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Source:

Verification regulation of load cell

[Issued on July.18, 1985 and put into effect since May 1, 1986 by National Technical Bureau - JJG 391—85, National Measuring Verification Regulation of People's Republic of China]

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Calibration of Load Cells

1 Purpose

This procedure can be applied to the calibration of strain gauge load cells for force measuring and weighing in both directions tension-, compression - or tension and compression serving dual purpose (hereinafter referred to as load cell). It applies to new load cells, to gauges in service, and after repair. The calibration of other type of electric measuring load cells can be carried out in reference to this work instruction.

2 Technical Requirements

2.1 Label

The load cell and its suspensions should be steadily fastened in a solid box. The name of the producer (or the producer sign), type, specification, production number, production date of the load cell should be marked on its nameplate.

2.2 General Condition

The load cell and its suspensions shouldn't have any surface default which could affect its technical performance. The mounting parts should be all available. Normally they are not allowed to be exchanged.

The load cell should work well at room conditions.

2.3 Classification.

The classification of the grade of the load cell is shown in Table 1. The assessment period of the stability should be normally taken as 3 months, half year or one year, not less than 3 months.

2.4 Basic Characteristics.

The following 17 basic technical characteristics should be normally stated and available for each load cell.

2.4.1 Load characteristics:

Nominal loading, safe overload capacity, sensitivity, linearity, hysteresis, repeatability and stability. The allowable error of sensitivity should be given for new or repaired load cells.

2.4.2 Electric characteristics:

input resistance, output resistance, insulation resistance, zero output, rated voltage.

2.4.3 Temperature characteristics:

influence of zero point temperature, influence of temperature on output, temperature compensation range.

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Table 1 Classification: Grade of Load Cells

| Grade | High precision | | | Precision | | Normal | Name |
|-----------------|----------------------|-------|-------|-----------|-------|--------|------|
| | A | | | B | | | |
| Code name | 0.02S | 0.03S | 0.05S | 0.1S | 0.3S | 0.5S | 1S |
| | 0.02 | 0.03 | 0.05 | 0.1 | 0.3 | 0.5 | 1 |
| Allowable error | <i>L</i> | | | | | ±0.50 | ±1.0 |
| | <i>H</i> | | | | | / | / |
| | <i>R</i> | | | | | / | / |
| | <i>S_t</i> | ±0.02 | ±0.03 | ±0.05 | ±0.10 | ±0.30 | / |
| | <i>Z_t</i> | | | | | / | / |
| | <i>C_p</i> | | | | | / | / |
| II | <i>S_b</i> | ±0.04 | ±0.06 | ±0.10 | ±0.20 | ±1.0 | ±2.0 |

Note: (1) If the load cells of A and B grade temporarily cannot be calibrated covering the six main indexes of the allowable error I shown in Table 1, because of the limitation of the calibration condition, it is allowed that the grade may be determined on the basis of the calibration results of 4 indexes --- *L*, *H*, *R*, *Z_t*.

(2) If it is difficult to rapidly increase loading or to keep the load constant by use of the standard force exerting machine or the loading equipment, the creep recovery *C_r* is allowed to be used instead of the creep *C_p*. Its allowable error is the same as the one of *C_p*.


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Table 2

| Grade | A | B | C |
|-----------------------|------|------|------|
| Allowable error (%FS) | ±1.0 | ±2.0 | ±5.0 |

2.4.4 Creep characteristics:

The manufacturer should normally supply 17 basic technical characteristics for each load cell. Normally the following 9 properties should be calibrated: sensitivity S , linearity L , hysteresis H , repeatability R , zero output Z , influence of zero point temperature Z_t , influence of output temperature S_t , creep C_p (or creep recovery C_r) and stability S_b . **Note:** If the requirements of this clause temporarily cannot be met because of the limitation of the calibration condition, the manufacturer must at least supply the other 14 basic technical characteristics except stability, influence of output temperature and creep. The metrological department must at least calibrate the 5 technical characteristics of S , L , H , R and Z . The zero output of the load cell Z should comply with the data in Table 2.

