

INTERNATIONAL
RECOMMENDATION

OIML R 60-1

Edition 2021 (E)

Metrological regulation for load cells

Part 1: Metrological and technical requirements

Réglementation métrologique des cellules de pesée

Partie 1 : Exigences métrologiques et techniques



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Foreword

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This publication – reference OIML R 60-1:2021 – is an updated edition (developed by the OIML Certification System Management Committee) of OIML R 60-1:2017 (developed by Project Group 1 of OIML Technical Committee TC 9 *Instruments for measuring mass and density*). This updated edition consolidates the Amendment (2019-12-23) to R 60:2017, and includes other editorial and minor technical changes. It was approved for final publication by the International Committee of Legal Metrology at its 56th meeting in October 2021 and was sanctioned by the 16th International Conference on Legal Metrology in 2021. It supersedes the previous edition of R 60 dated 2017.

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Part 1 - Metrological and technical requirements

1 Introduction

Load cells comprise a distinct element or module within other complex instruments; they do not produce distinct quantitative values that are inherently identified or associated with denominations or units. The data that can be extracted from a load cell is simply a measurement of change in the output of the load cell in relation to the input. This relative change must be converted by other elements or modules within an instrument into values that are meaningful measurements which can then be used to identify a quantity.

Although strain gauge technology was a primary focus in the initial development of R 60, it is to be understood that load cells that operate using other principles may also be evaluated under this Recommendation.

2 Scope

2.1 This Recommendation prescribes the principal metrological static requirements and static evaluation procedures for load cells used in the determination of conformity to this Recommendation. It is intended to provide authorities with uniform means for determining the metrological characteristics of load cells used in measuring instruments that are subjected to metrological controls.

It is acknowledged that test procedures found in OIML R 60-2 are useful in the evaluation of load cells that are currently in service (i.e. primarily of the strain gauge design) however, there may be variations in designs for load cells that will require additional or modified test procedures to appropriately evaluate them. These additional test procedures may be annexed when necessary.

Except where otherwise specified, these requirements apply regardless of the technology or operating principle employed. The requirements and evaluation procedures in this Recommendation have been drafted to be non-specific with regard to load cell design and their operating principles.

2.2 This Recommendation utilises the principle that several measurement errors shall be considered together when applying load cell performance characteristics to the permitted error envelope. Thus, it is not considered appropriate to specify individual errors for given characteristics (e.g. non-linearity, hysteresis, effects of influence factors), but rather to consider the total error envelope allowed for a load cell as the limiting factor. The use of an error envelope allows the balancing of the individual contributions to the total error of measurement while still achieving the intended final result.

Note: The error envelope may be defined as the boundary of the combined individual errors (see Table 4) as a function of the force introduced by the applied load (expressed in mass units) over the measuring range. The combined error determined may be positive or negative and include the effects of non-linearity, hysteresis and temperature.

2.3 “Weighing modules” as noted in OIML R 76 [1], T.2.2.7 (see R 60, Annex A, A.2.1), are not covered by this Recommendation. Weighing instruments that include load cells and which give an indication of mass are the subjects of separate Recommendations. While digital load cells may be covered under this Recommendation, a load cell that produces an output consisting of more than digital “raw counts” is not covered. In the illustration from OIML R 76 below, the scope of R 60 would not extend beyond module #3.

