INTERNATIONAL RECOMMENDATION

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Traffic speed meters

Part 1: Metrological and technical requirements

Cinémomètres pour la mesure de la vitesse des véhicules

Partie 1: Exigences métrologiques et techniques

DRAFT

ORGANISATION INTERNATIONALE DE METROLOGIE LEGALE

INTERNATIONAL ORGANIZATION OF LEGAL METROLOGY

Contents

Contents 3
Foreword 5
Part 1: Metrological and technical requirements 6
1 Introduction 6
2 Scope 6
3 Terms and definitions 6
3.1 General 6
3.2 Mode of use 8
3.3 Working principle 9
3.4 Alignment 10
3.5 Errors and faults 13
3.6 Abbreviations 14
4 Unit of measurement 15
5 Categorisation of speed meters 15
6 Metrological requirements 16
6.1 Measuring intervals 16
6.2 Indicated speed value 16
6.3 Metrologically relevant speed value 16
6.4 MPE for stationary measurements 17
6.5 Linearity error limit for stationary measurements 17
6.6 Certainty of vehicle identification 17
6.7 Indicated distance and angle values 17
6.8 Requirements specific to across-the-road speed meters 17
6.9 Vehicle shape related measurement error 18
6.10 Requirements specific to Doppler-radar based speed meters 18
6.11 Requirements specific to range-finding based speed meters 18
6.12 Requirements specific to fixed-distance speed meters 19
6.13 Requirements specific to average speed meters 19
6.14 Requirements specific to image-based speed meters 19
6.15 Requirements specific to moving speed meters 19
6.15.1 MPE for moving measurements 19
6.15.2 Stationary mode 19
6.15.3 Ego speed meter 20
6.16 Minimum requirements for rated operating conditions 20
6.17 Rated operating conditions 21
6.17.1 Climatic classification 22
6.17.2 Mechanical tests classification 22
6.17.3 Electromagnetic tests classification 22
6.18 Disturbances 22
6.18.1 Fault limit value 22
6.18.2 Acceptable significant faults 22
6.18.3 Other causes of significant faults 22
6.18.4 Reaction to disturbances 23

6.19 Durability ... 23
6.20 Redundancy of the measuring process ... 23
6.21 Presumption of compliance ... 23
7 Technical requirements ... 23
7.1 General principles ... 23
7.1.1 High level metrological protection ... 23
7.1.2 Intended use ... 23
7.1.3 Possibility to carry out examinations and tests ... 24
7.1.4 Protection against fraud and misuse ... 24
7.1.5 Protection of the measurement, software and parameters ... 24
7.2 Indication of measurement results ... 24
7.2.1 Availability of the result of a manual measurement ... 24
7.2.2 Availability of the result of automatic measurement ... 24
7.3 Evidence file ... 24
7.4 Storing evidence files ... 25
7.5 Checking facilities ... 25
7.6 Alignment parameters of mobile speed meters ... 26
7.7 Aiming device ... 26
7.8 Modes ... 26
7.8.1 Enforcement mode ... 26
7.8.2 Test mode ... 26
7.9 Test interface ... 26
7.10 Software ... 27
7.10.1 Software identification (OIML D 31 [3], 6.1.1) ... 27
7.10.2 Fraud protection (OIML D 31 [3], 5.1.3.2) ... 27
7.11 Inscriptions – descriptive markings ... 27
7.12 Manual ... 28
7.13 Sealing ... 28
7.14 Verification marks ... 29
8 Metrological controls ... 29
8.1 Type approval ... 29
8.1.1 Documentation ... 29
8.1.2 Units submitted to type test ... 30
8.1.3 Visual inspection ... 30
8.1.4 Type evaluation tests ... 30
8.2 Initial verification ... 31
8.2.1 Visual inspection ... 31
8.2.2 Tests ... 31
8.2.3 Assessment of conformity ... 31
8.2.4 Marking and securing ... 31
8.3 Subsequent verification ... 31
8.3.1 Tests ... 32
8.4 In-service inspection ... 32
8.4.1 Test ... 32
9 Bibliography ... 32

Foreword

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This publication – reference OIML R 91-1, Edition 202x – was developed by Project Group 3 of OIML Technical Subcommittee TC 7/SC 4 – *Traffic speed meters*. It was approved for final publication by the International Committee of Legal Metrology at its xxth meeting in October 202x. It supersedes the previous edition of R 91 dated 1990.

There was also a change of title of the publication from “Radar equipment for the measurement of the speed of vehicles” to “Traffic speed meters” to make the publication as general as is possible regarding the different technologies implemented in the measuring principle.

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Part 1: Metrological and technical requirements

1 Introduction

This OIML Recommendation consists of four separate parts:

- Part 1: Metrological and technical requirements,
- Part 2: Test procedures,
- Part 3: Test report format,
- Part 4: Type evaluation report format, and

2 Scope

This Recommendation specifies the metrological and technical requirements, metrological controls and test procedures for speed enforcement devices for the measurement of traffic speed of vehicles on the road, hereafter, in short "speed meters". The Recommendation states the conditions that the speed meter must satisfy, when results of speed measurement are to be used in legal proceedings. The Recommendation does not cover the policy of setting speed or trigger limits for measurements.

The Recommendation covers both general requirements valid for all speed meters and specific requirements valid only for certain categories of speed meters (see clause 5).

3 Terms and definitions

3.1 General

3.1.1

speed meter

instrument that measures and displays the speed of a distant vehicle within specified error limits used for traffic enforcement cases

3.1.2

evidence file

electronic file containing all relevant data related to a speed measurement

3.1.3

standby mode

mode of operation in which no speed measurements will be performed

3.1.4

enforcement mode

mode of operation in which speed measurements for traffic enforcement cases are carried out

Note: The enforcement mode is the preferred mode for metrological control.

3.1.5

test mode

mode of operation in which speed measurements for test and examination purposes are carried out

3.1.6

user interface

interface that enables information to be interchanged between the user/operator and the measuring instrument or its (hardware) components or (software) modules

Note: Typical examples of user interfaces are switches, keyboard, mouse, display, monitor, printer, touchscreen, etc.

3.1.7

test interface

software or hardware interface from which measurement signals or data can be read or to which measurement signals can be inserted

Note: To record and analyse signals from field experiments or to insert recorded or artificial data, e.g. to support metrological control.

3.1.8

checking facility (OIML V 1 [1], 5.07)

facility that is incorporated in a measuring instrument and which enables significant faults to be detected and acted upon

3.1.9

manual measurement

speed measurement triggered by user interaction

3.1.10

automatic measurement

speed measurement triggered by the traffic situation without user interaction

3.1.11

trigger line

physical or virtual line segment on one or several lanes of the road at which automatic speed measurements are concluded

Note 1: The trigger line is typically perpendicular to the direction of the road.

Note 2: The trigger line is not necessarily in the same position for every measurement.

3.1.12

trigger distance

horizontal distance along the road from the speed meter to the trigger line

3.1.13

measurement section

straight or curved section on the road, on which the measured vehicle was driving during the measurement

Note 1: Its starting and end points are defined such that the measured speed value refers to the average speed on the measurement section.

Note 2: For a manual measurement, the measured vehicle drives on the measurement section after the measurement is triggered. For an automatic measurement, the measured vehicle leaves the measurement section on the trigger line.