2.5 Drift

At indoor conditions the percentage of the zero drift over the rated output of the load cell should over a time of 2 hours not exceed half of the acceptable error I shown in Table 1.

2.6 Other Relevant Technical Characteristics

The other relevant technical characteristics of the load cell (such as overload capacity, influence of non-axial load, natural frequency, circulation life, influence of external magnetic fields, vibration resistance property) should meet the requirements of the relevant technical documents (such as relevant national standards, shop instructions etc.).


3 Calibration Conditions

3.1 Standard Calibration Condition.

The calibration must be carried out under the following conditions:

- a. Ambient temperature: $20 \pm 2^\circ$.
- b. Relative humidity: $\leq 70\%$.
- c. Atmospheric pressure: 90~106 kPa (680~800mmHg)

Note: (1) If the above standard calibration condition cannot be met, the calibration can be carried out under the following room conditions which should then be noted in the calibration report with the calibration result. The ambient temperature change must not exceed 1° per hour during the load cell calibration. This note is also suitable as standard calibration condition in any other item of this work instruction.

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Room condition:

- a. Temperature: $20 \pm 10^\circ$.
- b. Relative humidity: $\leq 90\%$.
- c. Atmospheric pressure: 90~106 kPa (680~800mmHg)

(2) Deviations of the relevant technical characteristics caused by the actual service condition should be noticed. The calibration results can be revised when necessary.

3.2 Loading condition

- The load cell should be installed in a way that ensures the alignment of its main shaft line and its loading shaft line so that the influence of a loading declination or eccentric loading is reduced to a minimum.
- Compression
 1. The quality of the loading contact surface must be taken care of for any loading device. Both the support surface and the bottom surface of the load cell should be smooth without any rusty erosion, bruise and impurity.
 2. The load cell should normally have high, or low pressure-bearing cushions.
- Tension. The two ends of the load cell should have proper connection elements installed.

3.3 Temperature balance period.

The load cell should be kept under the standard calibration conditions for a time long enough to make sure that its temperature is stable and corresponds to the required standard calibration condition. The period for the temperature balance is suggested to be not less

than 8h.

3.4 Preheating.

Before the calibration the load cell, the display units, the load source and other accessories which are connected with it should be switched on for preheating the system. The preheating duration should meet the specification of the manufacturer. The calibration should not be carried out until all parts are stable.

Note: Load cells, measuring meters or load sources for which no specification is available should normally be preheated for half to one hour.

3.5 Atmospheric pressure.

Changes of the atmospheric pressure which might obviously affect the zero output of the load cell should be noticed.


3.6 Relevant Technical Indices

The relevant technical indices of the standard force-exerting device or the loading device for the load cell calibration should be in principle three times those of the calibrated load cell. The proper standard force-measuring device and loading device should be selected on the basis of the calibration contents and the relevant indexes of the calibrated load cell.

3.7 Precision Indices

The precision indices of the used indication meters should be at least three times those of the calibrated load cell during calibration.

The precision indices of the used load source should be at least five times of those of the calibrated load cell during calibration.

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3.8 Thermostat Container.

The adjustable temperature range of the thermostat container should not be less than the temperature compensation range of the load cell. It should normally be within $-30\sim+70^{\circ}$. The range of variation of the temperature of the environment should normally not exceed $\pm 1^{\circ}$. The temperature gradient should normally not exceed $3^{\circ}/h$.

4 Items and Method of Calibration

First time calibration for a new load cell or after repair

4.1 Preparations

- An exterior inspection can be done according to the requirement of item 2.2 of this procedure.
- The zero drift Z_d of the load cell within 2h should be measured after the load cell and its connected electronic devices have been preheated according item 3.4.

$$Z_d = \frac{\theta_{0\max} - \theta_{0\min}}{\theta_n} \times 100 [\%FS] \quad (1)$$

where,

$\theta_{0\max}, \theta_{0\min}$ --- the maximum and the minimum value of the zero output during the measuring time respectively.

θ_n --- The rated output of the load cell.

