

ORGANISATION INTERNATIONALE
DE MÉTROLOGIE LÉGALE



INTERNATIONAL RECOMMENDATION

Indicating and recording pressure gauges, vacuum gauges and pressure-vacuum gauges with elastic sensing elements (ordinary instruments)

Manomètres, vacuomètres et manovacuumètres indicateurs et enregistreurs à élément récepteur élastique (instruments usuels)

OIML R 101

Edition 1991 (E)

FOREWORD

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This publication – reference OIML R 101, edition 1991 (E) – was developed by the Reporting Secretariat SP 11-Sr 4 "Pressure gauges with elastic sensing elements" and the Pilot Secretariat SP 11 "Measurement of pressure". It compiles and supersedes the Recommendations R 17 and R 19 revised and approved by the International Committee of Legal Metrology in 1990, and R 94, sanctioned by the International Conference of Legal Metrology in 1988. It will be submitted to the International Conference of Legal Metrology in 1992 for formal sanction.

TERMINOLOGY

The terminology used in this Recommendation follows the *International Vocabulary of Basic and General Terms in Metrology* (VIM – 1984 edition) and the *Vocabulary of Legal Metrology* (VLM – 1978 edition). In addition, for the purposes of this Recommendation the following terminology applies.

T.1. Gauge pressure

A pressure greater than ambient pressure, the latter being considered as the datum point.

T.2. Vacuum

A pressure less than ambient pressure, the latter being considered as the datum point.

T.3. Ambient pressure

The pressure of the environment of the instrument, at the place and time of the measurements.

The ambient pressure may be atmospheric pressure, or it may have a value near to that of the atmospheric pressure when measurements are carried out in an enclosed, sealed space.

T.4. Steady pressure

A pressure that does not vary, or that varies continuously at speeds not exceeding:

1 % of the upper limit of the measuring range per second, for pressure gauges and vacuum gauges,

1 % of the sum of the upper limits of the measuring ranges per second, for pressure-vacuum gauges,

with the greatest pressure variation in one minute not exceeding 5 % of the above values.

T.5. Variable pressure

A pressure which varies in any way whatever, periodic or otherwise, at speeds between:

1 % and 10 % of the upper limit of the measuring range per second, for pressure gauges and vacuum gauges,

1 % and 10 % of the sum of the upper limits of the measuring ranges per second, for pressure-vacuum gauges.

T.6. Normal limit of the measuring range

The upper limit of the part of the measuring range acceptable for permanent operation of the instrument in service.

T.7. Absolute error of measurement

The difference between the indication of the instrument to be verified and that of the standard instrument, for the same pressure.

T.8. Hysteresis error

The difference between the indications of the instrument when the same pressure (except pressures at the lower and upper limits of the measuring range) is reached by increasing or decreasing the pressure.

INDICATING and RECORDING PRESSURE GAUGES, VACUUM GAUGES and PRESSURE-VACUUM GAUGES with ELASTIC SENSING ELEMENTS (Ordinary instruments)

1. Scope

This Recommendation applies to pressure gauges, vacuum gauges and pressure-vacuum gauges (ordinary instruments) with elastic sensing elements, intended for the measurement of the pressure (i.e. gauge pressure, or vacuum, or both) of liquids, vapours and gases by direct indication using a dial and a pointer (indicating instruments) or by continuous recording as a function of time (recording instruments).

The application of this Recommendation is limited to instruments in which the elastic deformation of the sensing element is mechanically transmitted to the indicating or recording device graduated in legal pressure units, and in which the upper limit of the measuring range is between 0.05 MPa and 1 000 MPa.

Note: Recording instruments covered by this Recommendation may be:

- single- or multi-channel recorders,
- with a chart in the form of a disc, strip or sheet,
- with one or several separate recording areas,
- instruments in which the movement of the chart as a function of time is ensured by a clock-work mechanism or an electric motor or both.

This Recommendation includes two sections:

- Section I: Metrological and technical requirements
- Section II: Verification method.