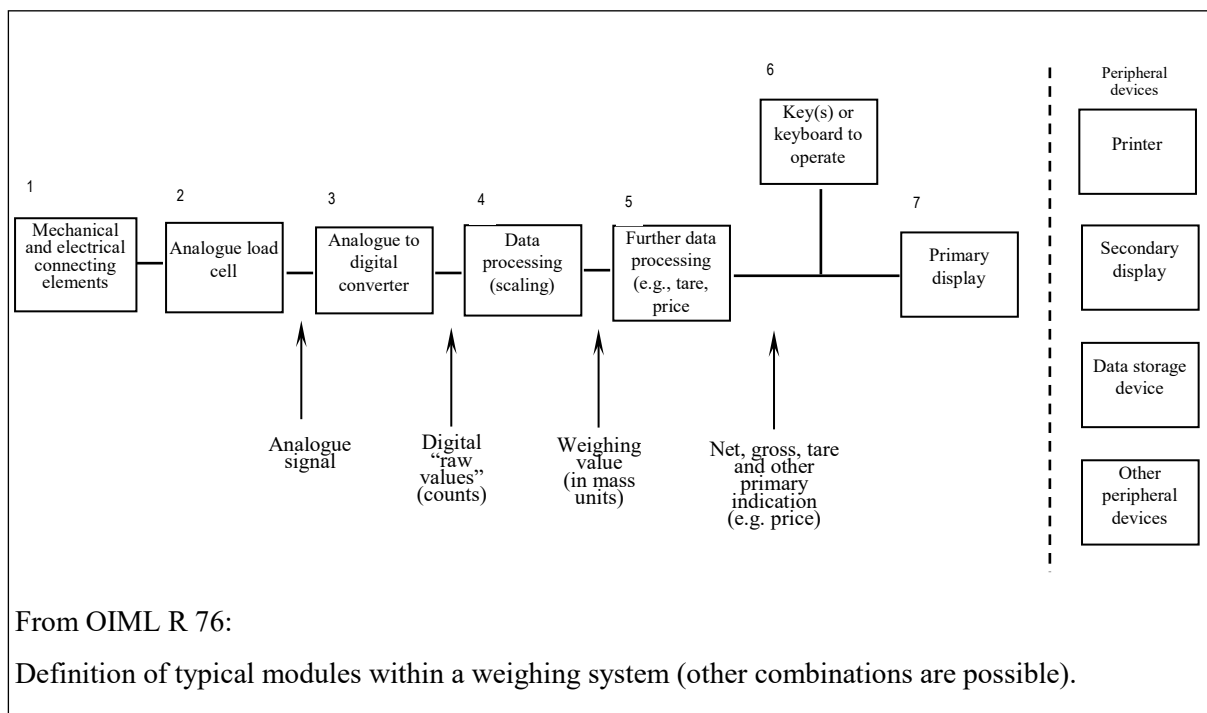


Figure 1 - Typical components in a weighing instrument

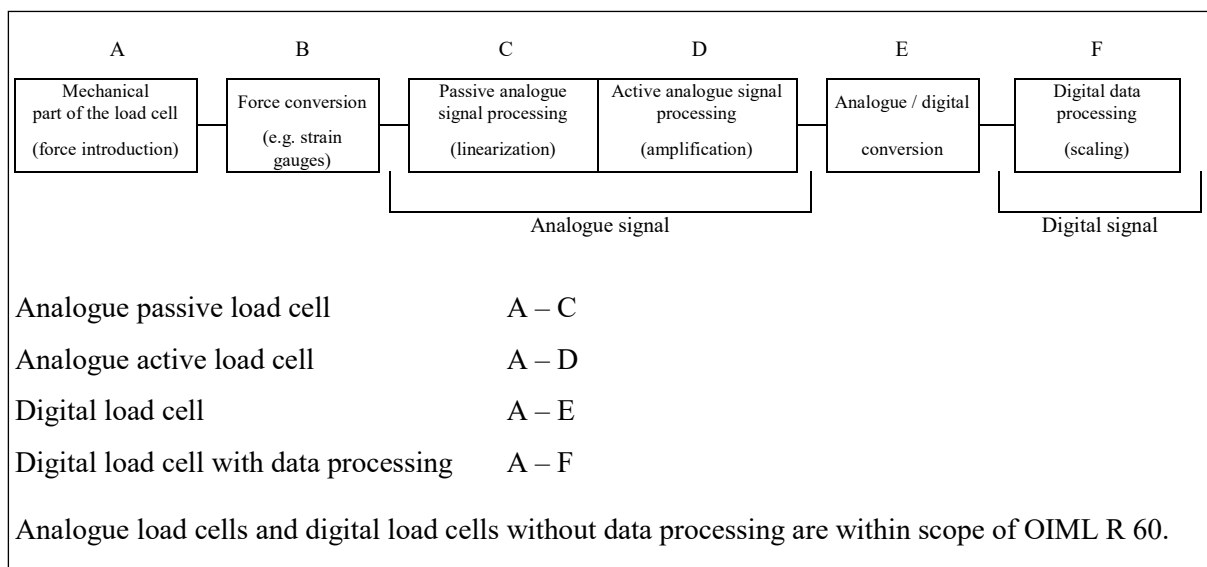


Figure 2 - Characterisation of load cell capabilities

3 Terminology (Terms and definitions)

The terms most frequently used in the load cell field and their definitions are given below (see 3.6 for an illustration of certain definitions). The terminology used in this Recommendation conforms to OIML V 2-200 *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms* (VIM) [2], to OIML V 1 *International Vocabulary of Terms in Legal Metrology* (VIML) [3], to OIML D 9 *Principles of metrological supervision* [4], to OIML D 11 *General requirements for measuring instruments* [5], and to OIML B 18 *Framework for the OIML Certification System (OIML-CS)* [6].

In addition, for the purposes of this Recommendation, the following definitions apply:

3.1 General definitions

3.1.1

durability [VIML 5.15]

ability of a measuring instrument to maintain its performance characteristics over a period of use

3.1.2

legal metrology [VIML 1.01]

practice and process of applying statutory and regulatory structure and enforcement to metrology

(For notes, refer to the VIML [3]).

3.1.3

load cell

measuring transducer that will produce an output in response to an applied load. This output may be converted by another device into measurement units such as mass

3.1.3.1

analogue-passive load cell

load cell from which the output provides either measurable data or direct information representing the measurand value

Note: The ratio between output and input may be adjustable and this type of load cell may utilise

- passive electronics (e.g. strain gauges), and
- passive temperature compensation elements

3.1.3.2

analogue-active load cell

load cell which is capable of performing the functions as described under “analogue-passive” load cell (3.1.3.1) and which also utilises active electronics

Note: This type of load cell may utilise the active electronics for

- gaining an electronic representation of the measurand value,
- active temperature compensation, and
- similar functions being of influence to the measurand value.

3.1.3.3

digital load cell

analogue-active load cell which includes an analogue to digital conversion device providing a representation of the measurand value in some unprocessed digital format

3.1.3.4

digital load cell equipped with further data processing (Figure 2, A–F)

analogue-active load cell which includes an analogue to digital conversion device providing a representation of the measurand value in some digital format and includes further digital processing (e.g. scaling)

3.1.4

marking [VIML 2.19]

affixing of one or more marks

(For notes, refer to the VIML [3]).

3.1.5

metrological supervision [VIML 2.03]

activity of legal metrological control to check the observance of metrology laws and regulations

(For notes, refer to the VIML [3]).

3.1.6

measuring transducer [VIM 3.7]

device, used in measurement, that provides an output quantity having a specified relation to the input quantity

3.1.7

performance test

test to verify whether the load cell under test is capable of performing its intended functions

3.1.8

rated operating condition [VIM 4.9]

operating condition that must be fulfilled during measurement in order that a measuring instrument or measuring system perform as designed

(For notes, refer to the VIM [2]).

3.1.9

sealing [VIML 2.20]

means intended to protect the measuring instrument against any unauthorised modification, readjustment, removal of parts, software, etc.

(For notes, refer to the VIML [3]).

3.1.10

type (pattern) evaluation [VIML 2.04]

conformity assessment procedure on one or more specimens of an identified type (pattern) of measuring instruments which results in an evaluation report and / or an evaluation certificate

(For notes, refer to the VIML [3]).

