Florida Test Method
for
Measuring Retroreflectivity of Pavement Marking Materials Using a Mobile Retroreflectivity Unit

Designation: FM 5-600

1. SCOPE

1.1 This test method covers measurement of the retroreflective properties of longitudinal pavement marking materials and raised pavement markings (RPMs), including the count of present RPMs, using a Mobile (vehicle mounted) Retroreflectivity Unit (MRU) operated up to posted roadway speeds at a prescribed geometry. The prescribed MRU geometry corresponds to the European Committee for Standardization (CEN) geometry and is the standard geometry adopted by ***ASTM E1710***.

1.2 This test method applies to the measurement of the pavement marking retroreflectivity using mobile instruments to ensure that night-time visibility is adequate.

1.3 This test method does not purport to address all the safety concerns, if any, associated with its use. It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

2.1 ASTM E1710: Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer

2.2 ASTM D7585/D7585M: Standard Practice for Evaluating Pavement Markings Using Portable Hand-Operated Instruments

2.3 ASTM E284: Standard Terminology of Appearance

2.4 ASTM E808 Standard Practice for Describing Retroreflection

2.5 ASTM D4280 Standard Specification for Extended Life Type, Nonplowable, Raised Retroreflective Pavement Markers

2.6 FDOT Mobile Retroreflectivity Unit Worksheet (Form 675-060-15)

2.7 FDOT Quality Assurance for Mobile Retroreflectivity Units

3. DEFINITION OF TERMS

3.1 The definition of the terms used in this document as well as other relevant terms can be found in ***ASTM E1710, ASTM E284***, and ***ASTM E808***. The definitions listed below are direct excerpts from the above references for the terms that are most relevant to the content of this document.

3.2 Definitions:

3.2.1 Retroreflection – a reflection in which the reflected rays are returned preferentially in directions close to the opposite of the direction of the incident rays, this property being maintained over wide variations of the direction of the incident rays.

3.2.2 Coefficient of retroreflected luminance, R_L – the ratio of the luminance of a projected surface to the normal illuminance at the surface on a plane normal to the incident light, expressed in millicandelas per square meter per lux ($mcd \cdot m^{-2} \cdot lux^{-1}$).

4. APPARATUS

4.1 The required field-testing apparatus consists of a vehicle equipped with the following devices:

4.1.1 Vehicle-mounted retroreflectometer.

4.1.1.1 In accordance with ***ASTM E1710***, the retroreflectometer must be capable of collecting data using the specified 30-meter geometry. See **Section 5.1** for more information regarding this 30-meter geometry.

4.1.1.2 The retroreflectometer must be capable of collecting pavement marking data at speeds up to 70 mph while accounting for horizontal wander and vertical movement of the host vehicle.

4.1.1.3 The retroreflectometer must be capable of measuring the retroreflectivity of longitudinal pavement markings ranging from 75 to 1,500 R_L (mcd·m-2·lux-1).

4.1.1.4 The retroreflectometer must be capable of detecting, counting, and measuring the retroreflectivity of RPMs ranging from 1,500 to 60,000 R_L (mcd·m-2·lux-1).

4.1.1.5 The retroreflectometer must be capable of being operated on either side of the host vehicle.

4.1.2 A distance measuring device (DMI) using either a mechanical or a Global Positioning System (GPS) based system with accuracy requirements defined in **Section 9.1**.

4.1.3 An operating system for data entry, acquisition, display, and storage.

5. SUMMARY OF TEST METHOD

5.1 Measurements of retroreflected luminance using a MRU must be conducted using the 30-meter geometry shown in **Figure 1**. The angles that are specified for the 30-meter geometry are as follows:

5.1.1 The entrance angle is fixed at 88.76° (co-entrance angle at 1.24°).

5.1.2 The observation angle is fixed at 1.05°.

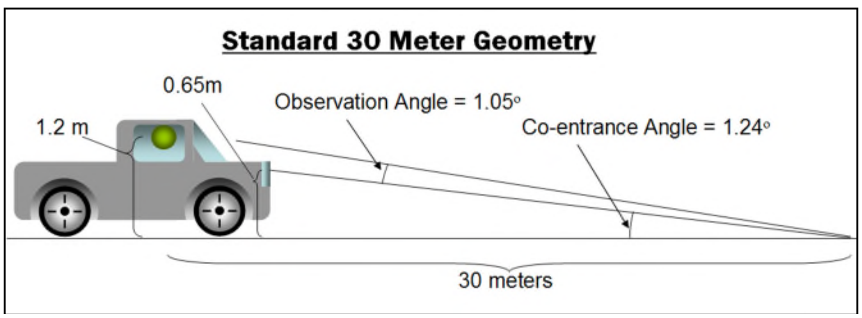

Figure 1. Standard 30-meter geometry specified in ASTM E1710

5.2 The MRU must meet calibration, system check, and verification requirements prior to data collection. See **Section 9** for additional information on meeting equipment requirements.

5.3 Retroreflectivity is measured with the MRU operating along the pavement marking survey section of a roadway.

6. SIGNIFICANCE AND USE

6.1 This test method permits determination of retroreflected luminance of in-service pavement markings and RPMs at speeds up to 70 mph. As such, this test method is widely applicable as a pavement marking assessment technique.

6.2 The quality of the pavement marking is determined by the coefficient of retroreflected luminance, RL, which depends on the materials used, age, and wear pattern.

6.3 Under the same environmental conditions, larger values of RL correspond to stripes or RPMs with greater visibility.

6.4 Retroreflected luminance of pavement markings degrade with traffic wear and require periodic measurement to ensure that sufficient visibility is provided to drivers.

7. PAVEMENT MARKING NOMENCLATURE

7.1 A standard naming convention was developed to identify each pavement stripe regardless of the number of lanes. **Table 1** shows an explanation of the nomenclature used.

7.1.1 The pavement marking nomenclature includes the direction of travel followed by the stripe type as identified in **Table 1**. For skip lines, a lane designation number is inserted between the direction and stripe type.

7.1.2 This nomenclature also pertains to the RPMs located along the stripe being tested.

7.1.3 As an example, based on the information shown below, the ascending skip line closest to the center line would be identified as R1SL; the edge line in the same direction would be identified as REL. **Figures 2 through 5** show examples of the naming convention for different scenarios.

Table 1 - Pavement Marking Nomenclature

Purpose	Code*	Description
Direction	L	Descending (down station) mileposts
	R	Ascending (up station) mileposts
Stripe Type	EL	White edge line
	CL	Yellow center line. **<u>All</u>** yellow stripes including yellow skip lines are considered as center lines. When collecting yellow center line pavement markings, white pavement marking such as turn lanes must not influence the yellow center line reflectivity.
	SL	White skip line. A lane designation number is placed between the Direction and the Stripe Type to indicate the order of the skip lines starting with the one closest to the center line

*Note: Directional codes only indicate the travel direction of the MRU, not the individual stripe (left or right stripe) nor the direction of stripe application.

