LOAD CELLS

# Type testing facilities for load cells in The Netherlands

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## 1 Introduction

NMi B.V. is the sole private enterprise laboratory in The Netherlands that carries out type testing in the field of legal metrology, and has been appointed as a "Notified Body" by the Dutch Government. Many OIML test certificates have been issued by NMi Certin, and the C-TM department (*Certin Type Approval Measuring Instruments*) has been active in type testing load cells since the late 1960's. Initially tests were based on national requirements, but since the publication of OIML R 60 *Metrological regulation for load cells* (1991), this Recommendation has been fully adopted. 95 out of the 173 OIML certificates for load cells have been issued by NMi Certin (as at March 15, 1999).

As a permanent member of OIML TC 9 *Instruments for measuring mass and density* (and also of the previous SP7-SR8) NMi was actively involved in the first drafts of OIML R 60 as well as in subsequent revisions.

NMi has laboratories in Delft and Dordrecht in the Western part of The Netherlands. The Type Approval Measuring Instruments department, where the load cells are tested, is located in Delft.

This article gives a brief tour of the load cell type-testing facilities, which mainly consist of:

- a 2.5/25 t dead weight/lever machine;
- a 550 kg dead weight machine;
- facilities (weights, load receptors, frames, etc.) to test smaller load cells manually;
- a hydraulic machine for minimum dead load output return test;
- a facility for barometric pressure tests;
- various temperature and climate test facilities;
- load cell indicators;
- thermometers, barometers, etc.

Several fully-automated tests are carried out and the technology used in processing is continuously updated (both dead weight machines are already on their third generation of control system).

All equipment (masses, thermometers, barometers, load cell indicators, etc.) is directly traceable to national standards, maintained by the National Standards Laboratory NMi VSL B.V., a sister company of NMi Certin B.V.

NMi facilities are also available to industry and to scientific laboratories for prototype testing, calibration, etc.

## 2 Facilities

All the mass standards and both the force generating machines are calibrated in kg (mass) rather than in newtons (force). If the equipment is used for calibration (in newtons), the acceleration of gravity and the effect of air buoyancy have to be taken into account.

### 2.1 Force generating facilities

#### *2.1.1 Facilities for small capacity load cells*

Load cells for small capacities (up to about 50 kg) are tested manually by mounting them onto (or under) a frame and the first load step is normally one of the load platforms. Platforms are available with calibrated masses of 0.5 kg, 1 kg, 2 kg, 5 kg and 10 kg; these platforms are adjusted within the tolerances of accuracy class $M_1$. A wide choice of standard weights is available in all accuracy classes.

For temperature tests, this setup can be mounted in the temperature chamber, described in 2.4 below.

#### *2.1.2 The 550 kg dead weight machine*

The NMi 550 kg dead weight machine mainly consists of built-in weights, a frame, a semi-fixed "table" and a

The 550 kg dead weight machine *(see 2.1.2)*

"cradle" in which the weights can be applied by means of electric motors, controlled by a computer.

The machine contains 110 weights of 5 kg each, made of stainless steel and adjusted to within $1 \times 10^{-5}$. As the masses are applied in pairs, the load increments can be any multiple of 10 kg.

The load cell is mounted between the table and the cradle in tension or compression.

The load is applied to the load cell via a loading pad for compression or an arrangement of rods, bearings, etc. for tension, depending on the type of load cell.

The construction of the machine might seem such that the mass of the cradle (ca. 70 kg) plus the loading pad, etc. would cause a relatively large dead load on the load cell. This dead load is, however, compensated by means of a lever situated at the top of the machine. This lever is provided with a counterweight that can be slid along it in order to adjust the pre-load. In practice, the system is always adjusted in such a way that there is a small constant pre-load (the specified minimum dead load) on the load cell.

