MULTI INTERVAL & MULTIPLE RANGE INSTRUMENTS

SCOPE

Section 4.12 of EN45.501 (OIML R76) requires that load cells have been tested in conformity with International Recommendation R60. These load cells can be applied in three groups of weighing instruments:

1) **Single interval instruments**
2) **Multiple range instruments**
3) **Multi-interval instruments**

This application note is meant to provide the user with a reasonably quick reference regarding the load cell requirements for Multiple Range (MR) and Multi-Interval (MI) systems. It also describes a standard system which is used by Revere Transducers to designate accuracy related parameters, such as Dead load Return (DR), to existing grades.
Key terminology and the requirements for single interval instruments, as well as a more traditional approach to MI and MR systems, are described in application note 09/4-10/01 "Legal Metrology".

1. ACCURACY DESIGNATION

Load cells are ranked, according to their overall performance capabilities, into differing accuracy classes or grades whose designations are "Class A", "Class B", "Class C" and "Class D". Each class corresponds, in terms of number of intervals which have been used during the pattern, to a specific grade of (non automatic) instruments according to the table below:

Class (R60) Load cell	Class (R76) System	Number of divisions
A	I	50,000 → unlimited
B	II	5000 → 100,000
C	III	500 → 10,000
D	IIII	100 → 1000

A load cell is coded by the alphabetical classification and the maximum number of load cell intervals (n_{max}) stated in units of 1000; for example C3 represents a Class C load cell which is certified for 3000 divisions.

Revere Transducers offers a wide range class C industrial load cells which are certified for 600 to 6000 divisions.

1.1 Utilisation

The smallest value of a quantity (mass) which may be applied to a load cell without exceeding the maximum permissible error is called the minimum verification interval (v_{min}). It is usually specified as follows:

$$v_{min} = E_{max} / Y$$

Where E_{max} represents the load cell rated capacity and 'Y' represents a certain value. The minimum verification interval is directly related to the load cell utilisation or minimum measuring range (MMR) and the load cell's temperature effect on minimum dead load output (T_{c0}) according to the formulas below:

$$MMR\,(kg) = v_{min} * n_{max}$$

$$MMR(\%) = n_{max} * 100 / Y$$

$$T_{c0}(\%S/5°C) = 0.7 * 100 / Y$$

Certain accuracy grades (A, B, C or D) identify an error envelope for the following parameters: linearity, hysteresis, temperature effect on span, creep and dead load return. Temperature effect on minimum dead load output is directly related to the minimum verification interval and is specified separately.
Multiple Range and Multi-interval systems, as well as systems with a high dead load compared to the measuring range, often require load cells with a small v_{min} in order to satisfy the requirements for the smallest scale division. These load cells are coded:

CxMRy

where x= n_{max}/1000 and y= Y/1000.

Alternatively, the following designation may be used:

Cx-Y

1.2 Dead load Return (DR)

Multi-interval and Multiple Range instruments require load cells with improved specifications on Minimum Dead Load Output Return (MDLOR). These requirements have resulted in load cells which have for example a C3 performance, while the performance for MDLOR equals 6000 divisions. Load cells with improved specifications on MDLOR are coded:

CxMIz

Where, z= Z/1000 and Z=Emax / (2 * DR)

Note: Recent documents have replaced MDLOR by Dead load Return (DR), a term which was already in use for weighing systems.

1.3 Examples

C3-10000:
A class C load cell which may be used in class III or IIII systems up to a maximum of 3000 divisions. The minimum verification interval equals E_{max}/10000. For a unit with a rated capacity of 1000kg, the following calculations can be made:

$$v_{min} = 1000 / 10000 = 0.1kg$$

$$MMR = v_{min} * n_{max} = 0.1*3000 = 300kg$$

$$MMR = n_{max}*100 / Y = 3000*100 / 10000 = 30\%$$

$$T_{c0} = 0.7*100 / Y = 70 / 10000 = 0.007\%S/5°C$$

C3MR20:
A class C load cell with a 3000 divisions performance and a minimum verification interval of E_{max}/20000.

C3MI6:
A class C load cell with a 3000 divisions performance for all parameters except for MDLOR or DR where the cell will have a 6000 divisions performance.