3.1.11

type approval [VIML 2.05]

decision of legal relevance, based on the review of the type evaluation report, that the type of a measuring instrument complies with the relevant statutory requirements and results in the issuance of the type approval certificate

3.2 Categories of load cells

3.2.1 Application of load

3.2.1.1

compression loading

applying a compressive force to the load receptor of a load cell

3.2.1.2

tension loading

applying a tension force to the load receptor of a load cell

3.3 Construction of load cells (see sections 1 and 2.1)

3.3.1

strain gauge

analogue resistive element that is attached to a load cell structure and that changes resistance depending on the deformation of the load cell structure when compression or tension forces are applied to the load cell

3.4 Metrological characteristics of a load cell

3.4.1

humidity symbol

symbol assigned to a load cell that indicates the conditions of humidity under which the load cell has been tested

3.4.2

load cell family

group of load cells which for the purposes of type evaluation are considered as one family and that are of:

- a) the same material or combination of materials (for example mild steel, stainless steel or aluminium);
- b) the same design of the measurement technique (for example strain gauges bonded to metal);
- c) when used, the same principle used to attach the strain gauge to the load cell;
- d) the same method of construction (for example shape, sealing of strain gauges, mounting method, manufacturing method);
- e) the same set of specifications (for example output rating, input impedance, supply voltage, cable details); and
- f) one or more load cell groups where all load cells within the group possess identical metrological characteristics (as listed in 5.1.5 – including: class; n_{LC} ; temperature rating, etc.).

Note: The examples provided are not intended to be limiting.

3.5 Range, capacity and output terms

3.5.1

load cell interval

subdivision of the load cell measuring range

3.5.2

load cell measuring range (for verification)

range between the maximum load of the measuring range $D_{\max}$ and minimum load of the measuring range $D_{\min}$

load cell measuring range = $(D_{\max} - D_{\min})$

3.5.3

load cell output

measurable quantity into which a load cell converts the measured input quantity

3.5.4

load cell verification interval (v)

load cell interval, expressed in units of mass, used in the test of the load cell for accuracy classification

3.5.5

maximum capacity ($E_{\max}$)

largest value of a quantity expressed in units of mass, which may be applied to a load cell

3.5.6

maximum load of the measuring range ($D_{\max}$)

largest value of a quantity expressed in units of mass which can be introduced to a load cell under test

3.5.7

maximum measuring range

range of values of the quantity expressed in units of mass that may be applied to a load cell

Note: maximum measuring range is the range between maximum capacity $E_{\max}$ and minimum dead load $E_{\min}$

maximum measuring range = $(E_{\max} - E_{\min})$

3.5.8

maximum number of load cell verification intervals (n_{LC})

maximum number of load cell verification intervals into which the maximum measuring range may be divided

3.5.9

minimum dead load ($E_{\min}$)

smallest value of a quantity (expressed in mass units) that may be applied to a load cell

3.5.10**minimum dead load output return (DR)**

difference of load cell output, expressed in units of mass at the minimum dead load ($D_{\min}$), measured before and after application of a load of $D_{\max}$

3.5.11**minimum load cell verification interval ($v_{\min}$)**

smallest load cell verification interval in units of mass into which the maximum measuring range ($E_{\max} - E_{\min}$) can be divided

3.5.12**minimum load of the measuring range ($D_{\min}$)**

smallest value of a quantity expressed in units of mass, applied to a load cell under test

3.5.13**number of load cell verification intervals (n)**

total of load cell verification intervals into which the maximum measuring range is divided

3.5.14**relative minimum dead load output return (Z)**

ratio of the maximum measuring range, to two times the minimum dead load output return, DR

Note: This ratio is used to describe multi-interval instruments.

3.5.15**relative minimum load cell verification interval (Y)**

ratio of the maximum measuring range, to the minimum load cell verification interval, $v_{\min}$

Note: This ratio describes the resolution of the load cell independent from the load cell capacity.

3.5.16**safe load limit ($E_{\lim}$)**

maximum load that can be applied without producing a permanent shift in the performance characteristics beyond those specified

3.5.17**warm-up time**

time between the moment power is applied to a load cell and the moment at which the load cell is capable of complying with the requirements

3.6 Illustration of certain definitions

The terms that appear above the central horizontal line (related to parameters $E_{\min}$ and $E_{\max}$) are parameters that are fixed by the design of the load cell. The terms that appear below that line (related to parameters $D_{\min}$ and $D_{\max}$) are parameters that are variable, dependent on the conditions of the test of a load cell (in particular, those load cells used in weighing instruments).

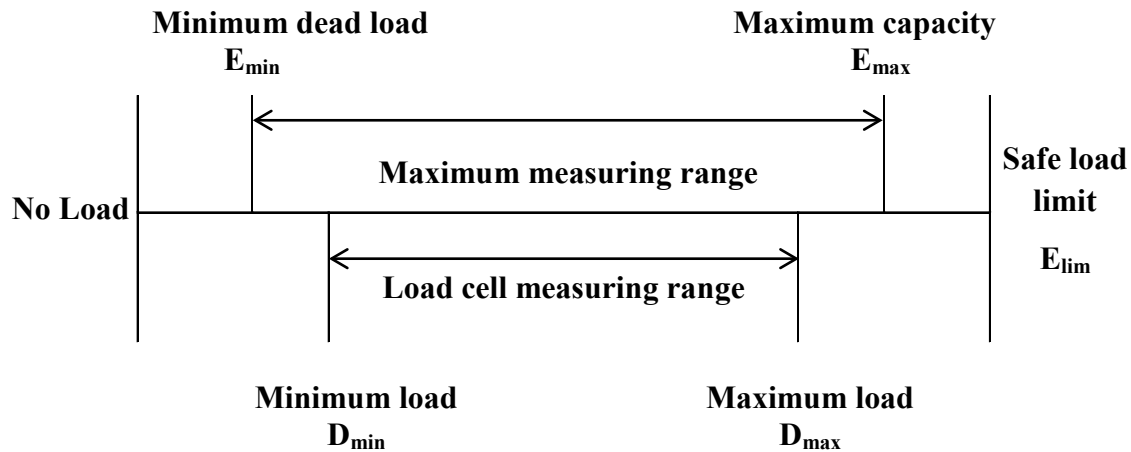


Figure 3 - Illustration of certain definitions

The following statements apply: (see also R 60-2, 2.7.3.4)

- a) $(D_{\max} - D_{\min}) \leq (E_{\max} - E_{\min})$
- b) $E_{\min} \leq D_{\min} \leq (0.1 E_{\max})$, and $(0.9 E_{\max}) \leq D_{\max} \leq E_{\max}$

3.7 Measurement and error terms

3.7.1 creep

change in load cell output occurring with time while under constant load and with all environmental conditions and other variables also remaining constant

3.7.2

apportioning factor (p_{LC})

value of a dimensionless fraction expressed as a decimal (for example, 0.7) representing that portion of an error observed in the (weighing) instrument which is attributed to the load cell alone

Note: This value is used in determining the MPE (see 3.7.10).

