Load Cell Approval Field and Laboratory Evaluation Manual

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In 2011 Measurement Canada began phasing in requirements for using approved load cells in selected Heavy Capacity Devices. The affected devices will have a note in the respective Notice of Approvals stating that the devices must be fitted with approved load cells to be considered Legal For Use in Trade.

Measurement Canada will not approve load cells separately, but rather will recognize the approvals from NTEP and OIML. *Approved load cells* are considered to be load cells covered by a *US NTEP* ***Certificate of Conformance*** (CoC) or an *OIML MAA* ***Certificate of Conformity***. In the case of the OIML Certificate of Conformity, it must have been issued under the Mutual Acceptance Arrangement (MAA). This can be confirmed by the presence of the stylized MAA logo on the certificate.

In addition to being approved, load cells must be used in accordance with the manufacturer specified and approved parameters. This means that the weighing system must be properly configured and the selected load cell must be appropriate for the configuration.

In order to facilitate understanding of the parameters and how to evaluate a load cell for a given weighing system, Measurement Canada has prepared this document. The calculations and explanations below should help the reader to select an appropriate load cell for their weighing system. Measurement Canada has prepared a *Load Cell Compatibility Worksheet* which will facilitate evaluation of the load cell. This worksheet is available in an automated Microsoft Excel® format or in a manual paper version from Measurement Canada.

1.0 Definitions

The following definitions will facilitate understanding of the calculations and may be useful to properly assess the suitability of a given load cell for an application.

Accuracy Class	- class of cells that are subject to the same accuracy requirements (OIML or NTEP)
C	- rated load cell output (mV) at excitation voltage (V)
CH	- *Condensating Humidity* tested load cell
DL	- actual dead load of the device
DR	- dead load output return
e (e_1, e_i)	- verification scale interval vsi (vsi for range/interval 1, vsi for range/interval i)
E_{max}	- maximum capacity of the load cell
E_{min}	- minimum dead load for the load cell
i	- variable indices indicator
IZSR	- initial zero Setting Range
Lim	- maximum safe working load for the load cell
Max (Max_1, Max_i)	- maximum capacity of the weighing device (range/interval 1, range/interval i)

Min	- minimum capacity of the weighing device
n (n_i)	- number of verification scale intervals (range/interval i)
n_{max}	- maximum number of verification scale intervals
n_{WI}	- maximum number of verification scale intervals of the weighing (instrument) element
n_{ind}	- maximum number of verification scale intervals for an indicator
n_{LC}	- maximum number of load cell verification intervals
N	- number of load cells in the weighing device
NH	- *Non Humidity* tested load cell
NUD	- non-uniform distribution (loading) correction
p, p_i	- apportioning factor of maximum permissible error (mpe).
p_{ind}, p_{LC}, p_{con}	- fraction of mpe for indicator, load cell and conducting (weighing/transfer) elements (if not otherwise stated by the applicant $P_{ind} = 0.7, P_{LC} = 0.5, P_{con} = 0.5$)
Q	- correction factor $Q = [(Max + DL + IZSR + NUD + T^{+})/Max]$
R	- reduction ratio of a load transmitting device (lever multiple)
SH	- *Static Temperature & Humidity* tested load cell
T (T^+, T^-)	- tare value (additive tare, subtractive tare)
T_{min}, T_{max}	- lower limit of temperature range, upper limit of temperature range ($-10°C$ *to* $40°C$)
$\triangle u_{min}$	- minimum input voltage per verification scale interval
U (U_{min}, U_{max})	- nominal voltage of power supply (minimum voltage, maximum voltage)
U_{exc}	- load cell excitation voltage
U_{min}	- minimum input voltage for indicator
U_{MRmin}	- measuring range minimum voltage for indicator
U_{MRmax}	- measuring range maximum voltage for indicator
v_{min}	- minimum load cell verification interval
Y	- ratio to minimum load cell verification interval: $Y = E_{max}/V_{min}$
Z	- ratio to minimum load cell dead load output return: $Z = E_{max}/(2 \times DR)$

2.0 Calculations & Compatibility

In order to ensure that an appropriate load cell is selected for a given device, the following checks must be completed. Items identified as mandatory must be addressed. Items identified as optional are recommended, but not required to be addressed. Completion of the *Load Cell Compatibility Worksheet* will facilitate selection of a suitable load cell.

