INTERNATIONAL
RECOMMENDATION

OIML R 65

Edition 2006 (E)

Force measuring system of uniaxial material testing machines

Système de mesure de force des machines uniaxiales
d'essai des matérieux

ORGANISATION INTERNATIONALE
DE MÉTROLOGIE LÉGALE

INTERNATIONAL ORGANIZATION
OF LEGAL METROLOGY

Contents

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This publication - reference OIML R 65, edition 2006 (E) - was developed by the OIML Technical Subcommittee TC 10/SC 4 *Material testing machines*. It was approved for final publication by the International Committee of Legal Metrology in 2006 and will be submitted to the International Conference of Legal Metrology in 2008 for formal sanction. This Edition supersedes the previous edition of OIML R 65 (Edition 2000).

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Force measuring system of uniaxial material testing machines

1 Scope

1.1 This Recommendation gives the metrological and technical performance requirements and the inspection and testing procedures necessary for the metrological control of the force measuring system of uniaxial material testing machines subject to national laws and regulations. For metrological control, requirements for initial and subsequent verification only are covered since, in general, type evaluation is not considered to be practical for these measuring systems.

Note 1: Material testing machines that are not subject to laws and regulations and, hence, are not subject to metrological control, may require identical performance for their application.

Note 2: Most of the requirements of OIML R 65 are consistent with those of ISO 7500-1:2004 "Metallic materials - Verification of static uniaxial testing machines - Part 1: Tension/compression testing machines - Verification and calibration of the force-measuring system". It should be noted, however, that in ISO 7500-1:2004 the terms "calibration" and "calibration procedure" correspond to the words "test" and "test procedure" used in this Recommendation. In particular, concerning the test (calibration) procedure for the testing machine, Annex A of OIML R 65 is consistent with the informative Annex C "Alternative method of testing machine classification" of ISO 7500-1:2004.

1.2 The requirements for reference force measuring instruments for verifying the force measuring system of material testing machines are addressed in ISO 376:2004 "Metallic materials - Calibration of force proving instruments used for the verification of uniaxial testing machines".

1.3 Auxiliary instruments and devices associated with tension and compression testing are not covered in this Recommendation.

2 Application

2.1 Material testing machines are used principally for determining the strength of materials, creep, stress relaxation, or other mechanical properties.

2.2 These testing machines carry out tension or compression tests by the application of specific forces. The mechanical properties of materials are determined from the knowledge of the force applied and a measurement of strain or deformation that occurs with time in specific materials.

3 Terminology

3.1 Material testing machine

Device (or assembly of devices) for testing material specimens to determine one or more of their mechanical properties. The device (or assembly of devices) may be in a fixed location or portable.

3.2 Portable material testing machine

Material testing machine that is specifically designed to be moved from place to place without major disassembly and adjustments to its performance characteristics.

3.3 Force measuring instrument

Instrument that measures the force applied by the force generating device of a material testing machine.

3.4 Reference force measuring instrument

Force measuring instrument that has been calibrated and tested with force standards traceable to national standards.

3.5 Repeatability

Closeness of agreement among the results of successive measurements of the same measurand according to the following conditions:

- repeated over a short period of time by the same observer; and
- carried out at the same location under similar ambient conditions, using the same measuring instrument and test procedures.

3.6 Reversibility

Difference in values of indicated force obtained for discrete force values first from measurements with increasing forces and then with decreasing forces.

3.7 Resolution

Smallest difference between indicated values or smallest change of force in the measuring range that can be observed or recorded and quantified at any applied force.

3.8 Accuracy class

Class of measuring instrument that meets certain metrological requirements that are intended to keep errors within specified limits.

3.9 Maximum permissible error (mpe)

Maximum value of the error permitted by laws, regulations, or specifications for a given measuring instrument.

4 Description of a material testing machine

4.1 A material testing machine shall have a frame, force producing system, force indicating and/or recording device(s), and auxiliary devices as described in 4.3.

4.2 Indicating and recording devices may be analog or digital. The scales, indications and recordings shall be clear and well defined. When the indicated or recorded values are not in force units, an appropriate conversion factor shall be provided. Examples of indicating devices include a pointer on a scale, a traveling poise on a graduated beam, a digital indicator, a graphical recorder and a computer output.

