russia)	GOST R-Ex
AQSIQ (China)	NEPSI
MHLW (Japan)	TIIS
IEC (Australia)	IEC-Ex

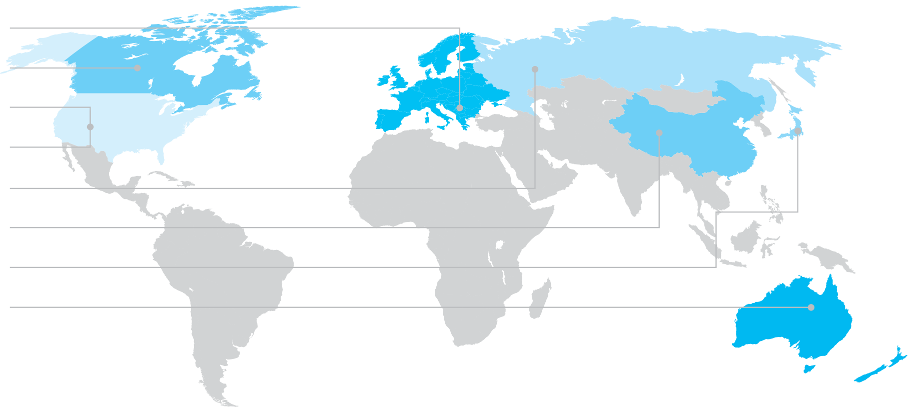


Figure 1-10: Hazardous area guidelines and standards in the world

APW weigh modules comply with the standards of ATEX, CSA, FM and NEPSI. APW weigh modules can be used in the Ex zones 1 and 2 (divisions 1 and 2, class 1), where an atmosphere at risk of explosion from gases or vapors can form during normal operation. In the Ex zone-1, where an atmosphere at risk of explosion from gases or vapors can form **occasionally** during normal operation, a weigh module is supplied with power from a special power supply placed in the hazardous area. In the hazardous area, all communication is done with the current loop interface and intrinsically safe cables. The power supply transfers the data communication from the weigh module to an interface converter, which is placed in the safe area. The interface converter has the function to convert the interface from current loop to RS232 or RS422. This way, the weigh module can communicate with a PLC or PC. Figure 1-11 below shows a typical system configuration built with these components.

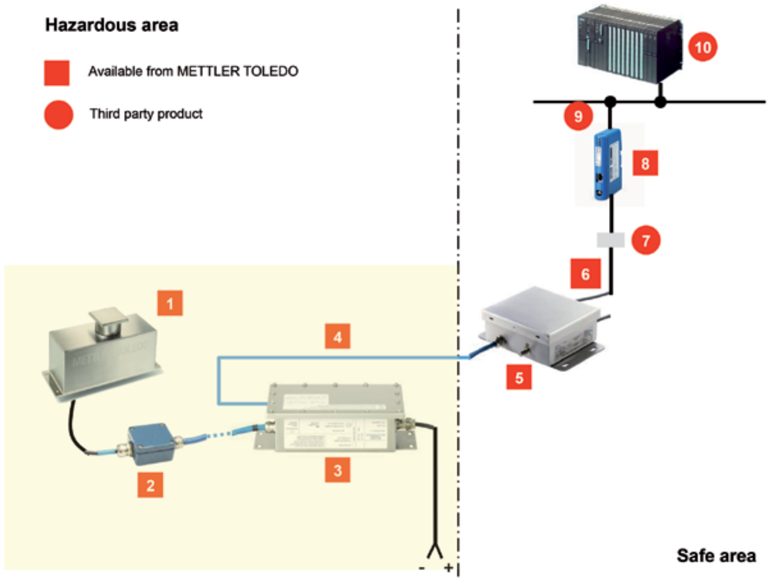


Figure 1-11: Typical configuration in the hazardous areas
1: Weigh module
2: Terminal-Box and 6-wire Ex-i cable
3: Power supply
4: 4-wire Ex-i cable
5: Interface converter
6: RS232 or RS422 cable
7: Gender changer (male-to-male)
8: Fieldbus module
9: Fieldbus cable
10: PLC

RoHS: The Restriction of Hazardous Substances Directive is designated 2002/95/EC. It was adopted by the European Union in February 2003. The RoHS directive took effect on July 1, 2006, and is required to be enforced and become law in each member state. This directive restricts (with exceptions) the use of six hazardous materials in the manufacture of various types of electronic and electrical equipment. These substances are:
- Lead (Pb)
- Mercury (Hg)
- Cadmium (Cd)
- Hexavalent chromium (Cr6+)
- Polybrominated biphenyls (PBB)
- Polybrominated diphenyl ether (PBDE)

The maximum permitted concentrations in non-exempt products are 0.1% or 1000 ppm (except for cadmium, which is limited to 0.01% or 100 ppm) by weight.

APW weigh modules comply with the RoHS directives.

MID: The Measuring Instruments Directive (2004/22/EC) is a directive by the European Union for ten different instruments and system types with a measurement function.

It contains all technical requirements and error limits for the relevant types of measuring instruments and is applicable to all measuring instruments that perform measurement tasks in the public interest in health care; public safety and security; environmental protection; consumer protection; tax collection; and general commercial applications. Among others, automatic weighing instruments are governed by this directive.
The Weighing Instruments Directive is implemented as national law in the EEA and Switzerland as follows: If a country already has a national law relating to one of the instruments covered in the Measuring Instruments Directive, the corresponding module of the Measuring Instruments Directive must be implemented as national law and replace the formerly existing law. If a country has no national law relating to an instrument type, implementation of the corresponding module in national law is voluntary.
APW weigh modules don`t have this approval.

Hygienic Design: The most important guidelines regarding hygienic design are given below:
- EHEDG
- NSF

EHEDG is a Europe-based organization, which provides guidance on the hygienic engineering aspects of manufacturing safe and healthy food. This is achieved through equipment certification to assist equipment suppliers and food manufacturers.

Equipment design should ensure easy cleaning, which helps to prevent bacterial contamination of food during production.

General specifications according to EHEDG:
- Min. AISI 300 series steel (e.g. 304, 316, 316L resp. 1.4301, 1.4401, 1.4404): Easy to clean material, non-corrosive glues
- Radius inside corners > 3 mm, no corners with < 90°
- No horizontal parts to avoid remaining water (bacteria)
- Smooth surface (Ra < 0.8 µm, no holes, easy to clean etc.)

NSF provides health and safety risk management solutions. It is a guideline that establishes the minimum food-protection and sanitary requirements for materials, design, construction and performance of commercial food equipment and their related components. It is an independent, non-profit organization, and is U.S. based. It is increasing cooperation with EHEDG on hygienic-design testing.

NSF established a standard for hygienic design and construction requirements for meat and poultry production: General specifications according to NSF are the following:

- Use corrosion-resistant metals as surface material: AISI 304 (at least) or stainless steel of a type appropriate for application
- Surfaces: Free of imperfections, R_A < 0.81 µm
- Geometry: Radius inside corners > 3,2 mm (1/8″) and no corners with < 90°
- Fasteners (e.g., screws, bolts, rivets) shall be avoided
- No stick welding

Both guidelines have very similar specifications. It is assumed that they will converge into a single universal guideline in the future.

APW weigh modules don`t have an approval for hygienic design, but they enable safe and easy-to-clean applications thanks to the following features:

- Wash-down feature with an IP rating of IP66, which permits cleaning of the surfaces with powerful water jets and ensures the removal of contamination and dirt.
- Housing and weighing pan are made of stainless steel (1.4404 resp. 316L) to resist aggressive cleaning agents, which helps to better remove any potential contamination and dirt.

Selection Criteria

The second chapter is about the selection criteria of the weigh module. Here, the key target is to determine the right weigh module for the application. For this purpose, this chapter is divided into the following sections:
- Weighing Requirements
- Required Approvals
- Environmental Requirements
- Application Requirements
- Mechanical Requirements
- Connectivity Requirements

After the analysis of the above requirements, the user should be able to select the right weigh module for the target application.

Weighing Requirements

In an application, weighing requirements can be summarized as follows:
- Capacity
- Readability
- Accuracy
- Speed

Capacity: Capacity of the weigh module should be selected such that it is higher than the sum of the heaviest product weight to be weighed plus the weight of the weighing platform and the weight of the container. This statement can be formulized as follows:

$C \geq W_{max} + W_P + W_C$; C: Capacity of the weigh module, ; W_{max} = Biggest product weight, W_P = Weight of the weigh platform, W_C = Weight of the container

Readability: Readability of the weigh module should be selected according to the process requirements. However, it should be kept in mind that readability is not the same as accuracy. Readability can be set to any desired value with a software command. Here, it is important to check the minimum possible readability of the weigh module. This value should be lower than the process tolerance given in grams. This relation is shown below:

$R_{max.} \leq PT$; R_{max} : maximum readability of the weigh module ; PT: Process tolerance given in grams

For example, if the process tolerance is defined as 1 mg, the minimum readability of the weigh module should be 1 mg or lower.

Some weigh modules can increase the number of displayed digits with a special command. However, this increase in digits doesn`t necessarily mean that the weigh module can show these values accurately. This is rather about the accuracy of the weigh module.

Accuracy: Accuracy of a measurement is defined as closeness of agreement between a measured quantity value and a true quantity value of a measurement. Figure 2-1 shows the relationship between accuracy, precision and trueness with a good example. Accuracy of a weigh module depends on multiple factors. These are given in the formula below:

$$U = 2 \times \sqrt{V_w + V_r + V_e \times W^2 + V_a \times W^2 + V_k \times W^2}$$

U: Measurement uncertainty (= inaccuracy)
W: Actual weight placed on the weighing sensor
Vw: Deviation of repeatability
Vr: Rounding error deviation
Ve: Deviation of the corner load
Va: Deviation of the non-linearity
Vk: Deviation of the calibration weight

Repeatability is the biggest contributor to accuracy. The effects of the corner load and non-linearity can be neglected at automated applications with a low weighing range. Also, rounding error and deviation of the calibration weight are negligible when using precise calibration weights.

