

The Modular Concept For Load Cells

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Introduction

History and motivation

Modular Concept for NAWIs

Modules, definitions, responsibilities

Compatibility of modules

Necessary technical and metrological data

Modules of mechanical and electrical connecting elements and analog load cells

Mechanical structure, load transmission, load cell

Conclusion

Practice:

- some kind of electronic weighing instruments simply cannot be tested as a whole because of their dimensions such as truck scales, hopper scales, etc.

Challenge:

- Manufacturers and testing bodies had to find alternative ways to test huge or hard to handle instruments.

Basic Idea:

- to test metrologically relevant parts (modules) with reduced (partial) error limits defined by so-called “ p_i factors”.

Metrological experience:

- Mechanical, electronic and digital components of a weighing instrument can be tested separately
- There are “non-critical” types of weighing instruments, such as weighbridges, platform scales, hopper scales, crane scales, with or without lever system
- Some types of load receptor construction/design for load cells may be generally used
- There are generally acceptable designs of load transmission devices suitable for different LC types
- Types of load cells are suitable for different load receptor types

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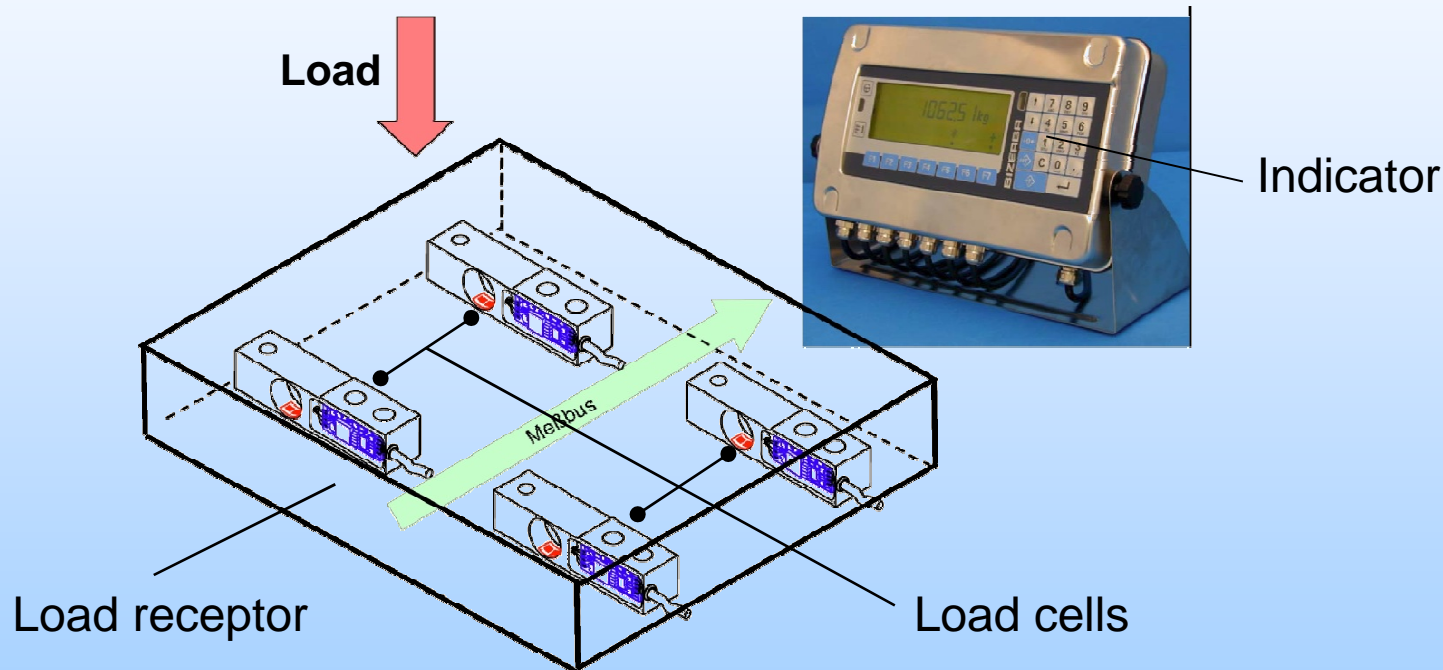
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It is not always useful or feasible
to test the whole weighing instrument



The load cell is the metrological heart of a weighing instrument
and it is tested according to OIML recommendation R60

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Further metrological experience:

The modular concept cannot be applied for

- Single bending beam load cells
- Digital load cells
- Weighing instruments build in trucks
- Moveable pallet weighers
- Dynamic applications

Essential:

A definition of requirements for general acceptance of modules in type approvals of weighing instruments

OIML R76 (1988):

- First idea of separate testing of metrologically relevant parts or modules of a weighing instrument

OIML R76 (1992):

- three main modules: load cell, electronic indicator connecting elements. The fractions p_i for each module can be chosen in the range 0.3 ... 0.8.