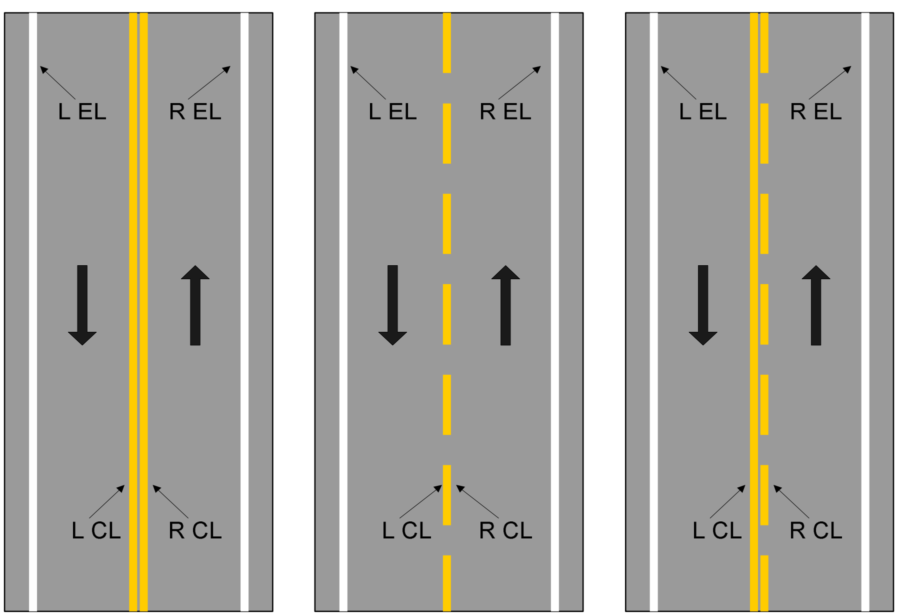

Figure 2. Pavement marking nomenclature for a two-lane roadway

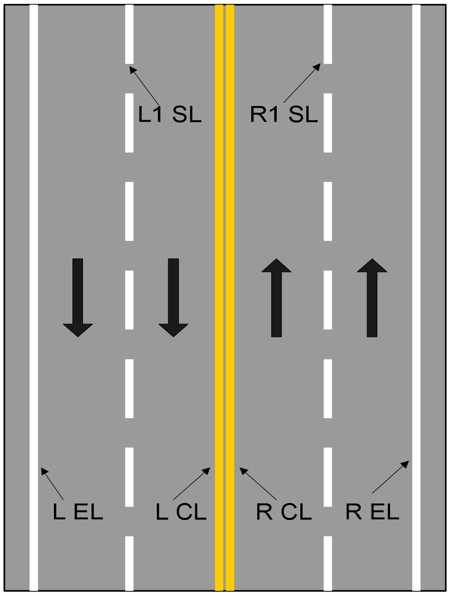

Figure 3. Pavement marking nomenclature for a four-lane non-divided roadway

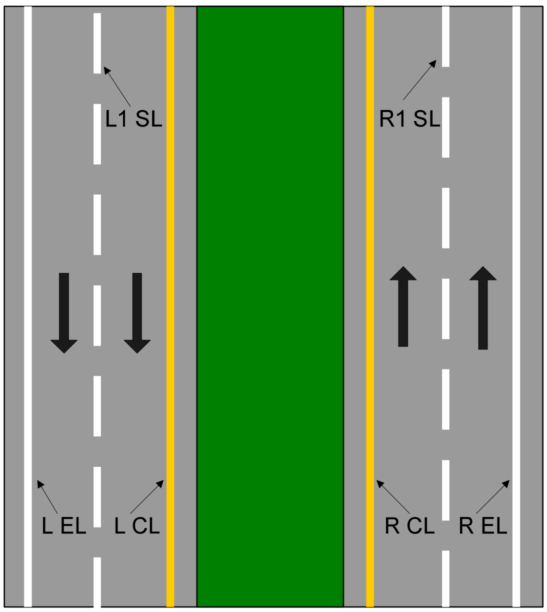

Figure 4. Pavement marking nomenclature for a four-lane divided roadway

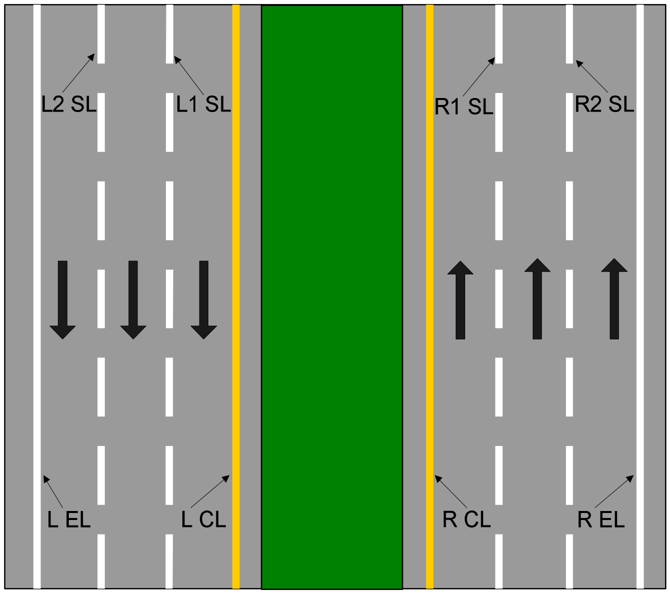

Figure 5. Pavement marking nomenclature for a multi-lane divided roadway

8. DATA ACQUISITION SYSTEM

8.1 Retroreflectivity data must be collected and processed using the software provided by the MRU manufacturer, service provider, or Department approved source.

