ANNEX B

Compliance of DELTA LTL-M with the EN 1436

LTL-M is a vehicle mounted instrument for the measurement of the coefficient of retroreflected luminance R_L of road markings (and road surfaces) in the unit of $mcd \cdot m^{-2} \cdot lx^{-1}$. It works by the principles described in section 1.

Figure 1: DELTA LTL-M.

EN 1436:2018 "*Road marking materials - Road marking performance for road users and test methods*" - sets detailed requirements to both handheld and vehicle mounted instruments in a normative annex B "*Measurement method for the coefficient of retroreflected luminance R_L*".

The table 1 below indicates a complete compliance of the DELTA LTL-M with this annex. Some difficult issues are considered further in the following sections 2, 3, 4, 5, 6, 7 and 8.

NOTE: Reference to EN 1436 is for convenience There are similar requirements in ASTM WK61036 "*Standard Test Method for Measurement of Retroreflective Pavement Markings Using a Mobile retroreflectometer Unit (MRU)*". Besides, what works in Europe will work anywhere.

Table 1: Compliance of DELTA LTL-M with EN 1436 annex B.

Clause in EN 1436	Requirements	Compliance by DELTA instruments	Explanations
B.2	Spectral match to allow measurement of white and yellow road markings within ± 5 %	**Yes**	This is tested for each individual instrument
B.3 and B.4.3.1	Measured area of minimum 50 cm^2 Side angle angle within ±5° Observation angle α of 2,29° ± 0,05° Illumination angle ε of 1,24° ± 0,05° Other limitations in accordance with clause B.3	**Yes**	Refer to section 2
B.4.1	Measuring range of 1 to minimum 2.000 $mcd \cdot m^{-2} \cdot lx^{-1}$ with adequate linearity	**Yes**	This is tested for each individual instrument
B.4.3.2	Suppression of daylight signal	**Yes**	Refer to section 3
B.4.3.3	Suppression of changes of signal from tilts and shifts in height	**Yes**	Refer to section 4
B.4.3.4	Placement of the measured field on the road marking surface	**Yes**	Refer to section 5
B.4.3.5	Longitudinal coverage of the road marking surface	**Yes**	Refer to section 6
B.5	Calibration of measuring equipment	**Yes**	Refer to section 7
B.8	Uncertainty of measurement	**Yes**	Refer to section 8

1 Principles of the LTL-M

The LTL-M has a powerful flashlamp for illumination and a digital camera for detection. The flash is very short and synchronized with the exposure of the camera, which is also very short.

The measurements are at a rate of 25 per second.

The LTL-M uses the principle of reversibility in the sense that the flashlamp is mounted at the location where the camera should have been and vice versa.

Optics at the flash lamp determines the illuminated field so that it is included within the field measured by the camera.

The size and the location of the illuminated field is shown in figure 1.

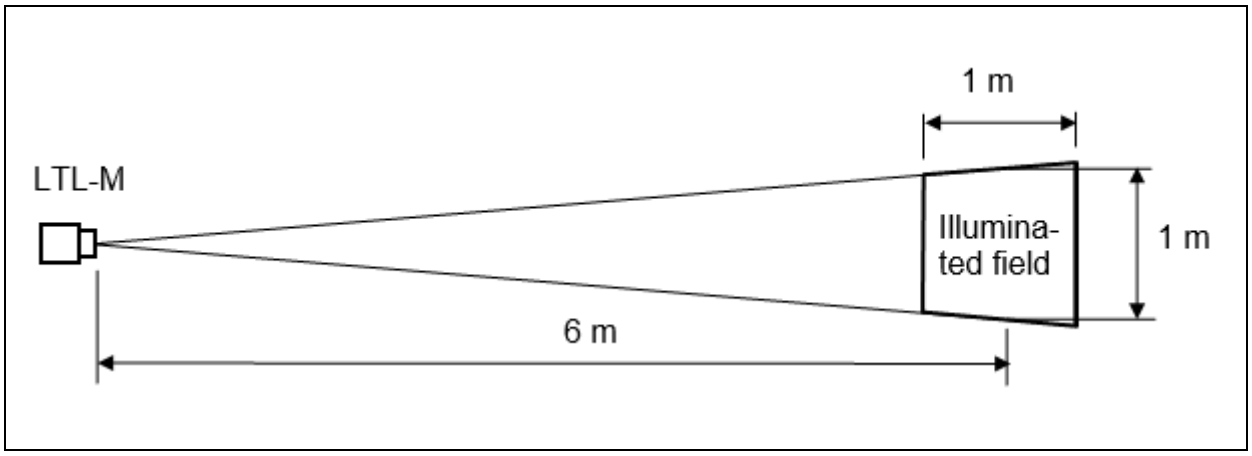


Figure 1: Illuminated field of the LTL-M as seen from above.

Suitable software locates a longitudinal road marking within the illuminated field, if any. The software also locates two longitudinal lines, whenever they form a double line. Additionally, the software determines the widths of lines, and the fronts and ends of broken lines. As the driving speed is also known, a complete account of the geometry is provided. Further, the software determines the R_L value of each of the lines.

