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Certification of a High Capacity Force Machine for Testing of Load Cells According to OIML R60

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Abstract

Force Standards Machines are calibrated according to EN 10002 part 3 (ISO376) or PTB Standards, DKD or VGM [1,2,3]. Here, the absolute value of the force is of essential interest. For load cells, however, which shall be applied in weighing machines, the interest for the absolute force value is of second order, because weighing machines have to be adjusted and calibrated in the field. This procedure allows weighing machines to be adjusted with higher accuracy than force transducers can be calibrated. Basic ideas and results for the certification of a high capacity and high accuracy force machine used for testing of load cells are presented.

1. Introduction

In PTB load cells are tested as modules of weighing instruments for more than 25 years. Especially for testing of load cells of higher capacities with $E_{max} \geq 10t$ force standard machines are used. Normally each pattern tested in PTB is accompanied by test results of the manufacturer. This means that every measurement is a comparison between the respective load cell manufacturer and PTB.

Today it becomes more and more of economic interest to accept test results gained by the manufacturer. In this case certified test equipment will be required. For any acceptance at first the error schemes for load cells and force machines have to be considered.

2. Error Scheme

2.1. Load Cell Testing

Tests and error limits for load cells according to OIML R60, Issue 2000, are based on regulations for weighing instruments, OIML R76. [4,5,6]

In general an error envelope has to be met, this means a summarized evaluation of linearity, hysteresis and temperature behaviour of span in a temperature range of -10°C to

+40°C, hereby the first calibration at 20°C becomes reference for all other following tests. Watching traceability or absolute calibration is less necessary.

Also creep and zero return have to be tested in the complete temperature range of –10°C to +40°C.

Load cells in weighing instruments are installed permanently and normally applied with additional dead load, There is no direct request for any built in and out procedure, replacement or rotation in the regulations. The tests only are applied in one application position.

The evaluated error values for LCs are related to the maximum capacity and not to the actual load.

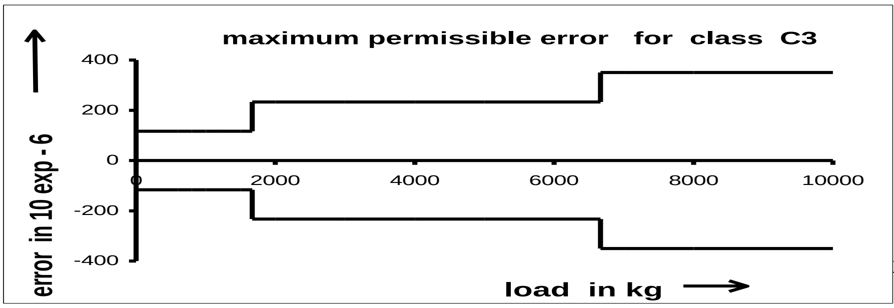

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Figure 1. Error envelope for LCs acc. to OIML R60 related on maximum capacity

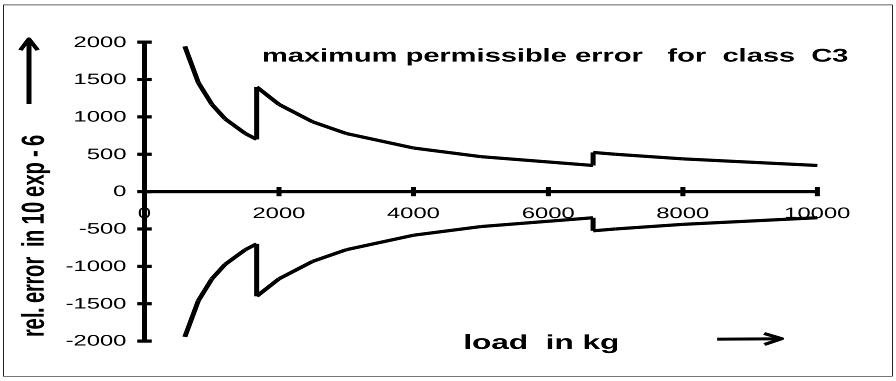


Figure 2. Error envelope for LCs with the same limits by referring to the actual load

- In weighing machines load cells of higher capacity normally are mechanically arranged in parallel to support a weighing platform.

