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INVESTIGATING TYPE EVALUATION OF WEIGHING INDICATORS BASED ON DIGITAL LOAD CELL SIMULATOR

Wenjun He[1], Kun Ma[2], Kai Zhang[3], Shucheng Wang[4], Ping Liu[5]

[1,2] Shandong Provincial Key Laboratory of Metrology and Measurement, Shandong Institute of Metrology, Jinan 250014, China
[1] hbhwj@163.com, [2] 18615188897@wo.cn
[3,4,5] Shandong Provincial Key Laboratory of Metrology and Measurement, Jinan 250014, China
[3] 527270637@qq.com, [4] 759877911@qq.com, [5] 17437140@qq.com

Abstract:
The paper describes the difference in the standards of measurement for weighing indicator. A digital load cell simulator with high resolution for type evaluation of weighing indicators was developed and its traceable calibration was also presented by DC voltage ratio method using a 7.5-digit multimeter with dual channel. The type evaluation method of weighing indicator was investigated and the performance test effect on the indication error was also discussed.

Keywords: weighing indicator; load cell simulator; type evaluation; traceable calibration

1. INTRODUCTION

Weighing indicator (WI) as the core part of the electronic weighing apparatus has been listed into the key management measuring instruments in China. The current National Standard (GB 7724-2008 electronic weighing meter) [1], Verification Regulation (JJG649-2016 Digital Weighing Indicators (Weighing Indicators)) [2] and Program of Pattern Evaluation (JJF 1624-2017 Digital Weighing Displays (Weighing Indicators)) [3] are implemented. These legal documents are technically minimal modifications to the International Recommendations OIML R76: 2006 [4] or its IDT (identical) Chinese National Standard GB/T 23111-2008 [5].

Type evaluation is an important legal metrological method to ensure high quality performance of WI. In the evaluation, load cell simulator (LCS) as a novel standard to measure WI is increasingly employed and investigated.

The main function of LCS is to simulate the output signals of various resistance strain load cell to test the electronic weighing meter and to realize the weights-less calibration of weighing instrument. It is particularly suitable to be used as the type evaluation test standard of WIs and the non-automatic or automatic weighing instrument under the circumstances that they are not convenient to be loaded or unloaded by weights or force standard machines.

In this paper, LCS traceable calibration was presented by voltage ratio method. Type evaluation of WIs was investigated by a digital load cell simulator (DLCS) standard. The indication error of WI for weighing performance testing and the effect of static temperatures were also studied.

2. PRINCIPLES OF TEST STANDARDS

Various methods with the corresponding test standards or standard devices such as standard voltage source, potentiometer, standard load cell and standard simulator can be used to measure WI. Comparison of the methods with different applicable conditions or advantages [6] is shown in Table 1.

Table 1: Comparison of several methods with different test standards or standard devices

Method Characteristics	Test standards or standard devices		
	voltage source / potentiometer	load cell	load cell simulator
Input loop	No	Yes	Yes
Monitoring indicator	Need	No need	No need
Standard force source	No	Yes	No
Error transfer	Itself and indicator	Itself and source	Itself
Working efficiency	Ordinary	Low	High

From Table 1, LCS was determined to be the optimal standard for testing indicator, especially as a digital form.

LCS can receive a steady external voltage, generally ranging from 5 V to 20 V consistent with that required by the actual load cell, originating from the excitation of WI or the stable output of a DC (direct current) voltage source. After the excitation of WI, LCS is capable to output a signal (or in the form of voltage) which can become the input signal of WI. The maximum signal outputted by load cell is called the rated output (C) under the rated capacity.

A stable output signal is proportional to LCS, generally in the range of (0 to 10) mV/V, through a precise resistance network circuit such as the popular Wheatstone bridge road circuit, Kelvin bridge road circuit and other DC resistive voltage divider circuit [7]. Its basic principles and structure are consistent with those of a resistance strain type load cell.

3. CALIBRATION OF LCS BY A DC VOLTAGE RATIO METHOD

Similar to real load cell, LCS has the typical I/O characteristics that it can stably output adjustable fixed ratio of signal voltage to excitation voltage.

DC resistive volt ratio box is a device consisting of a resistance network having a fixed proportion to provide an output voltage equal to a predetermined fraction of the input voltage. The volt ratio box adopts the principle of resistance voltage division.

