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Metallic materials — Verification of static uniaxial testing machines —

Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system

Matériaux métalliques — Vérification des machines pour essais statiques uniaxiaux

Partie 1: Machines d'essai de traction/compression — Vérification et étalonnage du système de mesure de force

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 7500-1 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 1, *Uniaxial testing*.

This third edition cancels and replaces the second edition (ISO 7500-1:1999) which has been technically revised.

ISO 7500 consists of the following parts, under the general title *Metallic materials — Verification of static uniaxial testing machines*:

— *Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

— *Part 2: Tension creep testing machines — Verification of the applied load*

Metallic materials — Verification of static uniaxial testing machines —

Part 1:
Tension/compression testing machines — Verification and calibration of the force-measuring system

1 Scope

This part of ISO 7500 specifies the verification of tension/compression testing machines.

The verification consists of

— a general inspection of the testing machine, including its accessories for the force application;

— a calibration of the force-measuring system.

NOTE This part of ISO 7500 addresses the static verification of the force-measuring systems. The calibration values are not necessarily valid for high-speed or dynamic testing applications. Further information regarding dynamic effects is given in the Bibliography.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 376, *Metallic materials — Calibration of force-proving instruments used for the verification of uniaxial testing machines*

3 Terms and definitions

For the purposes of this document, the following term and definition apply.

3.1
calibration
set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards

See VIM[1].

NOTE 1 The result of a calibration permits either the assignment of values of measurands to the indications or the determination of corrections with respect to indications.

NOTE 2 A calibration may also determine other metrological properties such as the effect of influence quantities.

NOTE 3 The result of a calibration may be recorded in a document, sometimes called a calibration certificate or a calibration report.

4 Symbols and their meanings

Symbols and their meanings are given in Table 1.

Table 1 — Symbols and their meanings

Symbol	Unit	Meaning
a	%	Relative resolution of the force indicator of the testing machine
b	%	Relative repeatability error of the force-measuring system of the testing machine
f_0	%	Relative zero error of the force-measuring system of the testing machine
F	N	True force indicated by the force-proving instrument with increasing test force
F'	N	True force indicated by the force-proving instrument with decreasing test force
F_c	N	True force indicated by the force-proving instrument with increasing test force, for the complementary series of measurements for the smallest range used
F_i	N	Force indicated by the force indicator of the testing machine to be verified, with increasing test force
F_i'	N	Force indicated by the force indicator of the testing machine to be verified, with decreasing test force
$\overline{F}_i$, $\overline{F}$	N	Arithmetic mean of several measurements of F_i and F for the same discrete force
$F_{i\,max}$, $F_{i\,min}$ F_{max}, F_{min}	N	Highest or lowest value of F_i or F for the same discrete force
F_{ic}	N	Force reading on the force indicator of the testing machine to be verified, with increasing test force, for the complementary series of measurements for the smallest range used
F_{i0}	N	Residual indication of the force indicator of the testing machine to be verified after removal of force
F_N	N	Maximum capacity of the measuring range of the force indicator of the testing machine
g_n	m/s^2	Local acceleration due to gravity
q	%	Relative accuracy error of the force-measuring system of the testing machine
r	N	Resolution of the force indicator of the testing machine
v	%	Relative reversibility error of the force-measuring system of the testing machine
ρ_{air}	kg/m^3	Density of air
ρ_m	kg/m^3	Density of the dead weights

5 General inspection of the testing machine

The verification of the testing machine shall only be carried out if the machine is in good working order. For this purpose, a general inspection of the machine shall be carried out before calibration of the force-measuring system of the machine (see Annex A).

NOTE Good metrological practice requires a calibration run prior to any maintenance or adjustments to the testing machine.

6 Calibration of the force-measuring system of the testing machine

6.1 General

This calibration shall be carried out for each of the force ranges used and with all force indicators in use. Any accessory devices (e.g. pointer, recorder) that may affect the force-measuring system shall, where used, be verified in accordance with 6.4.6.