The part of a road marking that is within the illuminated field defines the length of the measured area. The width of the measured area is defined by the width of the road marking.

As an example, a continuous road marking of a width of 10 cm has a length of the measured field of 100 cm and a width of 10 cm resulting in a measured area of 100×10 =1000 cm^2.

To avoid fluctuation and drift of the calibration, the camera has a look to the flashlamp by means of two glass plates as shown in figure 2.

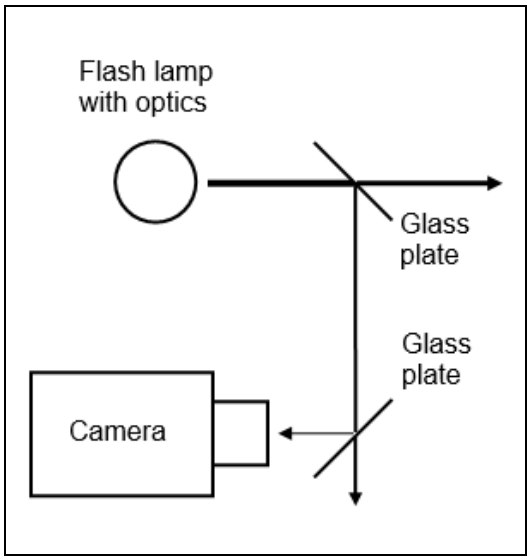


Figure 2: Two glass plates used to give the camera a look to the flashlamp.

The image of the flashlamp is placed in a separate part of the camera image and its average luminance is determined by the software.

The R_L value of a part of a road marking within the illuminated field is determined as:

$R_L = F \times L_{road\ marking} / L_{flashlamp}$

where F is a calibration factor,

$L_{road\ marking}$ is the average luminance of a road marking within the illuminated field,

and $L_{flashlamp}$ is the average luminance of the flashlamp.

2 Compliance with clauses B.3 and B.4.3.1

The measured field is clearly much larger than the minimum of 50 cm^2 requested in EN 1436 clause B.3. Therefore, the interesting matter for vehicle mounted instruments is the longitudinal coverage of the surface of a road marking. Refer to section 6.

The maximum side angle is limited by width of the illuminated field of 0,5 m at the distance of 6 m. Accordingly, the maximum side angle is ± arctan(0,5/6) = ± 4,7°. This is within ± 5,0°.

At the distance of 6 m, the LTL-M complies with the requirements of an observation angle α of 2,29° ± 0,05° and an illumination angle ε of 1,24° ± 0,05°. At shorter or longer distances the angles are slightly different as shown in figure 3.

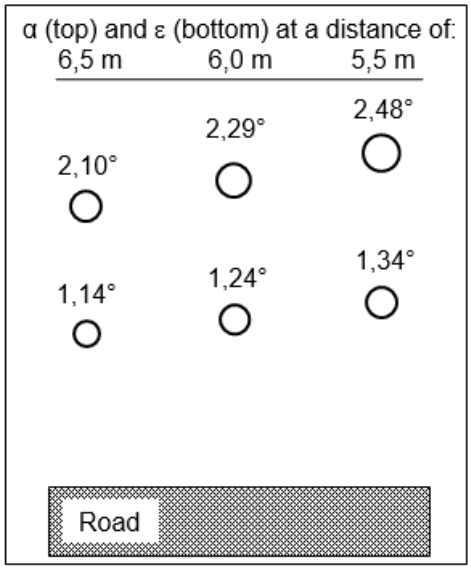


Figure 3: Values of α and ε for three distances.

This seems like a deviation from the above-mentioned requirements for the angles α and ε.

However:

a) EN 1436 allows for deviations of α and ε for vehicle mounted instruments in clause B.4.3.1,
b) The deviations are small, about 8 %,
c) The ratio between ε and α does not change and, therefore, R_L values road markings tend not to change.

In total, there is compliance with EN 1436.

NOTE: DELTA handheld instruments use collimating optics that simulate infinite distance and thereby keeps α and ε constant. This is not possible for vehicle mounted instruments as that would require optics as wide as the measured field.

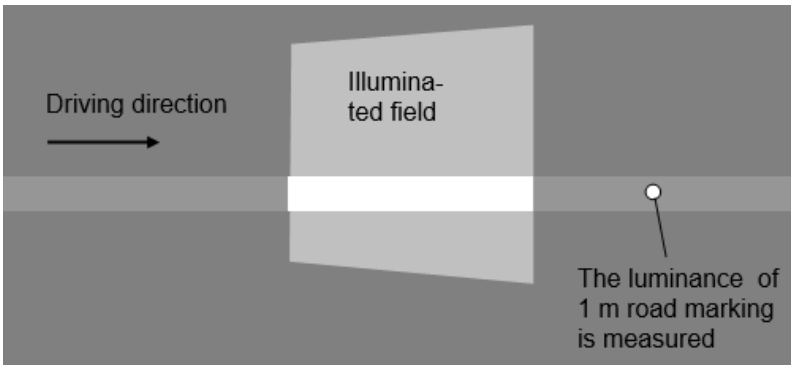
3 Suppression of daylight

In the short duration of a flash, it produces a much stronger illumination that daylight.