3.7.3

durability error [VIML 5.16]

difference between the intrinsic error after a period of use and the initial intrinsic error of a measuring instrument

3.7.4

expanded uncertainty

quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand (OIML G 1-100 *Guide to the Expression of Uncertainty in Measurement*) [7]

3.7.5**fault [VIML 5.12]**

difference between the error of indication and the intrinsic error of a measuring instrument

(For notes, refer to the VIML [3]).

3.7.6**fault detection output**

electrical representation issued by the load cell indicating that a fault condition exists

3.7.7**hysteresis error**

difference in load cell output readings for the same applied force between the reading obtained by increasing the load from minimum load ($D_{\min}$), and the reading obtained by decreasing the load from maximum load ($D_{\max}$)

3.7.8**initial intrinsic error [VIML 5.11]**

intrinsic error of a measuring instrument as determined prior to performance tests and durability evaluations

3.7.9**load cell intrinsic error**

error resulting from a load cell, determined under reference conditions

3.7.10**maximum permissible error (MPE) [VIM 4.26]**

extreme value of measurement error, with respect to a known reference quantity value, permitted by specifications or regulations for a given measurement, measuring instrument, or measuring system

(For notes, refer to the VIM [2]).

3.7.11**measurement error [VIM 2.16]**

measured quantity minus a reference quantity value.

Note: The term “measurement error” in this Recommendation refers to load cell measurement errors.

(For additional notes, refer to the VIM [2]).

3.7.12**measured quantity (value) [VIM 2.10]**

quantity value representing a measurement result

(For notes, refer to the VIM [2]).

3.7.13**non-linearity**

deviation from the average of the values of load cell signals from a straight line through zero force applied and maximum force applied

3.7.14

repeatability error

difference between load cell output readings taken from consecutive tests under the same loading and environmental conditions of measurement

3.7.15

resolution [VIM 4.14]

smallest change in a quantity being measured that causes a perceptible change in the corresponding indication

(For notes, refer to the VIM [2]).

3.7.16

significant durability error [VIML 5.17]

durability error exceeding the value specified in the applicable Recommendation

(For notes, refer to the VIML [3]).

3.7.17

significant fault [VIML 5.14]

fault exceeding the applicable fault limit value

(For notes, refer to the VIML [3]).

3.7.18

span stability

capability of a load cell to maintain the load cell output of the load cell's measuring range over a period of use within specified limits

3.7.19

temperature effect on minimum dead load output

change of the signal output under minimum dead load due to a change in ambient temperature

3.7.20

temperature effect on sensitivity

change in sensitivity due to a change in ambient temperature

3.7.21

type approval mark [VIML 3.07]

mark applied to a measuring instrument certifying its conformity to the approved type

3.8 Influences and reference conditions

3.8.1

disturbance [VIML 5.19]

influence quantity having a value within the limits specified in the relevant Recommendation, but outside the specified rated operating conditions of a measuring instrument

3.8.2**influence factor [VIML 5.17]**

influence quantity having a value which ranges within the rated operating conditions of a measuring instrument

(For notes, refer to the VIML [3]).

3.8.3**influence quantity [VIM 2.52]**

quantity that, in a direct measurement, does not affect the quantity that is actually measured, but that affects the relation between the indication and the measurement result

(For examples and notes, refer to the VIM [2]).

3.8.4**rated operating condition [VIM 4.9]**

operating condition that must be fulfilled during measurement in order that a measuring instrument or measuring system perform as designed

(For notes, refer to the VIM [2]).

3.8.5**reference (operating) condition [VIM 4.11]**

operating condition prescribed for evaluating the performance of a measuring instrument or measuring system or for comparison of measurement results

(For notes, refer to the VIM [2]).

3.9 Abbreviations

AC	Alternating Current
CH	Cyclic Humidity
DC	Direct Current
DR	Minimum Deadload Output Return
EMC	Electro Magnetic Compatibility
EUT	Equipment Under Test
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
I/O	Input/Output
LC	Load Cell
MPE	Maximum Permissible Error
NH	No Humidity
OIML	International Organisation of Legal Metrology
SH	Steady-State Humidity
VIM	International Vocabulary of Metrology – Basic and General Concepts and Associated Terms
VIML	International vocabulary of terms in legal metrology

4 Description of load cells

A load cell provides an output proportional to a force resulting from applying a load. Load cells may be used as a single transducer or applied together with other load cells in a system where the design allows such application. The term “load cell” in this Recommendation is not limited to any particular type of technology or design principle.

While many technologies are used in the design of load cells, those used in legal metrology applications are commonly designed to provide an electrical output relative to a mechanical input. Both analogue and digital outputs are recognised in load cells within that category. Although strain gauge technology was a primary focus in the development of R 60, it is to be understood that load cells that operate using other principles may also be evaluated under this Recommendation. Variations of transducers that operate using alternative basis of input/output may include, but are not limited to pressure (e.g. hydraulic, pneumatic), vibratory frequency and magnetic forces.

The term load cell may describe an elemental component/module or a somewhat more complex instrument including constituents that perform functions such as signal filtering and analogue-to-digital conversion.

5 Metrological requirements

5.1 Principle of load cell classification

The classification of load cells into specific accuracy classes is provided to facilitate their application to various measuring systems. In the application of this Recommendation, it should be recognised that the effective performance of a particular load cell may be improved by compensation means within the measuring system with which it is applied. Therefore, it is not the intention of this Recommendation to require that a load cell be of the same accuracy class as the measuring system in which it may be applied. Nor does it require that a measuring instrument, indicating in units of mass for example, use a load cell which has been approved during a separate type evaluation. All data/items found in 5.1.1 to 5.1.7 shall be specified by the manufacturer.

5.1.1 Accuracy classes and their symbols

Load cells shall be ranked according to their overall performance capabilities into one of the four accuracy classes whose designations are as follows:

Class A; Class B; Class C; Class D.

5.1.2 Maximum number of load cell verification intervals

The maximum number of load cell verification intervals, n_{LC} , into which the maximum measuring range $E_{max} - E_{min}$ (see 3.5.8) can be divided in a measuring system shall be within the limits presented in Table 1.