A weigh module must be selected such that its repeatability is smaller than the process tolerances. If relative process tolerances are used (given in percentage), repeatability should be smaller than the process tolerances throughout the weighing range of the application. Following relations hold:

- Rep. ≤ PT [g] ; Rep. = repeatability, PT [g]: absolure process tolerances in grams
- Rep. ≤ PT [%] * W_{min}; Rep. = repeatability, PT [%]: relative process tolerances in percentage, W_{min} = Minimum net weight (product) used in the application.

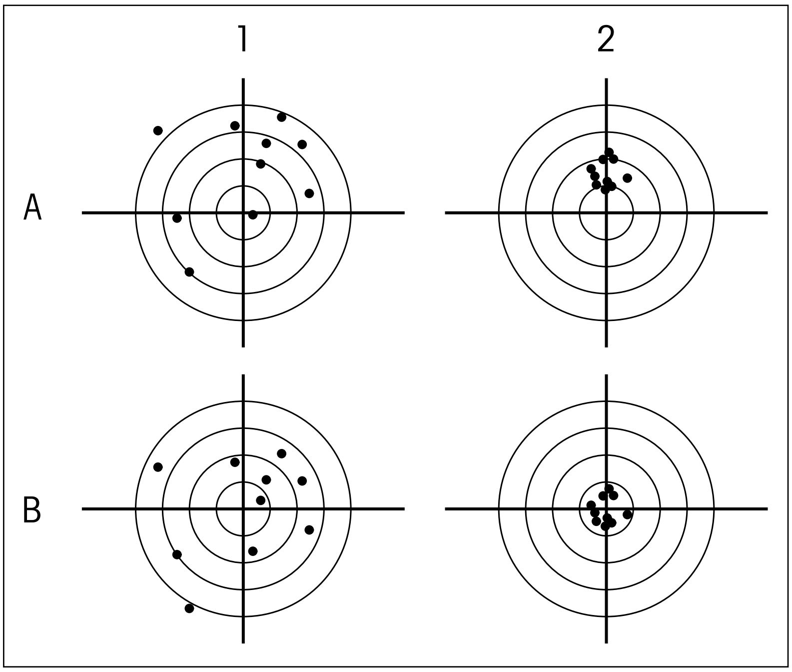


Figure 2-1: Explanation of the relationship between accuracy, precision and trueness.
Row A shows measuring points with systematic error (lack of trueness);
row B measuring points with no systematic error (correct).

Column 1 shows scattered measurement points (lack of precision);
column 2 shows measuring points with virtually no scatter (precise).

For repeated measurements, accuracy requires correct and precise measuring points;
thus, in general, only the measuring points in B2 are accurate.

Speed: Speed is the last weighing requirement. There is a trade-off between weighing speed and accuracy. This relation is explained in section Process Optimization. Weighing speed can be defined as the time needed by the weigh module to process a weight value and display or send it to the control system in a stable and accurate way after a weight is placed. Settling time is the best indicator for the speed of the weigh module. Settling time of the weigh module must be shorter than the weighing speed requirement of the application. However, settling time specifications are made for the optimum environment. If the real environment is unstable, settling time can be longer than in the specifications. Stability criteria and filtering have an influence on the settling time. These topics are also covered in section Process Optimization.

Required Approvals

For selecting the right weigh module, required approvals must be known. Answer the questions below to help you select the right weigh module:

1. Is the application in a hazardous area where explosion might be a danger?

   Answer is "No":
   - Select a standard weigh module

   Answer is "Yes":
   - Grade the possibility of explosion:
     – Is it possible under normal conditions?
     – Or only possible under abnormal conditions?
   - Select a weigh module with a hazardous-area approval based on the possibility of explosion

2. Does the application require a hygienic design (EHEDG or NSF)?

   Answer is "No hygienic design needed":
   - Select a standard weigh module

   Answer is "Easy to clean is enough":
   - Select a weigh module with "wash-down" feature. With the wash-down feature and stainless steel materials, the weigh module is easy to clean.

   Answer is "Yes, hygienic design is needed":
   - APW weigh modules don`t have this approval. However, be aware that in the market there are not many module designs that can fully comply with hygienic design approvals.

3. Does the application require a legal-for-trade approval?

   Answer is "No":
   - Select a standard weigh module

   Answer is "Yes"
   - Select a weigh module with a legal-for-trade approval.

For more details on these approval types, you can refer to Approvals.

Environmental Requirements

In this step, the user has to determine the requirements imposed by the weighing environment. The environmental parameters that affect weighing are the following:

- Temperature
- Athmospheric humidity
- Air draft & air-pressure changes
- Vibrations
- Electrostatics
- Magnetism
- Over and under pressure
- Vacuum
- Radioactivity

Temperature: Ambient temperature influences weighing in a variety of ways. In the case of weigh modules, temperature changes cause expansion of components or changes in material properties. Weighed objects that are not acclimatized to the ambient temperature cause transient effects (e.g. air currents). Particularly in the case of high-resolution weighing, these effects can invalidate the result, either by causing systematic errors, or causing the measured value to drift, or by causing the repeatability to be worse. Although these deviations can be compensated for to some extent, temperature limits are specified for the operation of weigh modules. We distinguish between operating temperature range (typ. +10 to 30°C) and allowable ambient temperature (typ. +5 to 40°C). The weigh modules are compensated within the operating temperature range. Therefore, we always recommend using the weigh module within the operating temperature range.

The weigh modules should never be stored outside the allowable ambient temperature range. The specification of the temperature drift is usually expressed as limit value in 1/°C or 1/K.

It is recommended to have a thermal isolation between platform (weighing pan) and load cell in case the weighed objects do not have ambient temperature.

Weigh modules need time to warm up before they are ready to use. During the warm-up process, a drift can occur, which leads to unstable reading.

Athmospheric humidity: Ideally, the relative humidity (% RH) should be between 45 and 60%. Weigh modules should never be operated above or below the measuring range of 20 to 80% RH. Constant monitoring is advisable with high-resolution weigh modules. Changes should be corrected whenever possible. If humidity falls below 45% RH, the weighed objects can possibly be charged with static electricity, which can lead to unstable readings. On the other hand, if humidity is high, the weighed objects might absorb moisture, which has an influence on the weighing results. Above 80% RH, condensation can occur and can consequently cause errors or malfunction of the weigh module.

Air draft & air pressure changes: Air currents generate, through impact pressure or viscous friction, spurious forces onto the weighing platform and the weighing object. A direct consequence of this effect is the deterioration of the repeatability of the weighing value.

Pressure fluctuations can generate air currents, which will exert flow forces onto the weighing pan or the weighing cell, disturbing the weighing value, particularly for weigh modules with 5 and 6 decimal points (10 or 1 µg of readability).

Potential countermeasures include:
- Avoid air currents in the weighing environment
- Avoid air stream of cooling fans
- Use weigh module with a draft shield
- Use weighing platforms with a small surface area (including the use of grids to reduce the effect of air draft)
- If possible, use objects with small surfaces (e.g., small container)
- Do **not** use pressurized air for moving objects to or from the weighing platform.

Vibrations: Vibrations (translational as well as rotational) at the site of the weigh module may introduce deviations into the weighing value. Vibrations are caused by seismic movements and man-made noise, such as by machines, transportation, etc.

The smaller the readability of a weigh module (thus the higher the resolution), usually the more susceptible it becomes to vibrations. Direct consequence of the vibration is the deterioration of the repeatability of weighing value.

Potential countermeasures to avoid vibration are:
- Installing the weigh module in a vibration-free environment if possible
- Isolating or decoupling the weigh module mechanically from its environment
  (Use mechanical dampers if necessary)
- Using appropriate filtering to remove the vibrations from the weight signal (see Process Optimisation)
- If possible, using a custom weighing platform that is light and stiff

Electrostatics: Electrically charged weighing objects can exert an attracting or pushing force to the weighing platform. As a direct consequence, the weighing value can deviate from the actual mass of the object. Electrically non-conductive objects like glass, plastic, aluminum and ceramic can accumulate electrostatic charges. Even low electrostatic charges on the object can have a significant influence on the weighing result. As a result, the weighing value will drift as the object is slowly discharging. Figure 2-2 shows the electrostatic influence on a vessel being weighed.

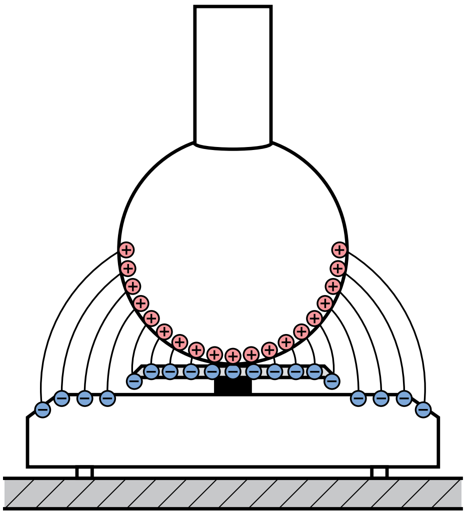


Figure 2-2: Electrostatic influence on a vessel being weighed

If electrostatic charging of an object cannot be avoided during the process, discharging the object before weighing is strongly recommended. For the evaluation of an appropriate de-ionizer, ask the supplier of the static-control device. They can provide best expertise.
Sources of electrostatic charges in industrial environments include:

- Flash lights and other lighting systems for optical quality control
- Chemical treatments during production (e.g. acids)
- Mechanical treatment and transport elements made of plastic material or aluminum (wheels, axels, belts)
- Charged handling robots
- Airflow on the surface
- Charge or discharge for galvanic processes (e.g. metalization).
- Low ambient humidity

Measures to remove electrostatic effects are given below:

- Avoid flash lights and other strong light energies right before the weighing process
- Use only anti-static/conducting materials in the entire assembly line. Pay special attention to plastic materials and aluminum.
- Use deionizers for electrostatic discharging
- Connect the weigh module to the earth ground potential
- Use electrically conductive materials for custom weigh pans/ platforms

Magnetism: Magnetic fields and magnetically permeable materials close to the weigh module can affect the weighing result. Even if the weigh modules are relatively immune to external magnetic fields, make sure that magnetic sources (e.g. electric motors) are kept away from the weigh module. If magnetic materials are weighed, stable weighing results can be achieved indeed, but with poor repeatability. This is because the result depends on the position where the weighed objects are placed.