WELMEC: (European Cooperation in Legal Metrology)

- Further enhancement of the modular concept, e.g. WELMEC Guide 2.4

OIML (2003):

- the OIML Certificate System for Measuring Instruments was extended to include modules and modular testing for all kinds of measuring instruments

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OIML R76 (2006):

- more detailed information concerning the definition of modules such as indicators, data processing devices, weighing modules and digital displays
- Definition of necessary tests for each module
- Description of conditions under which several modules can be combined to form a NAWI

OIML R51 (2006)

- Catchweighers

OIML R61 (2004)

- Filling Instruments

OIML R107 (2007)

- Totalising hopper weighers

Modular Concept of NAWIs

Definition

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Definition “Module” (OIML R76, T.2.2):

- Identifiable part of an instrument that performs a specific function or functions, and that can be separately evaluated according to specific metrological and technical performance requirements in the relevant recommendation. The modules of a weighing instrument are subject to specified partial error limits.
- Typical modules of a weighing instrument are: load cell, indicator, analog or digital data processing device, weighing module, terminal, primary display

Modular Concept of NAWIs

Typical modules

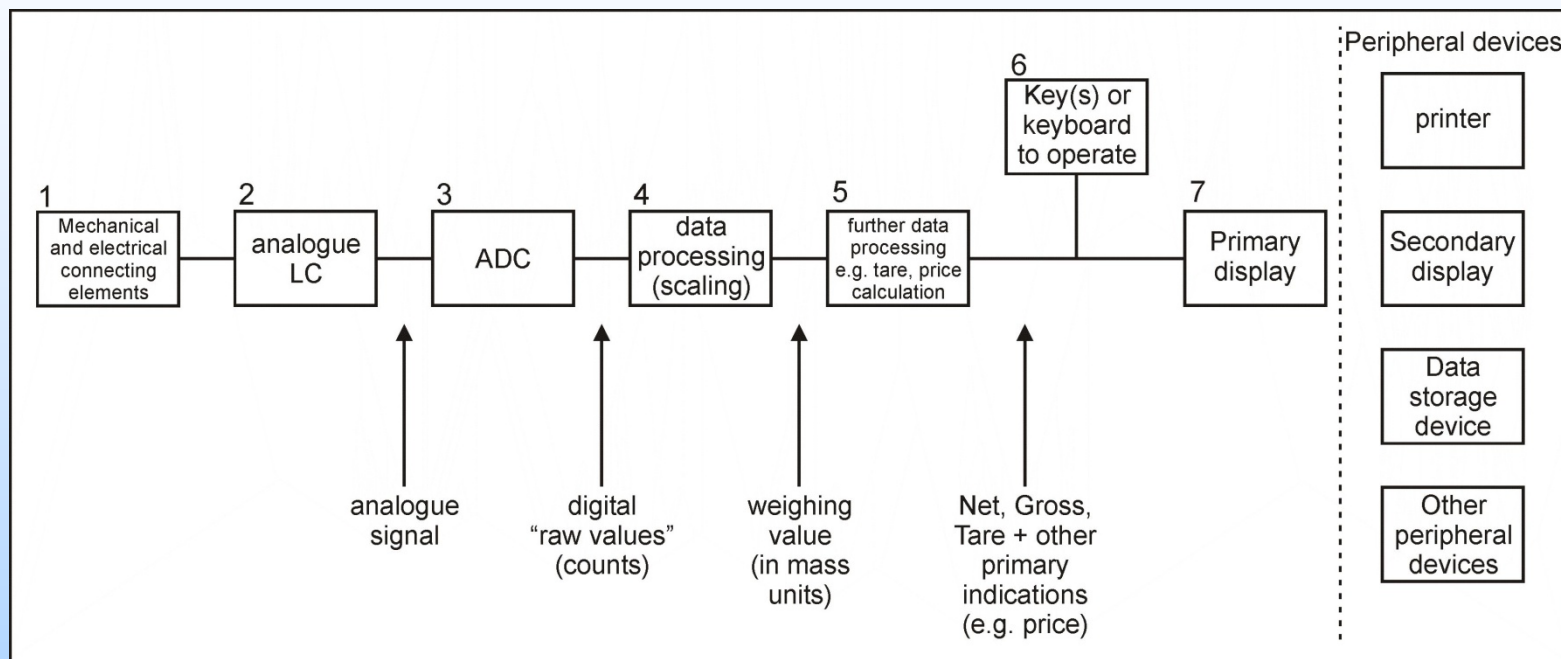
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Typical modules of a NAWI as defined in OIML R76-1
The NAWI can be supplemented by peripheral devices

Modular Concept of NAWIs

Typical modules and parts of a NAWI

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Part or component of the NAWI	Connecting elements	Analogue load cell	ADC	Data processing	Further data processing	Keyboard to operate	Primary display
analogue load cell		●					
digital load cell		●	●	○			
Indicator			○	●	○	○	●
analogue data processing device			●	●	○	○	
digital data processing device				○	●	○	
Terminal					○	●	●
primary display							●
weighing module	●	●	●	●	○	○	

Modular Concept of NAWIs

Responsibilities of the manufacturer

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- Basically, it is the choice of the manufacturer whether he applies for a module certificate or for a certificate for a complete instrument.
- With a module certificate he will be responsible only for his own module, e.g. an indicator.
- **Important:**
With a certificate for a complete instrument the manufacturer will take over full responsibility for the NAWI, including all modules (indicator, load receptor, load cell, etc.)