3.2 Mode of use

3.2.1

ego speed

speed (relative to the road surface) of the speed meter during a measurement

3.2.2

ego speed meter

instrument measuring the speed of the vehicle in which the moving speed meter is installed

3.2.3

stationary measurement

speed measurement at zero ego speed, i.e. the speed meter is not moving during the measurement

Note: In other documents, stationary measurements are sometimes called static measurements or measurements from a static point.

3.2.4

stationary speed meter

speed meter which is designed for stationary measurements and does not correct for non-zero ego speed

Note: A stationary speed meter is either fixed or mobile.

3.2.5

moving speed meter

speed meter installed in a vehicle which is intended to be in motion during measurements

Note: An ego speed meter is part of a moving speed meter.

3.2.6

moving measurement

speed measurement using a moving speed meter with non-zero ego speed

3.2.7

mobile speed meter

stationary speed meter which can be moved to different locations between measurements

Note 1: Stationary speed meters installed in a vehicle or on a trailer are also considered as mobile speed meters.

Note 2: Portable speed meters which are used hand-held or which are (temporarily) installed on a tripod or similar temporary stand to guide the hand of the operator for a limited series of measurements are also considered as mobile speed meters.

3.2.8

fixed speed meter

stationary speed meter permanently installed in a cabinet, on a fixed pole or a similar fixed stand

3.3 Working principle

3.3.1

Doppler-radar based speed meter

speed meter emitting microwave radiation and detecting the Doppler shift of the radiation reflected by moving objects

3.3.2

range-finding based speed meter

speed meter emitting pulsed or modulated radiation and detecting the range (distance) from the radiation reflected by objects

Note: 2D and 3D laser scanners and hand-held LIDAR speed meters are examples belonging to this category.

3.3.3

fixed-distance speed meter

speed meter incorporating two or more detection points at fixed distances and detecting the transit time of the vehicles between the detection points

Note: Laser or light barriers, inductive loop detectors, and pressure-sensitive barriers (piezoelectric) are examples belonging to this category.

3.3.4

average speed meter

fixed-distance speed meter with closest detection fields separated by more than 50 m

Note: Average speed meters are also referred to as *section speed meters*.

3.3.5

image-based speed meter

speed meter incorporating one or more video or photo cameras and determining the speed of the vehicles by image processing

3.3.6

beam width

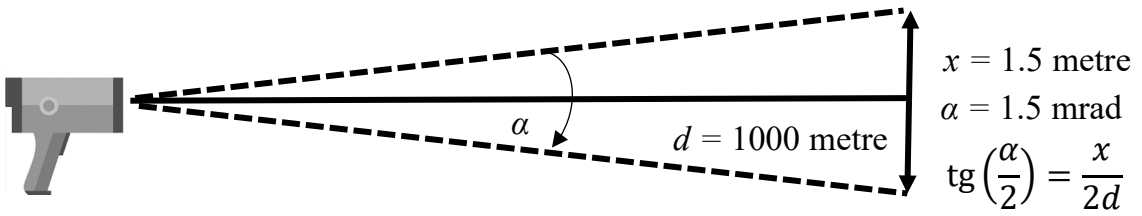
angular span of a radiation beam in the horizontal plane

Note 1: The angular span of a radiation beam in the vertical plane is referred to as *vertical beam width*

Note 2: The beam width of a Doppler-radar based speed meter is commonly measured between half-maximum-power points (or -3dB points) on each side of the main lobe.

Note 3: Beam widths can be expressed in angles or metres (at a specified distance). Angles are typically given in degrees (e.g. for Doppler-radar based speed meters) or in milliradians (mrad; e.g. for hand-held LIDAR speed meters). Figure 1 shows an example.

Figure 1 – Illustration of a beam width of 1.5 mrad or 1.5 metre at a distance of 1000 metre



3.3.7
fixed beam
radiation beam emitted in a fixed angle from the speed meter

3.3.8
scanning beam
radiation beam emitted in a periodically changing angle from the speed meter

3.3.9
detection point
point on the road at which passing vehicles are detected

3.3.10
detection field
section on the road containing all possible locations of a detection point (considering the possible variation of the location of the detection point)

3.3.11
section distance
closest driving distance between entry and exit detection fields of fixed-distance speed meters

3.3.12
hash algorithm
function that converts a data string into a numeric string output of fixed length

Note 1: Hash algorithms are designed to be collision-resistant, meaning that there is a very low probability that the same string would be created for different data.

Note 2: Hash algorithms are used for software identification, authentication of measurements, protection of settings etc.

Note 3: Typical hash algorithms are SHA-2 (256-bit hash) or stronger.

3.4 Alignment

3.4.1
centre line
line starting from the speed meter lying in the centre of the region monitored by the speed meter (see Figure 2)

Note 1: For a speed meter with a fixed beam the centre line is in the centre of the beam.

Note 2: For a speed meter with a scanning beam the centre line is in the centre of the scanning region.

3.4.2
reference point
point on the housing of the speed meter which serves as a reference for all distance measurements to the speed meter (see Figure 2)

3.4.3
azimuth angle of speed meter
horizontal angle between the course of the road and the centre line of the speed meter (see Figure 2)

Note: In other documents, the azimuth angle of speed meter is sometimes called the horizontal alignment angle.

3.4.4

elevation angle of speed meter

vertical angle between the road surface and the centre line of the speed meter (see Figure 2)

Note: In other documents, the elevation angle of speed meter is sometimes called the vertical alignment angle.

3.4.5

side distance of speed meter

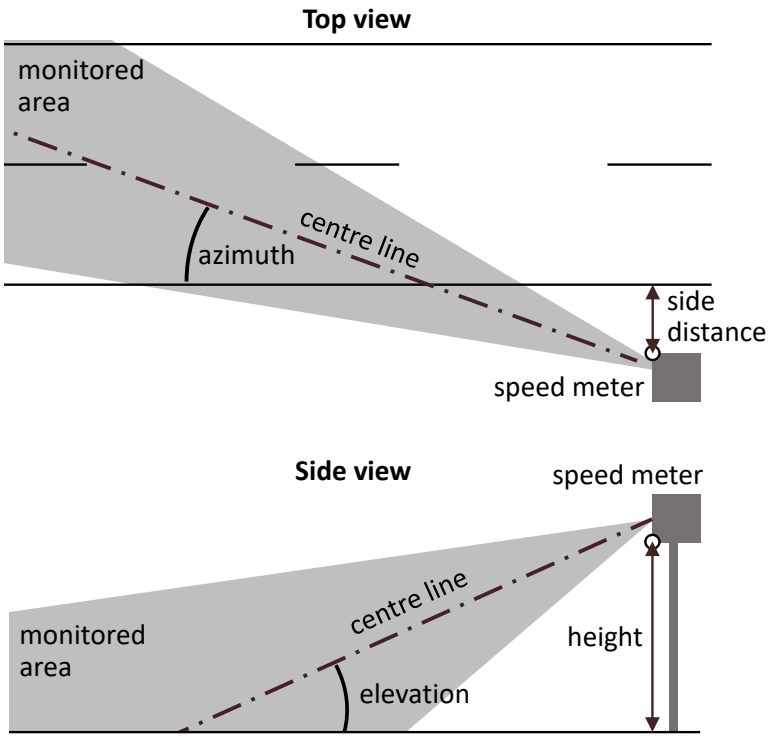
horizontal distance from the reference point of the speed meter to the closest edge of the closest lane (see Figure 2; inner edge of the lane marking)

3.4.6

height of speed meter

vertical distance from the reference point of the speed meter to the road surface (see Figure 2)

Figure 2 – Illustration of several alignment parameters of speed meter (azimuth, elevation, side distance and height). The reference point on the speed meter is marked as a circle. The centre line does not necessarily start from the reference point.