4.3 The auxiliary devices needed vary depending on the intended use of the machine. Examples of auxiliary devices include devices that:

- support, hold or grip the test specimens;
- control the rates of applied force, for measuring the duration of an event;
- perform the calculations on the test data; and
- measure the displacement or extension.

5 Metrological requirements

5.1 Force indicating devices

5.1.1 Analog indicating and recording devices

The resolution of an indicator shall be the change in force represented by the ratio of the width of the pointer to the center-to-center distance between two adjacent scale graduation marks (scale interval). The ratios may be 1/2, 1/5 and 1/10; however, the ratio of 1/10 shall require a scale spacing equal to or greater than 2.5 mm. Indicators shall have the zero and maximum values of their ranges clearly marked, and the pointer and scale marks shall be equal in width. For graphical recorders, the pen or marker widths and line spacings of the recorder shall correspond to the pointer widths and scale spacings of the indicator, respectively, for the purpose of determining the resolution.

5.1.2 Digital indicating devices

The resolution shall be one increment of the number on the numerical indicator, if the indication does not fluctuate by more than one increment when the instrument is unloaded or loaded by a constant force. Otherwise, the resolution shall be taken as being equal to half the range of fluctuation plus one digit. Indications shall include the zero and maximum values of their ranges and shall indicate the sign and value of the measurand. For machines that automatically select or extend the measuring range, the resolution shall be determined for each decade of the indicating device.

5.1.3 Testing and verification

The force measuring system shall be tested and verified using an appropriate reference force measuring instrument that meets the requirements of ISO 376:2004 “Metallic materials - Calibration of force-proving instruments used for the verification of uniaxial testing machines” and that is traceable to national standards.

5.2 Accuracy class and maximum permissible errors in force indications

5.2.1 The accuracy class of a material testing machine (column (a) of Table 1) shall be established by at least two successive force applications at five discrete force values within the measuring range.

5.2.2 The repeatability in percent (column (c) of Table 1) of the successive force applications at any discrete force value shall be the absolute value of the difference between the maximum and minimum error in percent.

5.2.3 The percentage error at each discrete force application shall be within the maximum permissible error of force indication given in column (b) of Table 1 (see also A.4.4).

5.2.4 The relative resolution shall be determined at the discrete force values specified in 5.2.1 above the first one-fifth of the force range. The value of the relative resolutions obtained shall be within those maximum permissible values specified in column (d) of Table 1 for each accuracy class (see also A.4.5).

5.2.5 The relative reversibility error shall be determined for the discrete force values specified in 5.2.1, first with increasing forces and then with decreasing forces within the measuring range and according to 3.6. The values of relative reversibility (in percent) obtained shall be within those maximum permissible values specified in column (e) of Table 1 for each accuracy class (see also A.4.6).

Note: If the machine is not used for applying decreasing forces, a test for reversibility is not required.

Table 1 Accuracy classes of material testing machines

(a) Accuracy class of the force indication range	(b) Maximum permissible error (mpe) of force indication	Maximum permissible relative values		
		(c) Repeatability %	(d) Resolution %	(e) Reversibility (if required) %
0.5	± 0.5	0.5	0.25	± 0.75
1	± 1.0	1.0	0.5	± 1.5
2	± 2.0	2.0	1.0	± 3.0
3	± 3.0	3.0	1.5	± 4.5

5.2.6 The assigned accuracy class for a material testing machine shall be assigned based on all results of testing in sections 5.2.2, 5.2.3, 5.2.4 and 5.2.5 (if required) achieving that accuracy class.

5.3 Force measuring range

5.3.1 The force measuring range(s) for a testing machine shall include the specified maximum capacity and lower limit for the appropriate accuracy class.

5.3.2 The lower limit of the measuring range shall not be less than the value established by multiplying d by r, where d is the number of scale intervals for the device as specified in Table 2, and r is the resolution as determined in 5.1.1 or 5.1.2.

A measuring range shall not include any part of the force indication range outside the range of forces applied during the verification tests. For material testing machines with two or more force indication ranges, the lower limits of each measuring range shall be established.