If the testing machine has several force-measuring systems, each system shall be regarded as a separate testing machine. The same procedure shall be followed for double-piston hydraulic machines.

The calibration shall be carried out using force-proving instruments with the following exception. If the force to be verified is below the lower limit of the smallest capacity force-proving device used in the calibration procedure, use known masses.

When more than one force-proving instrument is required to calibrate a force range, the maximum force applied to the smaller device shall be the same as the minimum force applied to the next force-proving instrument of higher capacity. When a set of known masses is used to verify forces, the set shall be considered as a single force-proving instrument.

The calibration should be carried out with constant indicated forces, F_i. When this method is not feasible, the calibration can be carried out with constant true forces.

NOTE 1 Calibration can be carried out using a slowly increasing force. The word “constant” signifies that the same value of F_i (or F) is used for the three series of measurements (see 6.4.5).

The instruments used for the calibration shall have a certified traceability to the international system of units.

The force-proving instrument shall comply with the requirements specified in ISO 376. The class of the instrument shall be equal to or better than the class for which the testing machine is to be calibrated. In the case of dead weights, the relative error of the force generated by these weights shall be less than or equal to ± 0,1 %.

NOTE 2 The exact equation giving the force, F, in newtons, created by the dead weight of mass m, in kilograms, is:

$$F = mg_n \left[1 - \frac{\rho_{air}}{\rho_m} \right] \tag{1}$$

This force can be calculated using the following approximate formula:

$$F = mg_n \tag{2}$$

The relative error of the force can be calculated, using the formula:

$$\frac{\Delta F}{F} = \frac{\Delta_m}{m} + \frac{\Delta g_n}{g_n} \tag{3}$$

6.2 Determination of the resolution

6.2.1 Analogue scale

The thickness of the graduation marks on the scale shall be uniform and the width of the pointer shall be approximately equal to the width of a graduation mark.

The resolution, r, of the indicator shall be obtained from the ratio between the width of the pointer and the centre-to-centre distance between two adjacent scale graduation marks (scale interval). The recommended ratios are 1:2, 1:5 or 1:10, a spacing of 2,5 mm or greater being required for the determination of one-tenth of a scale division.

6.2.2 Digital scale

The resolution is taken to be one increment of the count of the numerical indicator, provided that, when the instrument is unloaded and the motors and controls system are operating, the indication does not fluctuate by more than one increment.

6.2.3 Variation of readings

If the readings vary by more than the value previously calculated for the resolution (with the calibration of the force-indicating instrument unloaded and with the motor and/or drive mechanism and control on for determining the sum of all electrical noise), the resolution, r, shall be deemed to be equal to half the range of fluctuation plus one increment.

NOTE 1 This only determines the resolution due to system noise and does not account for control errors, i.e., in the case of hydraulic machines.

NOTE 2 For auto-ranging machines, the resolution of the indicator changes as the resolution or gain of the system changes.

6.2.4 Unit

The resolution, r, shall be expressed in units of force.

6.3 Prior determination of the relative resolution of the force indicator

The relative resolution, a, of the force indicator is defined by the relationship:

$$a = \frac{r}{F} \times 100 \qquad (4)$$

where

r is the resolution defined in 6.2;

F is the force at the point under consideration.

The relative resolution shall be determined at each calibration point and shall not exceed the values given in Table 2 for the class of machine being verified.

6.4 Calibration procedure

6.4.1 Alignment of the force-proving instrument

Mount tension force-proving instruments in the machine in such a way as to minimize any effects of bending (see ISO 376). For the alignment of a force-proving instrument in the compression mode, mount a platen with a ball nut on the instrument if the machine does not have an incorporated ball cup.

NOTE If the machine has two work areas with a common force application and indicating device, one calibration could be performed, so that e.g., compression in the upper work area equals tension in the lower work area, and vice versa. The certificate should carry an appropriate comment.