- The final adjustment and calibration for the weighing purpose is made in place of service by using mass standards having their own uncertainty

2.2. Force Measurement

- The calibration of force transducers contains the absolute values. The indicated uncertainty is related to the actual force and not to the maximum capacity.

- Normally the linearity is of less interest.

- Calibration is not possible at the place of use.

The uncertainty budget contains errors of traceability, repeatability and reproducibility under constant temperature conditions.

3. Estimation of Errors

3.1. Requirements for LCs According to OIML R60

This chapter deals with the estimation of different effects that influence the accuracy of load cells. The load application is used for the following error limits:

A Error envelope according to R60 No 5.1.1

B Creep and minimum dead load return (DR) according to R60 No 5.3

C Span variation

C1 after treatment with cyclic damp heat test according to R60 No 5.5.3.1 and

C2 only for LCs equipped with electronics, span stability test according to R60 No 6.3.6.

During all the loading and temperature cycles the pattern is inserted into the test equipment for Test A and Test B and should not be built out off in the meantime. For the tests C1 and C2 the replacing effect here called reproduceability becomes of higher interest.

Table 1 presents error limits calculated out of the regulations of OIML R60. To meet the envelope condition for linearity, temperature effect on span and repeatability the maximum permissible error mpe is estimated. This estimation assumes an equal distribution for linearity, TC of span and repeatability. Other effects are described by the regulation OIML R6

Table 2 shows the calculated error limits for two common samples for linearity, temperature coefficient of span, repeatability, stability and reproduceability.

Table 1. Estimation of error fractions

LC tests acc. to OIML R60	*error envilope* No 5.1.1, *estimation for*			*DR / creep* No 5.3		*special span effects*	
						No 5.5.3.1	No 6.3.6 *)
	linearity	*TC span*	*repeatability*	DR	20-30min	*cycl.humidity*	*span stability*
mpe	**p_{LC}/ n**	**p_{LC}/ n**	**p_{LC}/ n**	**0,5 / Z**	**0,1575 / Z**	**1 / n**	**0,5 / n**
(notes)	at 0,5 * E_{max}	at E_{max}	at E_{max}		0,15*1,5*p_{LC} / Z		

*) only for LCs equipped with electronics

n, Z (DR), p_{LC} = metrological load cell parameters

Table 2. Examples of error limits in view to OIML R60

	error envilope			DR	creep (20-30)	cycl.humidity	span stability
Example 1							
p_{LC} = 0,7							
n = 3000	*linearity*	*TC span*	*repeatability*	*stability*		*reproduceability*	
Z = 3000							
mpe	**2,3E-04**	**2,3E-04**	**2,3E-04**	**1,7E-04**	**5,3E-05**	**3,3E-04**	**1,7E-04**
Example 2	error envilope			DR	creep (20-30)	cycl.humidity	span stability
p_{LC} = **0,7**							
n = **6000**	*linearity*	*TC span*	*repeatability*	*stability*		*reproduceability*	
Z = **12000**							
mpe	**1,2E-04**	**1,2E-04**	**1,2E-04**	**4,2E-05**	**1,3E-05**	**1,7E-04**	**8,3E-05**

Table 3. mpe requirements for loading device

	error envilope			DR	creep (20-30)	cycl.humidity	span stability
factor 1/3	*linearity*	*TC span*	*repeatability*	*stability*		*reproduceability*	
for example 1	*7,8E-05*	*7,8E-05*	*7,8E-05*	*5,6E-05*	*1,8E-05*	*1,1E-04*	*5,6E-05*
for example 2	**3,9E-05**	**3,9E-05**	**3,9E-05**	**1,4E-05**	**4,4E-06**	**5,6E-05**	**2,8E-05**

3.2. Requirements for Loading Device Test Equipment

Neglecting the errors of the indicator the minimum requirement for the uncertainty of a normal is 1/3 of the uncertainty of the client.

