

# CERTIFICATION OF STRAIN GAUGE LOAD CELL FAMILIES

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*Abstract: Testing and certification of load cell families from a few kg up to some 100 t on base of the new OIML R60 (1999) respectively WELMEC 2.4 and OIML R76 are described. New developments of multi-interval load cell design and tests for application in weighing instruments are presented.*

*Keywords: Load cell, Certification, OIML*

## 1 MEANING OF MODULAR LOAD CELL TESTING

Weighing instruments for trade, safety and health are under control of legal metrology in the most countries. Load cells (LC) transform the gravitational force of the mass into an electronic measurable signal. In view of accuracy the load cell is the heart of a weighing machine.

Weighing instruments with maximum capacities (Max) of up to 100 kg can be tested and approved as a complete unit. Variations in the construction of a weighing machine, but also high capacity weighing machines of up to some 100 tons make modular testing necessary.

The following list shows references to modular load cell testing according OIML R60 in various regulations of weighing legal metrology [1,2]. It is mentioned that OIML R60(1991) has been revised to R60(1999), up to end of the year 2000, however, the old regulation may be applied.

R76 For pattern approval of a modular concept or for OIML-certificate for „**Nonautomatic weighing instruments**,“ (NAWI) acc. to EN45501 respectively OIML-R76, R60 is obligatory.

For all other regulations for weighing instruments OIML R60 may be helpful and shall be accepted to receive a pattern approval.

R50 Continuous totalizing automatic weighing instruments (belt weighers)

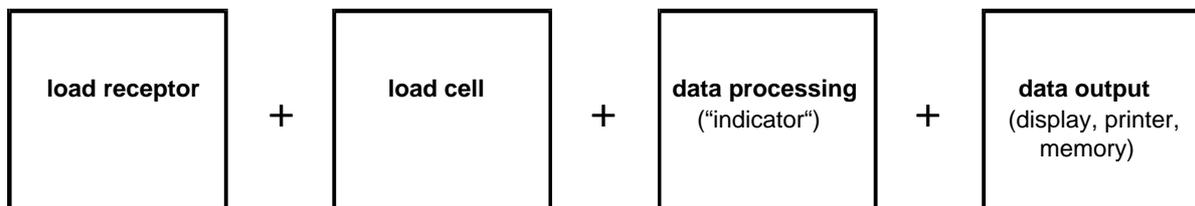
R51 Automatic catchweighing instruments (Max up to 50 kg only dynamic tests without reference to R60, above 50 kg static tests according to R60)

R61 Automatic gravimetric filling instruments

R106 Automatic rail-weighbridges

R107 Discontinuous totalizing automatic weighing instruments (totalizing hopper weighers)

The classic separation into modules of a non automatic weighing instrument (NAWI) is shown in Figure 1.



**Figure 1.** Classic NAWI module concept

The following table gives an overview of the mainly used principles and the certified accuracies, the estimated numbers of the yearly produced lot and the number of the different designs [3].

Table1 confirms the dominance of strain gauge load cells, especially for modular construction of weighing instruments under legal control. The following figures show series of load cells which are of the same construction and therefore belong to the same load cell family ( terms defined in Chapter 3).

**Table 1.** Principles of load cells, their importance and properties

| LC Principle                                                                      | Strain gauge                       | EFC <sup>1)</sup>                                            | vibrating wire             | tuning fork                 |
|-----------------------------------------------------------------------------------|------------------------------------|--------------------------------------------------------------|----------------------------|-----------------------------|
| accuracy class & $n_{LC}$<br>(linearity, hysteresis, temperature effects on span) | A -<br>B 15 000<br>C 3 000 → 6 000 | 6 000 000 <sup>2)</sup><br>A 300 000<br>B 50 000<br>C 10 000 | A -<br>B 10 000<br>C 6 000 | A -<br>B 20 000<br>C 10 000 |
| creep $Z \geq n_{LC}$                                                             | 3 000 → 15 000                     | $n_{LC}$                                                     | 20 000                     | 20 000                      |
| number of produced load cells per year <sup>3)</sup>                              | >1 000 000                         | >100 000                                                     | >20 000                    | >2 000                      |
| number of designs <sup>3)</sup>                                                   | 10 000                             | 500                                                          | 50                         | 10                          |
| module capacities                                                                 | 0,5 kg – 1000 kg                   | 0,5 g – 1000 g                                               | 0,5 kg – 5 kg              | 100 g - 500 g               |
| application                                                                       | traded as load cell                | traded as scale or weighing module                           |                            |                             |
| loading principle                                                                 | compression, tension, beam         | suspended platform – hanging platform                        |                            |                             |