Magnetic and magnetically permeable objects exert a mutual attraction. The additional forces that arise are wrongly interpreted as a load. Practically all objects made of iron (steel) are highly permeable to magnetic forces (ferromagnetic). If possible, demagnetize the magnetic forces by placing the weighing sample in a vessel made of Mu Metal film, for example. Since the magnetic force decreases with increasing distance, the sample can be distanced further from the weighing pan by using a non-magnetic support. The same effect can be achieved by means of a hanger. The "below weighing" setup is available on most weigh modules of METTLER TOLEDO.

Over / Under pressure: There is no general statement about the influence on over and under pressure.

Possible problems are:
- Magnet coil (See Figure 2-3)
  There is a silicone part that is used to seal the coil. Due to over and under pressure, the seal can break. As a consequence, the coil would absorb humidity, which has a negative influence on the sensitivity behavior.
- Electronic
  Components, like capacitors and quartz with hollow spaces, are critical. Life time will be shorter.

Allowed range for weigh modules is between 0 m (1013,25 hPa) and 4000 m (606,3 hPa) above mean sea level.

Vacuum: A vacuum is space that is devoid of matter. Traditional weigh modules do not work in such areas. APW weigh modules are not recommended for the vacuum environment due to the following reasons:
- The capacitors might be destroyed in the long run. We do not have any experience with extended vacuum behavior.
- After establishing a vacuum, there is a transient time of several hours for the weighing result to be free of drift.
- The coil of the MFR load cell is encapsulated. A vacuum might destroy this encapsulation and load drift behavior upon humidity changes might get worse.
- The cooling behavior of the devices will drastically change as there is no transport media (air, gas).

Figure 2-3: Magnet coil

A possible solution is a magnetic suspension balance. Those devices decouple the weigh module with a pair of electromagnets from the vacuum chamber. See Figure 2-4 for such a balance.

Radioactivity: Weighing within the radioactive environment is not recommended. Possible problems are influences on the electronic components as well on the used material, such as coil and Monobloc.Experience is lacking because of difficult environment and requirements.

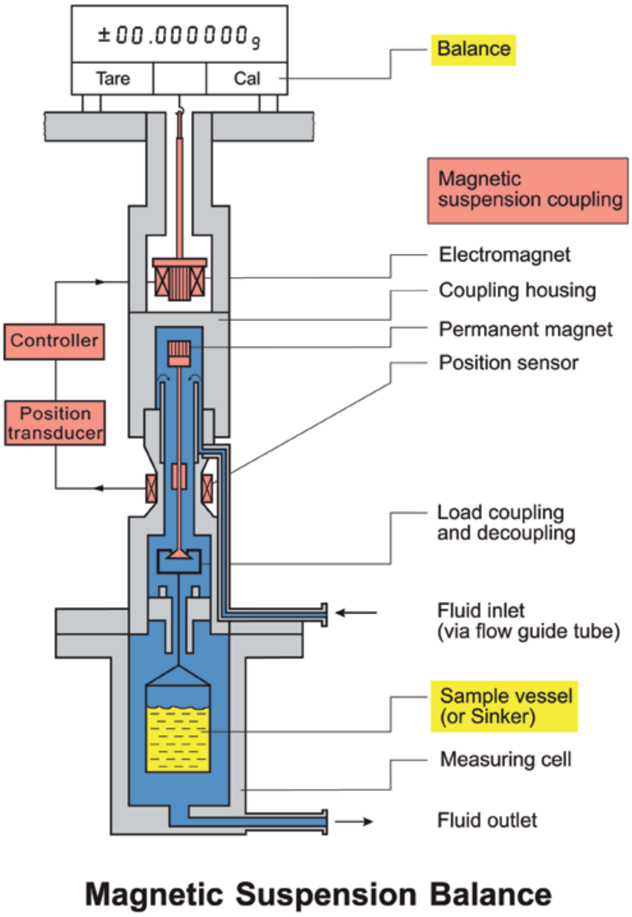


Figure 2-4:
Diagrammatic cross section and operating principle of a magnetic suspension balance

Application Requirements

APW weigh modules can be configured for 2 application types:
• Control weighing
• Fillling/Dosing

In control weighing, the weight of the final good is measured at the end of the production. The target is to measure the final weight of the product with maximum possible accuracy and stability. Usually, this application type is less time-critical, since measuring accurate and stable weight values have more importance than fast weighing. At the end of the production, one single stable and accurate weight value is needed by the control system in order to conclude the process.

Filling, dosing and dispensing processes cause permanent change of the weight value during operation and can therefore be classified as dynamic processes in contrast to control weighing, which is typically the measurement of static weight values. For these processes, it is mandatory to supply fast linear and reliable weighing values in a continuous mode to ensure correct and repeatable results. This application type is usually more time-critical and providing fast weighing values is more important than accurate and stable weight results.

For these 2 application types, stability criteria and filtering have to be defined differently. It is possible to configure APW weigh modules for both application types. The details of these operations are explained in Process Optimization.

Mechanical Requirements

When selecting a weigh module, the following mechanical requirements have to be considered:
- Mechanical dimensions
- Mechanical interfaces
- Materials

Mechanical dimensions: When selecting a weigh module, mechanical compatibility of the weigh module with the machine design has to be considered. Selected weigh module must fit to the reserved space in the machine and should not cause any stress or tension forces due to incompatible design.

It should be noted that any emerging positive or negative overloads due to flawed mechanical integration can damage the weigh module. Therefore, enough space should be reserved for the weigh module in the machine design. If the weigh module has an external electronic box, it must be ensured that there is enough room reserved in the machine design also for this additional unit.

You can refer to the mechanical drawings of the weigh module in order to integrate it correctly into your machine design. METTLER TOLEDO provides detailed mechanical drawings based on requests from the customer.

Mechanical interfaces: As explained in Mechanical Interfaces, weigh modules have 2 mechanical interfaces: a weighing interface and a support interface. If the standard weighing interface doesn`t fit to the machine design or application, the user can build his own custom weigh platform, which will be explained in more detail in Mechanical Design.

If there is not enough space to permit weighing from above or if it is difficult to feed the weighing object onto the weighing platform, weighing from below can be considered as an alternative approach. Details on this feature will be explained in Mechanical Design.

Materials: A weigh module usually consists of various materials. The specifications of the used materials can be found in the respective section of the operating instructions. Most of the materials used for MT weigh modules are FDA approved, but it is in the responsibility of the user to ensure compliance with the regulations in the application field.

If a cleaning process is involved in the application, it is important to make sure that the resistance to the employed chemicals can be provided by the used materials. Frequent exposure to chemical stress can lead to abrasion of seals or plastic parts over time. Regular and preventive maintenance avoids bigger damages and ensures longevity.

Connectivity Requirements

As already explained in Connectivity with Control Systems, APW weigh modules provide various data interfaces to connect to control systems. Here, the following questions must be answered by the customer in order to design the connectivity concept for his machine or setup:

- Which communication interface do you want to use in order to communicate with the weigh module?
- Do you want to have direct connectivity between the PLC and the weigh module or can you tolerate a converter unit in between?
- Can you tolerate the existence of an external electronic unit/box?

These 3 questions are crucial when designing the connectivity concept. Based on the answers to these questions, the customer can select a weigh module. Some answers may cause a contradiction. In that case, the customer has to find a compromising solution.

Installation

The third chapter deals with the installation, integration and parametrization of the weigh module inside the customer`s machine. This chapter contains the following sections:

- Mechanical Design
- Electrical Installation
- Configuration
- Process Optimization

These 4 steps aim to make the weigh module ready for its operation.

Mechanical Design

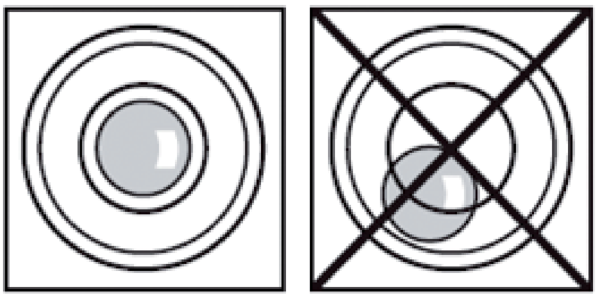
Mechanical design is a very important step in machine design because it has a direct influence on the weighing performance. A good mechanical design enables the weighing device to perform at its best, whereas a poor mechanical design can only cause troubles that can compromise weighing accuracy. Therefore, we recommend a very careful study of this section before beginning with the design.