2.1 Accuracy Classes (Mandatory)

The accuracy class(es) of the load cell(s) used must meet the requirements for the device as defined in NAWDS. For example, a Class III NAWDS device may use an OIML Class C or an NTEP Class III load cell. The table below identifies suitable load cell classes for each of the NAWDS device classes.

Corresponding Accuracy Classes

NAWDS device	OIML / R60 Load Cell	NTEP Load Cell
I	A	I
II	B	II
III	C	III
IIII	C, D	III, IIII
IIIHD	C	III, IIIL

2.2 Temperature Limits ($T_{min/max}$) (Mandatory)

If no value for the load cell is specified, then $T_{\min} = -10\,°C$ and $T_{\max} = 40\,°C$ may be assumed. The temperature range for the load cell must be equal to, or greater than, the approved temperature range of the load receiving element (LRE).

2.3 Apportioning Factor - Fraction of the Maximum Permissible Error (p) (Mandatory)

In order to apportion the permissible errors amongst the major components of the device, an apportioning factor is used. The default values will be used unless the NOA allows for manufacturer specified values.

Indicating Element (IND)

If no value for the indicating element is indicated in the NOA for the indicating element, then $p_{ind} = 0.7$. The fraction may be stated within the range $0.3 \le p_{ind} \le 0.7$.

Load Cell (LC)

If no value for the load cell is indicated in the OIML or NTEP Certificate, then $p_{LC} = 0.5$. The fraction may be stated within the range $0.3 \le p_{LC} \le 0.7$.

Connecting Elements (CON)

The connecting elements include all elements other than the indicating element and the load cells. Typically, this is the load receiving or weighing element. If no value for the connecting elements is indicated in the NOA for the weighing or load receiving element, then $p_{con} = 0.5$. The fraction may be stated within the range $0.3 \le p_{con} \le 0.7$.

Note: if approved load cells are **not** required, then $p_{LC} = 0$ and $p_{con} = 0.7$.

Apportioning Factor for $LRE = p_{con}{}^2 + p_{LC}{}^2$

$$LRE = \left(p_{con}{}^2 + p_{LC}{}^2\right) = (0.5^2 + 0.5^2) = 0.50$$

e.g. $IND = p_{ind}{}^2 = 0.7^2 = 0.49$

$$Total = (0.50 + 0.49) = 0.99 \leq 1$$

In all cases, the fractions chosen must satisfy the equation $p_1{}^2 + p_2{}^2 + p_3{}^2 + \ldots p_i{}^2 \leq 1$ as per NAWDS 10.

If a manufacturer wishes to deviate from the default values, the new values must be expressed in the NOA/NOCA issued by Measurement Canada for the load receiving element and indicator as well as in the certificate for the chosen load cell(s).

2.4 Number of Verification Scale Intervals (n_{ind}) (Mandatory)

The number of actual configured verification scale intervals (n_i) must be less than or equal to the number of verification scale intervals (n_{ind}) that the indicating element was approved for.

$$n_{ind} \geq n$$
$$(n = Max/e)$$

For a multi-interval or multiple range device, this calculation must hold true for each of the weighing intervals (*i*) or ranges.

$$n_{ind} \geq n_i$$
$$(n_i = Max_i / e_i)$$

2.5 Maximum Capacity of the Load Cell (E_{max}) (Mandatory)

The maximum capacity of the load cell shall be sufficient for the weighing device configuration and shall satisfy the condition:

$$E_{\max} > Q \times Max \times \left(R/N\right)$$

Where:

E_{max} = the load cell capacity

Q = correction factor $Q = [(Max + DL + IZSR + NUD + T^+)/Max]$

Max = Maximum capacity of the weighing device

R = reduction ratio of lever system

$$reduction\ ratio = \frac{force\ on\ loadcell}{force\ on\ LRE} = \frac{1}{scale\ multiple}$$

Note: R=1 for direct mounting/no levers.