Table 1 - Maximum number of load cell verification intervals (n_{LC}) according to accuracy class

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

5.1.3 Minimum load cell verification interval

The minimum load cell verification interval, $v_{\min}$, shall be specified by the manufacturer (see 3.5.11 in combination with 3.5.15).

5.1.4 Supplementary classifications

Load cells shall also be classified by the intended manner in which a load is applied to the load cell wherever there would be a risk of confusing the manner of loading (i.e. compression loading, tension loading or universal). A load cell may bear different classifications according to the intended manner in which a load is applied to the load cell. The manner of loading for which the classification(s) applies(y) shall be specified. For multiple capacity load cells, each capacity shall be classified separately.

5.1.5 Complete load cell classification

The load cell shall be classified corresponding to the following six parameters:

- accuracy class designation (see 5.1.1 and 6.2.4.1);
- maximum number of load cell verification intervals (see 5.1.2 and 6.2.4.5);
- intended manner of the application of the load, if necessary (see 5.1.4 and 6.2.4.2);
- special limits of working temperature, if applicable (see 6.2.4.3);
- humidity symbol, if applicable (see 6.2.4.4); and
- additional characterisation information, as listed below in Figure 4, 5.1.6, and 5.1.7.

An example illustrating the six parts of the load cell classification is shown in Figure 4.

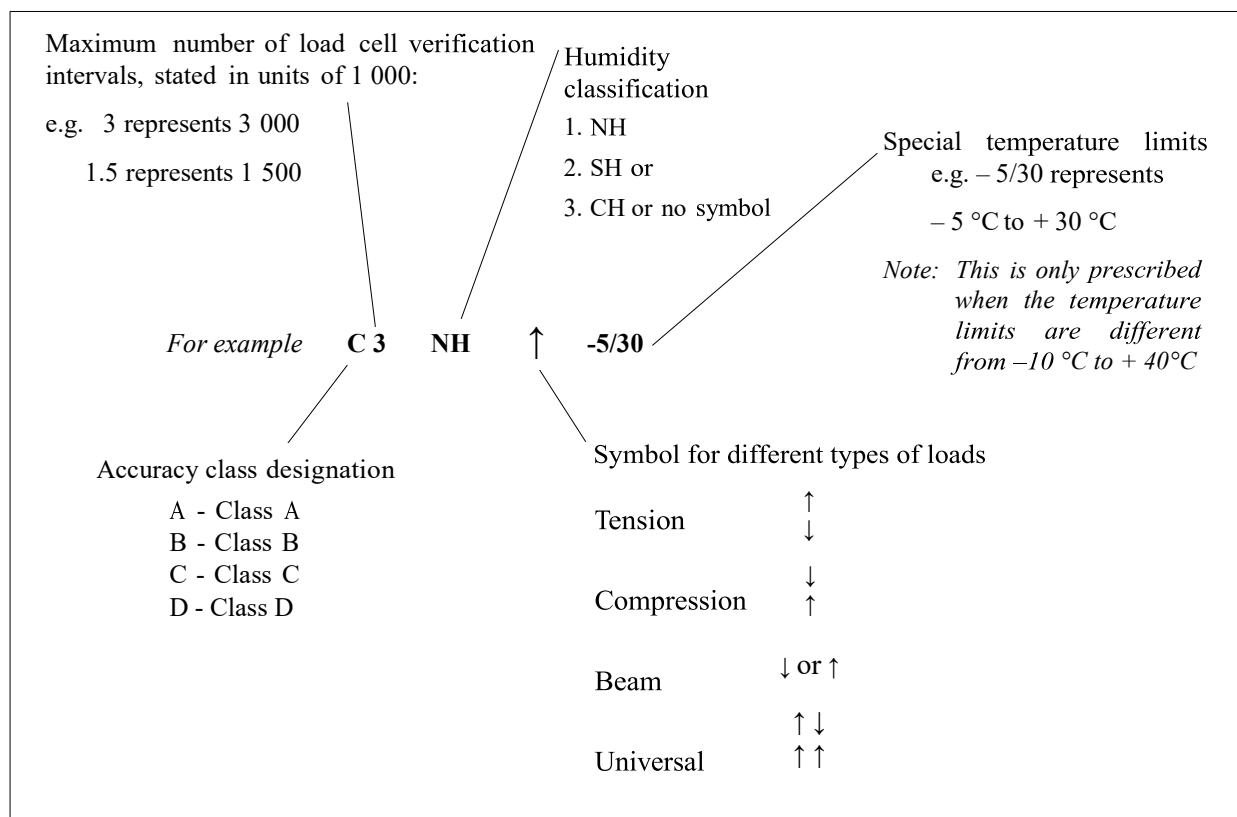


Figure 4 - Complete load cell classification

5.1.6 Standard classification

Standard classifications shall be used; examples are shown in Table 2.

Table 2 - Examples of load cell classification

Classification symbol	Description
C2	Class C, 2 000 intervals
C3 ↓ 5/35 ↑	Class C, 3 000 intervals, compression, + 5 °C to + 35 °C
C2 NH	Class C, 2 000 intervals, not to be subjected to humidity test

5.1.7 Multiple classifications

Load cells that have comprehensive classifications for the manner in which the load is applied to the load cell shall be accompanied by the relative information for each classification. An example is shown in Table 3. An illustration of the standard classification symbols, using an example, is shown in Figure 4.

Table 3 - Examples of multiple classifications

Classification symbol	Description
C2 ↑	Class C, 2 000 intervals
C1.5 ↓	Class C, 1 500 intervals
C1 ↓ ↑ - 5/30	Class C, 1 000 intervals, compression, – 5 °C to + 30 °C
C3 ↑ ↓ - 5/30	Class C, 3 000 intervals, tension, – 5 °C to + 30 °C

5.2 Measuring ranges

5.2.1 Minimum load of the measuring range ($D_{\min}$) (see 3.5.12)

The value of the smallest load applied to a load cell during test which is expressed in units of mass shall not be less than $E_{\min}$ (see 3.5.9).