Mechanical design is the first step in preparing the weigh module for operation. This step includes the following considerations:

- Support surface
- Custom-weighing platform
- Weighing from below
- Applying and removing weighing objects
- Overload protection

Support surface: Following points must be considered when designing the support surface:

- Determine the floor properties in the location where the system is to be set up. Make sure that no building vibrations are transferred to the support surface via the floor.
- Provide a support surface that is mechanically isolated from vibrations and shocks.
- Use mechanical damping elements between the system and the support surface if vibrations cannot be mechanically isolated.
- Support surface has to be stiff because a stable mechanical base is mandatory for precise and fast weighing results.
- Maximum permissible slope (deviation from horizontal) must not be exceeded. See general data in the operation manual of the individual weigh module.
- Leveling bubble (See Figure 3-1) is available as an accessory or integrated in some weigh module types to check the inclination of the weigh module at any time.
- Use attachment points in the base plate to screw the weigh module to the support surface. See installation data, like screw specification and proceeding, in the operation manuals of the individual weigh module type.
- The surface must be absolutely plane to prevent the base plate from twisting.
- When weigh module has a connector at the bottom, support surface must be cut out according to the drawing at the connector locations. When below weighing option is used, support surface must be cut out according to the drawing at the below weighing interface. See drawings / drill hole templates in the operating manual of the individual weigh module type.
- Make sure that the weigh module housing is electrically connected with the support surface. We additionally suggest to connect all conducting parts of the system, such as weigh-module support or handling robot arm, star shaped to earth ground (avoid ground loops).



(a) (b)

Figure 3-1: Refer to leveling bubble for correct horizontal position of the weigh module
(a) Horizontal position
(b) Inclined position

Custom weighing platform: In some applications, a custom weighing platform is required in order to fit the standard weighing interface to the application requirements. In this case, a custom weighing platform can be built upon the weighing pan adapter by using the mounting screw holes (See Figure 3-2).

When building a custom weighing platform, there are some points to considered to achieve the best weighing performance. These are:

- Surface area: Surface area of the weighing platform has a direct relation with susceptibility to air draft. Weighing platforms with a big surface area are more vulnerable to air draft, and consequently weighing accuracy can be negatively effected. This influence is particularly visible after the 5th decimal point (readability 10 µg and 1 µg). To reduce this effect, custom weighing platforms should be designed with as little surface area as possible and in a grid form, where applicable, in order to let air through the holes and limit the influence of the air draft (See Figure 3-3). A draft shield can also be designed to block the movement of air above the weighing platform.

Figure 3-2: Adapter weighing pan.
Custom weighing platform can be built at the top by using the 4 mounting screws.

Figure 3-3: Weighing pan designed as a grid
Grids can help to reduce the influence of the air draft, especially for 5th and 6th decimal points

- Material: The material of the custom weighing platform has to be selected from electrically conductive material in order to prevent the accumulation of electrostatic charges. These charges can exert an electrostatic force and compromise the weighing accuracy. Therefore, non-conductive materials like plastics or acylic glass should not be used as weighing platform material.
- Weight & Stiffness: The weight and the stiffness of the weighing platform have a direct influence on the susceptibility to vibrations. These 2 factors determine the resonance frequency of the weighing platform. Resonance frequency of the weighing platform has to be designed to be as high as possible in order to reduce the effect of the vibrations on the weigh module. This can be achieved by designing a light and stiff weighing platform, which doesn`t bend too much under the application of force.

- Eccentricity: A custom weighing platform has to be designed so that its center of gravity lies at the load application point or as close as possible. Failing to do that might lead to an additional bending force on the load application point, which can damage the weigh module over the long term (See Figure 3-4). This effect can only be understood after a high number of load cycles, when the weigh module gets broken due to fatigue failure. To avoid that, concentric weighing platforms have to be used as much as possible

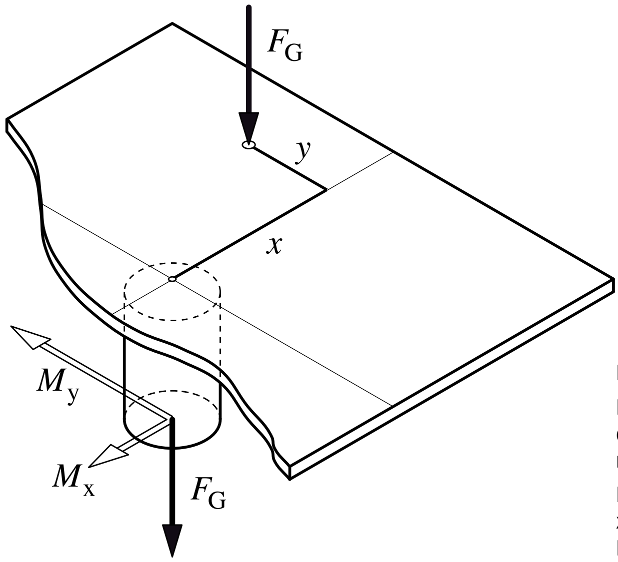


Figure 3-4: Effective forces in eccentric loading

Eccentric loading causes the load cell to experience a torque in addition to the weight force, which may cause a deviation in the measurement value

FG: weight force of load
x, y: eccentricity of placement
Mx, My: mechanical couples caused by the eccentric loading

Weighing from below: Weighing below the module is an alternative to weighing from above. The weighing object is not placed on the weighing platform; instead it is held by an application-specific supporting device that is located below the module and permanently connected to the weigh module. There is no weighing platform, and so there is no basic load. The upper opening is closed with the cover accessory so that no extraneous objects or dirt can penetrate into the interior of the module. If your supporting device is the same weight as the basic load, the entire weighing range is available to you with no restrictions.

Weighing below the module can be used:
- If it is difficult or inappropriate to feed the weighing object onto the weighing platform.
- If there is not enough space to permit weighing from above.
- If weighing from above might soil or contaminate the load cell

Benefits
- Solves many critical applications under special physical conditions like heat, a very cold environment, contamination, radiation or limited space
- Enables weighing of objects in liquids

Limitations
- Weighing below is not allowed when using legal-for-trade weigh modules

You can refer to the operating instructions of the individual weigh module type for more details on how to prepare the weigh module for weighing from below.

Applying and removing weighing objects:
Excessive additional forces or vibrations affecting the weighing platform as a result of applying or removing the weighing object can impair the weighing duration and the result.
Make sure that you keep additional forces and vibrations to a minimum when applying or removing the weighing object. APW weigh modules are protected against vertical overload but lateral impacts should be avoided as much as possible.

The weighing object should come to rest on the weighing platform as quickly as possible once it has been applied. If the weighing object is pushed sideways onto the weighing platform by a feed mechanism, height differences between the weighing platform and feed mechanism should be avoided. Ideally the height difference should be less than 0.3 mm.

Make sure that the object or its center of gravity is as close to the center of the weighing platform as possible during weighing or that it is always applied in the same way.

Do **not** use pressurized air for moving objects to or from the weighing platform. This can compromise weighing accuracy and make it difficult to measure a stable weight.

It is not recommended to move the weigh module toward the weighing object. These kind of setups can cause shock overloads inside the weigh module due to the dynamic movement in a short time. Shock overloads are always difficult for the weigh module to handle with and might lead to failure over the long term.

Overload protection: In industrial environments, weigh modules are open to all different kinds of overloads. APW weigh modules have integrated overload protections, but also this protection has a limit. In general, make sure that no overloads apply to the weigh module in a non-operating or operating state. If overloads are continuously present in the weighing environment, it might reduce the life of the weigh module.

Figure 3-5: Good practice for applying & removing weighing objects
Weighed object is placed on the weighing pan gently with a robotic arm. This way, vibrations and shocks can be minimized and the stability can be reached within shortest time

APW weigh modules have a robust overload protection in vertical direction, but in general weigh modules are more vulnerable against lateral forces and dynamic overloads. It is particularly important to protect the weigh module against dynamic overloads since this impact can be transferred over the mechanical stops to the inside of the weigh module due to the inert nature of the material.
Below, are definitions regarding overloads:

- Overload: Load that exceeds the available maximum load for the corresponding weigh module. In the event of overload, the weigh module responds with a status of "+", as in "S +."
- Overload protection: Mechanical device that protects the load cell from overloading by interrupting the transmission of force from the load receptor to the load cell as soon as an excessive load or force acts on the load receptor.
- Static overload: An overload with no momentum. A motionless resting object on the weigh platform, which is heavier than the maximum capacity of the weigh module can cause a static overload.
- Dynamic overload: An overload, which is applied together with a momentum. A falling object onto the weigh platfrom from a certain height can cause a dynamic overload even though it is lighter than the maximum capacity of the weigh module.
- Vertical overload: An overload which is applied in the vertical direction against the weigh platform.
- Horizontal overload: An overload which is applied in the horizontal direction (also lateral overload) against the weigh platform
- Concentric overload: An overload that is applied directly onto the load receptor.
- Excentric overload: An overload that is applied excentrically (not directly onto the load receptor point). This kind of overload can cause a bending moment (if force application direction is vertical) or torsion moment (if force application direction is horizontal) on the weigh platform

You can refer to Figure 3-6 for the directions of the above mentioned overload types.

Exact overload protection values can be found in the operating instructions of the individual weigh module type.