N = number of load cells in the system

NUD = an increase in load cell capacity to address non uniform distribution of the load on the LRE. NUD may be assumed for typical constructions of weighing devices when no other estimations are presented. NUD can be estimated from the following rules:

- Weighing device with lever work and one load cell, or with load receptors which allow only minimal eccentric load application (hopper or tank), or with one single point LC: 0% of Max
- other conventional Weighing Device: 20% of Max
- On-board weighing systems, over head track scales, etc: 50% of Max
- Multi-platform weighing device: 50% of Max

Specifying a value greater than zero for NUD will result in a larger load cell being required for the device. This increase in load cell capacity is to accommodate extra loading on a portion of the LRE that may otherwise damage the device. NUD is to be determined and specified by the manufacturer and may be equal to zero if appropriate.

2.6 Load Cell Parameters (Mandatory)

2.6.1 Minimum Dead Load of the Load Cell (E_{min}) (Mandatory)

The minimum load caused by the load receiving element (LRE) must equal or exceed the minimum acceptable dead load of a load cell (often quoted as a percentage of E_{max}; E_{min} may also be equal to zero in some cases):

$$E_{\min} \leq DL \times \left(R/N \right)$$

2.6.2 Maximum Number of Load Cell Intervals (n_{LC}) (Mandatory)

For each load cell the maximum number of load cell intervals, $n_{LC,}$ shall not be less than the number of verification scale intervals, n, of the device:

$$n_{LC} \geq n$$

On a multiple range or multi-interval device, this applies to any individual weighing range (i) or partial weighing range:

$$n_{LC} \geq n_i$$

On a multi-interval device, the minimum dead load output return, DR, shall satisfy the condition:

$$DR \times \left(E/E_{Max} \right) \leq 0.5 \times e_1 \times \left(R/N \right)$$

or

$$\left(DR/E_{\max} \right) \leq 0.5 \times \left(e_1/Max \right)$$

Where: $E = Max \times \left(R/N \right)$ is the partial loading of the load cell when loading the weighing or load receiving element with Max.

Acceptable Solution
Where DR is not known, then satisfying the following equation is acceptable

$$n_{LC} \geq Max/e_1$$

(preferred solution)

Furthermore on a multiple range instrument where the same load cell(s) is (are) used for more than one range, the minimum dead load output return, DR, of the load cell shall satisfy the condition

$$DR \times \left(E/E_{\max} \right) \leq e_1 \times \left(R/N \right)$$

or

$$\left(DR/E_{\max} \right) \leq \left(e_1/Max \right)$$

Acceptable Solution
Where DR is not known, then satisfying the following equation is acceptable

$$n_{LC} \geq 0.4 \times \left(Max_r/e_1 \right)$$

(preferred solution)

2.7 Minimum Load Cell Verification Interval (v_{min}) (Mandatory)

The minimum load verification interval, v_{min} , 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:

$$v_{\min} \leq e \times \left(R/\sqrt{N} \right)$$

Note: v_{min} is measured in units of mass. 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.

2.8 Electrical Data with Regard to the Weighing Instrument (Mandatory)

The actual load cell signal per verification scale interval, Δu, must be greater than the minimum input voltage per verification scale interval for the indicator (Δu_{min}).