Note: This index is normally measured for one time, at most three times. The mean value will

be taken as the final result.

4.2 Calibration Method

The characteristics of the load cell can be calibrated according to the following procedures.

- The ambient conditions and the calibrating conditions should be compared and checked if they meet the requirements given in item 3.
- The load cell should be put on the standard force-exerting machine and preloaded three times, up to the nominal load and then returned to zero each time.

Note: This item may not be carried out when the execution for the load characteristics of the load cell is not required under the condition of pre-loading.

- The electric driving mechanism may be inspected or adjusted if necessary, the measuring range and the zero point of the indicating meter should be adjusted and the zero output should be read.
- On having pre-loaded three times, the formal calibration can start in one min.
- The load should be progressively increased up to the nominal one with the same increment. Each load step should be kept for a certain time and the output value may be read when it has stabilized.

Note: (1) The load keeping time is recommended to be 5s, 15s, 30s and 1min 30s. The selection should be noted.

(2) The load increment may be not equal, when the loading condition of the standard force-exerting machine is limited. The first load step should normally be 10-20% of the

nominal one.

(3) The number of load steps must not be less than 5 (zero load is not included), 10 steps are recommended.

- Once the nominal load has been reached the same method can be used for progressive reducing. Each load step should be kept for a certain time and the output value may be read when it has stabilized.
- When the load returns to zero and stays there for 1 min., the zero output can then be read. The zero point of the indicating meter can be readjusted when necessary.
- The procedure of loading and unloading should be carried out at least three times.
- The relevant technical indices (see Figure 1) can be calculated from the following formulae with the above calibration result.

$$\text{Zero output } \theta_0 = \frac{1}{m} \sum_{j=1}^m \theta_{0j} \quad (2)$$

Expressed as percentage of the nominal output:

$$Z = \frac{\theta_0}{\theta_n} \times 100 \text{ [% of the rated output]} \quad (3)$$

which is simplified as \sim %FS.

Output at the rated load:

$$\theta_{n0} = \frac{1}{m} \sum_{j=1}^m (\theta_{nfr} - \theta_{0j}) \quad (4)$$

$$\text{Linearity } L = \frac{\Delta\theta_L}{\theta_n} \times 100 \text{ [%FS]} \quad (5)$$

Hysteresis

$$H = \frac{\Delta\theta_H}{\theta_n} \times 100 \text{ [%FS]} \quad (6)$$

Repeatability

$$R = \frac{\Delta\theta_R}{\theta_n} \times 100 \text{ [%FS]} \quad (7)$$

where,

m number of the calibration adjusting cycles

θ_{0j} output reading at zero load at the time of the measuring at the j^{th} cycle ($j=1, 2, \dots, m$);

θ_{nfr} output reading at nominal load at the measuring of the j^{th} time;

$\Delta\theta_L$ the maximum value of the deviation between the mean advance calibration curve and the straight line of two mean end points;

$\Delta\theta_H$ the maximum value of the deviation between the return mean calibration curve and the advance one;

$\Delta\theta_R$ the maximum value of the output range at each load point during the repeat-calibration.

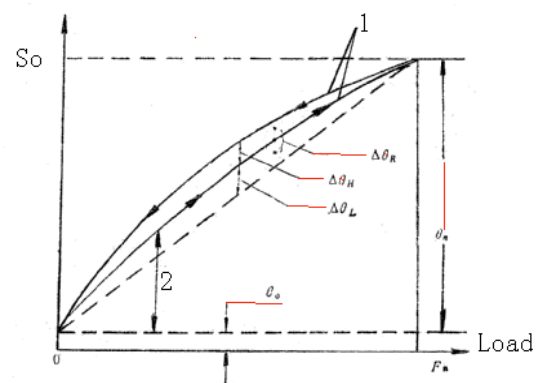



Figure 1

S_o output signal, F_n rated load, θ_n rated output, θ_0 zero output, $\Delta\theta_R$ repeatability, $\Delta\theta_H$ hysteresis, $\Delta\theta_L$ linearity, 1 calibration curves, 2 output