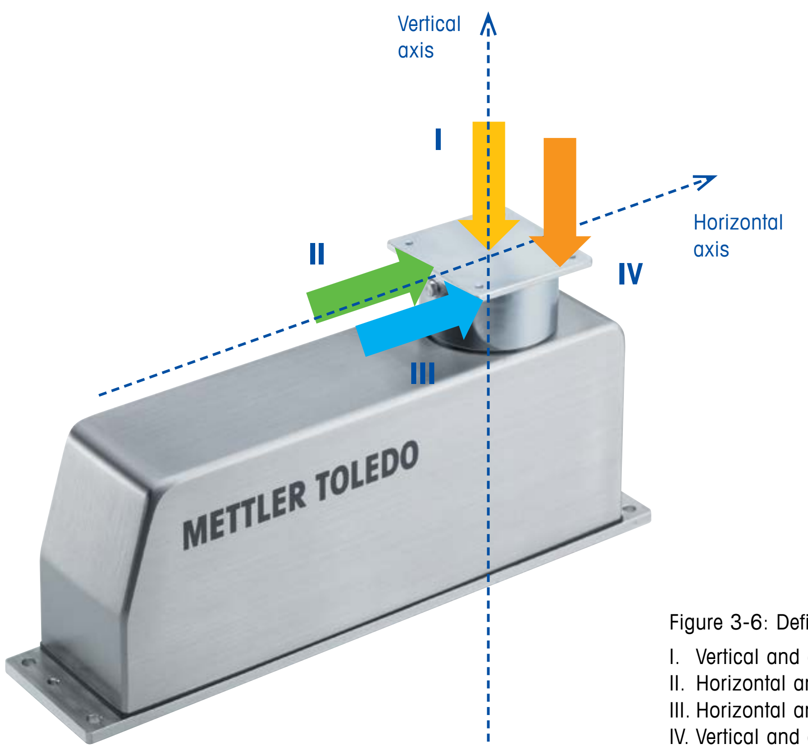


Figure 3-6: Definition of overload directions

I. Vertical and concentric
II. Horizontal and concentric
III. Horizontal and eccentric
IV. Vertical and eccentric

Electrical Installation

The following points must be considered when making the electrical installations:

- Open wires: In a wash-down application, it is important to place connection modules with terminal strips (See Figure 3-7) inside a housing, where open wires are protected against water ingress. Wiring must be made correctly on terminal strips before powering up the weigh module. Confusing the power pins with data pins might damage the weigh module. Wires shouldn`t be plugged in or out when the weigh module is under voltage. This action might damage the weigh module.
- Long transmission cables: It is important to observe maximum allowable cable length of the physical transmission medium. Long transmission cables should be isolated against electro-magnetic interference by using shielded cables and twisted pairs. Data cables should be separated and isolated from power lines.
- Tailor-made cables: METTLER TOLEDO recommends using standard cables and advises against tailoring cables to extend the cable range. Electromagnetic behavior and the reliability of the data communication is only tested for standard cables. Therefore, no guarantee can be given for longer tailor-made cables.
- Power Supply: Use a stable power supply, which has no voltage fluctuations. If voltage fluctuations can not be prevented, use a voltage regulator to deliver a constant voltage value to the weigh module. APW weigh modules work with 12 to 24 VDC nominal (10 - 29 VDC). The power supply must be approved by the respective national test center of the country in which the weigh module will be used.

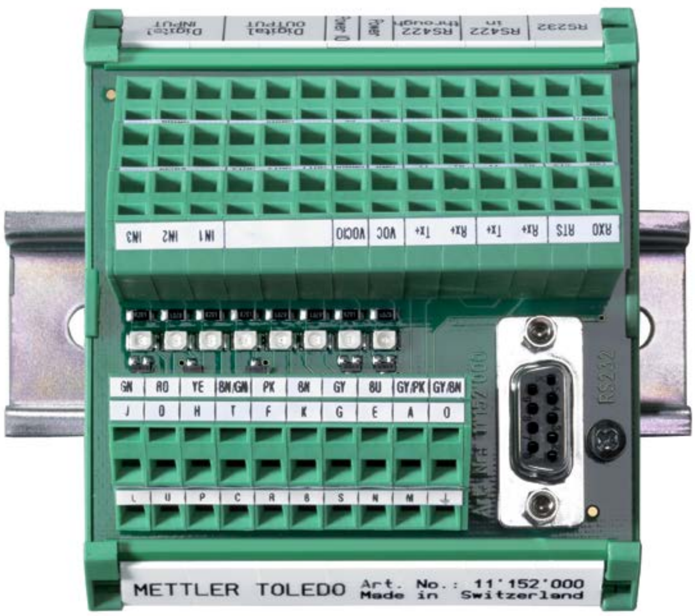


Figure 3-7: Connection module with terminal strips,

Configuration

Configuration is the name of the process in which the weigh module is programmed with software commands such that it can fulfill the tasks required by the application. APW weigh modules can be configured with MT-SICS commands explained in Communication Protocols. For more details on these commands, you can refer to MT-SICS Reference Manual (11 781 363 F).

As already explained in Weighing Requirements, there is a trade-off relationship between weighing accuracy and speed. In Process Optimization, this trade-off relationship is explained in more detail and the optimization process is shown together with an example.

This section gives you the order in which to configure the weigh module. For more details on specific command examples, you can refer to the operating instructions of the individual weigh module type.

The following questions need to be clarified before starting with the configuration:

- What sort of weighing process is involved (control weighing or dispensing to a specified target weight)?
- What level of accuracy (expressed in display increments) must be achieved?
- What weighing rate (e.g. 100 per minute) is required?
- Is it a multiline- or a point-to-point connection?

These questions form the basis for the configuration of the weigh module.

The following commands can be sent before the operation in order to configure the weigh module :

1. Define the interface parameters if communication is done via RS232 or RS422 interfaces (MT-SICS command: COM)
2. Configure weigh module for daisy chain configuration if multiline connection is needed (MT-SICS commands: PROT, NID, M45)
3. Set the readability (MT-SICS commands: RDB, M23)
4. Define stability criteria (MT-SICS command: USTB)
5. Select filter properties based on weighing type (MT-SICS command: M01)
6. Set filter damping (MT-SICS command: M01, M02, FCUT)
7. Internal and external adjustment/Test (MT-SICS commands: C0 to C4 and TST0 to TST3)
8. Update Rate for Continuous Weight Transmission (MT-SICS command: UPD)

The following commands can be sent during the operation to get weighing values from the weigh module:

1. Transmission of weight value (MT-SICS commands: S, SC, SI, SIR, SIS, SNR, SR)
2. Taring functions (T, TA, TAC, TC, TI)
3. Reset functions (Z, ZC, ZI)

Process Optimisation

As already explained in Weighing Requirements, there is a trade-off relation between weighing accuracy and speed. This section is about the optimization of this relationship.

Before starting with the optimization of a weighing process, accuracy and speed requirements must be well-known. These two parameters also form the dimensions of a trade-off relation. User can`t maximize both parameters at the same time, it is rather a compromise between the two parameters where the application requirements form the mimimum prerequisites of optimization.

In Figure 3-8, you can see this unproportional relation between speed and accuracy. The curve shows the boundary of possibility with the weigh module. The region to the left of the curve includes the accuracy and speed combinations that are achievable by the weigh module. The region to the right of the curve forms the impossible combinations.

Within the "region V," user has the freedom to operate between the application requirements and the boundary of possibility for the weigh module. Accuracy is usually defined with absolute or relative process tolerances, and speed is usually defined as the weighing speed (Refer to Weighing Requirements for more details). Within the boundaries of region V, user can choose any accuracy-speed combinations.

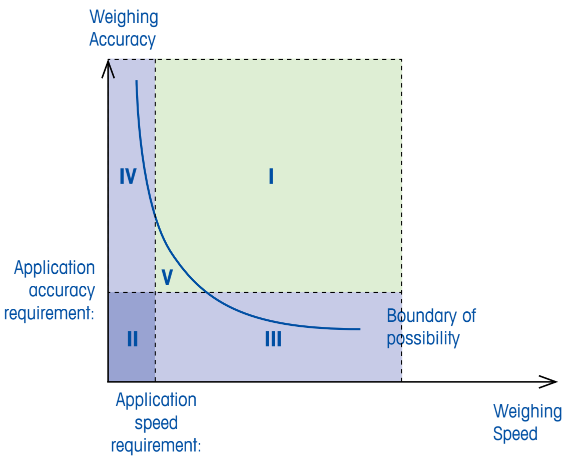


Figure 3-8: Graph showing the trade-off relation between weighing accuracy and speed

Region-I: Both accuracy and speed are acceptable by the application

Region-II: Both accuracy and speed are unacceptable by the application

Region-III: Speed is acceptable by the application but not the accuracy

Region-IV: Accuracy is acceptable by the application but not the speed

Region-V: Degree of freedom for the user to configure the weighing speed and accuracy

In control weighing, the accuracy requirement is much more demanding than the speed requirement, whereas for filling/dosing, this relation is exactly the opposite. In Figure 3-9 and Figure 3-10, you can see these differences. As you can see from both figures, the user has a totally different optimization space (region V) for both application types.

Basically, the user has 2 tools with which he can influence the weighing accuracy and speed.
These are the following:
- Stability criteria
- Filter settings

Stability criteria: Stability criteria of a weigh module needs to be defined in order to distinguish between stable and dynamic weight values. In control weighing, a single stable weight value is needed, whereas in filling / dosing, continuous dynamic weight values are needed. Weighing speed is not so important in control weighing because only one weight value is needed, but in filling or dosing, it is the critical parameter because continuous weight transmission has to be in line with the PLC`s cycle time in order to close the filling valve at the right time.

By considering this dependency on the application type, stability criteria can be defined with the MT-SICS command "USTB." This command has 3 parameters: "Function," "Tolerance" and "Time." "Function" defines for which kind of commands this stability criteria needs to be implemented. Possibilities are S (send weight), T (tare) and Z (zero setting) commands. "Tolerance" defines the acceptable fluctuation of the weight value as number of digits in order for a weight value to be regarded as stable.

The "time" parameter defines the duration during which the weight values should stay within the defined "tolerance" in order to be regarded as stable.