The signal per verification scale interval, Δu, is calculated as follows:

$$\Delta u = \left(C / E_{\max} \right) \times U_{exc} \times \left(R / N \right) \times e$$

where;

C	(mV)	rated load cell output at maximum excitation voltage (U_{exc})
U_{exc}	(V)	load cell excitation voltage (actual nominal voltage used)
R		reduction ratio of a load transmitting device (lever multiple)
N		number of load cells used
Δu_{min}	(µV)	minimum input voltage per verification scale interval for the indicator
e		verification scale interval

for multiple range or multi-interval weighing device, $e = e_1$

2.9 Input resistance of a Load Cell (R_{LC}) (Optional)

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

$$R_{L\min} \leq \left(R_{LC} / N \right) \leq R_{L\max}$$

R_{Lmin}	(Ω)	minimum load cell impedance
R_{Lmax}	(Ω)	maximum load cell impedance
R_{LC}	(Ω)	actual load cell impedance
N		number of load cells

Note: R_{Lmin} and R_{Lmax} are the limits of the allowed impedance range for the electronic indicator for the actual applied load cell input impedance(s).

This information, if not specified in the Notice of Approval, shall be taken from the manufacturer's specifications for the device in use.

2.10 Connection Cable (Optional)

Additional cable between the indicator and an analog load cell or analog load cell junction box respectively is only allowed with indicators using fully implemented six wire systems (i.e. sense system).

If a Notice of Approval for a device specifies a value for the ratio of the cable length to the cross section of one wire (m/mm²), or specifies a maximum cable impedance, for a given material (copper, aluminum, etc.), this criteria must be considered when installing the system.

Load cell cables should never be cut to length.

Note: When using lightning barriers or intrinsically safe (IS) barriers for explosion-proof applications, the excitation voltage at the load cells should be checked, to prove conditions are met for the minimum input voltage per verification scale interval (Δu_{min}) of the indicator.

2.11 Markings (Mandatory)

For NAWDS devices, please refer to NAWDS, **Field Inspection Manual, STP-03 - Marking**.

For all other devices, please refer to the table below:

Required Load Cell Markings				
Item	Markings	NTEP / Pub 14	OIML / R60	**MC**
1	Manufacturer Name or Trademark	1 (G-S.1)	1	**1**
2	Manufacturer Model	1 (G-S.1)	1	**1**
3	Serial Number	1 (G-S.1)	1	**1**
4	Year of Manufacture	N/A	2	**3**
5	Certificate Number	1(G-S.1)	2	**2**
6	Accuracy Class OIML or NTEP	2	1	**2**
7	Temperature Limits (if other than -10 ˚C to 40 ˚C)	2	2	**2**
8	Number of Divisions (nMax)	2	2	**2**
9	Single/Multiple Cell designation	2	N/A	**N/A**
10	Direction of Loading (if not obvious)	2	2	**2**
11	Minimum Deadload (E_{min})	2	2	**2**
12	Load Cell Capacity (E_{max})	2	1	**2**
13	Load Cell Safe Limit (E_{lim})	2	2	**2**
14	Minimum Number of Verification Interval (V_{min})	2	2	**2**
15	Humidity Classification	N/A	2	**3**
16	Electrical Characteristics (mv/V, impedance, etc.)	N/A	2	**3**
17	Apportionment Factor (p_{LC})	N/A	2	**3**
18	Relative V_{min} = "Y"	N/A	3	**3**
19	Relative DR = "Z"	N/A	3	**3**

Applicable to strain gauge load cells only.

Digital cells will report number of counts at E_{max} for cell rated output (mv/V)

Key

1 - Required to be marked on Cell
2 - Required to be available (optional on cell or accompanying documentation)
3 - Optional Information
N/A - Not Applicable

Reference

G-S.1 US National Institute for Standards & Technology (NIST) Handbook 44, General Code, S.1
Pub 14 US National Type Evaluation Program (NTEP), Publication 14
R60 International Organization of Legal Metrology, OIML R60
MC Measurement Canada requirements

3.0 Revisions

Version 1.00c - January 2012

Corrected formula in section 2.7.

Version 1.00b - June 10, 2011

Table 2.1 revision.

Version 1.00 - January 1, 2011

Original version.