6.4.2 Temperature compensation

The calibration shall be carried out at an ambient temperature of between 10 °C and 35 °C. The temperature at which the calibration is carried out shall be noted in the verification report.

A sufficient period of time shall be provided to allow the force-proving instrument to reach a stable period of temperature. The temperature of the force-proving instrument shall remain stable to within ± 2 °C during each calibration run. If necessary, temperature corrections shall be applied to the readings (see ISO 376).

6.4.3 Conditioning of the testing machine

The machine, with the force-proving instrument in position, shall be loaded at least three times between zero and the maximum force to be measured.

6.4.4 Procedure

The following method should be used: a given force, F_i, indicated by the force indicator of the machine, is applied to the machine and the true force, F, indicated by the force-proving instrument, is noted.

If it is not possible to use this method, the true force, F, indicated by the force-proving instrument, is applied to the machine and the force, F_i, indicated by the force indicator of the verified machine, is noted.

6.4.5 Application of discrete forces

Three series of measurements shall be taken with increasing force. For machines applying not more than five discrete levels of force, each value of relative error shall not exceed the values given in Table 2 for a specific class. For machines applying more than five discrete levels of force, each series of measurements shall comprise at least five discrete force levels at approximately equal intervals between 20 % and 100 % of the maximum range of the scale.

If a calibration is conducted at a force below 20 % of the range, supplementary force measurements shall be made at approximately 10 %, 5 %, 2 %, 1 %, 0,5 %, 0,2 % and 0,1 % of the scale down to and including the lower limit of calibration.

NOTE 1 The lower limit of the range can be determined by multiplying the resolution, r, by:

— 400 for class 0,5;

— 200 for class 1;

— 100 for class 2;

— 67 for class 3.

For testing machines with auto-ranging indicators, at least two force steps shall be applied on each part of the range where the resolution does not change.

NOTE 2 The force-proving instrument may be rotated through an angle of 120° before each series of measurements and a preload run undertaken.

For each discrete force, the arithmetic mean of the values obtained for each series of measurements shall be calculated. From these mean values, the relative accuracy error and the relative repeatability error of the force-measuring system of the testing machine shall be calculated (see 6.5).

The indicator reading shall be set to zero before each series of measurements. The zero reading shall be taken approximately 30 s after the force is completely removed. In the case of an analogue indicator, it shall also be checked that the pointer balances freely around zero and, if a digital indicator is used, that any drop below zero is immediately registered, for example by a sign indicator (+ or –).

The relative zero error of each series calculated shall be noted using the following equation:

$$f_0 = \frac{F_{i0}}{F_N} \times 100 \tag{5}$$

6.4.6 Verification of accessories

The good working order and resistance due to friction of the mechanical accessory devices (pointer, recorder) shall be verified by one of the following methods according to whether the machine is normally used with or without accessories:

a) machine normally used with the accessories: three series of measurements shall be made with increasing force (see 6.4.5) with the accessories connected for each force-measuring range used and one complementary series of measurements, without accessories, for the smallest range used.

b) machine normally used without accessories: three series of measurements shall be made with increasing force (see 6.4.5) with the accessories disconnected for each force-measuring range used and one complementary series of measurements with the accessories connected for the smallest range used.

In both cases the relative accuracy error, q, shall be calculated for the three normal series of measurements, and the relative repeatability error, b, shall be calculated from the four series. The values obtained for b and q shall conform to those listed in Table 2 for the class under consideration, and the following further conditions shall be satisfied:

— for calibration with constant indicated force:

$$100\left|\frac{F_i - F_c}{F_c}\right| < 1{,}5\,|q| \tag{6}$$

— for calibration with constant true force:

$$100\left|\frac{F_{ic} - F}{F}\right| < 1{,}5\,|q| \tag{7}$$

NOTE In the equations, the value of q is the maximum permissible value given in Table 2 for the class under consideration.