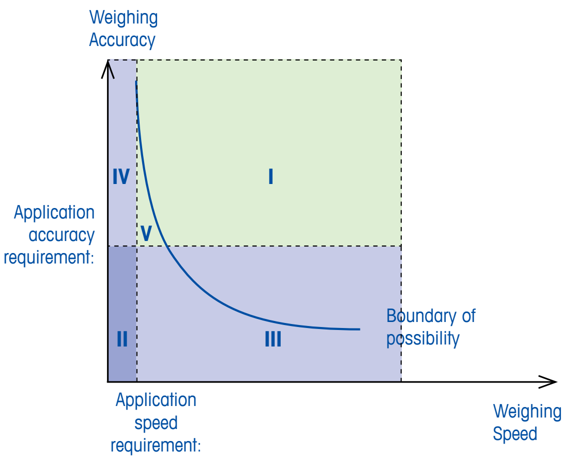


Figure 3-9:
Graph for control weighing

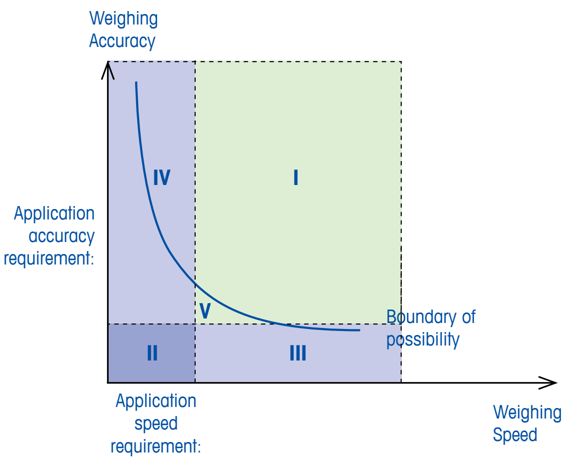


Figure 3-10:
Graph for filling/dosing

Figure 3-11 shows how the stability criteria is evaluated. On the left, the weight value is transmitted as a stable value at the end of the observation period (t), since the weight values stayed within the predefined tolerance (5d) during the observation period.

On the right, the weight value is transmitted as a dynamic value at the end of the observation period since the weight values don`t stay within the predefined tolerance (5d) during the observation period (t).

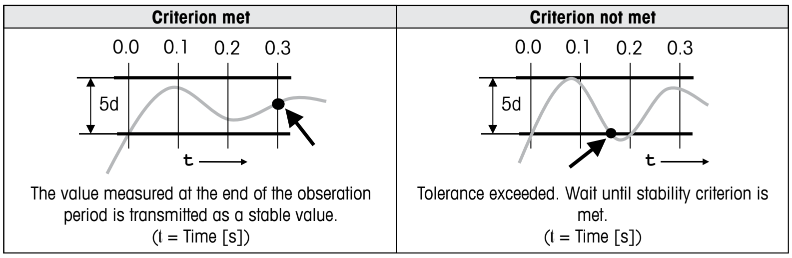


Figure 3-11:
Depiction of the stability criteria

There is a trade-off relation between the stability criteria and weighing speed. The stricter the stability criteria is, the slower the weighing speed becomes. The user has to adjust the stability criteria according to the application`s accuracy and speed requirements.

It depends on the filtering and the environmental conditions, if the stabilization criteria can be met and stable weight values can be released.

Figure 3-12 shows different stability criteria. If the application requires more accuracy, the stability window should have fewer digits along the vertical direction and longer monitoring time along the horizontal axis. This is depicted by the window no. 3.

If the application requires less accuracy and faster speed, the setting can be the opposite way, thus many digits and less monitoring time. This is window No. 1.

If the same accuracy can be obtained with less monitoring time, the stability time can be shortened without compromising the accuracy. This optimum balance is depicted by the window no. 2.

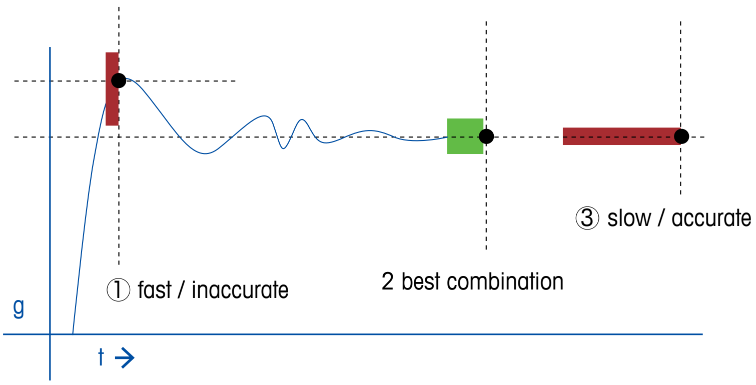


Figure 3-12:
Finding the optimum stability criteria

Filtering: Filters are used to enable the usage of weigh modules in an environment with vibrations (translational as well as rotational). In order to select most appropriate filter settings, the following factors need to be considered:
- Application type (control weighing or filling/dispensing)
- Accuracy requirements (very low to very high)
- Speed requirements (very low to very high)
- Vibration intensity of the environment (very low to very high)

Different filter types are available. These are given below:
- Adaptive filter
- Linear filter

Adaptive Filter: Used for control weighing
MT-SICS command: M01_0

The purpose of control weighing is to determine the current weight of the weighing object with reproducibility as quickly as possible after it is applied and to transmit the measurement value. Therefore, it involves determining a single-weight set.

Adaptive filters, whose damping depends on the change in weight over time, are ideal for this job. When the weighing object is applied, the change is large but the damping is very weak. As the change in weight reduces in the stabilization phase, damping increases ,which leads to increased repeatability because the external influences have little effect. Adaptive filters, set with the command "M01_0" therefore enable you to determine a weight very quickly yet with reproducibility.

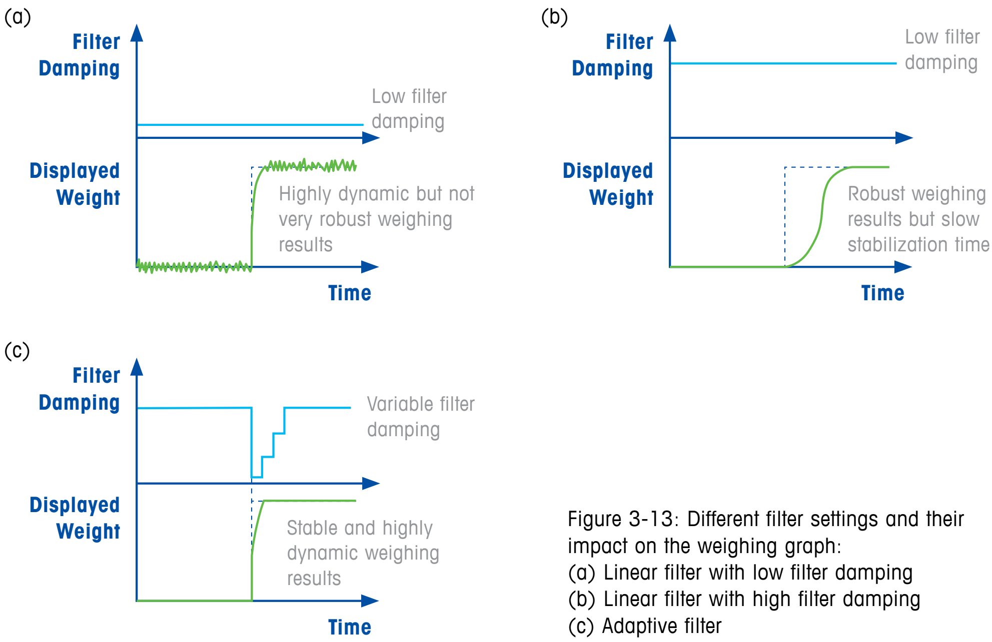


Figure 3-13: Different filter settings and their impact on the weighing graph:
(a) Linear filter with low filter damping
(b) Linear filter with high filter damping
(c) Adaptive filter

Linear (Fixed) Filter: Used for filling / dosing

MT-SICS command: M01_2

In this application, the job of the weigh module is to measure the increase in weight with as little delay as possible and to forward it to the control system. This information allows the system to regulate the flow such that the target weight is achieved as quickly and precisely as possible.

Filters with fixed damping (linear filters) are suitable for this type of weighing application. Because it involves determining the weight increase, the weigh module must respond immediately to even the smallest weight change.

Filter damping: Used at linear (fixed) filters

Filter damping determines how quickly the weigh module responds to a change in weight, as well as how sensitive it is to external interference. The stronger the filter damping you set, the more slowly the module will respond to a small weight change and the less sensitive it will be to environmental influences, such as air movements and vibrations. This also increases the measurement precision that can be achieved (repeatability). Filter damping can be configured with the M02 command.
You must determine the level appropriate to your situation by carrying out tests. We advise to start with the strongest damping ("M02_4") and to reduce it gradually based on repeatability measurements.

Setting the Limit Frequency: Used at linear (fixed) filters
MT-SICS commands **M01_2** and **FCUT**

You can use the command "FCUT" to set any cut-off frequency of the fixed filter in a range from 0.001 Hz to 20 Hz.

If FCUT is < 0.001 (is interpreted as 0), the predefined values according to the command "M02" are used.

The commands M02 and FCUT have similar function. FCUT command overrides any settings for ambient conditions (M02) in sensor mode.

Optimization: In summary, optimization tasks can be carried out with the following steps:
- Select the right filter type based on the application type: Adaptive filter for control weighing and linear filter for filling/ dosing
- If linear filter is selected, find the best-fitting filter damping by carrying out repeatability tests in the place of use with different damping options

At the end, it is important to reach the desired repeatability value within an acceptable settling time. If both targets (speed and accuracy) can`t be reached at the same time, vibration intensity of the environment must be reduced. Isolate or decouple the weigh module mechanically from its environment or use mechanical dampers if necessary.

Maintenance

The last chapter is reserved for the maintenance of the weigh module. This process involves the operations of cleaning and calibration. If these processes are not implemented properly, it can lead to a damage of the weigh module or inaccurate weighing. Therefore, it is advised to study this section carefully before doing these tasks on the weigh module.