The unit of LCS or load cell output signal is mV/V, originating from the ratio between the excitation voltage (1 V to 20 V level, unit V) and the output signal voltage range (1 mV to 100 mV level, unit mV). Due to the same type voltage unit, the unit of LCS or load cell output signal is essentially regarded as a dimensionless one. Therefore, it is perfectly reasonable to regard LCS as a DC resistance volt ratio box with fixed ratio. If the rated output of LCS is C mV/V, it can be used theoretically as a resistive volt ratio box with the fixed minimum volt ratio of $1000/C$.

Since there is no prescribed classification of measuring instruments for LCS in the current Chinese metrological management catalogue of apparatus. Based on the above reasonable analysis, the calibration of LCS was performed by DC voltage ratio method according to the current verification in force of JJG 531-2003 for DC resistive volt ratio box [8].

Figure 1 presents the principle diagram of load cell simulator (LCS) calibration by DC voltage ratio method. The standard DC voltage generator provides high accuracy and stability of the voltage to be the source of the excitation voltage (U_{in} or U_{exc}) of LCS. Two standard multimeters or one multimeter with dual channel (standard A and/or B shown in Figure 2) were used. The multimeter standard A (or channel A) and standard B (or channel B) are to measure the real U_{in} with a different but slightly lower than the nominal output voltage of the standard voltage generator and the output voltage U_{out}, respectively. Once the reference output signal $(U_{\text{out}}/U_{\text{in}})_{\text{ref}}$ is determined, the testing values ratio $(U_{\text{out}}/U_{\text{in}})$ by the multimeter standard(s) can be used as its calibration value.

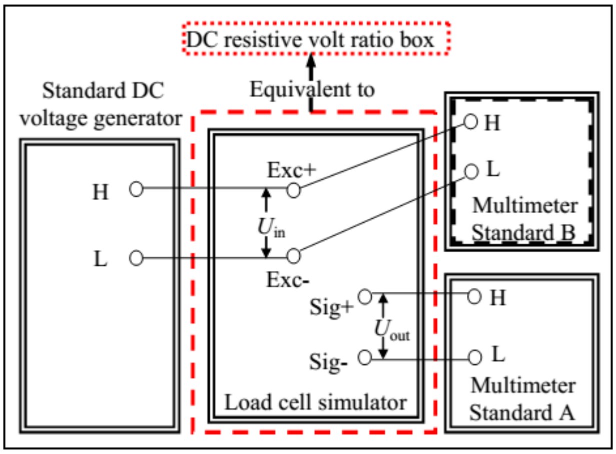

Figure 1: Principle diagram of load cell simulator (LCS) calibration by DC voltage ratio method

An XY2 DLCS with programmable and remote control functions, produced by Shanghai Yaohua Weighing System Co., Ltd., adopts Dot Matrix LCD display.

As shown in Figure 2, the XY2 type DLCS develops two modes to set the voltage signal. Mode 1 (see Figure 2a) is a way typing the predetermined value directly, while Mode 0 (see Figure 2b) designs a step-by-step method to add or subtract a predetermined step value each time by pressing “increase” and “decrease” key.

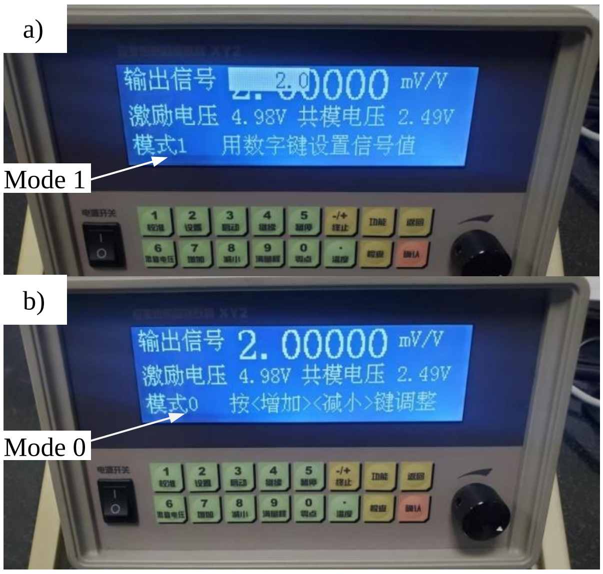

Figure 2: An XY2 type DLCS with different modes to determine the reference input voltage signal for WI. a) Mode 1: keying in the data directly; b) Mode 0: pressing the “increase” and “decrease” keys

The output voltage signal of LCS is the most important metrological parameter whether being used as a measurement standard to test WIs or equipment under test (EUT) of calibration. In its calibration as an EUT, the value is being as the calibration signal point, while the one is the reference output signal equivalent to the predetermined value of mass or verification scale intervals through related conversion formula [2] in the testing as a measuring standard.