Note: The place of the reference point is determined by the manufacturer. The reference point of this illustration is an example.

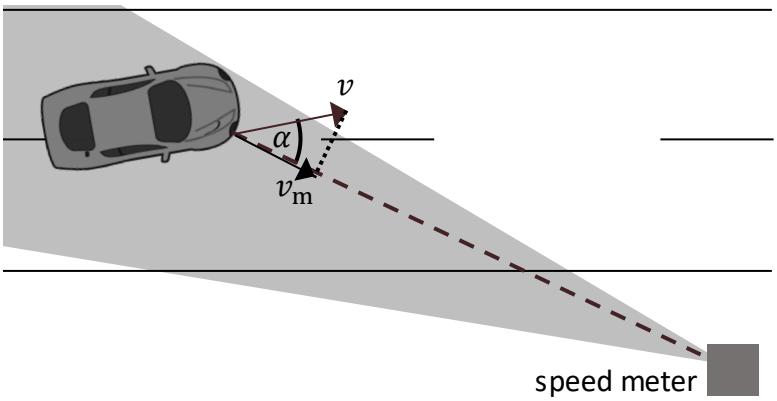
3.4.7

measurement angle

angle between the velocity vector and the line connecting the speed meter and the vehicle at the instance of the measurement (see Figure 3)

Note: The measurement angle has a horizontal and a vertical component. In Figure 3, only a horizontal component is present.

Figure 3 – Illustration of the horizontal component of the measurement angle α



3.4.8
angle measurement
measurement of the horizontal component of the measurement angle

Note: The measurement of the vertical component of the measurement angle is referred to as *vertical angle measurement.*

3.4.9
cosine error
measurement error due to a measurement angle which differs from the configured value, the nominal value or the value measured by the instrument

Note: The name of this term comes from the fact that the component of the velocity vector parallel to the line connecting the speed meter and the vehicle is given by $v_m = v \cdot cos(\alpha)$, where the measurement angle α has in general a horizontal and a vertical component.

3.4.10
along-the-road speed meter
speed meter without compensation for cosine error

Note 1: A variation of measurement angle will always lead to negative cosine errors (i.e. in favour of the accused driver) for this class of speed meters.

Note 2: Typical examples are hand-held LIDAR speed meters and fixed-distance speed meters.

3.4.11
across-the-road speed meter
speed meter with compensation for cosine error using either a measured value of the measurement angle, a configured value of the expected measurement angle or a combination of the two

Note 1: A variation of measurement angle can lead to negative or positive residual cosine errors for this class of speed meters.

Note 2: A speed meter that is installed above the road and compensates for cosine error is also referred to as across-the-road speed meter, for simplicity.

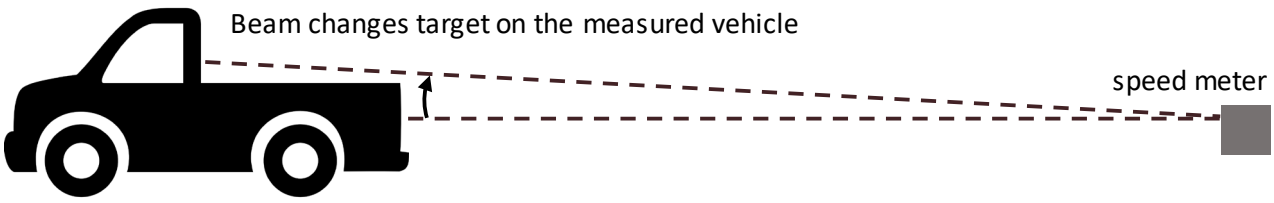
Note 3: Typical examples are most Doppler-radar based speed meters, 2D and 3D laser scanners and image-based speed meters.

3.4.12
aiming device
device to orient the speed meter such that the azimuth and/or elevation are correct

3.4.13
vehicle shape-related error
measurement error due to changing target area on the measured vehicle during the measurement

Note: The change can be manifold, *e.g.* a single step, multiple steps, or a gradual sliding.

Figure 4 – Exemplary arrangement where a vehicle shape-related error could occur



3.4.14
target switching
switching of the target from one vehicle to a different vehicle during the measurement

3.4.15
magnifying viewfinder
visual aid to magnify a target by a specified factor and to aim the measurement beam at the target

Note: It is to be used with handheld speed meters

3.5 Errors and faults

3.5.1
error of indication / measurement error (OIML V 1 [1], 0.04)
indication minus a reference quantity value

3.5.2
maximum permissible error / MPE (OIML V 1 [1], 0.05)
extreme value of error of indication, with respect to a known reference quantity value, permitted by specifications or regulations for a given measurement, measuring instrument, or measuring system

Note: The unit of the error of indication and of the MPE can be either absolute (e.g. km/h) or relative (e.g. %). Error values in relative units given in this recommendation are always relative to the absolute value of the reference (not to the value of the device under test or to any other value).

3.5.3
intrinsic error (OIML V 1 [1], 0.06)
error of indication, determined under reference conditions

3.5.4
initial intrinsic error (OIML V 1 [1], 5.11)
intrinsic error of a measuring instrument as determined prior to performance tests and durability evaluations

3.5.5

durability error (OIML V 1 [1], 5.16)

difference between the intrinsic error after a period of use and the initial intrinsic error of a measuring instrument

3.5.6

fault (OIML V 1 [1], 5.12)

difference between the error of indication and the intrinsic error of a measuring instrument

3.5.7

influence quantity (OIML V 1 [1], 0.07)

quantity that, in a direct measurement, does not affect the quantity that is actually measured, but affects the relation between the indication and the measurement result

Note: For speed meters the following quantities are examples of influence quantities: ambient temperature, measurement angle, acceleration of measured vehicle, distance and speed of other vehicles on the same or neighbouring lanes.

3.5.8

influence factor (OIML V 1 [1], 5.18)

influence quantity having a value which ranges within the rated operating conditions of a measuring instrument

3.5.9

disturbance (OIML V 1 [1], 5.19)

influence quantity having a value within the limits specified in Part 2 of this Recommendation, but outside the specified rated operating conditions of the measuring instrument

Note: An influence quantity is a disturbance if the rated operating conditions for that influence quantity are not specified.

3.5.10

significant fault (OIML V 1 [1], 5.14)

fault exceeding the applicable fault limit value defined in clause 6.18.1

Note: See supplements in clause 6.18.2.

3.5.11

linearity error

observed error in a measurement where all influence quantities have been minimized.

Note: Typically, the linearity error is determined using a simulator in the laboratory.

3.6 Abbreviations

MPE Maximum Permissible Error

EUT Equipment Under Test

LIDAR Light detection and ranging

AC Alternating current

DC Direct current

EM Electromagnetic

IEC International Electrotechnical Committee

ISO International Organization for Standardization

LF Low frequency band (30 kHz – 300 kHz)

VLF Very low frequency band (3 kHz – 30 kHz)

NSFa No significant fault shall occur after the disturbance

NSFd No significant fault shall occur during the disturbance

n/a not applicable

RF radio frequency

RH relative humidity

4 Unit of measurement

All quantities shall be expressed in SI units, unless a country's legal units are different.