5.2.2 Maximum load of the measuring range ($D_{\max}$) (see 3.5.6)

The value of the largest load applied to a load cell during test which is expressed in units of mass shall not be greater than $E_{\max}$ (see 3.5.5).

5.3 Maximum permissible measurement errors

Under the rated operating conditions in 5.6, the maximum permissible error (MPE) shall not exceed the values stated in 5.5.

The MPE is applicable after increasing as well as decreasing the force applied (i.e. they include hysteresis).

5.3.1 Maximum permissible errors for each accuracy class

The maximum permissible measurement errors for each accuracy class are related to the maximum number of load cell verification intervals (n_{LC}) specified for the load cell (see 5.1.2) and to the actual value of the load cell verification interval, v .

5.3.2 Type evaluation

The MPE (see 3.7.10) on type evaluation shall be the values derived using the expressions contained in the left column of Table 4. The apportioning factor, p_{LC} shall be chosen and declared (if other than 0.7) by the manufacturer and shall be in the range of 0.3 to 0.8: $(0.3 \leq p_{LC} \leq 0.8)^1$, where “ m ” is the value (expressed in mass) representing the force introduced by the load applied.

Table 4 - Maximum Permissible Errors (MPE) on type evaluation

MPE (+/-)	Load, m			
	Class A	Class B	Class C	Class D
$p_{LC} \times 0.5 v$	$0 \leq m \leq 50\,000 v$	$0 \leq m \leq 5\,000 v$	$0 \leq m \leq 500 v$	$0 \leq m \leq 50 v$
$p_{LC} \times 1.0 v$	$50\,000 v < m \leq 200\,000 v$	$5\,000 v < m \leq 20\,000 v$	$500 v < m \leq 2\,000 v$	$50 v < m \leq 200 v$
$p_{LC} \times 1.5 v$	$200\,000 v < m$	$20\,000 v < m \leq 100\,000 v$	$2\,000 v < m \leq 10\,000 v$	$200 v < m \leq 1\,000 v$

The value of the apportioning factor, p_{LC} shall appear on the OIML certificate, if the value is not equal to 0.7. If the apportioning factor, p_{LC} is not specified on the certificate then the value 0.7 shall be assumed. The maximum permissible error may be positive or negative and is applicable to both increasing and decreasing loads.

The limits of error shown include errors due to non-linearity, hysteresis and temperature effect on sensitivity over certain temperature ranges, specified in 5.6.1.1 and 5.6.1.2. Further errors, not included in the Table 4 limits of error, are treated separately.

5.4 Repeatability error

The maximum difference between the results of five identical load applications for classes A and B and of three identical load applications for classes C and D shall not be greater than the absolute value of the MPE for that load.

¹Associated with apportionment of error provisions contained within OIML R 76-1, 3.5.1 and 3.10.2.1 [1]; R 50-1, 2.2.33.2.2 [24]; R 51-1, 5.2.3.4 [25]; R 61-1, 5.2.3.3 [26]; R 106-1, 5.1.3.2 [27]; or R 107-1, 5.1.4.1 [28], when load cell is applied to such instruments.

5.5 Permissible variation of results under reference conditions

5.5.1 Creep

The difference between the reading taken upon the application of a maximum load ($D_{\max}$) and the reading observed within and after 30 minutes of exposure of 90 % to 100 % of $E_{\max}$ shall not exceed 0.7 times the absolute value of MPE for the applied load.

Regardless of any value declared by the manufacturer for the apportioning factor, p_{LC} , the MPE for creep shall be determined from Table 4 using the apportioning factor, $p_{LC} = 0.7$.

The difference in readings taken after 20 minutes of exposure to 90 % to 100 % of $E_{\max}$ and at 30 minutes of exposure to 90 % to 100 % of $E_{\max}$ shall not exceed 0.15 times the absolute value of MPE.

Example:

Load cell class: C3 (declared by the manufacturer)

Apportioning factor: $p_{LC} = 0.7$

Applied load: $D_{\max} = E_{\max}$ (test specification)

Maximum difference between the reading = $0.7 \times (0.7 \times 1.5 \nu) = 0.735 \nu$

Example:

Load cell class: C3 (declared by the manufacturer)

Apportioning factor: $p_{LC} = 0.7$

Applied load: $D_{\max} = E_{\max}$ (test specification)

Maximum difference between the initial reading = $0.15 \times (0.7 \times 1.5 \nu) = 0.1575 \nu$

5.5.2 Minimum dead load output return (DR) (see 3.5.10)

The difference between the initial reading of the minimum load output ($D_{\min}$) and the reading of $D_{\min}$ at the conclusion of the creep test (5.5.1), shall not exceed half the value of the load cell verification interval (0.5ν).

Note: It should be noted that DR is the minimum dead load output return expressed in mass units (g, kg, t). DR has to be adjusted in a value expressed in load cell verification intervals, ν .

5.6 Influence quantities (Rated operating conditions)

Load cells shall be evaluated under the conditions specified in 5.6.1–5.6.3. An evaluation may include additional special testing performed under conditions that vary from those specified in 5.6.1–5.6.3 if requested and specified by the applicant submitting the load cell for evaluation. This special testing may be performed in addition to, but not instead of testing under the specified conditions in 5.6.1–5.6.3.

Load cells that are equipped with functions typically performed by complete instruments may be required to be evaluated against additional requirements contained in other OIML Recommendations for those complete instruments. These additional evaluations are outside the scope of this Recommendation (see 2.3 and Figure 2).

5.6.1 Temperature

5.6.1.1 Temperature limits

Excluding temperature effects on minimum dead load output, the load cell shall perform within the limits of error in 5.3.2 over the temperature range of $-10\text{ }^{\circ}\text{C}$ to $+40\text{ }^{\circ}\text{C}$, unless otherwise specified as in 5.6.1.2.

Note: National legislation may prescribe alternative temperature limits outside of the range specified above as appropriate for local climatic conditions and the environmental conditions that can be anticipated.

5.6.1.2 Special limits

Load cells for which particular limits of working temperature are specified shall satisfy, within those ranges, the conditions defined in 5.3.2. The span of these ranges shall be at least:

- 5 °C for load cells of class A;
- 15 °C for load cells of class B;
- 30 °C for load cells of classes C and D.