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Compatibility Checking of Modules

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- **Essential for the modular concept:**
The compatibility of all modules making up the complete NAWI has to be established.
→ E.g. For modules with digital output, compatibility includes the correct communication and data transfer via the digital interface(s).
- An applicant (manufacturer) with a certificate for a complete instrument has finally the full responsibility for the NAWI and will be responsible for checking and declaring the compatibility of modules.
- Checking and declaring the compatibility of modules according to No 3.10.2.3 and Annex F of OIML R76

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Required Metrological Data of the NAWI:

Accuracy class of the weighing instrument.

Max	(g, kg, t)	Maximum capacity of weighing instrument according to T.3.1.1 (Max ₁ , Max ₂ , ..., Max in the case of a multi-interval weighing instrument and Max ₁ , Max ₂ , ..., Max _r in the case of a multiple range weighing instrument).
<i>e</i>	(g, kg)	Verification scale interval according to T.3.2.3. (<i>e</i> ₁ , <i>e</i> ₂ , <i>e</i> ₃) (in the case of a multi-interval or multiple range weighing instrument, where <i>e</i> ₁ = <i>e</i> _{min}).
<i>n</i>		Number of verification scale intervals according to T.3.2.5: $n = \text{Max} / e$ (<i>n</i> ₁ , <i>n</i> ₂ , <i>n</i> ₃) (in the case of a multi-interval or multiple range weighing instrument, where <i>n</i> _{<i>i</i>} = Max _{<i>i</i>} / <i>e</i> _{<i>i</i>}).
<i>R</i>		Reduction ratio, e.g. of a lever work according to T.3.3, is the ratio (Force on the load cell) / (Force on the load receptor).
<i>N</i>		Number of load cells
DL	(g, kg)	Dead load of load receptor: mass of the load receptor itself resting upon the load cells and any additional construction mounted on the load receptor.
<i>T</i> ⁺	(g, kg, t)	Additive tare.
<i>T</i> _{min}	(°C)	Lower limit of temperature range.
<i>T</i> _{max}	(°C)	Upper limit of temperature range.
IZSR	(g, kg)	Initial zero setting range, according to T.2.7.2.4: the indication is automatically set to zero when the weighing instrument is switched on, before any weighing.
NUD	(g, kg)	Correction for non-uniform distributed load**.

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Required Metrological Data of the NAWI:

 Q

Correction factor.

The correction factor, $Q > 1$ considers the possible effects of eccentric loading (non uniform distribution of the load), dead load of the load receptor, initial zero setting range and additive tare in the following form:

$$Q = (\text{Max} + \text{DL} + \text{IZSR} + \text{NUD} + T^+) / \text{Max}$$

** The values for the non uniform distribution of the load generally might be assumed for typical constructions of weighing instruments when no other estimations are presented.

- Weighing instruments (WIs) with lever work and one load cell, or WIs with load receptors which allow only minimal eccentric load application, or WIs with one single point load cell: 0 % of Max
e.g. hopper or funnel hopper with a symmetric arrangement of the load cells, but without shaker for material flow on the load receptor
- Other conventional WIs: 20 % of Max
- Fork lift scales, over head track scales and weighbridges: 50 % of Max
- Multi-platform weighing machine:
 - fixed combination: 50 % of $\text{Max}_{\text{total}}$
 - variable selection or combined: 50 % of $\text{Max}_{\text{single bridge}}$

NUD is in responsibility of the manufacturer

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F.2.1 Accuracy classes

The accuracy classes including temperature ranges and the evaluation of stability against humidity and creep of load cell(s) (LC) must meet the requirements for the weighing instrument (WI).

Table 13 – Corresponding accuracy classes

	Accuracy				Reference
WI	I	II	III	III	OIML R 76
LC	A	A*, B	B*, C	C, D	OIML R 60

* if the temperature ranges are sufficient and the evaluation of stability against humidity and creep correspond to the requirement in the lower class.

F.2.2 Fraction of the maximum permissible error

If no value for the load cell is indicated in the OIML Certificate, then $p_{LC} = 0.7$. The fraction may be $0.3 \leq p_{LC} \leq 0.8$, in accordance with 3.10.2.1.

F.2.3 Temperature limits

If no value for the load cell is indicated in the OIML Certificate, then $T_{min} = -10\text{ °C}$ and $T_{max} = 40\text{ °C}$. The temperature range may be limited, in accordance with 3.9.2.2.

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F.2.4 Maximum capacity of the load cell

The maximum capacity of the load cell shall satisfy the condition:

$$E_{\max} \geq Q \times \text{Max} \times R / N$$

F.2.5 Minimum dead load of the load cell

The minimum load caused by the load receptor must equal or exceed the minimum dead load of a load cell (a lot of load cells have $E_{\min} = 0$):

$$E_{\min} \leq \text{DL} \times R / N$$

F.2.6 Maximum number of load cell intervals

For each load cell the maximum number of load cell intervals, n_{LC} , (see OIML R 60) shall not be less than the number of verification scale intervals, n , of the instrument:

$$n_{\text{LC}} \geq n$$

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F.2.7 Minimum load cell verification interval

The minimum load verification interval, v_{\min} , (see OIML R 60) shall not be greater than the verification scale interval, e , multiplied by the reduction ratio, R , of the load transmitting device and divided by the square root of the number, N , of load cells, as applicable:

$$v_{\min} \leq e_1 \times R / \sqrt{N}$$

Note: v_{\min} is measured in mass units. The formula applies to both analog and digital load cells.