The unit of measurement applicable for speed measurement is kilometre per hour (km/h).

Note: The units of measurement in which the given instrument's measurement results will be presented, as well as their symbols, shall conform with the decisions of the General Conference of Weights and Measures (CGPM), OIML D 2 [2], and, if necessary, the detailed specifications of the appropriate part of ISO/IEC 80000 [3].

5 Categorisation of speed meters

Speed meters are categorised according to:

1. Mode of use:
   a. Stationary speed meter (speed meter is not moving during the measurement);
   b. Moving speed meter (from moving vehicle).

2. Principle of installation:
   a. Mobile speed meter (can be moved between several positions);
   b. Fixed speed meter (fixed at one position);
   c. Portable speed meter (can be used from hand or tripod).

3. Working principle of speed measurement:
   a. Virtually instantaneous speed measurement:
      - Doppler-radar;
      - Range-finding (e.g. LIDAR);
      - Fixed-distance (e.g. inductive loops, laser barriers, light barriers, etc.);
      - Image based.
   b. Average speed measurement between two remote positions:
      - Average speed meter (or section speed meter).

4. Triggering and camera
   a. Manual measurements (recommended with camera, possible to use system without camera);
   b. Automatic measurements (always with camera).

5. Compensation for cosine error
   a. Along-the-road speed meter (see 3.4.10)
   b. Across-the-road speed meter (see 3.4.11)

Note: The same speed meter might be assigned to several categories (e.g. stationary and moving mode of use implemented, mobile and fixed installations possible, etc.).

6 Metrological requirements

6.1 Measuring intervals

The specified speed measuring interval shall at least cover the interval from 20 km/h to 180 km/h. A greater upper limit and/or a smaller lower limit may be specified.

If further measurands are directly involved in the speed measuring process (e.g. distance or angle), the manufacturer shall specify the measuring intervals for each of these measurands.

The speed meter shall fulfil the requirements of this Recommendation for all combinations of values inside the specified measuring intervals. If the measured value of one of the measurands (speed and further measurands, if applicable) is outside its specified measuring interval, the speed meter shall not indicate the measured speed value.

Note: National regulations can allow the indication of a symbol or text, if the value of the measured speed is outside the speed measuring interval, but the values of all other measurands are inside their corresponding measuring intervals.

6.2 Indicated speed value

The speed values shall be indicated as integer numbers in units of kilometre per hour (km/h).

All indications (displays, printout, evidence image etc.) of the speed meter must show the same result.

Speed values with higher resolution, i.e. with further decimal digits, shall be restricted to the test interface, test mode or other means not used for legal proceeding.

The speed meter shall use a defined mathematical operation to obtain the indicated integer speed values from the higher resolution values. The absolute value of the difference between integer speed value and high-resolution speed value shall always be less than 1 km/h.

The instrument shall clearly indicate the driving direction of the measured vehicle (for example, departing or approaching vehicle).

If the sign of the speed value is used as indication of the driving direction, the minus sign shall represent a departing vehicle and the plus sign shall represent an approaching vehicle.

If data other than the speed value are indicated, these data shall not be able to be confused with the speed value.

6.3 Metrologically relevant speed values

The following speed values are metrologically relevant and shall be used to calculate errors and faults depending on the test and the applicable acceptance limit:

- The integer speed value used for legal proceedings is metrologically relevant during metrological field tests using real traffic and dynamic performance tests using traffic simulation. The applicable acceptance limits during these tests are the MPE for stationary measurements (6.4) and the MPE for moving measurements (6.15.1).
- The high-resolution speed value read from the test interface or in test mode is metrologically relevant during speed linearity tests at reference conditions and during influence factor and disturbance tests in the laboratory. These measurements are always stationary and the applicable acceptance limits during these tests are the linearity error limit (6.5) and the fault limit (6.18.1).
- The high-resolution ego speed value read from the test interface or in test mode is metrologically relevant during all tests of the ego speed meter and the applicable acceptance limits during these tests are the MPE for ego speed measurements (6.15.3) and the fault limit value for ego speed meters (6.18.1).

Note: The reference speed value used in all metrological controls shall not be rounded to integer values and shall be used with a sufficient number of significant digits.

6.4 MPE for stationary measurements

The following maximum permissible error (MPE) shall apply for stationary measurements within the rated operating conditions in all metrological controls:

a. ± 3 km/h at speeds up to and including 100 km/h, and
b. ± 3 % at speeds above 100 km/h.

The integer speed value from the EUT shall be used to calculate the measurement error.

6.5 Linearity error limit for stationary measurements

The following error limit shall apply for stationary measurements when all influence quantities are minimized or when one isolated influence factor is being examined:

a. ± 1 km/h at speeds up to and including 100 km/h, and
b. ± 1 % at speeds above 100 km/h.

The high-resolution speed value from the EUT shall be used to calculate the measurement error.

6.6 Certainty of vehicle identification

The construction of the speed meter and its speed measurement shall ensure, when the speed meter is used according to the operation manual, that measured speed cannot be attributed to the wrong vehicle, including when other vehicles are driving in the same or opposite direction or passing the measured vehicle.

If the speed meter records image evidence (photo or video) for the identification of vehicles, it shall record the image evidence of the measured vehicle and its surroundings at a specified moment and add it to the evidence file.

The speed meter shall cancel the measurement and shall not produce an evidence file if the measured vehicle was detected outside the detection field in which correct vehicle identification is certain.

Note 1: Possible solutions for certain vehicle identification are, for example, a sufficient restriction of the monitored area and a detection of vehicle positions. The detected positions shall be indicated in an appropriate manner, for example, as numerical values of distances or angles, as assignments to a predefined trigger line including an assignment of the lane, or as markings on the image evidence.

6.7 Indicated distance and angle values

If the speed meter indicates the distance and/or angle values to the measured vehicle according to 6.6,

- the distance values shall be indicated in units of meters with a resolution of at least 0.1 m,
- the angle values shall be indicated in units of degrees with a resolution of at least 0.1°,
- it shall be specified in the operating manual to which moment in the speed measurement process the indicated distance and/or angle values refer to.

6.8 Requirements specific to across-the-road speed meters

The reference point and the location and direction of the centre line shall either be evident or clearly indicated on the housing of the speed meter.

It shall be indicated in the manual, whether the compensation of the cosine error is based on configured parameters and/or on measured values of the horizontal and/or vertical measurement angles.

The interval of allowed values of the alignment parameters azimuth, elevation, side distance and height shall be specified by the manufacturer.

When the speed meter is aligned in accordance with the manual, the errors of measurement attributable to misalignment shall not be greater than ± 0.5 % for the specified interval of alignment parameters.

If the compensation of cosine error is based on configured parameters the manufacturer shall describe a procedure in the manual to retrospectively verify the parameters used in each measurement.

6.9 Measurement error under influence quantities

Stationary measurements (6.4) and moving measurements (6.15) shall comply with the respective MPEs regardless of vehicle shape, traffic density, other conditions on the road, influences from the environment or any other possible influence quantities.

Specific influence factor and disturbance tests shall ensure compliance with the linearity error limit for stationary measurements (6.5) or the fault limit value (6.18.1) (see R 91-2).

The speed meter shall incorporate checking facilities which prevent measurements if necessary.

6.10 Requirements specific to Doppler-radar based speed meters

The following quantities shall be stated by the manufacturer:

- characteristics of the frequency spectrum of the emitted microwave radiation;
- power of the emitted microwave radiation; and
- horizontal and vertical beam widths.