The excitation voltage ranges greatly from 1.8 V to 21 V, while the reference voltage of the DLCS remains from 5 V to 10 V. The calibrated DLCS satisfies the metrological requirements for type evaluation of WI with the maximum number of verification scale intervals ($n_{\mathrm{ind,max}}$) from 1 000 to 10 000.

The traceable calibration of the DLCS requires one to two 7.5-digit multimeters and one power supply with high stability and high resolution.

Figure 3 shows the schematic diagram for traceable calibration of the XY2 type DLCS (serial number: 1200992055) by using one 7.5-digit nano volt (type: Agilent 34420A, serial number: MY42001413) and one multifunctional calibrator (type: JH-3D, serial number: 173007) to generate DC voltage excitation.

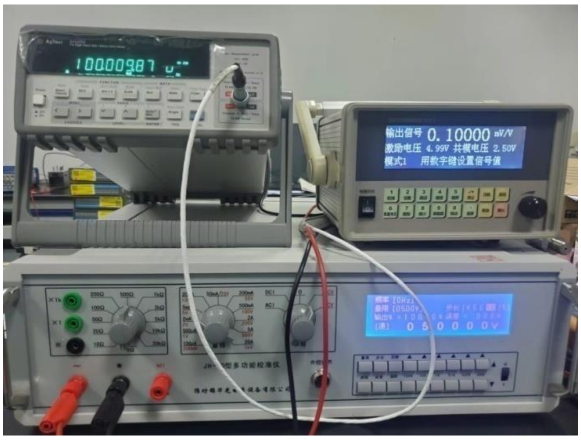

Figure 3: Schematic diagram for a traceable calibration of the DLCS

The reference excitation voltage is determined to be 4 values of 3.3 V, 5 V, 10 V and 20 V. The reference DLCS output signal magnification is to be 0.1 mV/V, 0.2 mV/V, 0.3 mV/V, 1 mV/V, 2 mV/V, and 3 mV/V. The calibration results of the DLCS output signal using excitation voltages of 5 V and 10 V are shown in Table 2.

4. RESEARCH ON TYPE EVALUATION OF WI BY DLCS

Figure 4 illustrates the principle diagram of a WI type-evaluated by a LCS standard. The excitation ports and signal ports between the LCS and WI are connected to each other with the consistent connecting relationship. The impedance simulator is connected within two ports of the excitation to adjust the input impedance of the LCS. In this research, monitoring the signal voltage of multimeter is not needed due to the usage of DLCS.

Table 2: Calibration results of the DLCS output signal using excitation voltages of 5 V and 10 V

Output signal reference (mV/V)	**Reference excitation voltage (V)**	**Indication value of digital multimeter (mV)**	**Calculated output signal value (mV/V)**
0.000 00	5	0.004 254	0.000 007
0.100 00		0.500 005	0.100 039
0.200 00		0.999 936	0.200 045
0.300 00		1.499 975	0.300 058
1.000 00		4.999 771	1.000 077
2.000 00		9.999 189	2.000 094
3.000 00		14.998 88	3.000 098
0.000 00	10	0.004 116	0.000 008
0.100 00		0.999 826	0.099 988
0.200 00		1.999 701	0.199 994
0.300 00		2.999 524	0.299 994
1.000 00		9.998 530	0.999 972
2.000 00		19.997 35	1.999 928
3.000 00		29.996 14	2.999 928