On a multiple range instrument where the same load cell(s) is (are) used for more than one range, or a multi-interval instrument, e is to be replaced by e_1 .

F.2.8 Input resistance of a load cell

The input resistance of a load cell, R_{LC} , is limited by the indicator:

$$R_{LC} / N \text{ has to be within the range for the indicator } R_{L\min} \text{ to } R_{L\max}$$

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3.10.2.1 Apportioning of errors

The error limits applicable to a module, M_i , which is examined separately are equal to a fraction p_i of the maximum permissible errors or the allowed variations of the indication of the complete instrument as specified in 3.5. The fractions for any module have to be taken for at least the same accuracy class and at least the same number of verification scale intervals, as for the complete instrument incorporating the module.

The fractions p_i shall satisfy the following equation:

$$p_1^2 + p_2^2 + p_3^2 + \dots \leq 1$$

The fraction p_i shall be chosen by the manufacturer of the module and shall be verified by an appropriate test, taking into account the following conditions:

- For purely digital devices p_i may be equal to 0.
- For weighing modules p_i may be equal to 1.
- For all other modules (including digital load cells) the fraction shall not exceed 0.8 and shall not be less than 0.3, when more than one module contributes to the effect in question.

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Table 7

Performance criteria	Load cell	Electronic indicator	Connecting elements, etc.
Combined effect*	0.7	0.5	0.5
Temperature effect on no load indication	0.7	0.5	0.5
Power supply variation	–	1	–
Effect of creep	1	–	–
Damp heat	0.7**	0.5	0.5
Span stability	–	1	–

* Combined effects: non-linearity, hysteresis, temperature effect on span, repeatability, etc. After the warm-up time specified by the manufacturer, the combined effect error fractions apply to modules.

** According to OIML R 60 valid for SH tested load cells ($p_{LC} = 0.7$).

The sign “–” means “not applicable”.

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Referring to R76-1, No 3.10.2.1 (“Acceptable solution”):

“For mechanical structures such as weighbridges, load transmitting devices and mechanical or electrical connecting elements evidently designed and manufactured according to sound engineering practice, an overall fraction $p_i = 0.5$ may be applied without any test, e.g. when levers are made of the same material and when the chain of levers has two planes of symmetry (longitudinal and transversal), or when the stability characteristics of electrical connecting elements are appropriate for the signals transmitted, such as load cell output, impedance, etc.”

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Question:

Has everybody the same understanding and interpretation of what has been “evidently designed and manufactured according to sound engineering practice”?

- The interpretation is and will remain the responsibility of the certification body (Issuing Authority).
- The responsible authority may require a representative complete instrument to be submitted for testing of correct functioning and check of compatibility if this is considered necessary

WELMEC Guide 2.4:

The European Union tried to find a common understanding about “generally acceptable constructions of load transmissions and load receptors”

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Type of NAWI	Load receptor Type		Load Cell Type : load transmission	
<i>scales with lever system</i>				
	all load receptors with lever system according to No. 6.3 EN 45 501		{ compression tension beam	co- 1-7-8 te- 1-2 be- 1-4-5-6
<i>scales without lever system</i>				
weighbridge	1 or more platforms	<i>in floor</i>	{ compression tension beam double ended beam	co- 2-3-4-5-6
	multiple platform with joint	<i>over floor</i> <i>in floor</i> <i>over floor</i>		te- 1-2 be- 2-3-7-8-9-10-11 de- 1-2-3
platform scale	1 or more platforms	<i>in floor</i>	{ compression " tension beam double ended beam	co- 2-3-4-5-6
	multiple platform with joint	<i>over floor</i> <i>in floor</i> <i>over floor</i>		co- 7-8 te- 1-2 be- 1-2-3-4-5-6-7-8 9-10-11 de- 1-2-3
	platform	maximum dimensions if necessary	single point	direct

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<i>scales without lever system</i>			
hopper scale	hopper suspended hopper supported	<div> <div>compression</div> <div>"</div> <div>tension</div> <div>beam</div> <div>double ended beam</div> </div>	<div>co- 2-3-4-5-6</div> <div>co- 7-8</div> <div>te- 1-2</div> <div>be- 1-2-3-4-5-6-7-8</div> <div>9-10-11</div> <div>de- 1-2-3</div>
	hopper, by unsymmetric loading maximum dimensions if necessary	single point	direct
crane scale	crab double crab hoist	<div> <div>compression</div> <div>tension</div> <div>beam</div> <div>double ended beam</div> </div>	<div>co- 2-3-4-5-6</div> <div>te- 1-2</div> <div>be- 2-3-7-8-10-11</div> <div>de- 1-2-3</div>
	hook	<div> <div>compression</div> <div>tension</div> <div>beam</div> </div>	<div>co- 7-8</div> <div>te- 2</div> <div>be- 4</div>
overhead track scale	rail (for combinations with platforms see „platform scale“)	<div> <div>tension</div> <div>beam</div> </div>	<div>te- 1-2</div> <div>be- 1-2-3-4-5-6-7-8</div> <div>9-10-11</div>
	rail maximum linear length if necessary	single point	direct