6.4.7 Verification of the effect of differences in piston positions

For hydraulic machines, where the hydraulic pressure at the actuator is used to measure the test force, the influence of a difference in position of the piston shall be verified for the smallest measuring range of the machine used, during the three series of measurements (see 6.4.5). The position of the piston shall be different for each series of measurements.

NOTE In the case of a double-piston hydraulic machine, it is necessary to consider both pistons.

6.4.8 Determination of relative reversibility error

When required, the relative reversibility error, v, shall be determined by carrying out a calibration at the same discrete levels of force, first with increasing force levels and then with decreasing force levels. In this case, the machine shall also be calibrated with decreasing force.

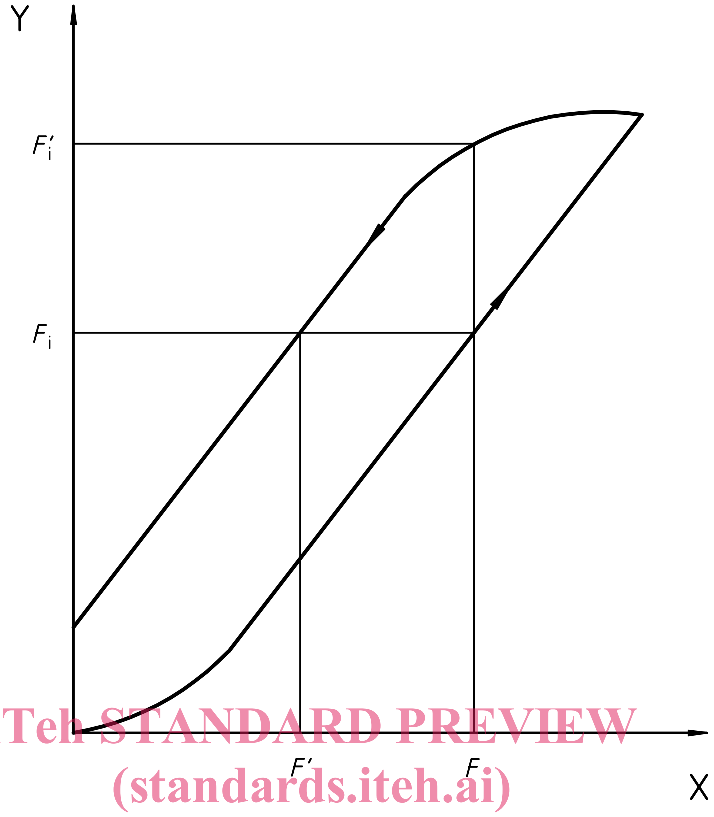
The difference between the values obtained with increasing force and with decreasing force enables the relative reversibility error to be calculated (see Figure 1), using the following equation:

$$v = \frac{F - F'}{\overline{F}} \times 100 \tag{8}$$

or, for the particular case of the calibration carried out with a constant true force:

$$v = \frac{F_i' - F_i}{F} \times 100 \tag{9}$$

This determination shall be carried out for the lowest and highest force ranges of the testing machine.



X True force

Y Force reading on the force indicator

Figure 1 — Schematic diagram for the determination of reversibility

6.5 Assessment of the force indicator

6.5.1 Relative accuracy error

The relative accuracy error expressed as a percentage of the mean true force, $\bar{F}$, is given by the equation:

$$q = \frac{F_i - \bar{F}}{\bar{F}} \times 100 \tag{10}$$

For the particular case of the calibration being carried out with a constant true force, the relative accuracy error is given by the equation:

$$q = \frac{\bar{F}_i - F}{F} \times 100 \tag{11}$$

6.5.2 Relative repeatability error

The relative repeatability error, b, for each discrete force, is the difference between the highest and lowest measured values with respect to the average. It is given by the equation:

$$b = \frac{F_{max} - F_{min}}{\bar{F}} \times 100 \tag{12}$$