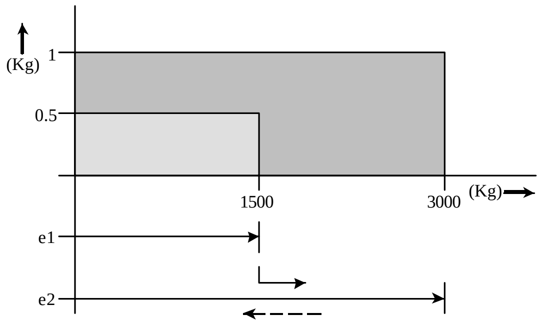
$$Z = z*1000 = 6*1000 = 6000$$

$$Z = \underline{E_{max}} /2*DR \Rightarrow DR = \underline{E_{max}} /2*Z = \underline{E_{max}} /12000$$

Note: Specifications for temperature effect on min. dead load output should be given separately in order to avoid confusion; i.e.: C3MI6, $v_{min} = E_{max}$/15000.

2.1 MULTIPLE RANGE SYSTEMS

Multiple range instruments have two or more weighing ranges with different maximum capacities and different scale intervals for the same load receptor, each range extending from zero to its maximum capacity.
On multiple range instruments, each range is treated basically as an instrument with one range. Switching while the instrument is loaded, from one weighing range to another is only allowed if the verification scale interval increases. Furthermore, it is not allowed to enter a lower range after a tare setting, or by using a preset tare value. An example of a multiple range instrument with two ranges is given in the diagram below:



Conditions for Multiple range instruments:
On a multiple range instrument the deviation on returning to zero from Max_i shall not exceed 0.5 e_i. Furthermore, after returning to zero from any load greater than Max_1 and immediately after switching to the lowest weighing range, the indication near zero shall not vary by more than e_1 during the following 5 minutes.
Zero setting in any weighing range shall be effective also in the greater weighing ranges, if switching to a greater weighing range is possible while the instrument is loaded.
The tare operation shall be effective also in the greater weighing ranges, if switching to a greater weighing range is possible while the instrument is loaded.
A preset tare value may only be transferred from one weighing range to another one with a larger verification scale interval but shall then be rounded to the latter.

The requirements for load cells are:

2.1 The maximum capacity shall satisfy the condition:

$$\underline{E_{max}} \geq Q*Max_r*R / N$$

Where:
E_{max} : maximum capacity of the load cell

Max_r : Maximum scale capacity (highest range)
N : Number of load cells
R : Reduction ratio
Q : Correction factor

The correction factor Q>1 considers the possible effects of eccentric loading, dead load of the load receptor (scale), initial zero setting range and non uniform distribution of the load.

Hence, the total capacity of all load cells should be larger or equal to the maximum capacity of the scale, the dead weight of the construction and the overall effect on zero-setting and zero-tracking devices. The overall effect of zero-setting and zero-tracking devices shall be not more than 4% and of the initial zero-setting device not more than 20%, of the maximum capacity. Further to this, the following eccentric loading conditions should be considered:

- On an instrument with a load receptor having n points of support, with $n \geq 4$, the fraction **1/(N-1)** of the sum of the maximum capacity and the maximum additive tare effect shall be applied to each point of support.
- On an instrument with a load receptor subject to minimal off-centre loading (e.g. tank, hopper) a test load corresponding to one-tenth of the sum of the maximum capacity and the maximum additive tare effect shall be applied to each point of support.

If the above considerations are applied on a platform scale with a capacity of 1500 kg and a dead load of 100kg, the individual load cell capacity can be calculated by:

Eccentricity behaviour tested with:
1/(N-1)*Max = 1/3*1500 = **500kg**.
Dead load weight distribution equals:
100/N = 100/4 = **25kg**.
Combined effect of zero-setting/tracking:
(24% of 1500)/N = 360/4 = **90kg.**
Hence, the load cell capacity (E_{max}) should at least be 500+25+90 = **615kg**.

2.2 The maximum number of load cell intervals shall satisfy the condition:

$$n_{lc} \geq n_i$$

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_i for range i (i=1,2, etc.), e.g. a 3000d class III weighing instrument should have class C3 load cells or better.

2.3 The minimum load cell verification interval shall satisfy the condition:

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

The minimum load cell verification interval v_{min} shall not be greater than the verification scale interval e_1 of the smallest range multiplied by the reduction ratio R of the load transmitting device and divided by the square root of the number N of load cells. This formula can be rewritten as:

$$e_1 \geq \frac{v_{min} * \sqrt{N}}{R}$$

Note: The reduction ratio R can be calculated by dividing the load acting on the total number of load cells by the load acting on the load receptor (scale). For non-lever scales R=1!