4.3 Asymmetry

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After the loading – unloading procedure has been finished, load cells of grade A should be turned 3 times around their main shaft line by 90° respectively, i.e. the angle between the pressure cushion position vector of the standard force-exerting machine and the load cell position vector (simplified as direction angle) should be changed from 0° to 90° , 180° , and 270° . After each turn the load should be exerted on the load cell up to the nominal one, the rated output $\theta_{n\varphi}$ can be read. The arithmetic mean of $\theta_{n\varphi}$ at 4 direction positions (including 0° direction position) is taken as the rated output of the load cell θ_n . The rated output θ_n of load cells of grade B or C is $\theta_n = \theta_{n0}$.

4.4 Relative Deviation

The relative deviation S_e between the nominal sensitivity value S_0 and the actual measured one S can be calculated and judged whether it meets the requirement for the acceptable error of sensitivity with the following formulae:

$$S = \frac{\theta_n}{U} [\text{mV/V}] \quad (8)$$

$$S_e = \frac{S_0 - S}{S} \times 100 [\%FS] \quad (9)$$

where, U is the mean value of the voltage of the load cell.

4.5 Creep

Creep and creep recovery can be calibrated by the following procedures.

- The environmental condition and the calibrating condition should be checked whether they meet the requirements

given in chapter 3.

- The load cell should be installed on the standard force-exerting machine and pre-loaded three times, up to the nominal load and then returned to the zero point each time. The pre-load should not be exerted on a load cell, at least within 24 hours before the calibration if the exertion of the pre-load affects the calibration result.
- The electric drive may be inspected and adjusted if necessary, the measuring range and zero point of the indicating meter should be adjusted and the zero output should be read
- The rated load should be exerted as fast as possible (the loading duration should not usually exceed 5s, static weights are the best), after loading (5s~10s is recommended) the output should be read. Then the following outputs should be read at fixed time intervals within 30 min.
- The load should be unloaded as fast as possible (the unloading duration shouldn't usually exceed 5s), after unloading (5s~10s is recommended) the output should be read. Then the following outputs should be read in fixed time intervals within 30 min.
- The relevant technical indices (see Figure 2) can be calculated by the following formulae

$$\text{Creep } C_p = \frac{\theta_2 - \theta_3}{\theta_n} \times 100 [\%FS] \quad (10)$$

$$\text{Creep recovery } C_r = \frac{\theta_5 - \theta_6}{\theta_n} \times 100 [\%FS] \quad (11)$$

Note: (1) When creep C_p is given, the loading time ($t_1 - t_0$) and the first reading time ($t_2 - t_1$) should be recorded. When the creep recovery C_r is given, the unloading time ($t_4 - t_3$) and the first reading time ($t_5 - t_4$) should be noted.

(2) This index is usually measured one hour. time, at most 3 times. The mean value can be taken as the final result for this index. The time interval between two consecutive measurements should not be less than half an