Section I

METROLOGICAL AND TECHNICAL REQUIREMENTS

2. Unit of measurement of pressure

2.1. The unit of measurement of pressure is the pascal, Pa.

2.2. Scales of pressure gauges, vacuum gauges and pressure-vacuum gauges shall be graduated in Pa or its multiples: kPa, MPa and GPa, according to the rules of the International System of Units, SI.

The bar and its submultiples, especially the mbar, may be used insofar as they are admitted by national regulations, and until there is an international decision on their use.

4. Metrological characteristics

4.1. Error of measurement and hysteresis error

4.1.1. The maximum permissible intrinsic error, including hysteresis, is:

- a) $\pm 0.8 A$, for new or repaired instruments,
- b) $\pm A$, for instruments in service,

where A is the product of the accuracy class index (subclause 3.2) and one hundredth of:

- the upper limit of the measuring range, for pressure gauges and vacuum gauges,
- the sum of the upper limits of the measuring ranges, for pressure-vacuum gauges.

4.1.2. The hysteresis error shall not exceed the maximum permissible error, as specified in 4.1.1, after loading the instrument with the full-scale pressure for 15 minutes at pattern evaluation and 5 minutes at verification of new or repaired instruments.

4.1.3. The instrument shall comply with the requirements in 4.1.1 under the following reference conditions:

- a) the instrument shall be installed in the attitude of use as specified by the manufacturer;
- b) the variation in pressure shall be slow and continuous, in order to avoid the effect of the inertia force;
- c) the temperatures of the instrument, of the standard instrument and of ambient air shall be $+ 20\text{ °C}$ with deviations that do not cause a variation of indication greater than $1/5$ of the maximum permissible error of the instrument;
- d) the relative humidity shall not exceed 80 %;
- e) there shall be no vibrations or shocks liable to produce an oscillation of the pointer or stylus with an amplitude greater than $1/10$ of the smallest scale spacing;
- f) the end of the coupling of the instrument and that of the standard instrument shall be in the same horizontal plane;
- g) the medium (gas or liquid) used to transmit the pressure at the time of verification (except where a particular medium is specified for the instrument to be verified) shall be:
 - an inert gas for instruments with an upper limit of the measuring range not exceeding 0.5 MPa,
 - a non-corrosive liquid for instruments with an upper limit of the measuring range exceeding 0.5 MPa,

except for instruments for which the changeover from gas to liquid, and vice versa, does not cause a change in indication greater than $1/5$ of the maximum permissible error; for such instruments any medium, gas or liquid, may be used.

4.1.4. If an instrument has been graduated under nominal conditions other than the reference conditions specified in 4.1.3, it shall be checked for conformity with the requirements in 4.1.1 and 4.1.2 under those nominal conditions, when the difference between the nominal conditions and the reference conditions causes a variation of indication exceeding 1/5 of the maximum permissible error.

4.2. Variation of indication under rated operating conditions

4.2.1. The variation of indication of instruments due to temperature variation shall not exceed:

$$\pm \alpha (t_2 - t_1), \%$$

where:

t_1 is the reference (4.1.3.c) or the nominal temperature (4.1.4), °C

t_2 is the ambient air temperature (3.3), °C

α is the temperature coefficient specified in national regulations, %/°C.

4.2.2. Under the effect of vibrations within the specified limits (3.3), the variation of indication shall not exceed the maximum permissible error as specified in 4.1.1.b.

4.3. Constancy of indications in service

The constancy of the technical and metrological qualities of the instruments in service shall be such that the requirements in 4.3.1, 4.3.2 and 4.3.3 are complied with.

4.3.1. Pressure gauges and pressure-vacuum gauges shall be capable of withstanding a pressure

- a) equal to the upper limit of the measuring range, L, for 6 hours (indicating instruments) or 24 hours (recording instruments),
- b) exceeding the upper limit of the measuring range, L, by a value Δp as shown in the Table below, for 15 minutes:

L (MPa)	Δp (% of L)
$L \leq 60$	10
$60 < L \leq 1\ 000$	5

On completion of this test and after the instrument has been under ambient pressure for one hour, the requirements in 4.1.1.b shall be complied with.