<sup>1)</sup> electromagnetic force compensation, <sup>2)</sup> used for mass comparator, outside of legal metrology <sup>3)</sup> estimated number  
(A,B,C accuracy classes,  $n_{LC}$  number of load cell intervals,  $E_{max}$  capacity, Y factor for smallest interval, Z factor for creep)



**Figure 2.** Compression strain gauge load cell family type RTN.. (Schenck)  
 $E_{max}$ : 1 t - 470 t,  $n_{LC}$  = 5000, Y = 24 000, Z = 7500



a)



b)

**Figure 3.** Compression strain gauge load cell families (Revere Transducers Europe)

a) Family CSP-M,  $E_{max}$ : 5t – 100t

b) opened junction box of improved digital type family SCC,  $E_{max}$ : 10 t – 100 t,  $n_{LC}$  = 4000, Y = 20 000

## 2 TESTS FOR CERTIFICATION OF ONE LOAD CELL TYPE

According to OIML R60 (1999) the following tests have to be performed for certification of new load cell types:

- R60-A.4.1 load cell error  
testing at increasing and decreasing load at least 7 steps in each loading direction at the temperatures 20°C / 40°C / -10°C / 20°C  
evaluation of accuracy: linearity, hysteresis, repeatability and variation of span and zero (MDLO) output
- R60-A.4.2 & 3 creep error and dead load output return (DR)  
measuring by keep load over 30 minutes and afterwards unloading both in a specified time for change of load according to Table 6 of R60 at the temperatures 20°C / 40°C / -10°C / 20°C
- R60-A.4.4 barometric pressure effects
- R60-A.4.5 or 6 humidity effects (part of the long time stability check, 4.5 cyclic humidity treatment or 4.6 static humidity treatment)
- R60-A.4.7 ... additional tests for load cells equipped with electronics (immunity from disturbance or noise and long time stability)
- R60-A.4.7.2 warm-up time
- R60-A.4.7.3 power voltage variations
- R60-A.4.7.4 short time power reductions
- R60-A.4.7.5 bursts (electrical fast transients)
- R60-A.4.7.6 electrostatic discharge
- R60-A.4.7.7 electromagnetic susceptibility (electromagnetic fields 26 MHz – 1000 MHz)
- R60-A.4.7.8 span stability (long time stability)

## 3 TESTS FOR CERTIFICATION OF A LOAD CELL FAMILY

In practice test certificates are issued for a complete load cell series under **one** type name. A series may consist of several families which have to be considered separately. The additional tests according to R60-A.4.7.. for digital load cells shall be applied to one pattern of the family only.

### 3.1 Basical ideas for selecting of test samples

For the selection of test samples out of a LC family the following **definitions** for load cell family and group are presented.

#### *Load cell family*

For the purposes of type evaluation/approval, a load-cell family shall consist of load cells that are of

- the same material or combination of materials  
(for example, mild steel, stainless steel or aluminium);
- the same design of measurement technique  
(for example, strain gauges bonded to the metal and measuring shear forces);
- the same method of construction  
(for example, shape, sealing of strain gauges, mounting method, manufacturing method);
- the same set of specifications  
(for example, material stress and output rating, input impedance, supply voltage, cable details); and
- one or more groups each with the same performance specifications ( see below ).

#### *Load cell group*

All load cells possessing identical metrological characteristics (for example, class,  $n_{LC}$ , temperature rating, Y, Z, etc.) are considered to be a *group* within the family.