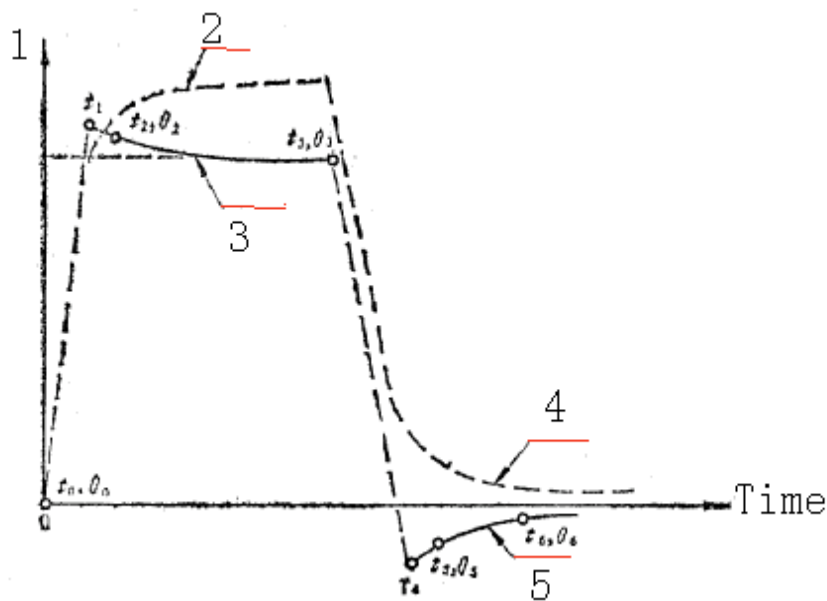


Figure 2

- 1 output, 2 positive creep, 3 negative creep, 4 positive creep recovery, 5 negative creep recovery
- t_1-t_0 --- the duration from zero load to rated load;
 t_2-t_1 --- the duration from the rated load being reached to the first reading (5~10s);
 t_3-t_2 --- the duration of the creep observation (30 min);
 t_4-t_3 --- the duration of unloading (nearly equals to t_1-t_0);
 t_5-t_4 --- the duration between the zero load being reached and the first reading;
 t_6-t_5 --- the duration of the creep recovery observation (30min);
 $\theta_0, \theta_2, \theta_3, \theta_5, \theta_6$ --- the output readings relevant to the time t_0, t_2, t_3, t_5, t_6 .


4.6 Influence of Temperature

The influences of the difference between the temperatures at zero point and at the output can be calibrated by the following procedure:

- The ambient condition and the calibration condition should be compared with the

criteria given in chapter 3.

- The load cell should be kept in the thermostat container of the standard force-exerting machine (usually with an attached cable of the load cell).
- The load cell should be preloaded three times up to the nominal load and then returned to zero point each time. One min after the preloading, the formal calibration

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can start.

- The electric driving mechanism may be inspected and adjusted if necessary, the measuring range and zero point of the indicating meter should be adjusted and the zero output should be read.
- When the nominal load is exerted, reached and kept for 30s, the output should then be read. After that, the load cell should be unloaded down to zero and kept for 1 min, and then the zero output should be read. The electric driving mechanism and the zero point of the indicating meter may be re-adjusted if necessary, the zero output should be read again. This procedure should be continuously carried out at least three times.
- The temperature of the thermostat should be increased to the upper range for the load cell. After the temperature is really stable, the above procedures should be repeated.

Note: It is acceptable that the calibration can be carried out at a temperature lower than the upper limit if the temperature of the thermostat cannot reach the upper limit of the compensation temperature range.

- The temperature of the thermostat should be decreased to the lower limit of the compensation temperature range of the load cell. After the temperature is stable, the above loading and unloading procedures should be repeated.

Note: It is acceptable that the calibration can be carried out at a temperature higher than the lower limit if the temperature of the thermostat cannot reach the lower limit of the compensation temperature range.

- The temperature of the thermostat should be returned to the standard calibration condition. After the temperature is really stable, the above procedures should be repeated.
- The relevant technical indices can be

calculated by the following formulae.

$$Z_{th} = \frac{\frac{\theta_{0h} - \theta_{0s}}{\theta_n}}{\frac{T_h - T_s}{10}} \times 100 \quad [\%FS/10K]$$

Influence of zero point temperature

$$Z_{tl} = \frac{\frac{\theta_{0l} - \theta_{0s}}{\theta_n}}{\frac{T_l - T_s}{10}} \times 100 \quad [\%FS/10K]$$

(12)

$$S_{th} = \frac{\frac{(\theta_{nh} - \theta_{0h}) - (\theta_{ns} - \theta_{0s})}{\theta_n}}{\frac{T_h - T_s}{10}} \times 100 \quad [\%FS/10K]$$

Influence of output Temperature

$$S_{tl} = \frac{\frac{(\theta_{nl} - \theta_{0l}) - (\theta_{ns} - \theta_{0s})}{\theta_n}}{\frac{T_l - T_s}{10}} \times 100 \quad [\%FS/10K]$$

(13)

Where,


T_h, T_s, T_l the upper limit temperature, standard calibration temperature and the low limit temperature by the time of calibration respectively;

$\theta_{0h}, \theta_{0s}, \theta_{0l}$ the relevant zero output average values of T_h, T_s and T_l respectively;

$\theta_{nh}, \theta_{ns}, \theta_{nl}$ the relevant output reading average values of T_h, T_s and T_l at the rated load respectively;

θ_n --- the rated output.