2.4 The minimum dead load output return of the load cell shall satisfy the condition:

$$\frac{Max_r}{e_1} \leq 2.5 * Z$$

The maximum capacity of the highest range, divided by the smallest scale interval shall be smaller or equal to 2.5 times the specified dead load return. *Where Z is not specified, it may be substituted by the number of load cell divisions n_{lc}:*

$$\frac{Max_r}{e_1} \leq 2.5 * n_{lc}$$

For example, a class III, 4 load cell, multiple range platform scale with a dead load of 200kg will have two ranges with the following specifications:

range 1 ($n_1 * e_1 = Max_1$): 3000*0.5=1500kg
range 2 ($n_2 * e_2 = Max_r$): 3000*1.0=3000kg

1) Load cell capacity:

The eccentricity performance will be tested with Max_r/(N-1) $\Rightarrow$ 3000/(4-1)=1000kg.
The dead load weight distribution over the cells equals 200/4 = 50kg
The combined effect of zero setting / tracking equals (24% of 3000)/N = 720/4 = 180kg
The minimum load cell capacity should be 1000+50+180 = 1230 kg. In order to allow for dynamic load effects and because of availability, load cells with a rated capacity of **2000kg** will be selected.

2) Load cell accuracy class:

A class III system requires the use of class C load cells while the maximum number of scale intervals should be smaller or equal to the maximum number of load cell verification intervals. The maximum number of scale intervals for any range is 3000. Hence, the required load cell accuracy grade is **C3**.

3) Minimum verification interval:

By applying the formula given at point 2.3, the minimum value for v_{min} can be calculated:

$$V_{min} \text{ £ } \frac{e_1 * R}{\text{Ö } N} \text{ Y } v_{min} \text{ £ } \frac{0.5}{2} \text{ Y } v_{min} \text{ £ } 0.25kg$$

The value for “Y”, with a selected rated load cell capacity of 2000kg can be calculated by:

$$V_{min} = \frac{E_{max}}{Y} \text{ Y } Y \text{ ³ } \frac{E_{max}}{v_{min}} \text{ Y } Y \text{ ³ } 8000$$

4) Dead load output return:

By applying the formula given at point 2.4, the dead load output return (DR) can be calculated:

$$\frac{Max_r}{e_1} \text{ £ } 2.5*Z \text{ Y } Z \text{ ³ } 0.4*\frac{Max_r}{e_1} \text{ Y}$$

$$Z \text{ ³ } \frac{60000}{10} \text{ Y } Z \text{ ³ } 6000$$

Alternatively, where Z is not specified it may be substituted by n_{lc}: $n_{lc} \geq 2400$.

Hence, the load cell specifications for this system are:

Rated capacity (Emax): *2000kg*
Accuracy grade: *C3*
Min. Verification interval: *Y³8000*
Dead load return (Z or n_{lc}): Z³2400

2.5 Output per scale interval

It is important to ensure compatibility by verifying the output per scale division with the required minimum signal level for the measuring device. The output per scale division (in mV) can be calculated by:

$$\frac{U_E * S * Max_1 * 1000}{N * E_{max} * n_{lc}}$$

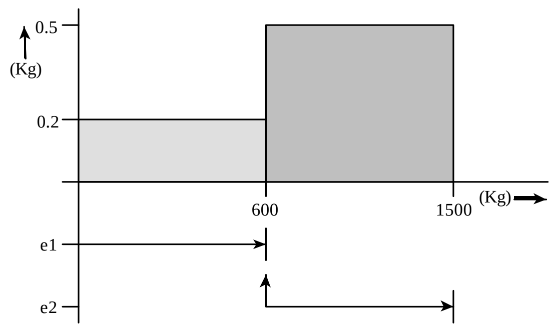
where:
U_E : Excitation voltage
S : Rated output load cell
Max_1 : Maximum capacity of the smallest range
N : Number of load cells
n_{lc} : Number of scale divisions

The output per verification scale interval, at an excitation voltage of 10V and a load cell rated output of 2mV/V, for the example above will be:

$$\frac{10*2*1500*1000}{4*2000*3000} = 1.25mV$$

3 MULTI-INTERVAL SYSTEMS

A multi-interval weighing instrument has one weighing range, which is divided into partial weighing ranges, each with different scale intervals. The weighing range is determined automatically according to the load applied, both on increasing and decreasing loads.
With its partial weighing ranges, a multi-interval instrument offers the end-user more flexibility than multiple range instruments. It is possible to enter a lower partial range after a tare setting or by using a preset tare-value. An example of a multi-interval



weighing instrument with two partial ranges is given in the diagram below:

Conditions for Multi-interval instruments:

On a multi-interval instrument, the deviation on returning to zero as soon as the indication has stabilised, after the removal of any load which has remained on the instrument for one half hour, shall not exceed 0.5 e_1.
The maximum preset tare value shall not be greater than Max_1 and the indicated or printed calculated net value shall be rounded to the scale interval of the instrument for the same net weight value.