There is an additional small reduction of the influence of daylight by the of the principle of reversibility because it makes the luminance of the illuminated field almost twice as high as would have been obtained with the normal arrangement (because there are no shadows in the camera image).

As a further precaution for reducing signal from daylight, the software determines the luminance of a road marking to the front of the illuminated field and subtracts this luminance from the luminance of the road marking in the next image. This is illustrated in figure 4.

Figure 4: Measurement of the luminance of a road marking to the front of the illuminated field.



The idea is that, when driving at speed, the illuminated field will be at the location where the daylight luminance is measured in the next image.

This is accurate, when the driving speed is 90 km/h (corresponds to 1 m in 1/25 seconds). Even at other speeds, the subtraction is valuable and does reduce influence from daylight.

There is some complexity, when lines are broken and/or double lines, but the software handles this complexity.

The above-mentioned precautions together bring a strong suppression of daylight - to virtually zero.

4 Suppression of changes of signal from tilts and shifts in height

For each flash/exposure, the software determines the locations of the front and the back of the illuminated field in the camera picture and use that information to derive the distance for each pixel in the camera picture. This is used to compensate for variation of illuminance in accordance with the distance law of illumination.

This makes the readings insensitive to lifts of the LTL-M, while the above-mentioned use of the principle of reversibility makes the readings insensitive to tilts.

This has been verified by means of samples of road markings.

In total, the readings are made as insensitive to lifts and tilts as DELTA handheld instruments, but with other means.

5 Placement of the measured field on the road marking surface

The measured field of the LTL-M is the illuminated field. As shown in figure 1, this field is 1 m wide and 1 m long. The width of 1 m allows cover of the full width of the road markings, while also allowing for ease of steering and clearance to objects near to the road markings.

Constant sensitivity in the transverse direction is assured during the calibration.

6 Longitudinal coverage of the road marking surface

As the rate of measurement is 25 per second and the length of the illuminated field is 1 m, the LTL-M measures 25 m per second. This means that the coverage is 100 % when driving at 90 km/h, above 100 % when driving slower, and less than 100 % when driving faster.

This, and the matter that the measurements include the full width of the road markings, makes the coverage impressive.

The camera images provide even more information. Refer to figure 5.

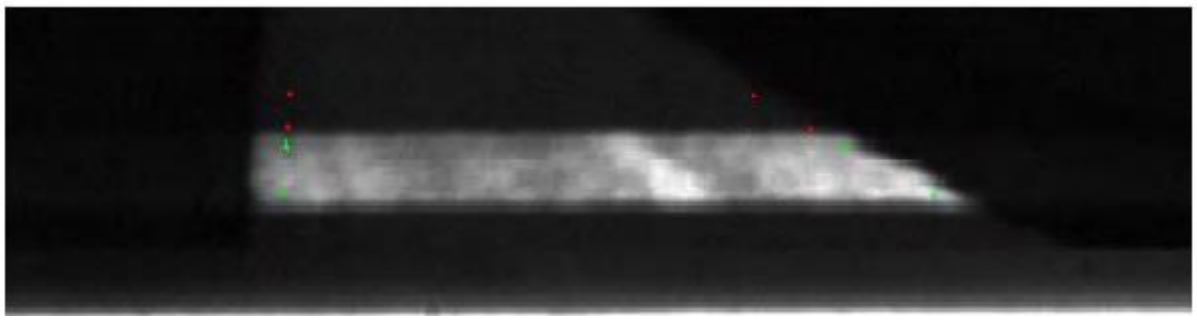


Figure 5: A wide edge line at a motorway with strong wear at the left-hand side towards the traffic.

7 Calibration

The value of the calibration factor F is determined by means of a calibration standard with a tilted white ceramic plate. This is as for DELTA handheld instruments, except that the ceramic plate is larger.

The R_L value of the calibration standard itself is calibrated in the DELTA laboratory with accreditation by DANAK. As with handheld instruments, the measured value is multiplied by 0,542. The expanded uncertainty is 3 $mcd \cdot m^{-2} \cdot lx^{-1}$.

When calibrating an LTL-M, the calibration standard is placed at 6 m distance and the LTL-M is aimed at the calibration standard. The value of the calibration factor is then adjusted until the reading of the LTL-M matches the R_L value of the calibration standard.

The calibration standard is normally in the center of the illuminated band, but it can also be moved in the transverse direction to verify constancy across the width of the illuminated field.

8 Uncertainty of measurement

Reference is made to the thorough clause B.8 of EN 1436. This is one of the statements:

Accordingly, uncertainty of measurement can be addressed in the following steps:

- calibration, refer to B.5,
- ability to cope with practical conditions including applicability for structured pavement markings, refer to B.4,
- compliance with the standard measuring condition, refer to B.3,
- spectral match including applicability in terms of colors of road markings, refer to B.2,
- precision (repeatability and reproducibility).

The DELTA LTL-M always did well in comparison measurements.