It is clear that the lever has to be in the horizontal position before a reading is taken. This is achieved by a feedback system consisting of an extension to the lever with sensors, controlling a motor which drives four spindles which in turn move the semi-fixed point (the table) up or down until the lever is horizontal. Then the reading can be taken (after a pre-determined time interval).

The weights are always applied progressively and in pairs, starting with the lower ones. This ensures that the center of gravity is as low as possible and remains along the vertical axis of the machine.

The design of the machine provides for enough space above the table (for compression) as well as under it (for tension) for a temperature chamber, described in 2.4. The machine and the temperature generating system are both controlled by a computer in such a way that a complete temperature test can be performed without the need for operator supervision.

The operator can preset the following data:

- maximum load;
- size of the increments;
- time intervals;
- number of cycles;
- in the case of a temperature test: the temperatures and the time interval after a change in temperature;
- the "exercise" of the load cell.

If the maximum load is not a multiple of the chosen increment, then the last step is the smaller one, in order to complete the selected maximum load.

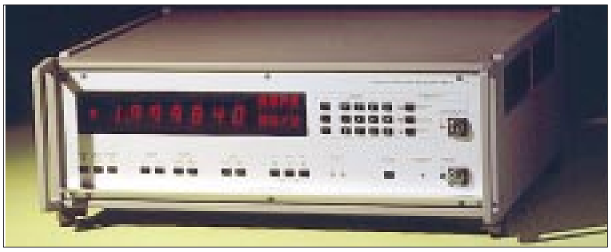
Furthermore, since the publication of OIML R 60 the machine has been provided with a double hydraulic ram which can lift or drop the cradle with the applied weights. This makes it possible to smoothly apply or remove the maximum (or any other) load and enables NMi to comply with the minimum dead load output return test as prescribed in subclause 7.2 of this Recommendation.

Without this facility, the time needed for the incremental application or removal of the masses and the leveling of the lever between the load steps would (especially in case of larger loads) by far exceed the time prescribed in OIML R 60, subclause 6.3.

### *2.1.3 The 2.5/25 t dead weight/lever machine*

The primary (dead weight) part of the 2.5/25 t machine is basically similar to the 550 kg machine, described in