4.3.2. Instruments shall be capable of withstanding a pressure varying continuously with a frequency not exceeding 1 Hz between the limits and for a total number of cycles indicated below:

L (MPa)	Limits of pressure variation (% of L)	Number of cycles
$0.05 \leq L \leq 10$	30 - 70	15 000
$10 < L \leq 60$	40 - 60	10 000
$60 < L \leq 160$	40 - 60	5 000
$160 < L \leq 1\ 000$	40 - 60	1 000

Note: For recording instruments, the chart moving mechanism shall be disengaged during this particular test.

On completion of this test and after the instrument has been under ambient pressure for one hour the requirements in 4.1.1.b shall be complied with.

4.3.3. Instruments shall be transported in packing that ensures that their metrological characteristics are maintained. When it is necessary to check the effect of transport conditions, the packed instruments shall be submitted to:

- a) an ambient air temperature of $-20\text{ }^{\circ}\text{C}$ (or in special cases $-50\text{ }^{\circ}\text{C}$) and $+50\text{ }^{\circ}\text{C}$ for 6 hours at each of those temperatures,
- b) shaking with an acceleration of 30 m/s^2 and a frequency of 80 to 120 shocks per minute, for 2 hours.

Subsequent to these tests the instruments shall comply with the requirements in 4.1.1.b.

Note: The inspection according to 4.3.1, 4.3.2 and 4.3.3 should be carried out during tests for pattern evaluation, and whenever necessary.

5. Requirements concerning indicating and recording devices

5.1. Indicating devices

5.1.1. Pointer

5.1.1.1. The tip of the pointer shall cover 1/10 to 9/10 of the length of the shortest lines of the graduation.

Note: This requirement does not apply to instruments whose scale and pointer are in the same plane and whose reading error does not exceed 1/5 of the maximum permissible error.

5.1.1.2. The tip of the pointer, at the reading point, shall be:

- for instruments of accuracy classes 1, 1.6, 2.5 and 4, in the form of an isosceles triangle whose base does not exceed the thickness of the thickest line of the graduation, and whose apex angle does not exceed 60° ,
- for instruments of accuracy classes 0.25, 0.4 and 0.6, in the form of a blade perpendicular to the plane of the scale, the thickness of the blade not exceeding that of the thinnest line of the graduation.

Note: Other shapes are authorized for the tip of the pointer, provided that the reading error does not exceed 1/5 of the maximum permissible error.

5.1.1.3. Instruments may be fitted with a device for adjusting the indications which alters the position of the pointer with respect to the scale.

5.1.2. Pressure scale

The numbering of the dial and the unit marked on it shall give directly the value of the measured pressure, without having to apply a factor.

5.1.2.1. The scale interval shall be chosen from the series:

1×10^n 2×10^n 5×10^n units of pressure

(where n is a positive or negative whole number, or zero),

and shall be close to the value of the maximum permissible error (4.1.1.b).

5.1.2.2. For linear scales the scale spacing shall be as constant as possible; the greatest scale spacing shall not exceed by more than 20 % the smallest scale spacing on the same scale.

5.1.2.3. The scale spacing shall not be less than 1 mm.

5.1.2.4. The thickness of the scale marks shall not exceed 1/5 of the least scale spacing.

5.1.2.5. The instrument may have complementary signs or lines of thickness exceeding that specified in 5.1.2.4, in order to

- indicate the permissible range of deviation of the tip of the pointer from the zero line,
- indicate the normal limits of the measuring range,
- take into account the supplementary pressure created by the column of liquid transmitting the pressure to the elastic sensing element,
- enable approximate reading at a distance, etc.

5.1.2.6. Scale numbering shall be subject to national regulations.

5.2. Recording devices

When a recording instrument is provided with a scale and a pointer enabling direct reading of the indications they shall comply with the requirements of 5.1.1. Moreover, the scale graduation shall be the same as that of the record chart, except where the latter is graduated in percent of the upper limit of the measuring range.