Table 2 Lower limit for the measuring range in d for each accuracy class of testing machine

Accuracy class	Lower limit for measuring range in d
0.5	400
1	200
2	100
3	67

5.4 A procedure for an overall test of the machine is given in Annex A.

6 Technical requirements

6.1 The frame shall provide adequate space to accommodate the force measuring equipment for verification of the machine. The manufacturer shall provide instructions for ensuring the necessary alignment of the axes of the frame of a testing machine with respect to the force mechanism in order to meet the performance requirements of this Recommendation.

6.2 Force producing system

6.2.1 The force producing system shall be capable of applying a force smoothly without significant shock or pulsations to the test specimen over the force indication range(s) of the machine. The force producing system may be mechanical, hydraulic, pneumatic or electrical, or combinations of these types.

6.2.2 Manual or automatic control of the force and displacement systems shall be controllable over the force measuring range(s) of the machine for performing evaluation tests and required calibrations.

6.3 Force indicating device

6.3.1 The testing machine shall include either:

- a permanently attached force indicating device (mounted within the frame or the force producing system); or
- a movable and interchangeable force indicating device.

If there is a change in the zero force indication due to the addition or removal of specimens or auxiliary equipment, there shall be provision for resetting zero.

6.3.2 Analog indications shall be defined by a sufficient set of numerals, words, symbols, units or combinations thereof, uniformly placed with reference to the scale marks and as close thereto as practical, but not positioned so as to interfere with the clarity of the observation or recording. In any series of scale marks, indications or recorded representations, the scale marks and units of a corresponding order of importance shall be uniform in size and character. Scale marks, indications, or recorded representations of secondary order of importance shall be clearly indicated or displayed in a smaller size or in less prominence than the principal indications with which they are associated. The force indicating device shall be constructed so as to minimize parallax errors or the vibration of pointers and pens when making observations. The pointer shall not bear against a stop at the zero or maximum capacity position. For testing machines with more than one indicating range, the scale that includes the maximum force of the machine shall be uppermost or outermost. Alternatively, only the force indication range being utilized shall be displayed.

6.4 The auxiliary devices required for tests shall have sufficient strength and hardness to resist permanent deformation and minimize wear during tests and verifications at forces up to their maximum capacities.

6.5 Markings

A testing machine shall bear the following information, permanently affixed and in a visible location:

- manufacturer's name or trademark and address;
- model and serial number;
- maximum capacity;
- type of applied forces (for example, tension, compression, or both); and
- voltage, frequency and power requirements.

6.6 The mechanisms and devices used to adjust the performance characteristics of the machine shall be designed so that a security seal or other means for providing security may be applied.

6.7 Manufacturers of material testing machines shall provide a manual or relevant software that clearly and concisely describes the operation, routine maintenance and checking of the machine; they shall also specify the operating range of the machine with regard to temperature and humidity.

7 Practical instructions

7.1 Testing machines and their accessories should be installed at locations where the ambient environmental conditions, building structures, vibration and other such factors do not adversely affect their operational or metrological characteristics.

7.2 The force measuring, indicating and recording devices should be installed so that their electrical connections are not adversely affected by the operation of the material testing machine or by adjacent equipment.

8 Metrological controls

8.1 Type evaluation

Note: Type evaluation is not considered to be practical for many material testing machines because of their size and/or complexity in reproducibility of components. Verification as indicated in 8.2, therefore, should be carried out at the site of application.

8.2 Initial verification

8.2.1 Initial verification of a material testing machine shall be carried out prior to the machine being put into service for testing applications covered by laws or regulations.

8.2.2 The user shall provide the responsible national body with a manufacturer's operating manual or relevant instructions and software for the measuring system. The user may also provide data and other information from a credible third party that support a determination of whether the performance of the force measuring system of a material testing machine meets the performance requirements according to this Recommendation.

8.2.3 The operating manual or relevant instructions and software shall be reviewed for completeness and clarity. The material testing machine shall be inspected in conjunction with a review of the manufacturer's specifications to determine whether it meets the resolution requirements for the indicating and recording devices, and all the technical requirements of clause 6.

8.2.4 The responsible authority shall carry out the following performance tests within the range of operating conditions specified by the manufacturer, or consider other acceptable test data that confirm the following:

- repeatability (5.2.2);
- maximum permissible errors of force indication (5.2.3);
- resolution (5.1.1, 5.1.2, 5.2.4);
- relative reversibility error, if required (5.2.5); and
- assigned accuracy class (5.2.6).