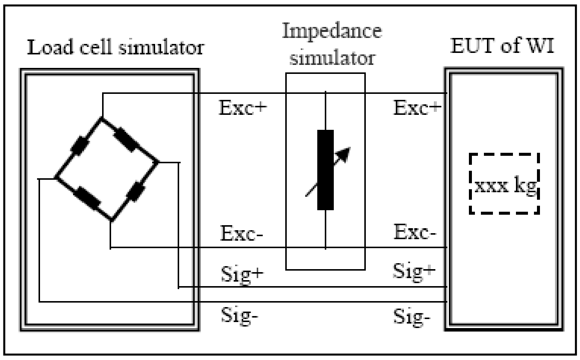

Figure 4: Principle diagram of a WI type evaluation test by LCS

A WI with the type of PL-485J produced by Shandong Aobang Automation Technology Co., Ltd. consists of weighing controller and a liquid-crystal display. The important metrological parameters are determined such as the maximum number of verification scale intervals ($n_{\mathrm{ind,max}}$) being 3 000, the input voltage per verification scale interval (Δu_{ind}) being 3 μV / e_{in} (here, e_{in} is verification scale interval for indicator), the accuracy class for the WI being medium accuracy marked with the symbol Ⅲ and the range of input signal voltage being 9 mV.

Figure 5 presents the schematic diagram of a WI type evaluation test circuit, in which the adjustable DC resistor connected between the excitation lines simulating load cell impedance. The WI connected to strain gauge LCS employs 4-wire principle of the load cell/LCS connection.

Figure 5: Schematic diagram of a WI type evaluation test circuit

4.1. Determination of Standard Signal and n_{ind}

The maximum input voltage and the input signal voltage can be calculated from equations (1) and (2) respectively.

$$U_{\max} = \Delta u_{\mathrm{ind}} \cdot n_{\mathrm{ind,max}} + U_{\min} \tag{1}$$

$$U = \Delta u_{\mathrm{ind}} \cdot n_{\mathrm{ind}} + U_{\min} \tag{2}$$

where $U_{\max}$ is maximum input voltage; $U_{\min}$ is minimum input voltage; Δu_{ind} is input signal voltage per verification scale interval; $n_{\mathrm{ind,max}}$ and n_{ind} are maximum number of verification scale intervals of indicator and the actual number one, respectively.

Equations (1) and (2) are usually used to test WI in the circumstances that the input signal cannot be given directly or the measurement standard needs an additional multimeter to monitor the input voltage. The DLCS has an advantage that it can offer the direct input signal of WI to make the process simple and efficient.

For type evaluation testing of WI with the DLCS in the present study, the most important thing is to determine the reference n_{ind} and the corresponding reference input signal $\left(\frac{U}{U_{\mathrm{exc}}}\right)$ from equation (3) transformed from equation A.1 in JJG 649-2016 [2].

$$\left(\frac{U}{U_{\mathrm{exc}}}\right) - \left(\frac{U}{U_{\mathrm{exc}}}\right)_{\min} = \frac{\Delta u_{\mathrm{ind}} \cdot n_{\mathrm{ind}}}{U_{\mathrm{exc}}} \tag{3}$$

where $\left(\frac{U}{U_{\mathrm{exc}}}\right)$ and $\left(\frac{U}{U_{\mathrm{exc}}}\right)_{\min}$ are the actual and minimum input signals, respectively and n_{ind} is the actual reference number of verification scale intervals of indicator.

From equation (3), the minimum and maximum of the input signal $\left(\frac{U}{U_{\mathrm{exc}}}\right)$ originating from the output of DLCS represent the zero point load (n_{ind} = 0) and $n_{\mathrm{ind,max}}$ respectively.

4.2. Evaluation of Error

For digital-indication WI with a device for displaying the indication with a smaller scale interval (not greater than 1/5 e_{ind}), the indication error E and the corrected error E_{c} for a certain load L (expressed in the form of n_{ind}) and the indicated value I noted are determined from equations (4) and (5).

$$E = I - L \tag{4}$$

$$E_{\mathrm{c}} = E - E_0 \tag{5}$$

where E_0 is the error calculated at zero (or at a load close to zero).

The determination of weighing performance for WI by the DLCS was performed by comparing the relationship between E_{c} of the noted load L (n_{ind}) and its maximum allowable error (MPE), as shown in Table 3.