The 2.5/25 t dead weight/lever machine *(see 2.1.3)*

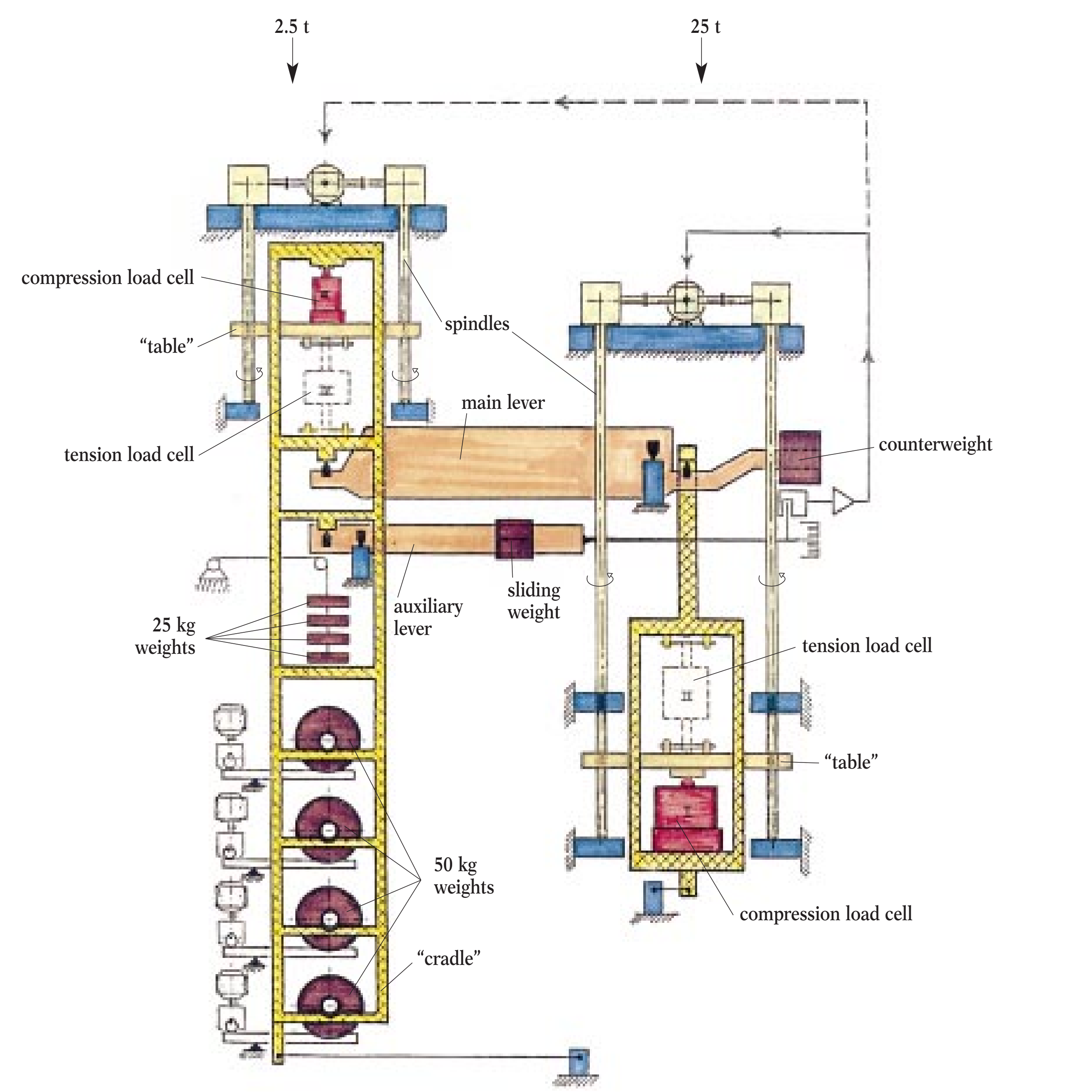


The HBM DMP 39 load cell indicator *(see 2.2)*

2.1.2 above. This machine contains 48 weights of 50 kg each plus four weights of 25 kg made of mild steel and protected with a special non-evaporating black varnish.

The weights are adjusted to within $1 \times 10^{-5}$. As the masses of 50 kg are applied in pairs and those of 25 kg individually, the load increments can be any multiple of 25 kg for the 2.5 t side and of 250 kg for the 25 t side. This machine also has a lever system, but in this case the lever does more than merely compensate the unwanted dead load on the load cell under test. The lever has a ratio of 10:1 and this allows for the possibility to generate loads up to 25 t in the secondary part of the machine. In this case, the lever reverses the direction of the load.

The design of the machine is such that on the 2.5 t side there is sufficient space at both load cell positions (compression and tension) to place a temperature cham-




Schematic diagram of the 2.5/25 t dead weight/lever machine *(see 2.1.3 and photo, bottom of page 6)*


The 25 t press *(see 2.3.3)* with cubic temperature chamber *(see 2.4)*

ber around the load cell under test. This is also the case at the position for a compression type of load cell on the high capacity side of the machine.

The leveling system is provided with an auxiliary lever which amplifies the deflection of the main lever by a factor of 8. This leveling system is an important contribution to the specified accuracy which was confirmed by international intercomparisons.

The auxiliary lever has a sliding weight which enables the application of a defined dead load of up to 60 kg in the primary part, and hence 600 kg on the secondary part.

Due to the working principle of the machine (applying the weights and subsequently leveling) the total application of larger loads is somewhat slow. To give an extreme figure, it can take up to 2.5 minutes to apply 25 t on a load cell (included leveling). This is far slower than the time prescribed in OIML R 60, subclause 6.3.