The frequency spectrum of the radiated microwave radiation shall be within the specified frequency band.

The frequency spectrum of the radiated microwave radiation shall be stable and the frequency of the peaks shall not drift for more than ± 0.2 % within 2 years.

The beam width shall be within ± 10 % from rated values.

The power of a possible secondary microwave beam (side lobe) emitted by the antenna shall not exceed −20 dB relative to the main radar beam and it shall not be used for measurement.

6.11 Requirements specific to range-finding based speed meters

The manufacturer shall define the operating wavelength of the device.

The manufacturer shall specify either a fixed pulse repetition rate, pulse time intervals, modulation and sweep frequencies or another characteristic of the time intervals between the pulses which shall be used to test the stability of the device.

The beam width, where only a single beam is used for the measurement, is measured and defined in the horizontal and vertical directions of the measurement beam during the type approval procedure. It shall be within ± 10 % of this value during use.

Maximum specified distance shall be smaller or equal to the distance where the beam width exceeds 1.5 metres, to prevent simultaneous measurement of more than one vehicle. A magnifying viewfinder with an optical magnification of at least 2x is mandatory for all distances over 600 metres.

For any kind of scanning beams, split beams, optical phase array, multiple sources or flood illumination, or any combination of those, the field of illumination (FOI) in vertical and horizontal angle shall be defined by the manufacturer. The radiance profile of illuminated areas, such as spots, lines or full FOI, shall be defined as function of vertical and horizontal angle. The radiance uniformity for patterned illumination of the FOI shall be defined by the manufacturer in percentage.

The FOI shall be within ± 5° of the specified values of the manufacturer. The radiance profile shall be within an envelope of ± 10 % from the nominal profile specified by the manufacturer. The radiance uniformity shall always be equal or higher than the value specified by the manufacturer.

6.12 Requirements specific to fixed-distance speed meters

Fixed-distance speed meters shall incorporate redundant speed measurements by either using three or more detection points or, if only two detections points are used, by other appropriate means.

The distance between detection points shall have a maximum permissible error of ± 0.5 %, also when a possible drift of the detection points is considered.

The signals of the sensors used to detect the vehicles at the detection points shall be continuously monitored.

If the distance between detection points is variable the manufacturer shall state the minimum and maximum distance between detection points.

6.13 Requirements specific to average speed meters

The size of detection field shall not exceed 0.5 % of the minimum section distance.

Image evidence and time stamp shall be recorded at all detection fields.

Time synchronisation between detection fields shall be achieved and maintained in a durable way. Checking of time synchronisation shall be carried out continuously. Speed measurements shall be inhibited immediately when check fails. The maximum permissible error for time measurement is 0.3 %.

All the requirements specific to fixed-distance speed meters (6.12) shall be fulfilled by average speed meters.

6.14 Requirements specific to image-based speed meters

The positions of the measured vehicle shall be marked or described in the video or image evidences.

The image-based speed meter shall not produce any measurements if the image quality is not sufficient to guarantee adherence to the listed MPE.

The different positions of the vehicle (and the distance between these positions) used to determine the speed of the vehicle shall be specified by the manufacturer.

All the requirements specific to across-the-road speed meters (6.8) and to fixed-distance speed meters (6.12), if applicable, shall be fulfilled by image-based speed meters.

6.15 Requirements specific to moving speed meters

6.15.1 MPE for moving measurements

The following maximum permissible error (MPE) shall apply for moving measurements within the rated operating conditions in all metrological controls:

Class A

a. ± 3 km/h at speeds up to and including 100 km/h, and
b. ± 3 % at speeds above 100 km/h.

Class B

c. ± 7 km/h at speeds up to and including 100 km/h, and
d. ± 7 % at speeds above 100 km/h.

The OIML certificate shall indicate the class of the instrument.

The integer speed value from the EUT shall be used to calculate the measurement error.

6.15.2 Stationary mode

It shall be possible to use moving speed meters in stationary mode for metrological control. The error and fault limits for moving speed meters in stationary mode shall be the same as for stationary speed meters (6.4).

The stationary mode shall be a test mode if the moving speed meter does not allow stationary measurements in enforcement mode.

If both stationary and moving measurements are possible in enforcement mode, the moving speed meter shall either:

a. switch automatically between moving and stationary modes (without user interaction), or

b. prevent measurements if the user tries to record stationary measurements when the patrol car is moving.

6.15.3 Ego speed meter

The ego speed shall be measured simultaneously with the relative speed of the target vehicle. The ego speed shall be displayed and stored in the evidence file with a resolution of at least 0.1 km/h. The ego speed with a resolution of at least 0.01 km/h shall be part of the output data of the test interface of moving speed meters and these values shall be used in metrological controls of the ego speed meter without any rounding or truncation.

Moving measurements shall not be possible if the ego speed meter is outside its rated speed measuring interval.

For the ego speed meter, the following MPE shall apply within the rated operating conditions (identical for classes A and B of moving speed meters):

a. ± 1 km/h at ego speeds up to and including 100 km/h, and

b. ± 1 % at ego speeds above 100 km/h.

The high-resolution ego speed value from the EUT shall be used to calculate the measurement error.

A technical description of the ego speed meter shall be included in the user manual. Changes to the vehicle (e.g. change of tyres) have to be clearly either allowed or declared as not possible. If changes are allowed, the user manual has to specify the necessary steps to guarantee adherence to the listed MPE.

Note 1: If the ego speed measurement is based on a revolution counter of a wheel of the patrol vehicle, the validity of the adjustment factor (linked to the effective rolling radius of the wheel) has to be checked at regular intervals, either automatically or by user interaction. No moving measurements shall be possible if the check of the adjustment factor was either not performed or failed.

Note 2: Depending on national legislation, after changing a tyre the verification might no longer be valid. In this case, a new verification must be performed.

6.16 Minimum requirements for rated operating conditions

Speed meters shall be designed and manufactured such that their errors do not exceed the MPE's under the operating conditions listed in Table 1. During influence factor testing, the linearity error limit given in clause 6.5 shall not be exceeded.

Table 1 – Minimum rated operating conditions

Point	Condition	Rated interval or value
A	Ambient temperature	From −10 °C up to +50 °C
B	Relative humidity	Up to 95 % condensing
C	Random vibration	10 Hz – 150 Hz, 7 m/s^2, 1 m^2/s^3, −3 dB/octave
D	DC mains voltage	As specified by the manufacturer

Point	Condition	Rated interval or value
E	AC mains voltage	$0.85 \times U_{nom2}$ to $1.1 \times U_{nom1}$ where U_{nom1} is the highest value of range, U_{nom2} is the lowest value of range.
F	AC mains frequency	$0.98 \times f_{nom2}$ to $1.02 \times f_{nom1}$ where f_{nom1} is the highest value of range, f_{nom2} is the lowest value of range.
G	Voltage of internal battery	All voltages between a new or freshly charged battery, down to the lowest voltage at which the instrument functions properly within the MPEs, according to the specifications given by the manufacturer, at the rated ambient temperature interval
H	Voltage of a road vehicle battery	12 V battery: 9 V to 16 V, at the rated ambient temperature interval 24 V battery: 16 V to 32 V, at the rated ambient temperature interval

When out of service, the speed meters shall be capable of withstanding storage temperatures from −25 °C to +70 °C.