The very high requirement of reproduceability for span stability tests on load cells equipped with electronics will hardly be verified as memory effects like hysteresis and creep influences span measurement.

Please note following differences:

- Repeatability includes the random condition of no change in load introduction, even a constant dead load may be applied.

- Stability describes the "no variation" of force during the load application.

- Reproduceability means a built in and out procedure but with the very best possible rebuilt in.

4. Certification of a Dead Load Test Equipment

This chapter describes the very first investigations for certification of a 60 t dead load machine used for commercial purposes (production control) in view of application for load cell testing according to OIML R60. For this purpose both a DKD calibration as normally applied to force standard machines, and an OIML R60 test for comparison have been made.

Results of three load cells - own serial products of the manufacturer - are presented, the 60 t dead load machine of the manufacturer is in use round the clock so that either a recalibration nor an adjustment of the machine has been made for this investigation.

On side of PTB two dead load machines the 1 MN Force Standard and the 100 kN Force Standard machine have been applied.

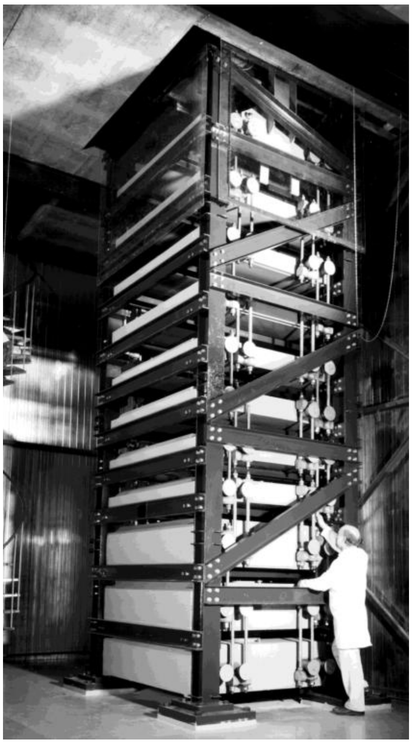
For evaluation of uncertainty of force and linearity a modified DKD (German calibration service) evaluation program was applied. The original program is in use on force calibration within DKD. Three load cells have been calibrated in the positions $0°$, $90°$, $180°$ and $270°$. The program calculates a function of equalization which allows the indication of the absolute counts and uncertainties related to the actual force.

The modifying of the program is the relation of the linearity onto the used measuring range and not on the actual load. The uncertainties presented in Table 4 are average values for loading between 40% and 100% of measuring range.

The presented uncertainties are based on rebuilt in effects under rotation round the load axis and will in case of the manufacturer machine not meet requirements of Table 3. The variation of linearity between measurements on manufacturer test equipment and PTB meets very well the requirements of Table 3.

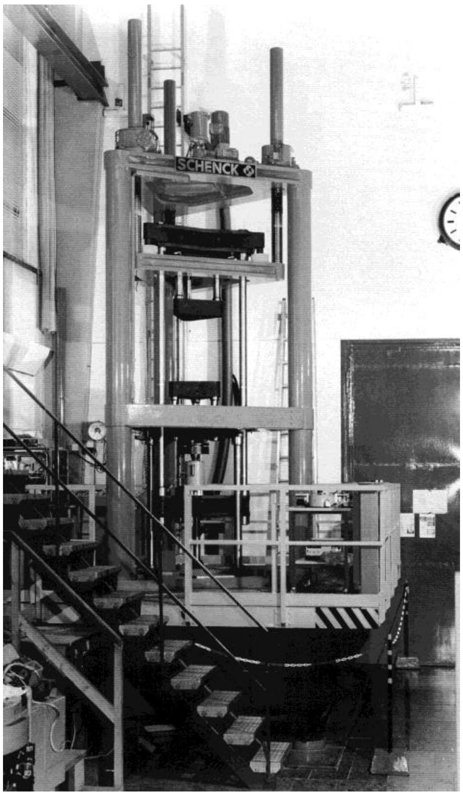
For better understanding of this constitution two comparison measurements according OIML R60 are presented. In Table 4 the over all test results are presented.