The operation of the computer-based control panel of this machine is very similar to the 550 kg machine described above, including the interface to the temperature generating system.

## 2.2 Load cell indicators

For the tests according to OIML R 60, NMi Certin uses type DMP 39 load cell indicators, manufactured by the German company HBM.

Since it was introduced in the late 1980's, this type of instrument is very common in the field of testing load cells. The DMP 39 is widely used by many sister-organizations as well as by manufacturers of load cells. It is an AC-system: the supply voltage for the load cells can be selected in steps of 1 V from 1 V to 15 V, 225 Hz. The input impedance of the instrument is > 100 MΩ and the input impedance of the load cell(s) connected can vary from 40 Ω to 3000 Ω (depending on the supply voltage). The resolution is 1.000.000 digits (it is possible to select lower resolutions) with an input (i.e. the output signal of the load cells) ranging from 2.5 mV/V to 250 mV/V. The linearity is specified to be within 0.0004 % of the span. The previously used “Servo Balans” DC indicator is still available, though in practice that instrument is nowadays only used on rare occasions for special projects.

## 2.3 Facilities for zero return tests

### *2.3.1 Small capacity load cells*

Small capacity load cells (max < 50 kg) are tested manually. For these capacities the minimum dead load output return test, the creep test and the temperature test are normally combined.

### *2.3.2 550 kg dead weight machine*

The 550 kg dead weight machine is provided with a double hydraulic ram which can lift or drop the cradle with the applied weights. This makes it possible to apply or remove the maximum (or any other) load smoothly and enables NMi to comply with the minimum dead load output return test as prescribed in subclause 7.2 of OIML R 60. Without this facility, the time needed for the incremental application or removal of the masses and the leveling of the lever between the load steps would (especially in the case of larger loads) by far exceed the time prescribed in OIML R 60, subclause 6.3.

### *2.3.3 25 t press*

As it is impossible to carry out suitable creep or zero return tests on the 2.5/25 t machine and a modification for this purpose was not possible at a reasonable cost, a simple hydraulic workshop press has been modified. However as the load is neither exactly defined nor entirely stable, this press is not suitable for a creep test though it does perform very well for the zero return test, allowing NMi to apply and remove a load in accordance with OIML R 60.

Within the frame, there is enough room to mount the same temperature chambers used in the force generating machines; hence it is possible to perform the zero return test at temperatures in the entire range from – 10 °C to + 40 °C. This facility has been designed to supplement the 25 t machine, so the press can achieve the same maximum load (25 t in compression).

The cylindrical temperature chamber *(see 2.4)*

## 2.4 Facilities for temperature tests

For temperature tests in either of the two force standard machines or for zero return tests under temperature-controlled conditions in the hydraulic press, two cylindrical and two cubic temperature chambers are available. The basic design of all these chambers is the same: a metal chamber is lined with a layer of polyurethane foam, within which runs a coiled copper pipe. This pipe is connected by a flexible and thermally insulated tube with a Cryostat, which cools or heats the circulating antifreeze liquid.

An important precaution to prevent thermal gradients is the thermally insulated floor of the chamber as well as the thermal insulation in the loading pad. The insulating material is “Celoron” (Novotext-ferrozell) which is a cloth-reinforced resin; this combines good thermal insulation with high resistance against compression forces.

Both cylindrical chambers have a divisible lid with a hole for the loading pad. The cubic ones have a door in the front, which allows far better access to the load cell under test and the auxiliary equipment in the temperature chamber.

There are three water-cooled cryostats, located outside the laboratory. One is connected to the 550 kg machine, the second is used for the 2.5/25 t machine and the third for the hydraulic press.

A permanent system of thermally insulated pipes and valves makes it easy to switch cryostats in case one of them ceases to function.

The relation between the temperature of the liquid and the final air temperature in the chamber has been established empirically: air temperatures of – 10 °C and + 40 °C require the liquid to be about – 20 °C and + 50 °C respectively. The exact values mainly depend on the chamber in use and on the length of the tube.