6.17 Rated operating conditions

The manufacturer shall state the following rated operating conditions in accordance with the minimal requirements from 6.16 based on the point of use and the principle of installation:

a. for speed measurement: measuring interval from minimum to maximum speed, including direction of traffic;
b. for vehicle identification, if necessary:
   - minimum and maximum distance to vehicle, where speed can be measured and vehicle identification is certain;
   - minimum and maximum angle or lateral distance to vehicle, where speed can be measured and vehicle identification is certain; and
   - maximum number of vehicles in simultaneous measurement.
c. for climatic influence factors:
   - minimum and maximum operating temperature;
   - minimum and maximum storage temperature and
   - climatic environment classification according to OIML D 11 [4].
d. for mechanical influence factors:
   - mechanical environment classification according to OIML D 11 [4].
e. for power supply and electromagnetic influence factors:
   - reference values for the power supply and
   - electromagnetic environment classification according to OIML D 11 [4].

6.17.1 Climatic environment classification

Speed meters and its parts shall be placed in the following classes according to OIML D 11 [4], 8.2.2 to determine climatic tests levels:

a. H1 – when they are used in enclosed environmentally protected environments, where local climate is controlled,
b. H2 – when they are used in enclosed environmentally protected environments, where local climate is not controlled and
c. H3 - when they are used in open air in moderate temperature zones.

Speed meters intended for exclusive use inside their own proprietary cabinet can be tested inside this cabinet. The cabinet should be identified as a part of the speed meter.

6.17.2 Mechanical environment classification

Speed meters and its parts shall be placed in the following classes according to OIML D 11 [4], 8.3 to determine mechanical test levels:

a. M2 – for static speed meters, including mobile speed meters (portable and handheld) and
b. M3 – for moving speed meters.

6.17.3 Electromagnetic environment classification

Speed meters and its parts shall be generally placed in the following classes according to OIML D 11 [4], 8.4 to determine electromagnetic tests levels:

a. E2 – when the power is provided by an alternating current (AC) mains supply or a direct current (DC) stand-alone supply and
b. E3 - when the power is provided by the battery of a vehicle ("vehicle DC").

For additional guidance, refer to OIML D 11 [4], 5.5, 8.4.2 and 8.5.

6.18 Disturbances

6.18.1 Fault limit value

A fault limit value of ± 1 km/h shall apply for stationary speed meters and moving speed meters in stationary mode. For ego speed meters, a fault limit value of ± 0.5 km/h shall apply.

In both cases the high-resolution speed value from the EUT shall be used to calculate the fault.

6.18.2 Acceptable significant faults

The occurrence of the following significant faults is acceptable

- significant faults arising due to the simultaneous presence of more than one cause, all of which are mutually independent,
- significant faults implying that no evidence file is produced and stored.

Note: The occurrence of such significant faults shall be documented in the test report.

6.18.3 Other causes of significant faults

The occurrence of the following events shall be treated as if a significant fault has occurred:

- if any malfunction occurs which might cause a measured speed to be assigned to the wrong vehicle,
- if a disturbance leads to the corruption of a stored evidence file.

6.18.4 Reaction to disturbances

Speed meters shall be designed and manufactured in such a way, that when they are exposed to disturbances under the limits specified in Part 2 of this Recommendation, either

a) significant faults do not occur, or

b) significant faults are detected and no measurement result is displayed and no evidence file is produced.

6.19 Durability

A speed meter shall be designed to maintain an adequate stability of its metrological characteristics over a period of time substantiated by the manufacturer, provided that it is properly installed, maintained and used according to the manufacturer's instruction when in the environmental conditions for which it is intended.

Note: A possible solution is if the requirements from 6.1 to 6.17 are met permanently during the time interval of 24 months or of the maximum time between subsequent verifications, whichever time interval is longer. The verification period is defined under the responsibility of the national metrological authorities (subsequent verifications).

6.20 Redundancy of the measuring process

The measuring process shall have sufficient redundancy to detect failures with influence on speed measurement.

Note: Examples with insufficient redundancy:

- average speed meter synchronised with GNSS (Global Navigation Satellite System) receivers only: if one of the receivers has an error or is jammed, time synchronization between the entry and exit portal is no longer present and large speed measurement errors are possible,
- fixed-distance speed meters with two pressure-sensitive barriers only: the front wheel of a light motorcycle jumps over the first barrier and is not detected, then the rear wheel is detected by the first barrier, then the front wheel is detected by the second barrier. In this situation, the measured time interval is significantly shorter than the correct time interval and therefore a large speed error is present.

6.21 Presumption of compliance

Speed meters according to this Recommendation are presumed to not comply with the requirements from 6.1 to 6.20, if they fail any one of the tests specified in the Part 2 of this Recommendation.

7 Technical requirements

7.1 General principles

7.1.1 High level metrological protection

A speed meter shall provide the highest level of metrological protection in order that any party affected can have confidence in the result of the speed measurement.

It shall be designed and manufactured to the highest level of quality with respect to the measurement technology and security of the measurement data.

7.1.2 Intended use

The technical and metrological solutions used in the speed meter shall take into account the intended use of the speed meter and any possible foreseeable misuse of it.

7.1.3 Possibility to carry out examinations and tests

The speed meter must be so designed as to enable the carrying out of each examination and test prescribed in this Recommendation.

7.1.4 Protection against fraud and misuse

The metrological characteristics of a speed meter shall not be influenced in any inadmissible way by the connection to it of another device, by any feature of the connected device itself or by any remote device that communicates with the speed meter.

Hardware components that are critical for metrological characteristics shall be designed so that they can be secured.

Security measures foreseen shall provide for evidence of an intervention.

The speed meter must not possess any characteristics that simplify or induce fraudulent use or misrepresentation of the actual speed.

7.1.5 Protection of the measurement, software and parameters

The speed measurement, software critical for speed measurement and metrological important parameters stored or transmitted shall be adequately protected against accidental or intentional corruption or alteration.

Legally relevant software shall be identified.

7.2 Indication of measurement results

Reading of the results (on the display, printed or recorded one) shall be reliable, easy and unambiguous under normal conditions of use.

The result of the measurement shall be displayed digitally by means of aligned digits.

The symbol of the measurement unit shall appear in close proximity to all indicated values of measured quantities. The characters used shall be at least 3 mm high.

7.2.1 Availability of the result of a manual measurement

Speed meters performing manual measurements shall indicate the measured speed accompanied by at least the local time of measurement with a resolution of at least one second. If no evidence files are stored, the indication shall remain visible and any further measurements shall be inhibited until the indication is cleared explicitly by an action of the operator.

7.2.2 Availability of the result of automatic measurement

Speed meters performing automatic measurements shall record and store evidence files for later processing and use.

7.3 Evidence file

At least the following items should be recorded in the evidence file:

a. Date and time of measurement,
b. Location of measurement,
c. Unique identification of measurement (e.g. current sequence number),
d. Speed of the measured vehicle with a resolution of 1 km/h, including an indication of the driving direction of the measured vehicle,
e. Speed limit (only for stationary speed meters),
f. Type designation,

g. Serial number of the speed meter,
h. One or several photos or video files of measured vehicle (if applicable),
i. Additional information relevant for vehicle identification (e.g. lane indicator, crosshair, marker, etc.), if the speed meter can cover several vehicles during the measurement (6.6),
j. Configuration of the speed meter,
k. Measured ego speed with a resolution of at least 0.1 km/h (only for moving measurements) and
l. Indication whether the measurement was moving or stationary (only for moving speed meters which allow stationary measurements in enforcement mode).