The bigger one of the absolute values of Z_{th} and Z_{tl} should be taken as the final influence value of the zero point temperature Z_t .

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The bigger one of the absolute values of S_{th} and S_{tl} should be taken as the final influence value of the output temperature S_t .

Note: (1) If the condition allows, the influences of the zero point temperature and the output temperature can better be calibrated separately. (2) If the calibration results at the standard temperature reached before and after the temperature increasing and decreasing do not coincide, the calculation should be done using these two results. The bigger one of the absolute values should be taken as the final relevant temperature influence index.

4.7 Random Calibration.

For the same lot of load cells of the same type, same dimension, manufactured by the same factory, a random-calibration of zero drift, creep and influence of temperature is allowed. The random-calibration rate must be at least 10% (not less than 3 sets). The random-calibration is only usually suitable to the load cell of B and C grade. The indices of the worst one must be taken as the one of this lot of load cells.

4.8 Repeat calibration.

The examination of the exterior, calibration of the load characteristics and the influence of asymmetry should be done during a load cell repeat-calibration. Z , L , H , R , the sensibility S_2 and the stability S_b of this calibration can be calculated upon the calibration results. S_b can be calculated by the following formula:

$$S_b = \frac{S_1 - S_2}{S_2} \times 100 \quad [\%FS] \quad (14)$$

where, S_1 is the sensibility of the load cell measured during the last calibration.

Note: When the calibrator thinks that the

change of the other relevant indices from the first time calibration might exceed the allowable error for the original grade, the re-calibration of these indices is suggested. The result of the re-calibration should be taken as one of the criteria for judging the grade of the load cell.

4.9 Check - Accept Calibration

New load cells should be in principle calibrated on the basis of above procedure (item 4.1 to 4.6). If the manufacturer and the user sign other agreements on checking and acceptance, the first calibration can be done following that agreement.


5 Treatment of calibration result and calibration period

5.1 Initial Calibration

For a load cell which is calibrated the first time, the grade can be determined upon the calibration results and a calibration certificate will be issued normally containing the following ten basic technical indices S , Z , L , H , R , Z_t , S_t , Cp , S_e , Z_d etc..

Note: (1) If Z or Z_d from the calibration result exceed the values for the relevant grade determination in Table 1, the grade of the load cell grade can be lowered, or the grade stays undetermined with the above-mentioned ten basic technical indices given.

(2) The output mean values of the advance and the return may also be attached to the calibration results respectively based on the actual need .

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5.2 Re-Calibration


For a load cell which is re-calibrated, the grade can be determined by a comparison of L , H , R , S_b obtained this time and Z_t , S_t , C_p (or C_r), Z_d obtained last time with the grade given in Table 1, then a calibration certificate will be issued containing six indices: S , Z , L , H , R , and S_b and the other technical indices which were obtained by the first calibration adopted. For the stability S_b , the calibration time interval (taken as $\sim\%FS/\times\text{month}$ or $\sim\%FS/\times\text{year}$) should be noted.

The treatment of the calibration results can be done the same way as the initial calibration for a new load cell which has been calibrated

according to paragraphs 4.1 - 4.6 . For a new load cell which has been calibrated according to a check-accept agreement between the manufacturer and the user, the final calibration results can be supplied upon the agreement, the grade can be determined using this work instruction as reference.

5.3 Calibration Period


The calibration period of the load cell can be divided into three months, half-year or one year depending on the calibration result of its stability.