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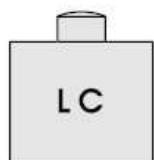
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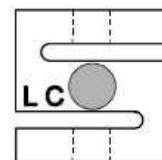
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Load cell construction and load transmission device

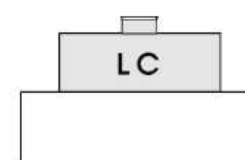
Basic construction principles for compression or tension



canister type (co, te)



S-type (co, te)

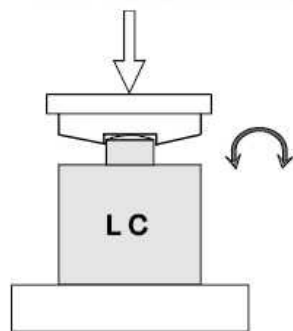


ring type (co)

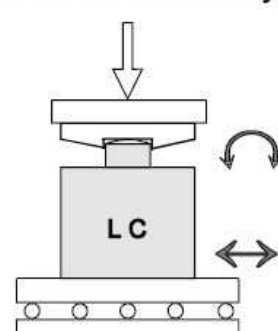
needs a stiff base plate

Compression LC

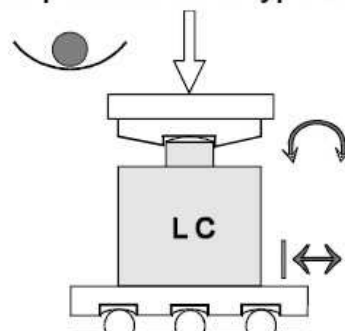
load transmissions shown for canister type, also possible for S-type and ring type



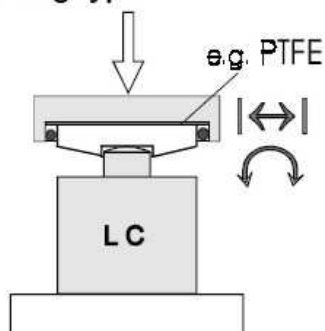
① half pendulum



② multiple ball bearing



③ ball support



④ low friction surfaces

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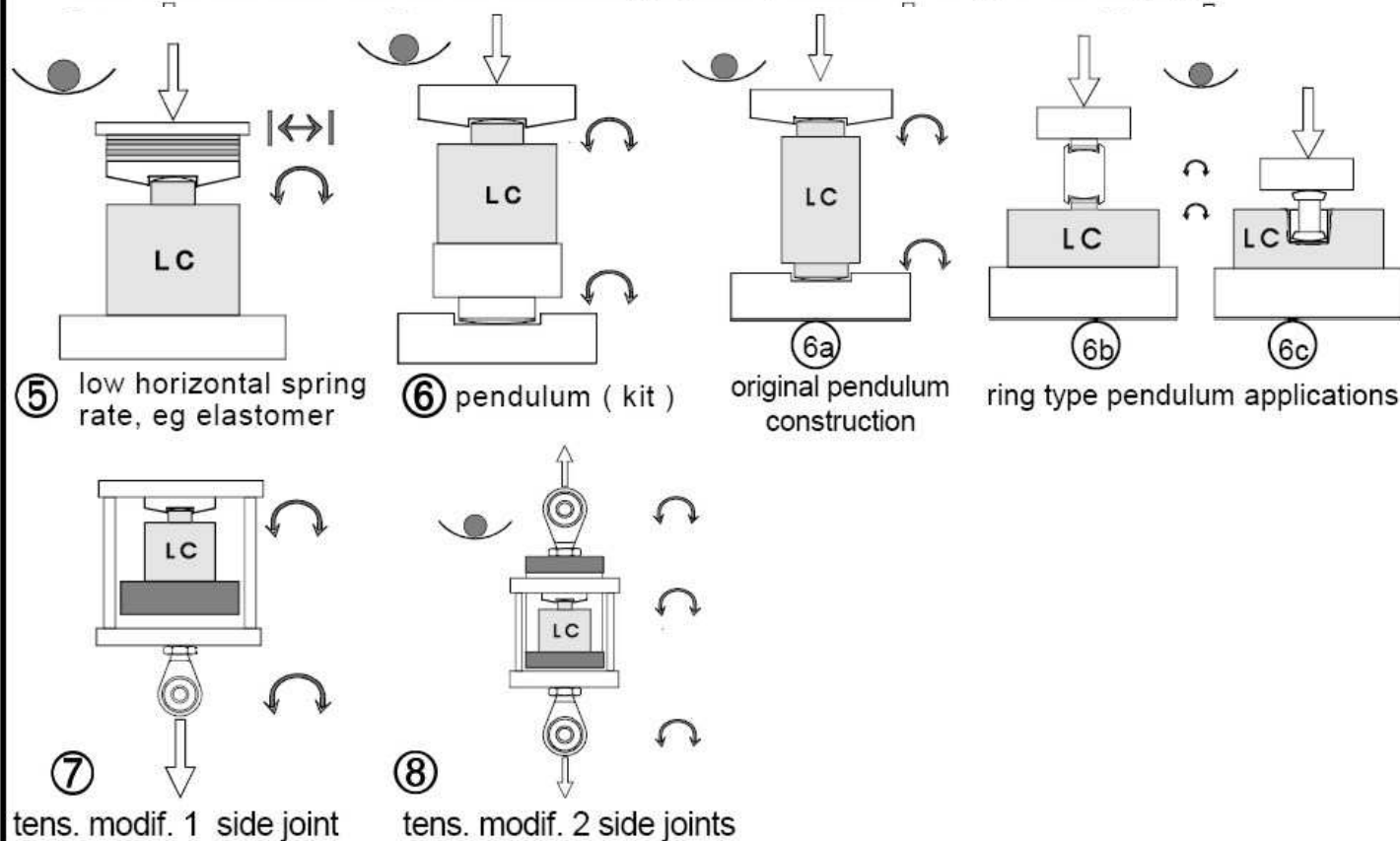
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Compression LC