## 2.5 Facilities for humidity tests

Among other facilities, the Type Approval Measuring Instruments department has several fully-programmable climate chambers. Temperature (– 20 °C/+ 100 °C) as well as humidity (20 %/98 % relative humidity at temperatures from + 5 °C to + 95 °C) are controlled by microprocessor. NMi uses these chambers, among others, for humidity tests on non-hermetically sealed load cells as prescribed in IEC 68-2-30 (test Db: 6 cycles + 25 °C/+ 40 °C at 95 % humidity). It is also very suitable for tests on the temperature behavior of unloaded load cells.

## 2.6 Facility for barometric pressure test

The simple prototype of the facility to test the influence of changes in barometric pressure on the zero output of load cells consisted of just a plastic washing-up bowl, a bucket, a flowerpot and two tubes. After this prototype had successfully been used for some time, the more convenient setup shown below was constructed.

The pressure in the chamber can easily be increased by a small hand-pump or by adding a small amount of water in the outer bowl.

The barometric pressure chamber *(see 2.6)*

## 3 Data processing

In order to standardize the processing of test data, NMi Certin developed MEAS R 60 (Measurement Administration System). This program is based on a spreadsheet program using Quattro Pro 5.0.

NMi operates with a LAN network by which the DMP 39 load cell indicator is connected to a laptop computer. When all the tests have been completed, the various calculations are performed automatically and the project engineer can print the OIML test report from his or her office.

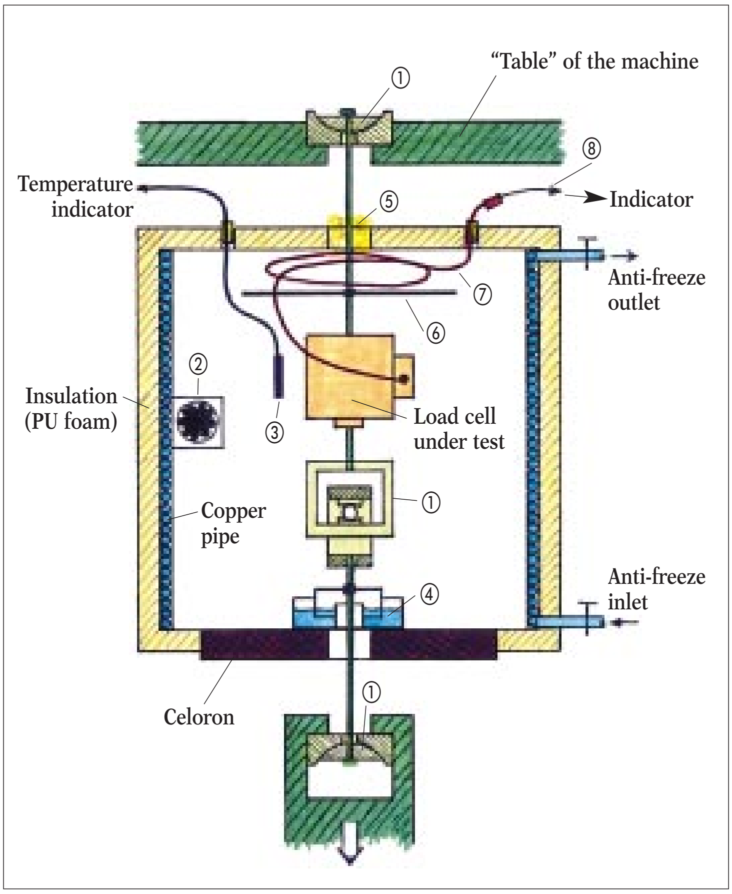
## 4 OIML R 60 and the NMi Certin B.V. test facilities

The facilities described in this paper allow NMi Certin B.V. to carry out all the tests on load cells up to 25 t that are prescribed in OIML R 60. For larger capacity load cells, in many cases it is possible to also carry out the tests in cooperation with laboratories of sister organizations.