a)



b)

Figure 3. 60 t dead load machine of the manufacturer a) Head of the test machine, b) Mass stack



a)

b)

Figure 4. a) Upper part of 1 MN Force Standard of PTB, b) with inserted temperature chamber

Figure 5. Load cell of 4-Column type

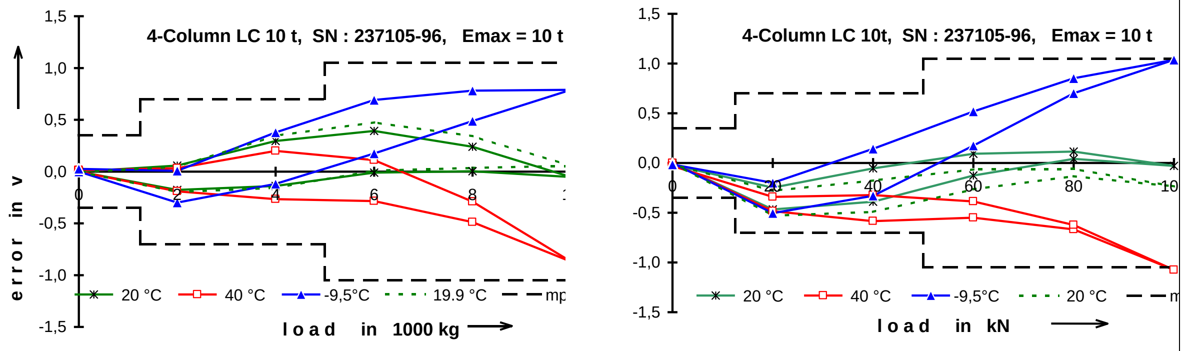
Figure 6. Load cell of Bending Ring type

Table 4. Calculated uncertainties for the certification of a 60t dead load machine

	reference measurement PTB	*repaeted measurement PTB*	*variation of span PTB*	*measurement on Place of Manufacturer*	*calculated accel. gravity test location*	*variation of linearity*
4-Column LC, 10t without dead load						
counts	8526508	8526666	1,9E-05	8363021	9,80817	5,6E-05
uncertainty	3,0E-05	3,5E-05		8,9E-05		
date	06.10.2000	03.11.2000		15.10.2000		
4-Column LC, 60t with 20kN (2t) dead load						
counts	7908476	7908063	-5,2E-05	7758793	9,81099	1,3E-05
uncertainty	3,0E-05	2,5E-05		1,4E-04		
date	04.10.2000	09.11.2000		13.10.2000		
Bending Ring LC, 60t with 20kN (2t) dead load						
counts	7881193	7881198	7,4E-07	7738236	9,81861	1,5E-05
uncertainty	3,7E-05	2,9E-05		6,3E-05		
date	10.10.2000	08.12.2000		14.10.2000		
adverage of calculated acceleration of gravity in Place of Manufacturer					9,81259	
rel. standard deviation						5,5E-04
acceleration of gravity at test location					9,81241	

5. Comparison of Load Cell Tests Acc. to OIML R60

A test report according to OIML R60 for one pattern contains at least 20 pages. To remain space only the test results showing load cell characteristics in a graphic are presented. Also the LC output signal of the unloaded LC in dependence of temperature, creep tests and others must be compared.