8.2.5 The test of the material testing machine for initial verification shall be carried out according to the overall test procedure given in Annex A.

8.3 Subsequent verification

8.3.1 Subsequent verification shall be carried out when the material testing machine is relocated, except for those machines that are designed to be portable, for which subsequent verification after relocation may not be required under normal conditions of use.

8.3.2 Subsequent verifications of material testing machines shall be carried out at intervals specified in national standards recognized by the responsible national body or in national laws or regulations. These verifications may depend on frequency of use, repair or modifications, and other factors that could adversely affect the performance of a testing machine.

8.3.3 The extent of the inspection and testing shall be the same as for initial verification (see 8.2).

8.4 Certificates, test reports and marks

8.4.1 The responsible national body shall provide the user with a certificate and/or approval mark and test report for the force measuring system of the material testing machine that successfully complies with verification tests.

8.4.2 The results of the test shall, as a minimum, contain the elements (information) according to the format provided in Annex B. A specific form may be developed according to national preference. The manufacturer shall be provided with specific information or comments on any failures of tests.

Annex A

Test procedure (Mandatory)

This test procedure applies for all verifications.

A.1 Inspection

A.1.1 An inspection shall be carried out before testing the force measuring system of the machine to ensure that it has been assembled and installed according to the manufacturer's specifications.

A.1.2 The ambient environmental conditions for the test shall be within the range of those specified by the manufacturer and shall be maintained to within ± 2 °C during the test period.

A.1.3 Any other conditions necessary for testing performance requirements specified by the manufacturer in the operating manual shall be established.

A.2 Testing shall be carried out for each of the force ranges specified for the force indicating device or devices. The force measuring system shall be tested as a unit.

A.3 Conditioning the testing machine

A.3.1 Ensure that the reference force measuring instrument used:

- is traceable to national standards;
- is appropriate for the accuracy class of the machine being tested; that is, the absolute value of the maximum permissible errors of the reference instrument shall not exceed 1/3 of the absolute value of the maximum permissible errors of the machine being tested;
- is properly mounted so as to ensure axial application of the force; and
- has temperature corrections applied to the readings. (If temperature compensating features are not inherent, the instrument shall be allowed to reach a stable temperature, and if necessary, the instrument manufacturer shall include the applicable temperature correction coefficients that compensate for the difference between the ambient temperature at testing and the temperature of the instrument during its calibration).

A.3.2 Apply a force to the machine at least three times with a value near the maximum force to be measured and with the reference force measuring instrument in position.

A.4 Test procedure

A.4.1 Check and adjust zero before each series of measurements. Record the zero indication approximately 30 seconds after the removal of each force applied as specified in A.4.2.

A.4.2 Apply a force to the machine and record the force indicated by the machine's indicating device and the reference force measuring instrument. Perform at least two series of measurements with increasing force, and for each series, measure at least five discrete forces suitably distributed between the lower and upper limits of the measuring range, including the upper and lower limits. The individual forces applied in each series should be approximately equal.

A.4.3 For machines designed to select automatically or extend ranges without the intervention of an operator, forces shall be selected starting with the minimum force and applying forces in overlapping decades so that the maximum force in a given decade is the minimum force in the next higher decade.

Apply at least five forces per decade with ratios to the minimum force equal to approximately 1:1, 2:1, 4:1, 7:1 and 10:1.

A.4.4 From the error of indication in percent at each force level selected, determine the repeatability as the absolute value of the difference between the maximum and minimum error in percent obtained for the application of at least two successive forces as follows:

$$\text{Repeatability} = \left| \frac{A_1 - B_1}{B_1} - \frac{A_2 - B_2}{B_2} \right| \times 100$$

Where: A_1 and A_2 = two successive forces presented by the machine's indicating device for increasing forces;

B_1 and B_2 = the respective forces indicated by the reference force measuring instrument.

The results shall be within the absolute value of the maximum permissible error specified in Table 1.

Note: For example, if the first application of force A_1 has an error of indication of 0.5 % and the second application of approximately the same force A_2 has an error of indication of – 0.2 %, then the repeatability error would be equal to 0.7 %. If more than two successive forces are applied, the difference in extreme (maximum and minimum) errors of indications shall be used to determine the repeatability.