The requirements for load cells are:

3.1 The maximum capacity shall satisfy the condition:

$$E_{max} \text{ ³ } \frac{Q*Max_r*R}{N}$$

3.2 The maximum number of load cell intervals shall satisfy the condition:

$$n_{lc} \text{ ³ } n_i$$

3.3 The minimum load cell verification interval shall satisfy the condition:

$$v_{min} \text{ £ } \frac{e_1 * R}{\text{Ö } N}$$

3.4 The minimum dead load output return of the

load cell shall satisfy the condition:

$$\frac{Max_r}{e_1} £ Z$$

The maximum capacity of the highest range, divided by the smallest scale interval shall be smaller or equal to the specified dead load return.

Example 1; a class III, 4 load cell, multi-interval platform scale with a dead load of 100kg will have two ranges with the following specifications:

range 1 ($n_1*e_1=Max_1$): 3000*0.2=600kg
range 2 ($n_2*e_2=Max_r$): 3000*0.5=1500kg

1) Load cell capacity:
The eccentricity performance will be tested with Max_r/(N-1) Y 1500/(4-1)=500kg.
The dead load weight distribution over the cells equals 100/4 = 25kg
The combined effect of zero setting / tracking equals (24% of 1500)/N = 720/4 = 90kg
The minimum load cell capacity should be 500+25+ 90 = 615 kg. In order to allow for dynamic load effects and because of availability, load cells with a rated capacity of **1000kg** will be selected.

2) Load cell accuracy class:
A class III system requires the use of class C load cells while the maximum number of scale intervals should be smaller or equal to the maximum number of load cell verification intervals. The maximum number of scale intervals for any range is 3000. Hence, the required load cell accuracy grade is **C3**.

3) Minimum verification interval:
By applying the formula given at point 3.3, the minimum value for v_{min} can be calculated:

$$v_{min} £ \frac{e_1*R}{Ö N} \text{ Y } v_{min} £ \frac{0.2}{2} \text{ Y } v_{min} £ 0.1kg$$

The value for “Y”, with a selected rated load cell capacity of 1000kg can be calculated by:

$$v_{min} = \frac{E_{max}}{Y} \text{ Y } Y ³ \frac{E_{max}}{v_{min}} \text{ Y } Y ³ 10000$$

4) Dead load output return:
By applying the formula given at point 3.4, the dead load output return (DR) can be calculated:

$$\frac{Max_r}{e_1} £ Z \text{ Y } Z ³ \frac{Max_r}{e_1}$$

$$Z ³ \frac{1500}{0.2} \text{ Y } Z ³ 7500$$

Hence, the load cell specifications for this system are:

Rated capacity (Emax):	*1000kg*
Accuracy grade:	*C3*
Min. Verification interval:	*Y³10000*
Dead load return (Z or n_{lc}): Z³7500	
Revere Transducers LC code:	***C3MI7.5***

5) Output per scale interval

The output per verification scale interval, at an excitation voltage of 10V and a load cell rated output of 2mV/V, for the example above will be:

$$\frac{10*2*600*1000}{4*1000*3000} = 1.0mV$$

Example 2; a class III multi-interval weighbridge, supported by 6 load cells and with a dead load of 12000kg, will have two ranges with the following specifications:

range 1 ($n_1*e_1=Max_1$): 3000*10=30000kg
range 2 ($n_2*e_2=Max_r$): 3000*20=60000kg

1) Load cell capacity:
The eccentricity performance will be tested with Max_r/(N-1) Y 60/(6-1)=12t. Note: some countries require corner evaluation with 1/3 of the maximum measuring range, regarding less of the number of load cells which are used to support the structure. For this example we will use a corner load of 15t.
The dead load weight distribution over the cells equals 12/6 = 2t
The combined effect of zero setting / tracking equals (24% of 60)/N = 14.4/6 = 2.4t
The minimum load cell capacity should be 15+2+2.4 ≈ 20t. In order to allow for dynamic load effects and because of availability, load cells with a rated capacity of **25t** will be selected.