5.2.1. Recording styli

5.2.1.1. Instruments may be single or multirecorders and may be fitted with one or more recording styli.

5.2.1.2. The construction of the styli shall permit their accurate positioning on the lines of the chart, and the instruments shall be provided with a device to zero the styli. This device shall not introduce any additional error in the recording.

5.2.1.3. The recording line shall be continuous and its thickness shall allow a resolution in conformity with the maximum permissible error.

Note: For a new stylus, a line having a mean thickness of 0.4 mm, not varying by more than ± 0.1 mm over the entire length of the line, and then not varying by more than a factor of two during the life of the stylus, is recommended.

5.2.2. Charts

5.2.2.1. Pressure scale

The scale marks of the chart shall conform to requirements of 5.1.2.1 to 5.1.2.4.

The numbering of the scale shall be in whole numbers between 0 and 100 and shall be uniformly distributed over the full width of the recording field.

Reading of the recording shall give the value of the measured pressure:

- directly with the unit inscribed on the scale, for pressure-vacuum gauges,
- directly with the unit inscribed on the scale or as a percentage of the upper limit of the measuring range, for vacuum gauges,
- directly with the unit inscribed on the scale or as a percentage of the upper limit of the measuring range or after multiplication by a constant factor of the chart, for pressure gauges; this factor shall be chosen from the following series:

0.01 0.1 (1) 10 100

5.2.2.2. Time scale

The interval of the time scale shall be specified in national regulations as a function of the given measuring conditions and the rate of displacement of the chart; the choice of this interval shall provide against any error of reading of the pressure that exceeds 1/5 of the maximum permissible error (4.1.1).

The duration of one revolution of the disc or drum carrying the recording chart shall be chosen from the following series:

1 2 4 6 8 12 16 24 168 h

and the rate of displacement of the chart, from the following series:

10 20 30 40 60 120 300 360 600 1 200 3 600 7 200 36 000 mm/h.

5.2.3. Fitting the chart

5.2.3.1. The chart-moving mechanism shall be such that the chart can easily be fitted by hand, with the inscribing stylus located on the correct line of the time scale.

5.2.3.2. The mechanism for fitting the charts, in disc or sheet form, shall permit them to be inserted and replaced and prevent them shifting or curling during rotation.

The forward feed mechanism for charts in strip form shall permit the rollers to be fitted and replaced, and the strip to unwind over its complete length, without deflections, wrinkles, creases or tears.

5.2.4. Recording

5.2.4.1. The error of the speed of displacement of the chart shall not exceed ± 5 minutes in 24 hours.

5.2.4.2. The line inscribed by the stylus moving over a stationary chart shall not deviate from the time line by more than ± 0.5 mm.

The line inscribed by the stationary stylus on a moving chart shall not deviate from the pressure line by more than a third of the maximum permissible error.

6. Inscriptions and designations

6.1. Indicating instruments

6.1.1. The dial shall bear the following inscriptions:

- a) the symbol of the unit of measurement,
- b) the upper limit of measuring range and accuracy designation,
- c) on the scales of vacuum gauges or on the vacuum part of the scales of pressure-vacuum gauges, the symbol for vacuum, "-" (minus sign) in front of or below the number indicating the limit of the measuring range,
- d) the nominal conditions of graduation (see 4.1.4), if they differ from the reference conditions,
- e) the normal attitude of use, if applicable,
- f) any other symbols or inscriptions of value in connection with the use of the instrument.

6.1.2. The dial or the casing shall, in addition, bear:

- a) the manufacturer's name and address, or his trademark,
- b) the serial number and year of manufacture.

6.2. Recording instruments

The inscriptions and designations borne on the casing shall include those of 6.1 and the following additional inscriptions:

- a) the value of the constant factor, if it differs from 1,
- b) the distance between styli (for multi-recorders),
- c) the rated voltage and frequency of the power supply (for recording instruments with a time movement by synchronous micromotors).

Additionally, the chart shall bear an identification mark or the manufacturer's name.