### 3.2 Selection of the test samples

- Load cells with the highest metrological quality (best group, data  $n_{LC}$ ,  $Y$ ,  $Z$  and temperature range) have to be tested. Load cells with lower classification of the same capacity are automatically included.
- Load cells with the smallest capacity of an accuracy group shall always be tested with all tests R60-A4.1 up to R60-A.4.6 (to spare time, tests A.4.4 to A.4.6 can be applied to a second pattern in parallel).
- Selection of next higher capacity LC to be tested
  - If the ratio of the largest capacity LC in the group to the last tested LC is greater than five (5), then another load cell shall be tested (but only tests R60-A.4.1 up to A.4.3).  
The choice of the next LC to be tested shall be such that the ratio of its capacity to the last LC capacity tested is smaller or equal to ten (10), and such that the total amount of load cells required is minimized.
  - If the ratio of the capacity of the next LC in the group to the capacity of the last tested load cell is greater than ten (10), then automatically, this next LC is required to be tested.

### 3.3 Example of a selection

Table 2 of the example is presented in test certificate for the load cell family type RTN, manufactured by Schenck.

To minimize the number of samples the error limits for a combination of the best characteristics ( $n_{LC} = 5000$ ,  $Z = 7500$ ,  $Y = 24000$ ) has been applied for the tests. The bold printed characteristics together with the bold printed capacities 1t, 10t and 100t cover all accuracies according the OIML-R60 recommendation. The abbreviation MI is chosen for applicability in multi-interval weighing.

**Table 2.** Example of selection of test samples (bold) out of a family to be certified

| Accuracy class                          |               | C3                                                                                                    | C4                                                                           | C5                                    | C3 MI 7,5 | C4 MI 7,5 |
|-----------------------------------------|---------------|-------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|---------------------------------------|-----------|-----------|
| Maximum number of load cell intervals   | $n_{LC}$      | 3000                                                                                                  | 4000                                                                         | <b>5000</b>                           | 3000      | 4000      |
| Maximum capacities                      | $E_{max}$     | 1 t / 2,2 t / 4,7 t / 10 t / 15 t / 22 t / 33 t / 47 t / 68 t / 100 t / 150 t / 220 t / 330 t / 470 t | <b>1 t / 2,2 t / 4,7 t / 10 t / 15 t / 22 t / 33 t / 47 t / 68 t / 100 t</b> |                                       |           |           |
| Minimum load cell verification interval | $v_{min}$ (Y) | $E_{max} / 20\ 000$                                                                                   |                                                                              | $E_{max} / \mathbf{24\ 000}$          |           |           |
| Minimum dead load output return         | $DR$ (Z)      | --                                                                                                    | --                                                                           | $\frac{1}{2} E_{max} / \mathbf{7500}$ |           |           |

A detailed example with more different accuracies and groups is printed in WELMEC 2.4 [2] or OIML R60, Annex B.

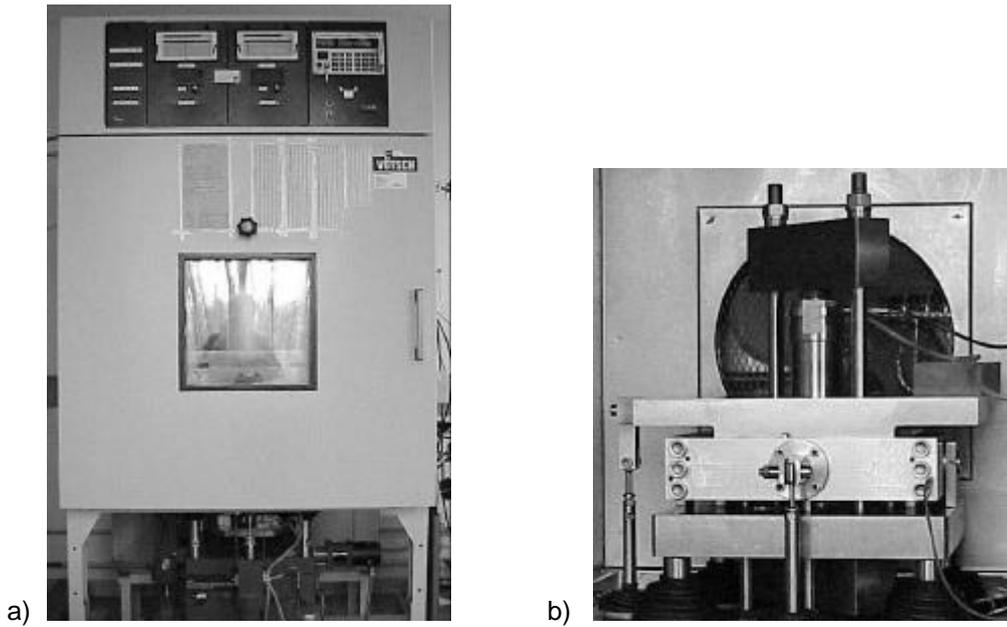
## 4 LOAD CELL TEST FACILITIES OF THE PTB

All load cell testings are done with dead weights or dead weight machines respectively.