load transmissions shown for canister type, also possible for S-type and ring type



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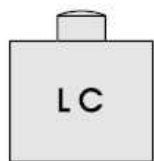
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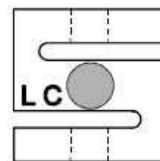
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Load cell construction and load transmission device

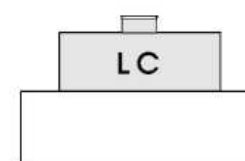
Basic construction principles for compression or tension



canister type (co, te)



S-type (co, te)

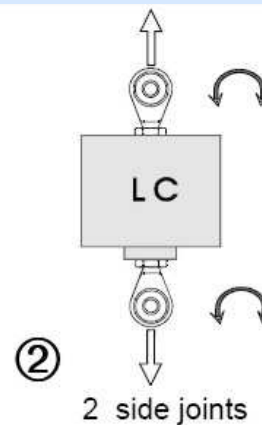
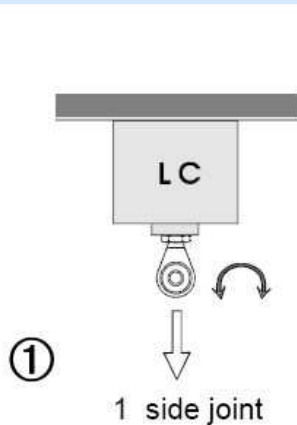


needs a stiff base plate

ring type (co)

Tension LC

shown for canister type, also suitable for S-type



further elements for all tension constructions for joints:

hook,
rope wire,
flexure strips

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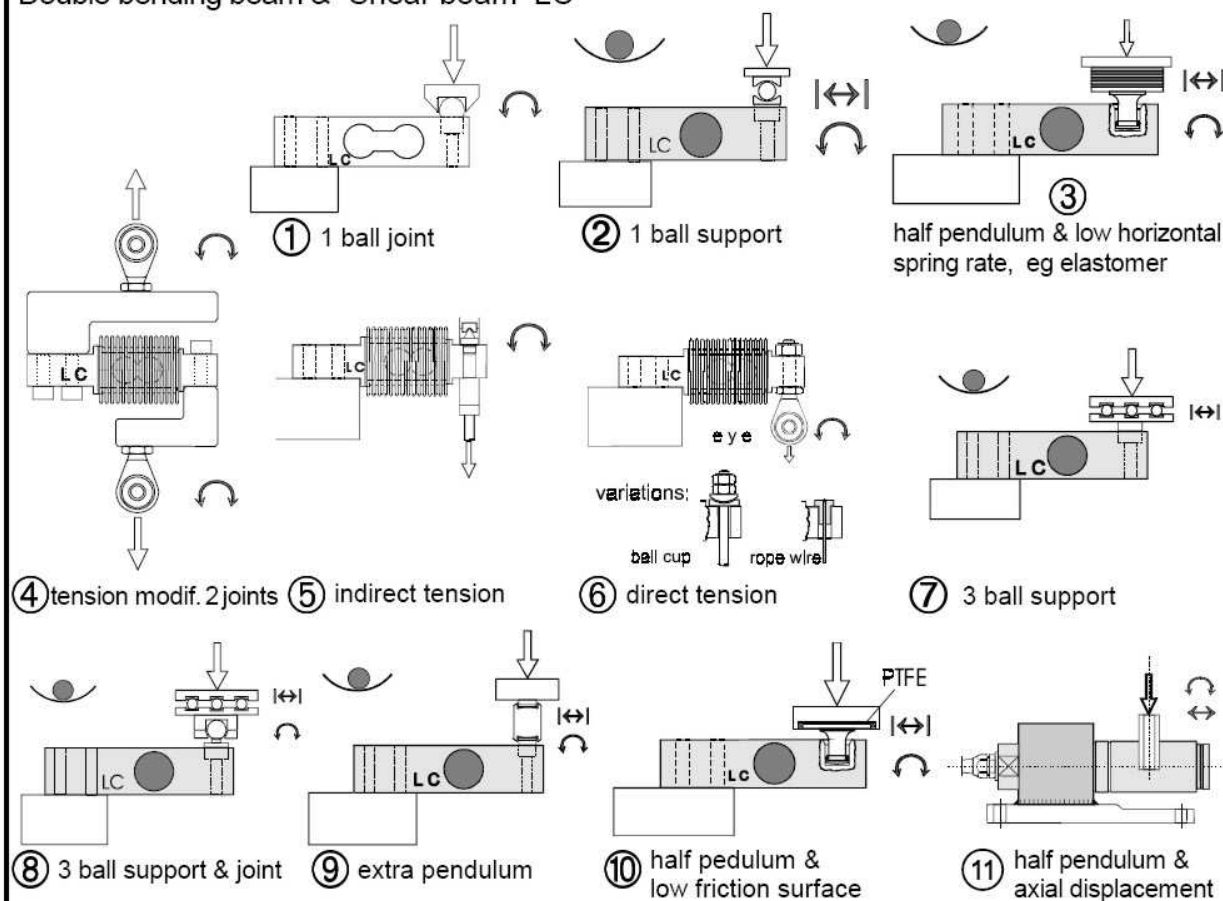
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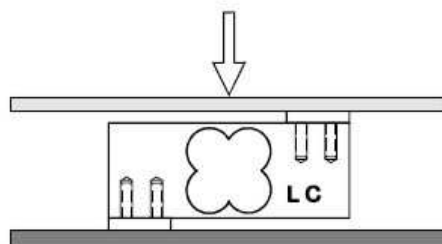
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Beam LC - Cantilever beam