7. Metrological controls

7.1. When, in any country, pressure gauges, vacuum gauges and pressure-vacuum gauges of the ordinary category of instruments are subject to State metrological controls, these controls shall include, according to the internal legislation of that country, either all or some of the following controls:

- a) pattern approval,
- b) initial verification of new or repaired instruments,
- c) periodic verification of instruments in service.

7.2. Each pattern of instrument produced by each manufacturer is evaluated to verify conformity of the metrological characteristics of the pattern with all the requirements of this Recommendation and with the relevant national regulations.

7.3. Instruments shall be submitted individually to initial and subsequent verifications. The periodicity of verifications shall be fixed by national regulations.

The verification method is given in section II.

Section II

VERIFICATION METHOD

8. Verification operations

Verification includes the following operations:

- a visual inspection,
- a preliminary check,
- the determination of the measurement errors and hysteresis errors,

and if applicable (according to the technological characteristics of the pattern):

- the determination of the error of the speed of displacement of the recording chart,
- a check of the recording device.

9. General requirements for verification equipment

9.1. The errors of the equipment used for the verification of instruments shall not exceed 1/4 of the maximum permissible error of the instruments to be verified.

9.2. A separator shall be used when the fluid in the instrument to be verified differs from that in the standard instrument; this separator shall not cause a change of indication greater than 1/10 of the maximum permissible error of the instrument to be verified.

9.3. The verification installation shall permit the pressure of the medium (gas or liquid) used to be increased or decreased continuously.

9.4. Instruments shall be verified under the reference conditions specified in 4.1.3 or the nominal conditions referred to in 4.1.4.

If condition 4.1.3.c is not met a correction shall be applied to the values indicated by the instrument to be verified (except when it is provided with a correction device for temperature) and the standard instrument.

If condition 4.1.3.f is not met the pressure due to the column of fluid used shall be taken into account and the necessary correction shall be applied, considering that the error due to the difference in level shall always be less than 1/10 of the maximum permissible error of the instrument to be verified.

The ambient air shall comply with any health and safety regulations at the workplace; in addition it shall not contain dust or impurities likely to corrode any part of the instrument with which it may come in contact.

10. Verification procedure

10.1. Visual inspection

10.1.1. The instruments to be verified shall generally conform to an approved pattern when there is a national regulation for pattern approval.

10.1.2. The instruments to be verified shall be in good condition, without visible traces of corrosion, dents, dust or dirt on the housing. The protective coatings of the instrument's components shall be undamaged.

10.1.3. The protective window in front of the dial or the recording chart shall be without defect (scratches, colour changes) liable to impair the reading of the indications.

10.1.4. The thread on the coupling, and the seal, shall be in good condition.

10.1.5. For recording instruments, the joint between the housing and the support of the recording chart shall be firm, preventing any oscillation of the support.

10.1.6. The form of the tip of the pointer or of the recording styli, and the graduations and inscriptions on the dial and housing of instruments, shall comply with the requirements specified in clauses 5 and 6.

10.1.7. The instruments presented for periodic verification shall bear the mark of the previous verification or be accompanied by the previous verification certificate.

10.2. Preliminary check

10.2.1. It is recommended that leak-tightness of the instrument be checked before the verification procedure is begun. For this purpose the instrument to be verified is connected of the verification installation and pressure is increased continuously up to the upper limit of its measuring range. The instrument is then disconnected and left to rest for three minutes; it is considered to be leak-tight if during the next two minutes the pressure drop does not exceed 1 % of the upper limit of the measuring range of the instrument.

10.2.2. When the pressure in the instrument to be verified is increased or decreased continuously, the instrument pointer or stylus shall move smoothly and without sticking.

10.2.3. At ambient pressure the pointer or stylus of the instrument to be verified shall rest at the zero scale mark. Any deviation from zero shall not exceed the value of the maximum permissible error, whether or not the instrument incorporates a zero-setting device.