5.6.1.3 Temperature effect on minimum dead load output

The minimum dead load output of the load cell over the temperature range, as specified in 5.6.1.1 or 5.6.1.2, shall not vary by an amount greater than the apportioning factor, p_{LC} , times the minimum load cell verification interval, v_{min} , for any change in ambient temperature of:

- 2 °C for load cells of class A;
- 5 °C for load cells of class B, C and D.

5.6.2 Barometric pressure

The output of the load cell shall not vary by an amount greater than the minimum load cell verification interval, v_{min} , for any incremental change in barometric pressure equivalent to 1 kPa.

5.6.3 Humidity

With respect to humidity conditions, this Recommendation defines 3 humidity classes: CH (cyclic humidity - as standard), NH (no humidity), and SH (steady-state humidity). In the case of class NH or SH, the class designation shall be marked on the load cell. In the case of class CH, class designation marking of the load cell is not mandatory.

5.6.3.1 Humidity error – CH or unmarked load cells

This requirement is only applicable to load cells marked CH or with no humidity symbol marking and not applicable to load cells marked NH or SH.

The influence of exposure to temperature cycles specified in R 60-2, 2.10.5.12 on the load cell output for minimum load shall not be greater than 4 % of the difference between the output on the maximum capacity, E_{max} , and that at the minimum dead load, E_{min} .

The influence of exposure to temperature cycles specified in R 60-2, 2.10.5.12 on the load cell output for the maximum load shall not be greater than the load cell verification interval, v .

5.6.3.2 Humidity error – SH marked load cells

This requirement is only applicable to load cells marked SH and is not applicable to load cells marked NH or CH or with no humidity symbol marking.

A load cell shall meet the MPE applicable to the load applied as specified in Table 4, when exposed to conditions of relative humidity variations as specified in R 60-2, 2.10.6.11.

5.7 Requirements for analogue-active and digital load cells

5.7.1 General requirements

In addition to the other requirements of this Recommendation, analogue-active load cells shall comply with the following requirements. The MPE shall be determined using an apportioning factor, p_{LC} greater than or equal to 0.7 and less than or equal to 0.8 ($0.7 \leq p_{LC} \leq 0.8$) substituted for the apportioning factor, p_{LC} , that is declared by the manufacturer and applied to the other requirements.

If a digital load cell equipped with further data processing (3.1.3.4) is configured with substantial additional electronic functions (e.g. display of indications, frequency counter) that are typical of an electronic weighing instrument, it may be considered outside the scope of this Recommendation and the load cell may need to undergo additional evaluation against requirements contained in other OIML Recommendations which are applicable to weighing instruments.

5.7.1.1 Faults

An analogue-active load cell shall be designed and manufactured such that when it is exposed to electrical disturbances either:

- a) significant faults do not occur; or
- b) significant faults are detected and acted upon.

If significant faults do occur, and the load cell is equipped with the intelligence to detect and act upon significant faults through the instrument that the load cell is installed in, the reporting of and acting upon significant faults would then be evaluated under the appropriate Recommendation for the complete instrument.

Messages of significant faults should not be confused with other messages presented.

Note: A fault in value that is equal to or smaller than the load cell minimum verification interval, v_{min} , is allowed.

5.7.1.2 Acting upon significant faults

When a significant fault has been detected, either the load cell shall be made inoperative automatically or a fault detection output shall be issued automatically. This fault detection output shall continue until the fault has been resolved.

5.7.1.3 Durability

The load cell shall be suitably durable so that the requirements of this Recommendation may be met in accordance with the intended use of the load cell.

5.7.1.4 Compliance with requirements

An analogue-active load cell is presumed to comply with the requirements in 5.7.1.1 and 5.7.1.3, if it passes the examinations specified in 5.7.2 and R 60-2, 2.10.7.

5.7.1.5 Application of the requirements in 5.7.1.1

The requirements in 5.7.1.1 may be applied separately to each individual cause or significant fault. The choice of whether 5.7.1.1 a) or 5.7.1.1 b) is applied is left to the manufacturer.

5.7.2 Influence quantities

5.7.2.1 Warm-up time

During the designed warm-up time of an analogue-active load cell there shall be no transmission of measurement results.

5.7.2.2 Mains power supply (AC)

An analogue-active load cell that operates from a mains power supply shall be designed to comply with the metrological requirements if the mains power supply varies in voltage from – 15 % to + 10 % of the supply voltage.

5.7.2.3 Battery power supply (DC)

An analogue-active load cell that operates from a battery power supply shall either continue to function correctly, or not provide a measurement result whenever the voltage is below the value specified by the manufacturer.

5.7.2.4 Maximum allowable variations during voltage variations

All functions shall operate as designed.

All measurement results shall be within maximum permissible errors.

5.7.2.5 Disturbances

When an analogue-active load cell is subjected to the disturbances specified in R 60-2, 2.10.7.5 to 2.10.7.10 (also summarised in Table 5), the difference between the load cell output due to a disturbance and the load cell output without disturbance (fault) shall satisfy the conditions in 5.7.1.1.

Table 5 - Influence factors and disturbances

Test	Subclause R 60-2, 2.10 test procedure	p_{LC}^*	Characteristic under test
Warm-up time	2.10.7.3	1.0	Influence factor
Power voltage variations	2.10.7.4		Influence factor
Short-time power reductions	2.10.7.5		Disturbance
Bursts (electrical fast transients)	2.10.7.6		Disturbance
Surge	2.10.7.7		Disturbance
Electrostatic discharge	2.10.7.8		Disturbance
Electromagnetic susceptibility	2.10.7.9		Disturbance
Immunity to conducted electromagnetic fields	2.10.7.10		Disturbance
Span stability	2.10.7.11		Influence factor

*Note: $p_{LC} = 0.7$ shall be used for analogue-active load cells during influence factors tests.

5.7.2.6 Span stability: maximum allowable variation requirements (not applicable to class A load cells)

When an analogue-active load cell is subjected to the span stability test specified in R 60-2, 2.10.7.11, the variation in the load cell span measurement results shall not exceed the greater of: half the load cell verification interval; or half the absolute value of the MPE for the applied test load $D_{\max}$.