Double bending beam & Shear beam LC



Single point LC

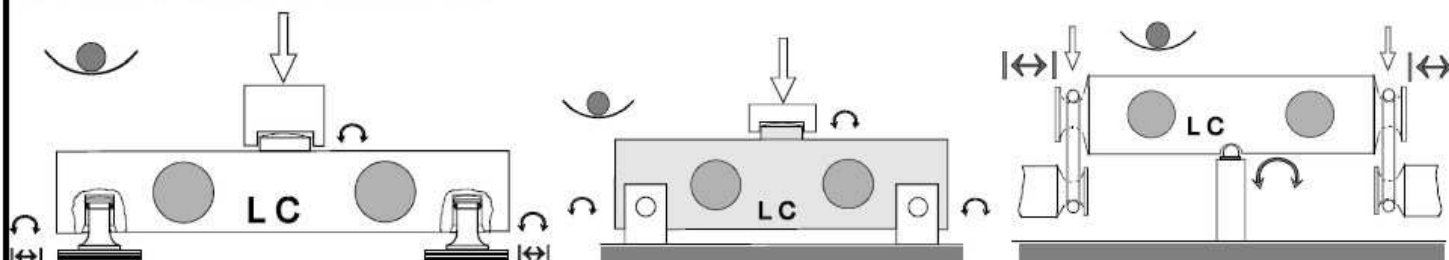


The single point LC has no degree of freedom for horizontal displacement or inclination, using more than one LC in a load receptor decoupling elements are necessary.

The load transmissions 1 to 10 for the beam LCs may be applied.

Max. platform dimensions may be mentioned in the TC or the TAC.

Double ended beam LC



① joint half, pendulum & eg elastomer

② 2 axis (free in hole) & joint

③ eyes

Constructions with fixed clamping at the two ends need for minimum displacement and inclination some elasticity of the supporting construction.

Load cell construction and load transmission device

The load transmission device is independent of the encapsulation, potting or housing and the mounting at the fixed end shown below

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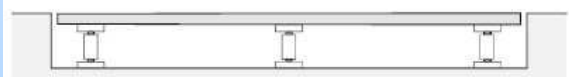
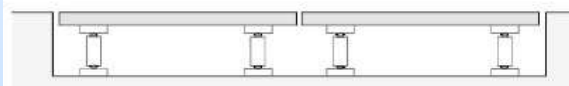
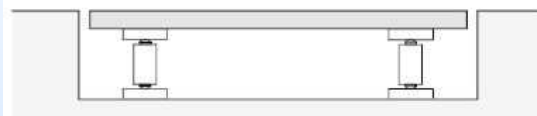
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Examples of load receptors considered as being common and non-critical