The evidence file shall be secured by appropriate means to ensure its integrity, security and authenticity.

Note: National regulations can prescribe a different list of items.

7.4 Storing evidence files

Speed meters that store evidence files shall provide secure and medium-term storage (for example, for 3 months) of data for further use in legal proceedings.

Evidence files shall be stored automatically after the measurement is done.

The measurement value stored shall be accompanied by all the relevant information that is necessary for future legally relevant use.

The data shall be protected by software means to guarantee the authenticity, integrity and correctness of the information related to the speed measurement.

Software displaying data from stored evidence files shall check automatically the authenticity and integrity of the data. If an irregularity is detected, the data shall be discarded or marked unusable.

Confidential private keys employed for protecting data shall be kept secret and secured in the system of the speed meter.

There must not be any possibility to read the private key, except by the cryptographic routines of the speed meter itself during the signing process of a new evidence file.

7.5 Checking facilities

Self-checking shall be carried out each time the speed meter is switched on. When performing automatic measurements, self-checking shall be carried out at least once per day.

Speed meters performing manual measurements shall use at least type N – non-automatic checking facility according to OIML D 11 [4], 3.19.2, and when performing automatic measurements, they shall use type I – intermittent automatic checking facility according to OIML D 11 [4], 3.19.1.2.

Self-checking shall cover all steps along the measurement chain, starting as early as practically possible in the detection and signal-forming chain and extending all the way to display/storage, for example by simulating a speed or a time interval (depending on the technology).

The frequency source used by the checking facility shall be independent from the frequency source used for the measurement process. When any error outside the permissible limit, significant fault, defect, or an error signal is detected, the speed meter shall give an error message and shall not allow any further measurements. The maximum permissible error for self-checking shall be ± 1 % for all simulated speed values (*i.e.,* also below 100 km/h).

Self-checking shall also cover the authenticity of all legally relevant parts of the software and of the parameters whose values do not depend on the site of measurement. Site-dependent parameters such alignment parameters, trigger line definition, lane definition, etc. do not have to be part of the self-checking. The speed meter shall constantly monitor the ambient temperature. When the operating temperature interval is exceeded, the speed meter shall give an error message and shall not allow any further measurements.

If the speed meter is located within an air-conditioned container, the speed meter shall constantly check the temperature inside the container. The manufacturer shall specify the operating temperature interval inside the container. When the operating temperature interval inside the container is exceeded, the speed meter shall give an error message and shall not allow any further measurements.

The speed meter shall constantly monitor its power supply lines. When the rated operating voltage interval is exceeded the speed meter shall give an error message and shall not allow any further measurements.

7.6 Alignment parameters of mobile speed meters

If a mobile speed meter has metrologically relevant alignment parameters, the user shall be requested to confirm their values after each start-up and before speed enforcement is possible.

It shall be possible to check the correct alignment of the speed meter during and after the measurement.

Note: Possible solutions could be:

- the vanishing point is located in a defined area on all recorded images, or
- virtual reference lines in the camera image match with the roadside.

7.7 Aiming device

Any aiming device shall be of robust construction such that its orientation is maintained under disturbances.

The manufacturer shall describe a procedure in the manual to verify the orientation of any aiming device.

7.8 Modes

7.8.1 Enforcement mode

It shall be clearly indicated when the instrument is in enforcement mode.

7.8.2 Test mode

The existence of a test mode is optional except if required for metrological control. The test mode shall not be accessible to the user and shall be protected (e.g. by a password). The test mode may be required for metrological control, e.g. if state-of-the art simulation in enforcement mode is not possible. The results of the speed measurements in enforcement mode and in test mode must be identical. The manufacturer is obligated to specify all differences between enforcement mode and test mode.

7.9 Test interface

The speed meter shall be equipped with a test interface, which outputs data or signals relevant for the purpose of metrological control.

The output data must be activated in enforcement mode and should include at least:

a. time stamp of the measurement;
b. measured speed value with a resolution of 1 km/h (legally relevant);
c. measured speed with a resolution of at least 0.1 km/h (see 6.2);
d. measured distance with resolution of at least 0.1 metres (if applicable);
e. measured angle with resolution of at least 0.1° (if applicable);
f. target position coordinates with resolution of at least 0.1 metres (if applicable);
g. lane information (if applicable)
h. measured ego speed with resolution at least 0.01 km/h (if applicable);
i. vehicle direction (if applicable);
j. version number and hash value of software (at start-up);

k. the result of a checking facility with a resolution of at least 0.1 km/h (if applicable);
l. identification based on the serial number;

If it is not possible to simulate the sensor input signal of a variety of traffic situations using state-of-the-art simulation a testing input interface is required.

7.10 Software

All software influencing the metrological characteristics of a speed meter shall be identified as such and shall be secured.

The whole software of the speed meter should be considered as legally relevant only if software separation is not implemented as described in OIML D 31 [5], 6.3.2.2.

7.10.1 Software identification (OIML D 31 [5], 6.2.1)

The software of the speed meter shall be clearly identified with a version number assigned by the manufacturer, and a state-of-the-art hash value. The identification shall be inextricably linked to the software itself and shall be calculated, then presented or printed on command or displayed during operation or at start up.

The hash algorithm shall be a standardised algorithm.

The software version and hash value shall be easily accessible and easy to readout. It shall be possible that these values are transferred to the testing interface during start-up or on request.

7.10.2 Evidence and prevention of intervention and prevention of misuse (OIML D 31 [5], 6.2.3 and 6.2.4)

The software shall be secured against unauthorized modification, loading, or changes by swapping the external memory device.

In addition to mechanical sealing, technical means may be necessary to secure measuring instruments having an operating system or an option to load software.

Software protection comprises appropriate sealing by mechanical, electronic and/or cryptographic means, making an unauthorized intervention impossible or evident.

Only clearly documented functions are allowed to be activated through the user interface, which shall be realized in such a way that it does not facilitate fraudulent use.

For the type approval procedure, the manufacturer of the measuring instrument shall declare and document all program functions that can be activated through the user interface. Non-documented functions shall not exist. The manufacturer shall state the completeness of the documentation of these functions.

Parameters that fix the legally relevant characteristics of the speed meter shall be secured against unauthorized modification. For the purpose of verification it must be possible to display or print the current parameter settings.

7.11 Inscriptions – descriptive markings

The speed meter shall be marked with a tamper-evident label on a visible part of the instrument with the following information:

a. manufacturer's trade mark/corporate name,
b. year of manufacture,
c. type designation/model number,
d. type approval mark according to national regulations,
e. serial number of the instrument,
f. speed measuring interval,

g. maximum and minimum measuring distance, if applicable,
h. ambient temperature range,
i. details of the electrical power:
   - in the case of mains power: the nominal mains voltage, frequency and power required;
   - in the case of power by a road vehicle battery: the nominal battery voltage and power required; and
   - in the case of an internal removable battery: the type and nominal voltage of the battery.

If the speed meter consists of several units, each unit shall bear at least markings a., b., c. and e. The main unit, visible to the user, shall bear all inscriptions.

The marking must be visible after mounting to casings and vehicles, without using a tool.

7.12 Manual

The manual shall be approved during the type evaluation.

The manual shall be in the official language(s) of the country (or another accepted language according to national legislation) and easily understandable.