10.3. Determination of the measurement errors and hysteresis errors

10.3.1. Conditions specific to indicating instruments

The number of pressure values at which the indicating instrument shall be verified and their distribution on the scale shall be chosen so as to exclude the possibility of errors exceeding the maximum permissible values of the error of indication as a result of incorrect or non-linear gauging.

The number of those values shall be, at least:

- 8 for accuracy classes 0.2, 0.25, 0.4, 0.5 and 0.6,
- 5 for accuracy classes 1, 1.6, 2 and 2.5,
- 3 for accuracy classes 4 and 5.

Note: it may be necessary that a greater number of values be adopted depending on the pattern of the instrument.

The readings shall be taken for increasing pressures and, after a rest period of five minutes at the upper limit of the measuring range, for decreasing pressures so as to determine hysteresis errors. The reading at zero shall be taken after a rest period of five minutes at ambient pressure.

10.3.2. Conditions specific to recording instruments

The measurement error for recording instruments may be determined by one of the following two methods:

- the applied pressure is adjusted to set the stylus on the line of the chart at which the verification is to be performed, and the pressure is read on the standard instrument;
- the value of the selected pressure is determined by means of a standard instrument, and then compared with the value read on the record chart.

The second method may be used only when the instrument being verified has been found to have a reading error less than 1/5 of the smallest scale interval of the chart.

The instrument shall be verified for at least five values of pressure evenly distributed throughout the measuring range, including the upper limit of the measuring range.

The measurement errors and hysteresis errors shall be determined after having stopped the drive mechanism of the strip or disk chart.

The values of the hysteresis error for multi-recording instruments shall be determined separately for each stylus of the instrument.

10.3.3. Conditions applicable for both indicating and recording instruments

10.3.3.1. Vacuum gauges with an upper limit of the measuring range of 0.1 MPa shall be subjected during verification to a vacuum of at least 90 % of that upper limit.

10.3.3.2. For pressure-vacuum gauges with a measuring range of pressure greater than or equal to 0.5 MPa, only the continuity of the movement of the pointer shall be checked within the part of the scale to indicate vacuum when the instrument to be verified is subjected to a vacuum varying continuously between 0 and 0.05 MPa. The indications of such instruments are not normally verified under vacuum.

Note: In the part of the scale to indicate vacuum, the limit value below which the indications are not verified is fixed according to the accuracy class of the instrument.

10.4. Determination of the error of the speed of displacement of the recording chart (if applicable)

The error in the speed of the chart shall be determined using a chronometer when the chart is driven by a clock mechanism. If the drive is a synchronous electric motor, a correction for the deviation of the power supply frequency from the nominal frequency shall be introduced according to the indications of a frequency meter, the error of which shall not exceed ± 0.1 Hz. The mains voltage shall not vary by more than ± 10 % of the nominal voltage.

Note: The correction is not necessary if the time is measured by a synchronous clock with the same mains supply as the instrument.

The error of the speed of displacement of the recording chart shall not exceed the value prescribed in 5.2.4.1.

10.5. Control of the recording device (if applicable)

10.5.1. The instrument to be verified shall be connected to the calibration installation providing the pressure. The driving mechanism of the strip or chart disk shall then be disconnected. When the pressure is increased to the upper limit of the measuring range or decreased to zero the line recorded by the stylus on the stationary chart shall be parallel to the time graduation line, any deviation not exceeding the value prescribed in 5.2.4.2.

10.5.2. The coincidence of the lines recorded by the stationary stylus on the moving chart with the pressure lines shall be checked at the following pressures:

- zero (or ambient),
- half the upper limit of the measuring range,
- the upper limit of the measuring range.

During this test disk charts shall make one complete revolution, and strip charts shall be displaced by not less than 200 mm.

The lines recorded by the stylus on the moving chart and the pressure lines on the chart shall coincide, any deviation not exceeding the value prescribed in 5.2.4.2.

10.5.3. There shall be no spillage of ink when the stylus or the chart is stationary or in motion. In addition provisions in 5.2.1.3 shall be met.

Printed in France

GRANDE IMPRIMERIE DE TROYES
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