- Small load cells up to 50 kg are loaded manually inside a climatic chamber.
- Load cells from 100 kg up to 5000 kg of compression, bending or tension typ are tested in the load cell test device shown in Figure 4.
- Load cells from 10 000 kg up to 100 000 kg are tested in the 1 MN force standard machine. Inside the compression part a temperature chamber will be placed, see Figure 5.

For humidity tests (cyclic-humidity) the climatic chambershown in Figure 6 is used.

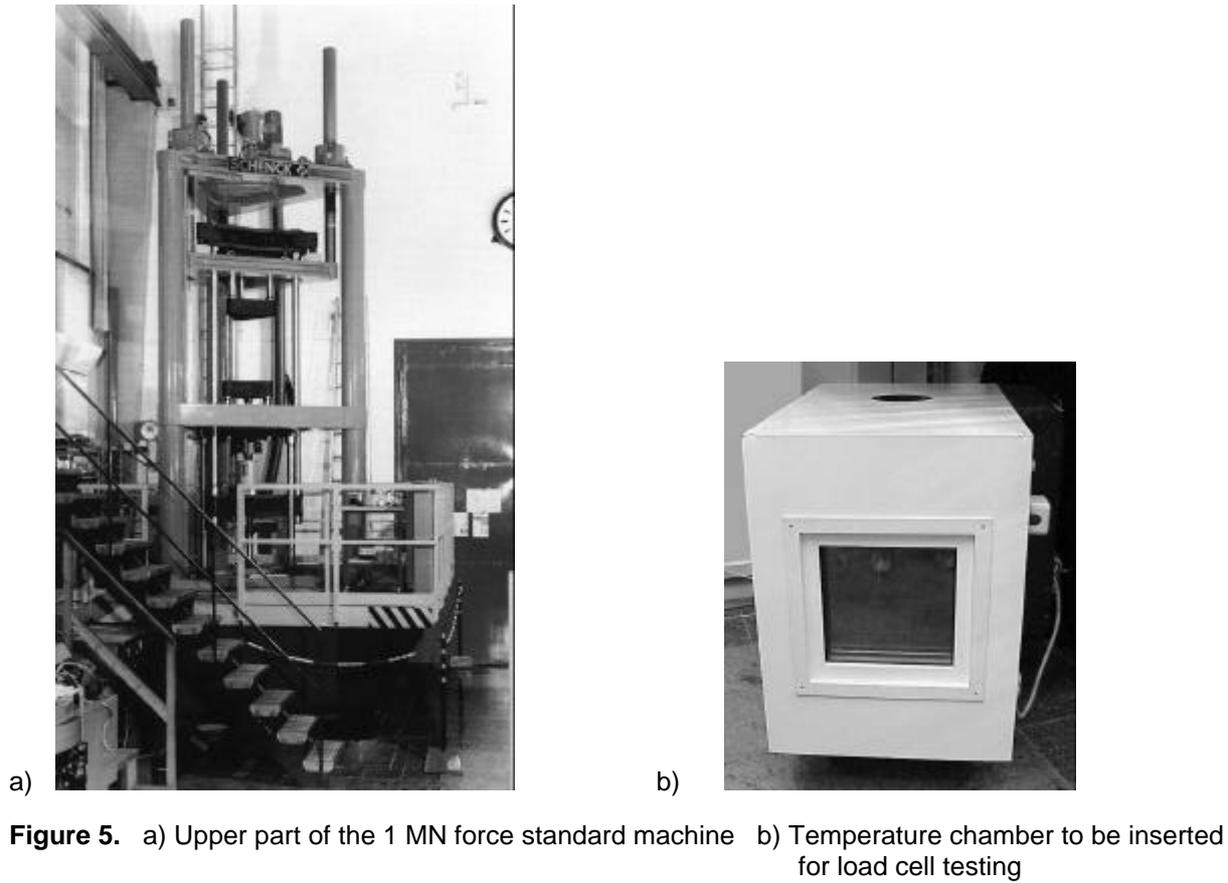
Electromagnetic interference tests for digital load cells are performed in a special anechoic chamber, see Figure 7.