a) test results of manufacturer

b) test results of PTB

Figure 8. Load cell characteristic of a 4-Column **10 t** LC

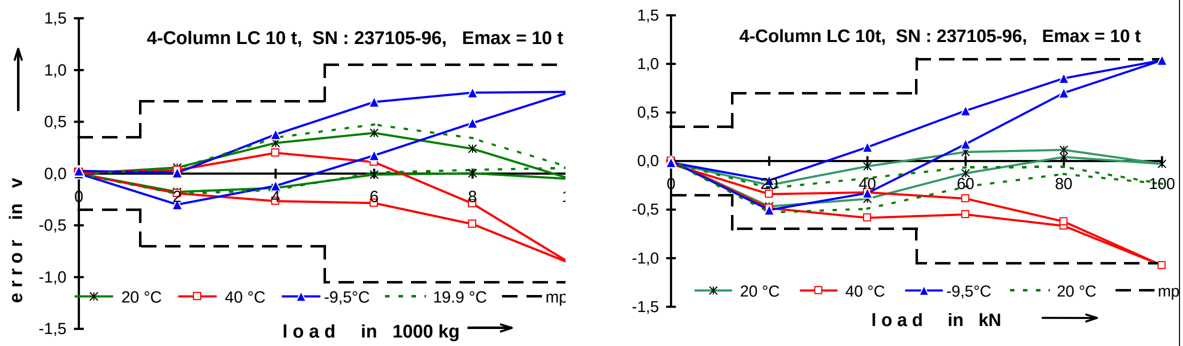
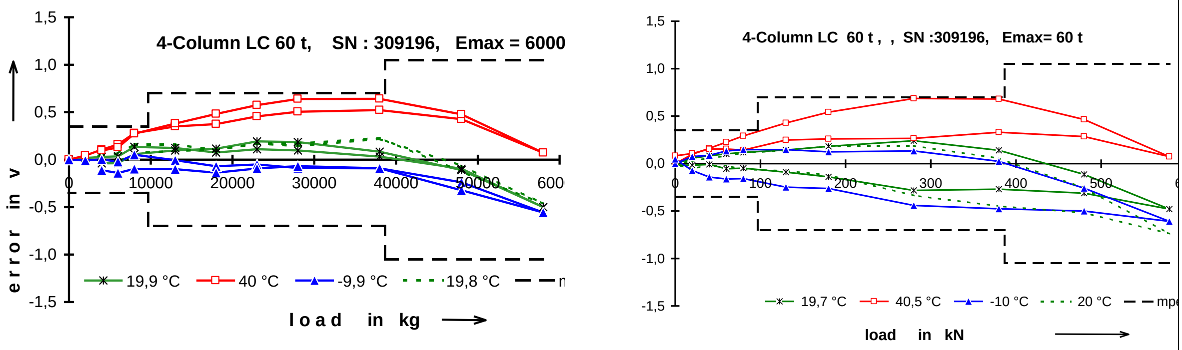


Figure 9. Load cell characteristic of a 4-Column **10 t** LC



b) test results of PTB

a) test results of manufacturer

Figure 10. Load cell characteristic of a 4-Column **60 t** LC

6. Conclusions and Aspects for Further Investigations

All effects of non reproduceability are combined reactions of variations caused by the test equipment and non uniform properties of transfer standards or tested patterns. During the measurements on the dead load test machines the tilting of the base plates caused by the loading has been checked. The over all tilting on PTB Standard Force machines was below 5 seconds. The tilting on the manufacturer test equipment was reproduceable, nonlinear and got maximal 100 seconds. Due to the cosinus function this value corresponds to a relative error of only 10^{-7} .

To separate in future tilting and displacing effects from effects of misadjusted mass stacks a more uniform sensor has to be chosen or at the end has to be developed. This is not only the interest of force measurement, it will be in the same order of interest for the application of load cells in weighing machines.

7. References

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