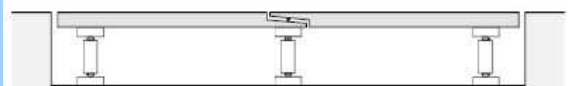
in floor



over floor



double platform with joint



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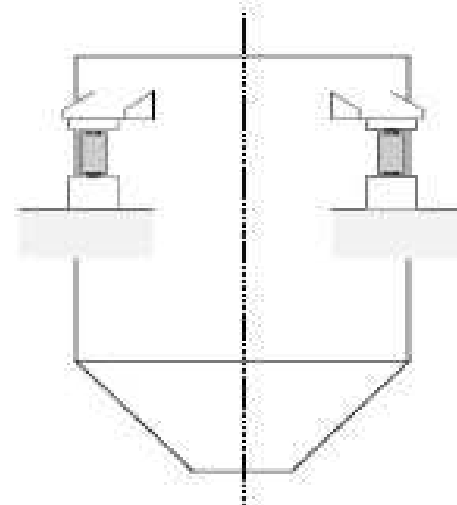
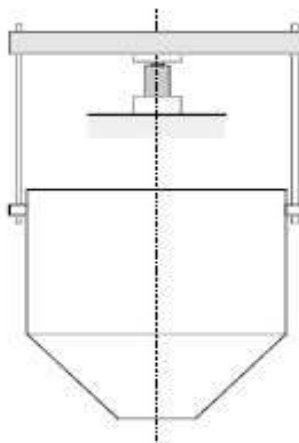
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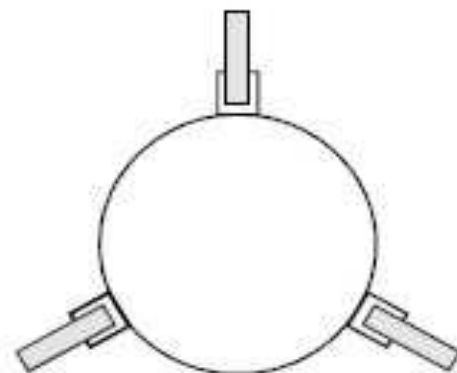
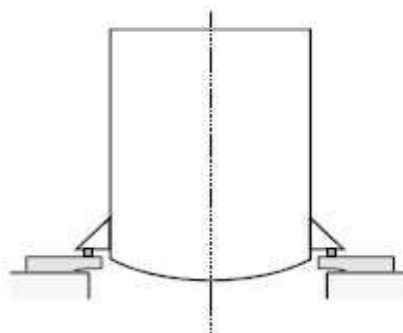
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hopper suspended



hopper supported



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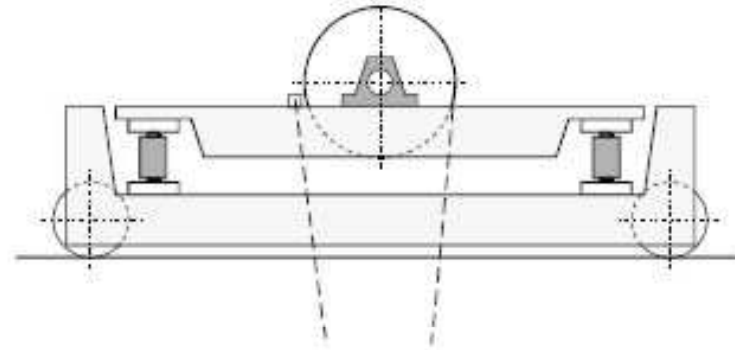
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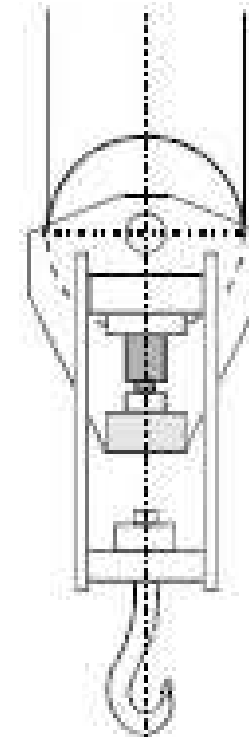
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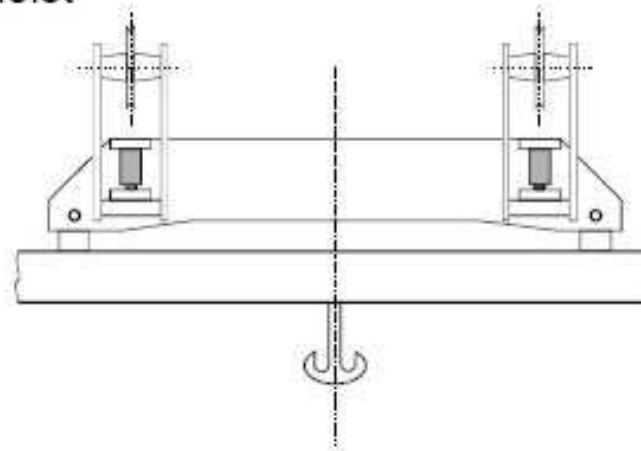
crab



hook



hoist



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- Since many years the modular concept is well established not only for NAWIs under R76 but also for AWIs, especially under R51, R61, R106 and R107.
- The possibility to issue OIML certificates for complete weighing instruments on the basis of modular tests has well proofed its worth.
- With the new edition of R76-1 (2006) the modular concept for NAWIs has been further clarified and improved. It is
 - adapted to recent progress in technology to include e.g. digital components and devices.
 - extended to allow OIML certificates to be issued for a number of typical modules such as indicators, data processing devices, terminals and weighing modules

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Conclusion

- Generally acceptable constructions of load transmissions, load cells and load receptors is useful.
- The constructions shown can (voluntarily) be used by OIML Issuing Authorities if they issue an OIML certificate for a complete instrument on the basis of indicator tests.
- In this case the schematic figures should be an inherent part of the OIML certificate issued

Conclusion

WELMEC 2.4 for load cells

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- The advantage for a manufacturer is that he needs not deliver specific drawings of load receptors and load transmission elements.
- A verification officer or field inspector could check whether the load receptor and the load transmissions conform to the examples given in the drawings and sketches listed in the OIML certificate or national type approval certificate, respectively
- In addition, of course, the manufacturer has to supply the filled in compatibility form according to Annex F of OIML R76 as explained above.

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