The information in the manual must be chosen and structured such that following all instructions in the manual is sufficient to guarantee that the speed meter fulfils all requirements, in particular obeys the error limits and ensures correct identification of the measured vehicle.

The manual shall include at least:

a. installation instructions,
b. operating instructions,
c. description of self-checking procedures,
d. maximum and minimum storage temperatures,
e. rated operating conditions,
f. all other relevant mechanical and electromagnetic environmental conditions,
g. mechanical and electromechanical environment classes,
h. safety and security conditions,
i. checks before or during measurement,
j. significance (meaning) of checking result,
k. description of (error) messages, and
l. information for correct interpretation of result

Installation instructions shall cover, if necessary, the acceptable:

a. minimum horizontal and vertical road curve radius,
b. intervals of installation height and side distance,
c. intervals of azimuth and elevation angles.

7.13 Sealing

Effective sealing means shall be provided by the manufacturer on all parts of the speed meter that are not materially or electronically protected in another way against unauthorized intervention that may affect its accuracy or integrity.

Sealing can be realised mechanically, electronically or by any other technical means, which provides clear evidence of any tampering with the protection of the speed meter.

This applies in particular to

a. adjustment means,
b. replacement of specific parts, if this replacement is expected to change the metrological characteristics, alignment or aiming of the speed meter, and
c. software integrity.

7.14 Verification marks

On the speed meter there must be enough space to put verification marks at visible spots.

8 Metrological controls

The metrological controls of speed meters may, in agreement with national regulations, consist of

a. type approval,
b. initial verification,
c. subsequent verification, and
d. in-service inspection.

Measures to ensure durability (see 6.19), which shall include assessments under items a. to d. above shall be taken subject to national regulations.

8.1 Type approval

8.1.1 Documentation

The documentation submitted with the application for type approval shall include, as far as applicable and in accordance with national regulations:

- metrological characteristics of the speed meter, including a statement about durability;
- technical and electronic specifications;
- functional description of the speed meter including its subassemblies and components;
- description of checking facilities to prevent measurements under certain conditions (see clause 6.9);
- drawings, diagrams and photos of the speed meter explaining its construction and operation;
- a list of interfaces specifying types, intended use, immunity to external influences;
- installation requirements and instructions;
- description and application of self-checking mechanisms;
- security sealing plan including drawings or photos;
- security measures for protection of software, settings and measurement data;
- panel layout (user interface);
- general information on the software (covering in particular the requirements in 7.10);
- operating instructions and operating manual that will be provided to the user;
- documents or other evidence that support the assumption that the design and characteristics of the measuring instrument comply with the requirements of this Recommendation,
- the documentation requested in OIML D 31 [5], 7.1,
- a sample of a recorded event (evidence file), and
- description of measuring principles or algorithms and how speed values for indication are obtained (including mathematical operation used to obtain integer speed values from high-resolution values).

The testing laboratory can request any additional more detailed documentation to be able to continue with the testing of the speed meter.

8.1.2 Units submitted to type test

Type evaluation shall be performed on at least one equipment under test (EUT), which represents the definitive type.

The evaluation shall include the examination and tests specified in part II of this Recommendation. Additional tests can be applied, if it is necessary due to the technology of the speed meter.

The applicant shall supply at least one production EUT for type testing.

The testing laboratory may carry out different tests simultaneously on two or three EUTs. In this case, the testing laboratory shall ensure that all submitted instruments are in conformance to type.

All accuracy and influence tests shall be performed on the same EUT, but disturbance tests may be performed on one more additional EUT. These additional EUTs shall also be submitted beforehand to the accuracy tests.

If an EUT does not pass a specific test and as a result has to be modified or repaired, the applicant shall carry out this modification to all EUTs supplied for testing.

If the testing laboratory cannot exclude that the modification has a negative influence on tests that already had a positive result, these tests shall be repeated.

The EUT may be adjusted, if necessary, before type approval testing begins. Thereafter, no adjustment shall be performed until all type approval testing is complete.

8.1.3 Visual inspection

The instrument and the documentation shall be given a visual inspection to obtain a general appraisal of its design and construction, and the documentation shall be studied.

In particular, the following aspects shall be examined:

a. measuring interval (6.1);
b. indicated speed value (6.2) and other values and information (6.7 and 7.3);
c. protection against fraud (7.10.2);
d. checking facility (7.5);
e. durability protection (6.19);
f. software (7.10);
g. storing of measurement results (7.4);
h. data transmission (7.1.5);
i. inscriptions (7.11);
j. operating manual (7.12);
k. sealing (7.13); and
l. suitability for testing (7.9).

8.1.4 Type evaluation tests

Type evaluation tests for speed meters include the following tests:

a. Metrological field test (OIML R 91-2, 4);
b. Metrological laboratory test by traffic simulation (OIML R 91-2, 5) (optional);
c. Influence factor and disturbance tests (OIML R 91-2, 6);
d. Tests specific to certain categories of speed meters (OIML R 91-2, 7);
e. Durability tests or other methods of estimating durability error; and
f. Software tests (OIML R 91-2,8).

8.2 Initial verification

Initial verification shall be carried out by the metrological authority to establish conformity of the speed meter to the approved type and/or the requirements of this Recommendation.

The speed meter shall comply with the requirements from clauses 6 and 7.

Initial verification control may be performed according to national regulations.

8.2.1 Visual inspection

Before testing, the speed meter shall be visually inspected for:

a. metrological characteristics,
b. prescribed inscriptions and positions for verification and control marks,
c. visual conformity with the approved type as described in the approval certificate, and
d. the speed meter shall be in good working order.

8.2.2 Tests

During the initial verification, the following test should be carried out:

a. laboratory accuracy test, or
b. field accuracy test.

It is allowed to combine or switch between those two tests.

The speed meter shall be fully assembled and operational.

8.2.3 Assessment of conformity

Assessment of conformity to the approved type and this Recommendation shall cover:

a. compliance of the instrument with the metrological requirements in clause 6, in particular with the MPE given in 6.4 and 6.15.1,
b. compliance of the instrument with the technical requirements in clause 7,
c. correct functioning of the complete speed meter, and
d. configuration of the speed meter as far as it has metrological relevance to speed measurement.

8.2.4 Marking and securing

According to national regulations, signing or marking of initial verification may follow 7.14.

National regulations may also require securing of speed meter installation parameters or other devices that might influence the metrological characteristics of the speed meter.

8.3 Subsequent verification

Subsequent verification shall be carried out by the metrological authority to trace the conformity of the speed meter to the approved type and/or the requirements of this Recommendation over operation time.

Subsequent verification control may be performed according to national regulations.

Subsequent verification shall be carried out in accordance with the same requirements as in 8.2 for initial verification with the same MPE as for initial verification.

Marking and securing may take place according to 7.14 and according to any additional requirements of national regulations.

8.3.1 Tests

During the subsequent verification, the following test should be carried out:

a. laboratory accuracy test, or
b. field accuracy test.

It is allowed to combine or switch between those two tests.

The speed meter shall be fully assembled and operational.

8.4 In-service inspection

In-service inspection shall be carried out in accordance with the same requirements as in 8.2 for initial verification, with the exception that the in-service MPE according to national regulations shall be applied. Marking and securing may remain unchanged or renewed according to 8.3.

8.4.1 Test

In-service inspection can be done according to the field accuracy tests.

9 Bibliography

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