6 Technical requirements

6.1 Software

Provision shall be made for appropriate sealing by mechanical, electronic and/or cryptographic means, making any change that affects the metrological integrity of the device impossible or evident.

Any embedded programming (i.e. firmware) that influences the raw count output of the load cell will be evaluated under the terms of this Recommendation. In addition, if the software modifies load cell performance, not exceeding the functions of analogue to digital conversion and the linearization of the load cell output, then that software shall be evaluated under the terms in this Recommendation and in accordance with OIML D 31 [8]. Any weighing instrument function shall be evaluated under other appropriate Recommendations for weighing instruments.

Functionality of any software which is not covered by this Recommendation, e.g. functionalities of weighing instruments, is outside the scope of this Recommendation and is therefore not evaluated. It may be required to undergo additional evaluations against other requirements contained in the applicable OIML Recommendations for weighing instruments.

The requirements which are relevant to the evaluation of load cells and provided in OIML D 31 [8] shall be fulfilled for the load cell by taking into account the following aspects.

- a) In general, for load cells, the severity level I, examined with validation procedure A, is required.
- b) For legally relevant software of digital load cells the following statements according to OIML D 31 [8] shall be applied.
 - 1) The exception described in OIML D 31, 5.1.1 [8] for an imprint of the software identification is allowed.
 - 2) The level of conformity of manufactured devices to the approved type is according to OIML D 31, 5.2.5 (subclause a) [8].
 - 3) Updating the legally relevant software of a load cell in the field is possible via verified or traced update according to OIML D 31, 5.2.6.2 and 5.2.6.3 [8].
 - 4) The software documentation shall include descriptions according to the applicable requirements of OIML D 31, 6.1.1 [8].

The validation procedures are described in OIML D 31, 6.4 [8].

6.2 Inscriptions and presentation of load cell information

Technical information markings including load cell classifications as indicated in 5.1.5 must be specified for the load cell(s).

6.2.1 Mandatory markings on the load cell

The following mandatory markings shall be clearly and indelibly marked on the load cell. When a sticker or data plate is used it shall be impossible to remove them without damaging them.

- a) Manufacturer's name or trade mark
- b) Manufacturer's type designation or load cell model
- c) Serial number

- d) Maximum capacity as: $E_{\max}$ = (in units g, kg, t)
- e) Year of production
- f) Type approval mark (if applicable)

If due to the limitation of the size of the load cell, it is impossible to apply all the mandatory markings, the manufacturer's name or trade mark, the load cell type designation, the serial number, and the maximum capacity shall be provided as a minimum on the load cell itself. All other mandatory information shall be provided in an accompanying document supplied by the manufacturer and submitted to the user. Where such a document is provided, the information required in 6.2.2 shall also be given therein.

6.2.2 Mandatory additional information

The following mandatory information shall be provided in a document accompanying the load cell supplied by the manufacturer and submitted to the user or, if space permits, they may be marked on the load cell. Where the information provided is associated with a specific unit of measure, the unit (g, kg, t) shall also be specified.

- a) Manufacturer's name or trade mark
- b) Manufacturer's type designation or load cell model
- c) Accuracy class(es); see 6.2.4.1
- d) Type of load; see 6.2.4.2
- e) Working temperature when required; see 6.2.4.3
- f) Humidity symbol when required; see 6.2.4.4
- g) Maximum capacity as: $E_{\max}$ =
- h) Minimum dead load as: $E_{\min}$ =
- i) Safe load limit as: $E_{\lim}$ =
- j) Minimum load cell verification interval as $v_{\min}$ (or relative minimum load cell verification interval, Y) =
- k) Value of the apportioning factor, p_{LC} , if not equal to 0.7; and
- l) Other pertinent conditions that must be observed to obtain the specified performance (for example, electrical characteristics of the load cell such as output rating, input impedance, supply voltage, cable details, mounting torque, etc.).

6.2.3 Non-mandatory additional information

In addition to the information required in 6.2.2, the following information may optionally be specified:

- a) for a weighing instrument (for example a multiple range instrument according to OIML R 76 [1]), the relative $v_{\min}$, Y , where $Y = (E_{\max} - E_{\min}) / v_{\min}$ (see 3.5.15);
- b) for a weighing instrument (for example a multi-interval instrument according to OIML R 76) [1], the relative DR, Z , where $Z = (E_{\max} - E_{\min}) / (2 \times DR)$ (see 3.5.14) and the value of DR (see 3.5.10) is set at the maximum permissible minimum dead load output return according to R 60-2, 2.10.1;
- c) other information considered necessary or useful by the manufacturer.

6.2.4 Specific markings

6.2.4.1 Accuracy class designation

Class A load cells shall be designated by the character "A", class B by "B", class C by "C" and class D by the character "D".

6.2.4.2 Designation of the type of load applied to the load cell

The designation of the type of load applied to the load cell shall be specified when it is not clearly apparent from the load cell construction, using the symbols shown in Table 6.

Table 6 - Symbols for different types of load transmission principles

Tension	↑ ↓
Compression	↓ ↑
Beam	↑ or ↓
Universal	↑ ↓ ↓ ↑

6.2.4.3 Working temperature designation

The special limits of working temperature, as referred to in 5.6.1.2, shall be specified when the load cell cannot perform within the limits of error in 5.3 to 5.6 over the temperature range specified in 5.6.1.1. In such cases, the limits of temperature shall be designated in degrees Celsius (°C).

6.2.4.4 Humidity symbols

- A load cell not designed to meet performance criteria evaluated under R 60-2, 2.10.5 or 2.10.6 shall be marked by the symbol NH.
- A load cell submitted for evaluation and designed to meet performance criteria evaluated under R 60-2, 2.10.5 shall be marked by the symbol CH or not be marked with any humidity classification.
- A load cell submitted for evaluation and manufactured to meet performance criteria evaluated under R 60-2, 2.10.6 shall be marked by the symbol SH.

6.2.4.5 Maximum number of load cell verification intervals

The maximum number of load cell verification intervals for which the accuracy class applies shall be designated in actual units (e.g. 3 000) or, when combined with the accuracy class designation (see 6.2.4.1) to produce a classification symbol (see 5.1.6), it shall be designated in units of 1 000.