**Figure 4.** Load cell test device for capacities 100 kg up to 5000 kg (upper part)  
a) climatic chamber ( top of the machine)    b) View of the baseplate with tilting facility



**Figure 4c.** Load cell test device 100 kg – 5000 kg (lower part)  
dead weight stacks of 400 kg, 800 kg, 2000 kg and 5000 kg

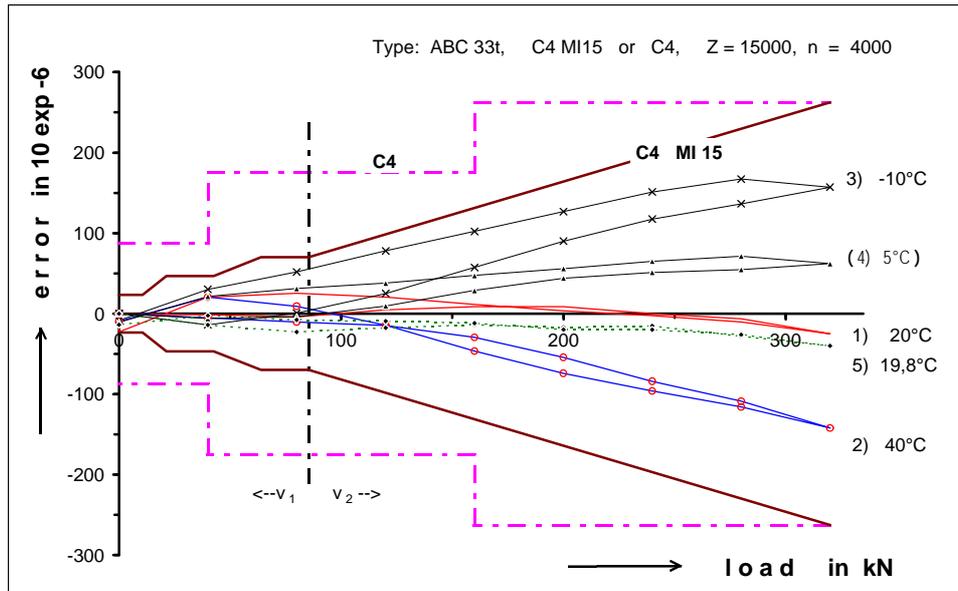


## 5 EXPERIENCES WITH CERTIFICATION OF LOAD CELLS

At the moment, load cell tests do not reflect sufficiently or pay attention to the following matters.

### 5.1 Error limits for multi-interval weighing modules

The error limits for a module load cell applied in multi-interval weighing has been presented in the poster session at the 16<sup>th</sup> international conference of IMEKO TC3 in September 1998 [4]. In 2000, the OIML TC9, working group R60, will discuss these ideas.



**Figure 8.** Error limits for a load cell class C4 and a multi-interval load cell C4 MI 15 applied on test results of a 33 t load cell

### 5.2 Tests for digital load cells according to R60-A.4.7

- Tests with electromagnetic fields (R60-A.4.7.7) on digital load cells of higher capacity are not applicable in **loaded condition** ( $E_{min}$ ) as described in the latest draft. Nevertheless a small dead load can become necessary in case that an automatic zero-tracking device can't be switched off.
- The error limit has to refer to  $Y$  ( $Y = E_{max}/V_{min}$ ) not to  $n_{LC}$ , because indicator testing uses the **smallest input voltage** corresponding to 1e of a weighing instrument.

### 5.3 Temperature gradient influence on load cells

Temperature gradients over time and over distance cause differences for comparison measurements and sometimes problems for application in mobile weighing instruments. This is particularly true for crane scales or fork lift scales working indoors and outdoors.

Temperature differences between mounting point and load introduction of the load cell during temperature testing should be recorded during the measurement. Load cells especially applicable in mobile weighing machines in quick changing temperature environments should be certified.

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