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Appendix 1

Cover page format of verification certificate

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| <p>(Name of calibrator)</p> <p style="text-align: center;">Certificate of Calibration</p> <p><u>Load cell</u> Number _____</p> <p>Name of calibrated device _____</p> <p>Type and specification _____</p> <p>Manufacturer _____</p> <p>Production number _____</p> <p>Device number _____</p> <p>Device owner _____</p> <p>Grade of load cell _____</p> <p>Director of laboratory _____</p> <p>Checker _____</p> <p>Calibration person _____</p> <p>Calibration date _____</p> <p>Valid to _____</p> |
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Appendix 2

Inside page format of verification certificate

| | |
|--|--------------------------------|
| Measuring range _____ | Room temperature _____ ° |
| Humidity _____ % | Atmospheric pressure _____ kPa |
| Calibration Result | |
| Sensitivity | S (mV/V) |
| Zero output | Z (%FS) |
| Linearity | L (%FS) |
| Hysteresis | H (%FS) |
| Repeatability | R (%FS) |
| Influence of zero point temperature | Z_t (%FS/10K) |
| Influence of temperature output | S_t (%FS/10K) |
| Creep C_p (or creep recovery C_r) | (%FS/30min) |
| drift of zero point | Z_d (%FS/ h) |
| Deviation of sensitivity | S_e (%FS) |
| Stability of sensitivity | S_b (%FS/ month) |
| | |
| | |
| Indicating meter _____ Standard force-exerting device _____ Driving load source _____ Driving voltage _____ | |



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Calibration record of creep

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Load cell owner _____; Manufacturer _____; Type & specification _____; Production number _____; Temperature _____ °C;
 Humidity _____ %; Atmospheric pressure _____ kPa; Driving voltage _____ V, DC _____ Hz, AC; Preheat _____ min,
 Variation _____ V; Preloading _____ times, up to _____ ft, kgf, N

| Calibrated items: C_p, C_r ; Register: $r = \Delta t =$ s, min, h | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|--------|
| Unit Decade | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Remark |
| 0 | | | | | | | | | | | |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| 8 | | | | | | | | | | | |

Indicating meter _____; Driving load source _____; Standard force-exerting device _____; Duration of loading t_i _____ s;
 Duration of unloading t_d _____ s; Stable duration _____ %FS/30min; Creep C_p _____ %FS/30min; Creep recovery C_r _____ %FS/30min
 Calibrator _____, Checker _____, Date _____

Appendix 8

Calibration record of natural frequency

Book number _____
Page _____



ITTC – Recommended Procedures

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Sample Work Instructions Calibration of Load Cells

Effective Date
2002

Revision
00

| Order number | Unit | Manufacturer | Type & spec | Production number | Time index (ms/grid) | Amplitude index (V/grid) | Period number | Time (ms) | Natural frequency f_0 (Hz) | Remark |
|--------------|------|--------------|-------------|-------------------|----------------------|--------------------------|---------------|-----------|------------------------------|--------|
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Driving load source _____; Driving voltage _____ V; Recording device _____; Driving method _____;
 Wave pattern quality _____; Temperature _____ °; Humidity _____ %; Atmospheric pressure _____ kPa;
 Calibrator _____, Checker _____, Date _____

Appendix 9

Book number _____

Page _____

Calibration record of zero drift



ITTC – Recommended Procedures

Sample Work Instructions Calibration of Load Cells

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| | |
|------------------------|----------------|
| Effective Date 2002 | Revision 00 |
|------------------------|----------------|

Load cell owner _____; Manufacturer _____; Type & specification _____; Production number _____;
 Driving voltage _____ V, DC, _____ Hz, AC; Preheat _____ min, Variation _____ V

| Time | Output (mV, μ V) | Temperature ($^{\circ}$) | Humidity (%) | Atmospheric pressure (kPa) | Time | Output (mV, μ V) | Temperature ($^{\circ}$) | Humidity (%) | Atmospheric pressure (kPa) | Remark |
|------|-------------------------|-------------------------------|-----------------|----------------------------------|------|-------------------------|-------------------------------|-----------------|----------------------------------|--------|
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Indicating meter _____; Driving load source _____; Zero drift Z_d _____ %FS/ _____ h; Temperature _____ $^{\circ}$; Humidity _____ %;
 Atmospheric pressure _____ kPa

Calibrator _____, Checker _____, Date _____