Calibration

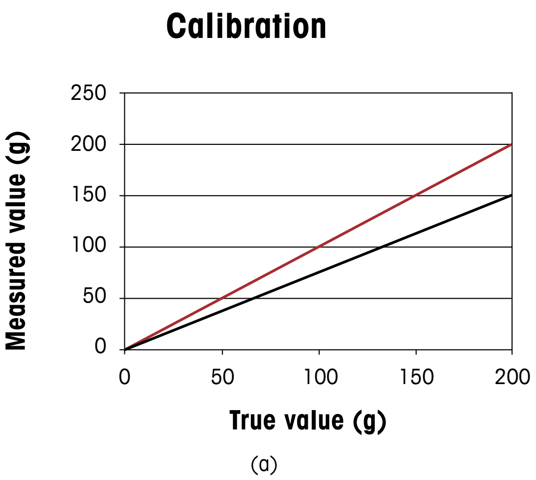
Calibration is an important process for keeping the weigh module within its specifications. It is defined as the action of determining the deviation between the measurement value and the true value of the weighed object under specified measurement conditions without making any changes.

In non-technical language, this term is used instead of the "adjustment," which is the action of setting a measuring instrument or standard so that the measured value is correct, or deviates as little as possible from the correct value, or the deviation remains within acceptable limits of error. In short, calibration is the act of determining the deviation from the true value and adjustment is the act to remove this deviation. See Figure 4-1 for this difference.

An adjustment of a weigh module can be carried out semi- or fully- automatically depending on the weigh module type with an external and/or an internal reference weight.
Adjustment of the weigh module becomes necessary after one of the following conditions emerges:

- Drift in weighing behavior/deviation of sensitivity over time
- Different local gravity at the place of use
- Reset has been made to factory settings e.g. after service
- Changes occurred in mechanical integration
- Changes occurred in ambient temperature

Occasional calibration might be necessary and is strongly recommen-ded to monitor and record the weighing performance. The calibration frequency depends on the individual weighing risks. The precision of adjustment by internal weights can be controlled and adjusted with certified external reference weights.



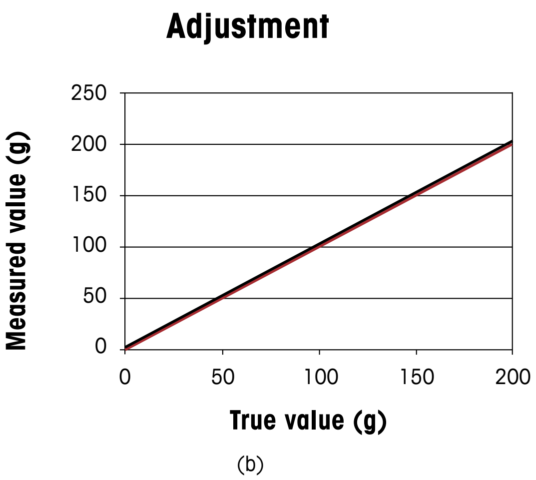


Figure 4-1: Comparison of Calibration with Adjustment
(a) Calibration Process
(b) Adjustment Process

Simple adjustment tasks can be performed by the user, whereas more complicated ones can be carried out by the service technicians. Some weigh modules even have an internal adjustment feature that can carry out adjustment without the intervention of an operator. These 3 calibration methods can be seen as the 3 pillars of calibration (See Figure 4-2).

Calibration by Service Technician: At the top of Figure 4-2, you can see the calibration by the service technician. The service technician can analyze the compatibility of the weigh module to the manufacturing specifications and make adjustments if needed. Following parameters can be checked during this analysis:

- Repeatability
- Sensitivity
- Linearity
- Hysteresis
- Eccentricity

The scope and the frequency of the visits by the service technician is regulated in the contract with METTLER TOLEDO. This frequency depends on the magnitude of the weighing risks. It is recommended to enable such checks in regular intervals not exceeding 12 months. This interval can be shorter if weighing risks are evaluated to be high.

User Tests: Second pillar in Figure 4-2 is routine testing by the user. This process involves occasional check of the weighing performance by the operator. Here, weighing performance is checked against process tolerances of the user. There are 2 types of test which can be done by the user:

- Sensitivity
- Repeatability

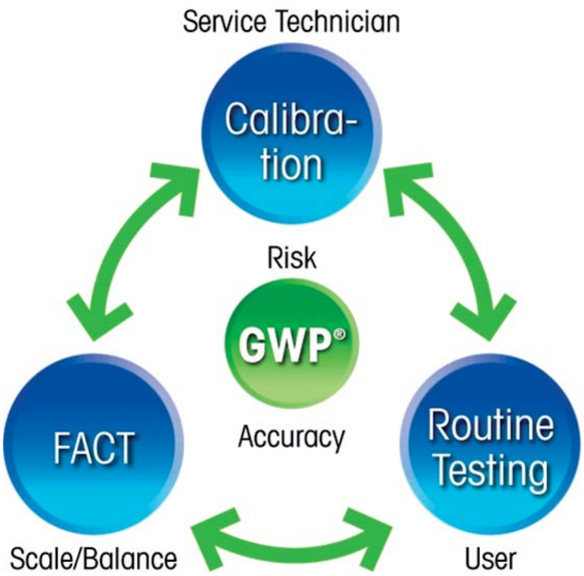


Figure 4-2: Three pillars of calibration:
(i). Calibration by service technician, (ii). routine testing by user and (iii). internal adjustment feature of the weigh module

The sensitivity test can be done with a test weight close to the maximum capacity of the weigh module. If the deviation is larger than the acceptable tolerance, it can be corrected with the sensitivity adjustment. The "C2" command can be used to perform sensitivity adjustment with external weight.

The repeatability test can be made with a test weight that is approximately 5% of the capacity of the weigh module. Ten successive measurements are made with the same weight and their standard deviation is calculated (See Specifications for the calculation of repeatability). If this value exceeds the acceptable tolerance, a service technician should be called to correct this deviation.

Tolerance classes of the test weights should be chosen based on the process tolerances of the application. The maximum error/variation of the test weight should have a negligible contribution to the total error. As a rule of thumb, the error of the test weight must be no more than 1/3 of the test tolerance.

Calibration Frequency: The frequency of these checks is dependent on the weighing risks. Weighing risks can be determined by answering the following questions:
- What is the required repeatability?
- How much load changes do you have per day?
- What is your application type?

You can refer to the Table 4-1 for the evaluation of the weighing risks based on these 3 questions. If you add the numerical values for each category, you end up with a number between 3 and 9. Table 4-2 shows the recommended calibration intervals based on this value.

	Weighing Risk	**Low [1]**	**Medium [2]**	**High [3]**
1	Required Repeatability	1–2 decimal points	3–4 decimal points	5–6 decimal points
2	Load changes / day	< 500	500–5000	5000 <
3	Application Type	Random check	Dispensing	100 % In-Process-Control

Table 4-1: Evalaution of Weighing RIsks

Total Weighing Risk	**Recommended Calibration Intervals**
3	12 months
4	9 months
5	6 months
6	4 months
7	3 months
8	2 months
9	1 month

Table 4-2: Recommended calibration intervals

Internal Adjustment: In Figure 4-2, the third and the last pillar is given as FACT. FACT stands for "Fully Automatic Calibration Technique" and is another name for the internal adjustment feature.

The internal adjustment mechanism (Figure 4-3) consists of one or more reference weights and a loading mechanism that is actuated either manually or automatically. This mechanism allows for convenient testing or adjusting of the sensitivity of the weigh module. Because the built-in weight cannot be lost, cannot be touched and is kept in a sheltered place inside the weigh module, this concept has advantages over testing or adjusting with an external weight, which is vulnerable to damage, dirt and other adverse effects; besides, it allows you to substantially reduce the frequency of such tests or adjustments with external reference weights.

The internal adjustment feature can be programmed to take place in defined calibration intervals automatically . It can be activated with the command "C3" and can also be programmed with the commands "M32" and "M33," such that it takes place in a given weekday and time automatically. The "M18" command can be used to configure the temperature criteria for this automatic adjustment. It can be activated automatically if the temperature changes by 0.5 Kelvin, 1 Kelvin or 2 Kelvin. For more details on commands, refer to the MT-SICS manual.