Table 3: Determination of reference n_{ind} and the evaluation of error for weighing performance test

Standard signal / mV/V	**Load, *L* / kg**	**Indication, *I* / kg** ↓	↑	**Add. load, *ΔL* / kg** ↓	↑	**Error, *E* / kg** ↓	↑	**Corrected error, E_{c} / kg** ↓	↑	**MPE / ±kg**
0.200 00	0.0	0.0	0.0			0.0	0.0		0.0	0.25
0.212 00	20.0	20.0	20.0			0.0	0.0	0.0	0.0	0.25
0.280 00	100.0	100.0	100.0			0.0	0.0	0.0	0.0	0.25
0.320 00	200.0	200.0	200.0			0.0	0.0	0.0	0.0	0.25
0.500 00	500.0	500.0	500.0			0.0	0.0	0.0	0.0	0.25
0.800 00	1 000.0	1 000.0	1 000.0			0.0	0.0	0.0	0.0	0.50
1.100 00	1 500.0	1 500.1	1 500.1			0.1	0.1	0.1	0.1	0.50
1.400 00	2 000.0	2 000.1	2 000.1			0.1	0.1	0.1	0.1	0.50
1.700 00	2 500.0	2 500.1	2 500.1			0.1	0.1	0.1	0.1	0.75
2.000 00	3 000.0	3 000.1	3 000.1			0.1	0.1	0.1	0.1	0.75

At least 10 different test loads (n_{ind}) including zero (n_{ind} = 0.0), Max (n_{ind} = 3 000.0), Min (n_{ind} = 20.0), and the values (n_{ind} = 500.0 and 2 000.0) at or near those at which the MPE sudden changes was selected. The standard signals were determined from equation (3) correspondingly and the value was input to the WI as illustrated in Figure 2. The weighing test process includes the loading (from zero up to Max) and unloading (reverse of loading, from Max up to zero) course. The MPE of test load is determined from the testing method of a module of non-automatic weighing instruments presented in OIML R76 [4].

As a separate module of the same accuracy class of (III) non-automatic weighing instrument, the MPE of the WI is equal to that of non-automatic weighing instrument multiplied by the corresponding value of the fractional error (p_i) adopted. The standard fraction is p_i = 0.5, although it may vary between 0.3 and 0.8. Specially, p_i = 0.0 for purely digital modules (digital data processing devices, terminals and digital displays of non-automatic weighing instruments) is determined.

In the present study, the value of p_i is 0.5. From the fact that the absolute value of E_{c} is smaller than that of the MPE at all test loads in Table 3 indicates the project of weighing performance was evaluated to be qualified.

The important performance tests such as the effect of the static temperatures were investigated. Table 4 shows the indication error of n_{ind} on the testing of static temperature from 20 °C, 40 °C, 0 °C, 5 °C and 20 °C (adjustable R = 125 Ω). Similarly, the comparison between the indication error and the MPE at the n_{ind} determined to be 0.0, 500.0, 2 000.0 and 3 000.0 make sure the test item is qualified.

Table 4: Indication error of n_{ind} on the testing of static temperature

Reference input signal / mV/V		0.2	0.5	1.4	2.0
Reference n_{ind}		0	500	2 000	3 000
Indication error E_{c} / kg	20 °C	0.0	0.0	0.0	0.1
	40 °C	0.1	0.1	0.2	0.3
	0 °C	-0.1	0.0	0.1	0.2
	5 °C	-0.1	0.1	0.2	0.2
	20 °C	0.0	0.0	0.1	0.1
MPE / ±kg		0.25	0.25	0.5	0.75

Due to 4-wire principle of the load cell/LCS connection in the present study, no sense function testing with six wire load cell connection is required. When 6-wire technology is used, WI has a sense input enabling it to compensate variations in load cell excitation voltage originating from the lengthened cables or the changes of cable resistance due to temperature. The detailed procedures and methods for testing sense function are presented in Annex C of OIML R 76 [4].

5. SUMMARY

DLCS is an optimal measurement standard for the type evaluation test of WI with medium accuracy class (III), due to the simple and efficient means to determine the standard signal and n_{ind} by a digital input mode. The traceable calibration was presented by voltage ratio method using a 7.5-digit multimeter with dual channel. In the type evaluation of WI, the most important thing is to determine the test loads expressed in the form of n_{ind} based on the metrological characteristics and requirements of the testing projects. The equation between the standard input signal and n_{ind} is related to U_{exc}, Δu_{ind} and the minimum input signal (or voltage).

6. REFERENCES

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