2) Load cell accuracy class:
A class III system requires the use of class C load cells while the maximum number of scale intervals should be smaller or equal to the maximum number of load cell verification intervals. The maximum number of scale intervals for any range is 3000. Hence, the required load cell accuracy grade is **C3**.

3) Minimum verification interval:
By applying the formula given at point 3.3, the minimum value for v_{min} can be calculated:

$$v_{min} \text{ £ } \frac{e_1*R}{\text{Ö} N} \text{ Y } v_{min} \text{ £ } \frac{10*1}{2.45} \text{ Y } v_{min} \text{ £ } 4.1kg$$

The value for “Y”, with a selected rated load cell capacity of 25t can be calculated by:

$$v_{min} = \frac{E_{max}}{Y} \text{ Y } Y \text{ ³ } \frac{E_{max}}{v_{min}} \text{ Y } Y \text{ ³ } 6124$$

4) Dead load output return:

By applying the formula given at point 3.4, the dead load output return (DR) can be calculated:

$$\frac{Max_r}{e_1} \text{ £ } Z \text{ Y } Z \text{ ³ } \frac{Max_r}{e_1} \text{ Y}$$

$$Z \text{ ³ } \frac{60000}{10} \text{ Y } Z \text{ ³ } 6000$$

Hence, the load cell specifications for this system are:

Rated capacity (Emax):	*25t*
Accuracy grade:	*C3*
Min. Verification interval:	*Y³6124*
Dead load return (Z or n_{lc}):	*Z³6000*
Revere Transducers LC code:	***C3MI6***

5) Output per scale interval

The output per scale interval, with an excitation voltage of 10V and a load cell rated output of 2mV/V, for the example above will be:

$$\frac{10*2*30000*1000}{6*25000*3000} = 1.33mV$$

3.5 Error tolerance envelope

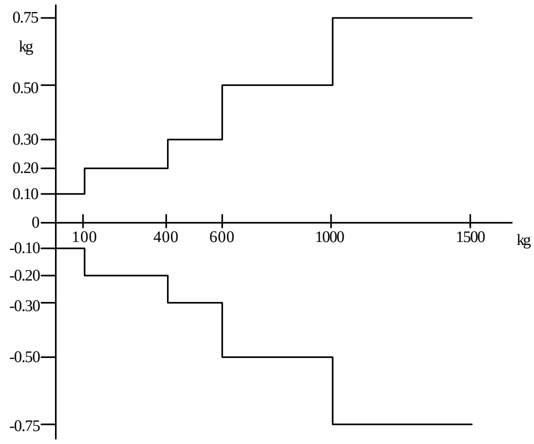
Multi-interval instruments have one error envelope which is based on the combined tolerances for the available ranges. The error envelope for the first example will be:

0 Y 500 e_1	max. error:	"0.5 e_1
500 Y 2000 e_1	max. error:	"1.0 e_1
2000 Y 3000 e_1	max. error:	"1.5 e_1
1200 Y 2000 e_2	max. error:	"1.0 e_2
2000 Y 3000 e_2	max. error:	"1.5 e_2

or in weight units:

0 Y 100 kg	max. error:	"0.10 kg
100 Y 400 kg	max. error:	"0.20 kg
400 Y 600 kg	max. error:	"0.30 kg
600 Y 1000 kg	max. error:	"0.50 kg
1000 Y 1500 kg	max. error:	"0.75 kg

Diagram error envelope:



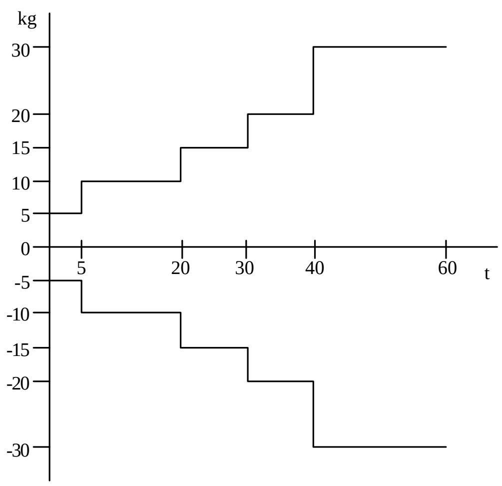
The error envelope for the second example will be:

0 Y 500 e_1	max. error:	"0.5 e_1
500 Y 2000 e_1	max. error:	"1.0 e_1
2000 Y 3000 e_1	max. error:	"1.5 e_1
1500 Y 2000 e_2	max. error:	"1.0 e_2
2000 Y 3000 e_2	max. error:	"1.5 e_2

or in weight units:

0 Y 5 t	max. error:	"5 kg
5 Y 20 t	max. error:	"10 kg
20 Y 30 t	max. error:	"15 kg
30 Y 40 t	max. error:	"20 kg
40 Y 60 t	max. error:	"30 kg

Diagram error envelope:



Note: MI-systems combine high accuracy with larger error limits at the end of the measuring range! This feature is extremely useful for systems with average mechanical integrity (i.e. mobile weighing systems, silos with force shunts, etc.).

4. SYSTEM OVERVIEW / LOAD CELL SELECTION

Range (e*n=Max) - kg	LC cap. (kg)[1]	n_{lc}	Y	μV/d[2]	Z (MR)[3]	Z (MI)	LC type[4]
0.02 * 3000 = 60 0.05 * 3000 = 150	100	3000	10000	1.00 2.50	3000	7500	SHBxR
0.05 * 3000 = 150 0.1 * 3000 = 300	200	3000	8000	1.25 2.50	2400	6000	SHBxR
0.1 * 3000 = 300 0.2 * 3000 = 600	500	3000	10000	1.00 2.00	2400	6000	SHBxR, HCB, RLC
0.2 * 3000 = 600 0.5 * 3000 = 1500	1000	3000	10000	1.00 2.50	3000	7500	RLC
0.5 * 3000 = 1500 1 * 3000 = 3000	2000	3000	8000	1.25 2.50	2400	6000	HCB, SSB, RLC
1 * 3000 = 3000 2 * 3000 = 6000	3500	3000	7000	1.43 2.86	2400	6000	RLC
1 * 3000 = 3000 2 * 3000 = 6000	5000	3000	10000	1.00 2.00	2400	6000	RLC, SSB
2 * 3000 = 6000 5 * 3000 = 15000	10000	3000	10000	1.00 2.50	3000	7500	RLC, SSB, CSP-M
5 * 3000 = 15000 10 * 3000 = 30000	25000	3000	10000	1.00 2.00	2400	6000	CSP-M
10 * 3000 = 30000 20 * 3000 = 60000	40000	3000	8000	1.25 2.50	2400	6000	CSP-M
20 * 3000 = 60000 50 * 2400 = 120000	60000	3000	6000	1.67 3.33	2400	6000	CSP-M

1) A dead load of approximately 20% of the measuring range has been used
2) At 10V excitation
3) Z may be substituted by n_{lc} when not specified in the certificate
4) These load cells are suitable for multi-interval (Z(MI)) applications. Considerably more load cells are suitable for multiple range applications (see table on the next page and RTE certificates).

Note: All configurations are based on 4 load cells.

5 LOAD CELL OVERVIEW

Revere Transducers offers a wide range of load cells which have improved specifications on temperature effect on minimum dead load output and/or dead load return. These load cells are particularly suitable for multi-interval, multiple range or systems with a high dead load compared to the measuring range. The table below provides a short overview:

LC type	E_{max}	n_{lc}	Y	Z
CSP-M	10Y60t	3000	12500	-
		3000	17500	-
		3000	12500	7500
		4000	12500	-
		4000	17500	-
SSB	0.5Y10t	3000	10000	-
		3000	20000	-
	2Y10t	3000	15000	8000
		4000	10000	-
		4000	20000	-
SHBxR	10Y500kg	3000	15000	-
		4000	15000	-
	100Y500kg	3000	15000	7500
ALC	0.25Y2t	3000	10000	-
		3000	20000	-
HCB	0.25Y2t	3000	10000	-
		3000	20000	-
		4000	13500	-
		4000	20000	-
		3000	15000	6000
	5t	3000	10000	-
		4000	12500	-
RLC	0.25Y10t	3000	10000	-
		3000	20000	-
	0.5Y5t	6000	15000	-
		6000	28000	-
	0.5Y10t	3000	10000	7500
		3000	20000	7500

Note: All load cells are certified according to OIML R60, accuracy class C. Please request a copy of the load cell certificate before final system configurations are made. A wide range of Astandard@ certificates is available for these and other load cells. Most certificates also include C1 and C2 accuracy grades.

For more information, application notes and load cell instructions for use, please contact:

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