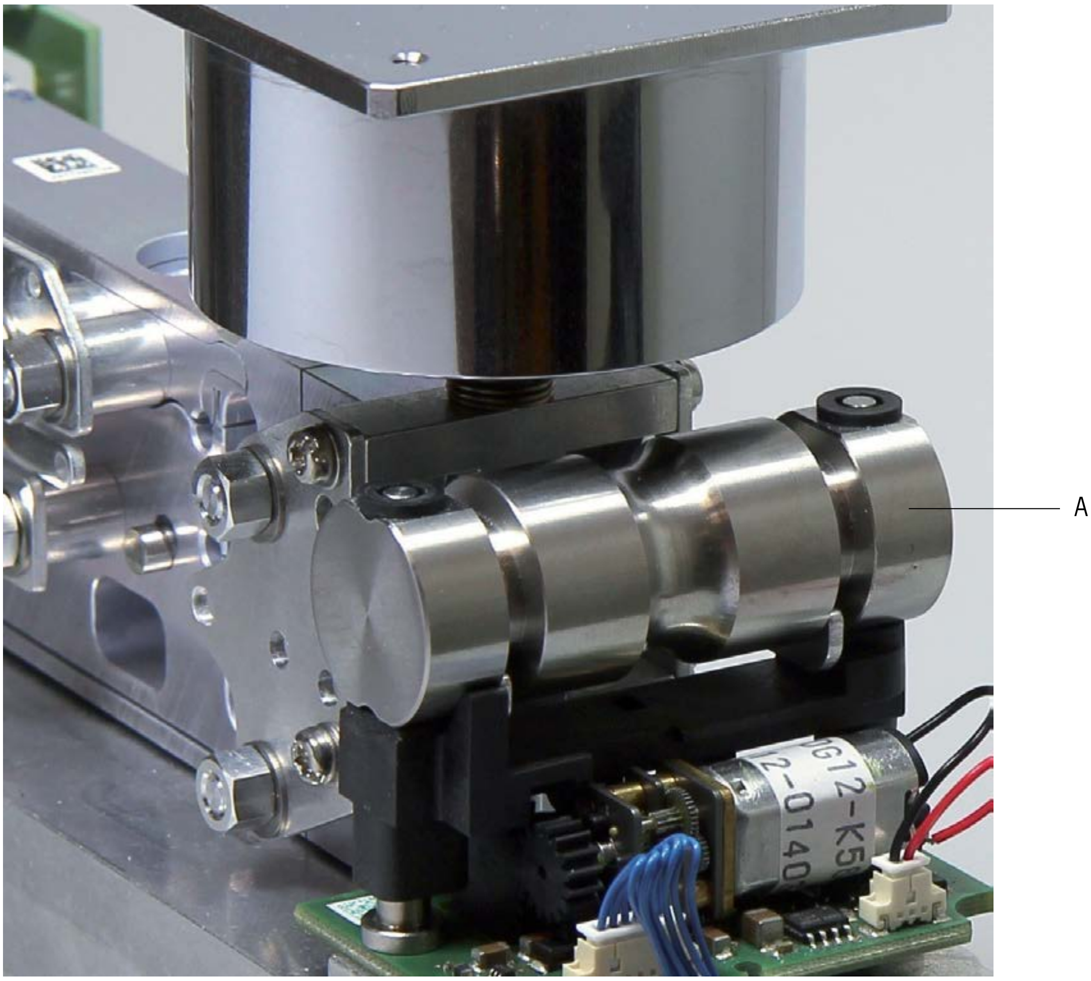


Figure 4-3: Internal weight inside a weigh module pointed by the line "A"

However, because the built-in test weight is not accessible, it cannot be declared as being traceable, because traceability requires that the weight can be removed and compared periodically with another reference of a higher accuracy class which is not possible. Nevertheless, the built-in weight can be tested against an external reference by comparing the weighing result of the built-in weight with the weighing result of an external reference weight that is weighed immediately thereafter; the very weigh module being the comparator.

With this comparison, the integrity of the built-in calibration mechanism can be tested. This comparison is called standard adjustment and can be done with the "C4" command. This comparison should be done in regular intervals. However, it is less frequent than the internal adjustment itself in order to preserve the integrity of the internal weight.

If a weigh module features such an adjustment mechanism, it should be (frequently) used, as it is a procedure that requires little to no effort, with the exception of a short interruption of use to the weigh module. As a consequence, routine sensitivity tests with external reference weights may then be performed less frequently.

Benefits:
- Eliminates drift and corrects temperature-deviation effects
- Reduces cost and effort because weigh modules with internal adjustment require less routine tests
- Calibration weights are protected from external influences, such as physical damage, corrosion and contamination
- Enables adjustment and functional tests in closed environments
- Ensures correct measurement function under working conditions
- Enables adaptation to local gravitation constant
- Protects personnel from activities in contaminated systems

Limitations:
- Weights formally not traceable to national or international standards
- Can only detect sensitivity errors

Different Adjustment Levels: APW weigh modules provide the possibility of sensitivity adjustment on two different levels, which are called factory level and user level.

An adjustment of sensitivity on user level can be carried out by any user without special software tools by sending MT-SICS commands. The adjustment on user level refers to the actual adjustment on factory level and user setup data, such as readability and filter criteria. The adjustment on user level is necessary to adjust sensitivity to the local environment (e.g. gravity) according to the actual weigh module sensitivity drift and can any time be neutralized by a factory reset (by "FSET" command). Adjustments on user level can be carried out with external reference weights, and depending on the weigh module type, also with the internal weight set.

The adjustment of sensitivity on factory level is executed the first time at the end of the production process in the factory by use of certified reference weights. After this, it can be carried out as often as necessary by METTLER TOLEDO service technicians with a special service software tool. An adjustment on factory level cannot be executed by users. The actual setting data of an adjustment on factory level can only be changed by execution of a new adjustment on factory level. An adjustment on factory level by METTLER TOLEDO service would be necessary if it is not possible to adjust on the user level to the true weight value, after repair and service of weigh modules.

Cleaning

Cleaning is the process of removing dirt, dust and other application remainders from the weigh module. This process can be done by either washing down the weigh module with liquid cleaning agents or doing a dry cleaning with a cloth. Liquid cleaning agents can be hot water or solutions that contain chemical agents in varying concentrations. This section explains different types of cleaning processes. The following cleaning categories exist:
- Cleaning without wash-down
- Cleaning with wash-down
- Cleaning with chemical agents

Cleaning without wash-down: The weigh module must be cleaned and maintained periodically according to the degree of soiling and intensity of use in order to guarantee its functionality, reliability and precision even during long-term use.

Use a damp cloth to clean the housing and weighing pan. Use conventional cleaning solutions but no aggressive solvents that could damage the seal sets.

It is very important to keep the area between the weighing platform and the upper part of the housing clean to ensure perfect operation of the module. Cleaning is made easier by the smooth surface of the stainless-steel housing.

Cleaning with wash-down: The factory-installed ″wash-down″ option is a unique seal set below the weighing platform that is activated by air pressure. The ″wash-down″ option allows the module to be cleaned with a water jet and at the same time protects the weighing sensor from dynamic overload because, when activated, it blocks the weighing platform.

Cleaning is needed for removing unwanted deposit on the machine due to overspill or mishandling. It is also necessary to avoid contamination in the production (i.e. pharma products, food products and chemical products). The wash-down feature of the weigh module can be activated in order to perform cleaning without having to remove the weigh module from the machine.

Weigh modules that don`t have a wash-down feature can only be washed with water jets after a plastic cover is placed on the weighing pan in order to protect the inside of the weigh module from water ingress. Weigh modules that have a wash-down feature can be washed after the wash-down feature is activated.

This can be done by inflating the wash-down bellows with air pressure through the plastic tubes on the underside of the weigh module.

Cleaning with chemical agents: The third method for cleaning involves the use of chemical cleaning agents. This method is used to kill the bacteria that might accumulate from food products, especially in liquid environments. Machines for food production are cleaned with chemical agents in order to prevent cross-contamination. The concentration of the chemical agent in the solution given as percentage determines the aggressiveness of the cleaning material.

It is recommended to avoid chemical cleaning agents as much as possible because this decreases the lifecycle of the weigh module components. Weigh module surface material is made of stainless steel and has high corrosion resistance. However, the seal sets used in the weigh module are made of rubber and have a limited lifecycle.

Seal sets must be replaced every 6 to 12 months by a service technician, if the weigh module is cleaned regularly with chemical agents. Seal sets must be replaced every 2 years if normal or no aggressive cleaning agents are used.

A second important aspect to consider is the resistance of the weigh module components against the used chemical agents. Housing of the APW weigh modules are made of stainless steel X2CrNiMo17-12 (1.4404 resp. 316L). The resistance of this material against the used chemical agent has to be checked before starting with the cleaning process.

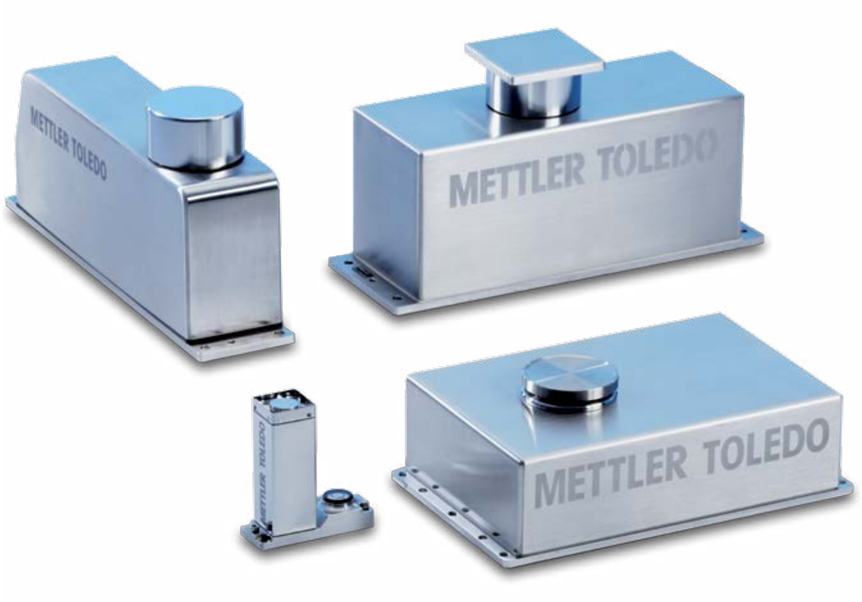
Important steps after cleaning: After warm or hot liquid cleaning of the weigh module, when the wash-down function is active, it's very important to take care of the following:

- Don't release the wash-down function before the vapor phase is over to avoid intake of vapor into the module and condensation during or after the cool down phase.
- Wait until the weigh module cools down to the operating temperature range
- After this phase is over, you can release the wash-down function, remove the weighing pan and dry clean the surface.
- When dry cleaning is done, add the weighing pan.
- Before starting with the weight measurements, perform an adjustment with the internal- (if included) or an external- weight and check the weighing function of the weigh module.

For your Notes

For your Notes

The Right Sensors
for Automated Weighing



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