## 5 Precautions during temperature tests

A typical example of a tension type load cell temperature test in the cubic temperature chamber is illustrated below.

In this setup, the load cell is mounted between bearings (1) to prevent side-loads. The 220 V fan (2) runs at 110 V in order to keep the dissipation low as well as to minimize unwanted forces due to the "wind" caused by the fan. The ambient temperature is measured (3) rather than the temperature of the load cell under test itself, as it is obvious that it is the environmental temperature that is relevant. The feed-through of the lower tension rod is a glycol-filled labyrinth (4) which prevents cold air from "falling" out of the gap. This cold air might not only cause a temperature gradient to occur, but can also lead to the risk of a layer of ice building up at temperatures in the chamber below zero.




**Tension type load cell temperature test in the cubic temperature chamber**
*(schematic representation; numbers refer to paragraph 5)*

The gap (5) in the top is simply closed with tissue paper as the influence of side forces at this spot is negligible. To prevent a temperature gradient caused by heat conduction through the upper tension rod, there is an aluminium or copper disk (6) which acts as a heat-sink to ensure that the rod is at ambient temperature. The cable (7) of the load cell (usually a four-wire system) is in the temperature chamber, and only a few centimeters and the plug to the extension cable (8) are located on the outside. This extension cable to the indicator is a six-wire system. The bottom of the chamber is made of Celoron for the test of compression-type load cells.

## 6 Not only type testing

The formal owner of the majority of the hardware described in this paper (including both the force generating machines) is NMi VSL B.V. (Van Swinden Laboratorium), the National Measurement Institute of The Netherlands. This is a sister-company of NMi Certin B.V., located in the same premises, so it is clear that traceability is ensured directly to the national standards of The Netherlands.

The Mechanics Department of NMi VSL B.V. carries out calibration of load cells and complete force measuring equipment, among others.

If, in case of force measuring machines, calibration has to be carried out in "round" newton values, this is achieved by applying additional weights manually.

These calibrations and other related tests are carried out commercially for various customers, for example scientific organizations, test laboratories, R&D departments of load cell manufacturers, etc.

For loads exceeding the capacity of the 250 kN machine, calibrations can be carried out up to 5 MN with a relative uncertainty ranging from $2.10^{-4}$ to $5.10^{-4}$ by means of transfer standards.

Incidentally, a related facility is the calibration facility for torque transducers - a topical subject due for the most part to changes in legislation concerning the maximum power transferred by the shaft to the propeller of fishing vessels. For this purpose, which also falls under the umbrella of legal metrology, a unique facility is available in The Netherlands for torques up to 400 kN·m.

At the moment, this equipment is just being transferred from Delft Technical University to NMi VSL B.V.

In this torque-generating machine, the torque is generated hydraulically and measured from 3.2 kN·m up to 32 kN·m with weights of 2 kN each and from 32 kN·m to 400 kN·m by means of force transducers connected to two arms of known length. The ranges of the transducers are +/– 100 kN·m and +/– 400 kN·m. For each range one pair of transducers is available.

The relative uncertainty of this facility is $2.10^{-3}$ in normal mode with the force transducers and $5.10^{-4}$ with the weights.

## References


| | |
|---|---|
| OIML R 60 (1991) | Metrological regulation for load cells* |
| EN 10.002-2 (1991) | Metallic materials - Tensile testing - Part 2: Verification of the force measuring system of the tensile testing machines |
| EN 10.002-3 (1994) | Metallic materials - Tensile test. Part 3: Calibration of force proving instruments used for the verification of uniaxial testing machines |


*Note: At the time of drafting this paper, R 60 (1991) is under revision. The new draft of R 60 has been approved by the members of OIML TC 9 and this version will be presented for approval by the CIML at its 34th Meeting in October 1999 (Tunis).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