A.4.5 For the forces applied according to A.4.4, determine the relative resolution in percent for each discrete force above one-fifth of the scale for each range as follows:

$$\text{Relative resolution } \alpha = \frac{r}{B} \times 100$$

Where: r = resolution of the indicator.

The results shall meet the requirements according to the assigned accuracy class given in Table 1.

A.4.6 If required, determine the relative reversibility error by application of discrete forces according to A.4.4 within the measuring range, first with increasing forces then with decreasing forces:

$$\text{Relative reversibility error } U = \frac{A - A^1}{B} \times 100$$

Where: A = indicated force for increasing values applied;

A^1 = indicated force for decreasing values applied; and

B = indicated force value of the reference force measuring instrument which has been calibrated for both increasing and decreasing forces.

The results shall meet the requirements for the assigned accuracy class given in Table 1.

A.4.7 Assign the accuracy class to the material testing machine based on the results of all tests carried out according to A.4.4, A.4.5, and A.4.6 (if required).

Annex B

Test Report Format (Informative)

This Test Report Format should be considered for use for initial and subsequent verifications and should include the information below.

Report No.: ..... OIML R 65, Edition 2006

B.1 Name and address of the testing laboratory(ies):

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B.2 Location at which the tests were performed (if other than indicated in B.1):

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B.3 Name and address of the manufacturer:

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B.4 Name and address of the applicant (if other than the manufacturer):

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B.5 Markings (identification) on the machine tested:

Manufacturer's name or trade mark: .....

Model number: .....

Serial number: .....

Force indicating device:

Type: .....

Model and serial number: .....

Force capacity: .....

Comments: .....
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B.6 Markings (identification) on the reference force measuring instrument used:

Manufacturer's name or trade mark: .....

Date of verification or calibration: .....

Comments: .....

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B.7 The operating manual has clear and complete instructions:

☐ Yes ☐ No

Comments: .....

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B.8 Force producing system

Type: ☐ Manual ☐ Automatic

Controllable force measuring ranges: ☐ Yes ☐ No

Comments: .....

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B.9 Force indicating device

Type: ☐ Analog ☐ Digital

Indications meet requirements: ☐ Yes ☐ No

Comments: .....

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B.10 List of all auxiliary devices included with the material testing machine at time of testing and verification:

1) .....
2) .....
3) .....
4) .....
5) .....
6) .....

Auxiliary devices are adequate and appropriate to carry out testing and verification:

☐ Yes ☐ No

Comments: .....
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B.11 Mechanisms used to adjust performance characteristics have a means for providing security against non-authorized use:

☐ Yes ☐ No

Comments: .....
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B.12 Force measuring range:

Minimum ..... Maximum .....

Comments: .....

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B.13 Resolution

Analog indicating device value: .....

Digital indicating device value: .....

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B.14 Repeatability and maximum permissible error

First series				Second series				Repeatability
Indicated value	Reference value	% error	Final zero indication*	Indicated value	Reference value	% error	Final zero indication*	%

* See A.4.1

Temperature: Before testing ..... °C; After testing ..... °C.

Maximum permissible errors: .....

Meets requirements: ☐ Yes ☐ No

Comments: .....

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B.15 Relative resolution

Resolution of indication: .....

Force value used for determination: .....

Relative resolution value: .....

Meets requirements: ☐ Yes ☐ No

Comments: .....

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B.16 Relative reversibility errors (if required)

Meets requirements: ☐ Yes ☐ No

Comments: .....

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B.17 For machines designed to select automatically or extend ranges, the information required in B.14 through B.16 and B.17 (if required) shall be repeated for each force decade tested according to A.4.3.

B.18 Brief statement of the conclusions as to whether the force measuring system tested meets the requirements of this Recommendation:

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B.19 Person(s) responsible for the testing:

Signature(s): ..... Signature(s): .....

Title(s): ..... Title(s): .....

Date: .....

Bibliography

[1] ISO 7500-1:2004 “Metallic materials - Verification of static uniaxial testing machines - Part 1: Tension/compression testing machines - Verification and calibration of the force-measuring system”

[2] ISO 376:2004 “Metallic materials - Calibration of force proving instruments used for the verification of uniaxial testing machines”