8.1.1 The MRU must be capable of compensating for changes in temperature without influencing the retroreflectivity of the pavement marking.

8.1.2 The MRU must be capable of compensating for changes in background reflectivity without influencing the retroreflectivity of the pavement marking.

8.1.3 The MRU must be capable of delineating between the high retroreflectivity levels of RPMs (>1,500 R_L) and lower retroreflectivity of longitudinal pavement markings (<1,500 R_L).

8.1.4 The acquisition system must be capable of reporting all retroreflectivity statistics required in **FDOT Form 675-060-15**. The acquisition frequency must be a minimum of 0.1-mile intervals (unless recommended otherwise) and be reported in millicandelas per square meter per lux (mcd·m-2·lux-1).

8.1.5 In order to mark roadway characteristics, such as bridges, intersections, pavement changes, etc., the acquisition system must be capable of recording manual trigger event codes during the data collection process. Additional information can be found in **Section 11.5**.

9. CALIBRATION AND STANDARDIZATION

9.1 The MRU must be equipped with a distance measuring instrument (DMI) or a Global Positioning System (GPS) to measure the distance traveled by the vehicle and location. The DMI distance must be within ±10.560 feet (0.2%) for a GPS-based DMI and ±5.280 feet (0.1%) for a mechanical DMI when measuring a one mile section of roadway. The GPS must be within an instantaneous horizontal positioning accuracy of ±10.0 feet or better. The DMI must be calibrated, and GPS verified on a 65-day basis or earlier as deemed necessary at locations designated by FDOT. Additionally, if using a mechanical DMI, a DMI recalibration must be performed anytime tires are changed, rotated, or air pressure is adjusted.

9.2 The MRU system must be inspected, calibrated, and its performance verified in order to meet the requirements of the **FDOT Quality Assurance for Mobile Retroreflectivity Units**.

9.2.1 The retroreflectometer unit is an optical measuring device, and proper calibration is critical.

9.2.2 Each retroreflectometer unit and associated calibration panels must be annually certified by a department approved source.

9.3 MRU operators must meet the operation and field performance requirements of the ***FDOT Quality Assurance for Mobile Retroreflectivity Units***.

9.4 The retroreflected luminance values obtained during measurements are highly dependent on proper equipment setup.

9.4.1 The MRU must conform to the 30-meter geometry for proper calibration.

9.4.2 A certified calibration standard must be used to calibrate or verify the retroreflective unit.

9.4.2.1 The retroreflected luminance of the calibration standard used for MRU calibration must be verified by a department approved facility using photometric range equipment at least once a year.

9.4.3 Using an approved calibration standard, the following items must be documented daily prior to use.

9.4.3.1 Identifying the approved calibration standard and reference the certified retroreflectivity value assigned to the calibration standard.

9.4.3.2 Anytime the retroreflectometer is repositioned from one side of the host vehicle to the other or powered off.

9.4.3.3 Record the date, time, and measurements obtained by the MRU. The retroreflectivity measurements must be within ±5% of the calibration standard's assigned value being used.

9.4.3.4 If additional equipment calibrations or verifications are performed throughout the day, results must be recorded.

9.4.3.5 Daily Logs must be provided to Department or available upon request.

9.5 Frequency of the Check and Calibration Procedures can be found in **Table 2**.

Table 2 – Frequency of Check and Calibration Procedures

Type of Test	**Testing Frequency**		
	Daily	Monthly	Bi-Monthly
Tire Pressure Check (**Section 9.1**)	X		
Distance Check and Calibration (**Section 9.1**)			X
Quality Assurance Testing (**Sections 9.2 & 9.3**)			X
Calibrations and Verifications (**Section 9.4**)	X		
Clean and Inspect Detector Optical Window (**Section 10.3**)	X		

10. PROCEDURE

10.1 Determine the location and project limits of the pavement marking survey section to be tested.

10.2 Warm up the MRU system prior to the survey for a period recommended by the manufacturer.

10.3 The detector optical window must be inspected and cleaned if necessary, prior to any data collection.

10.4 Must meet **Section 9** Calibration and Standardization requirements.

10.5 Ensure the beginning and ending locations of the pavement marking survey section are properly referenced so the retroreflected luminance can be reported accurately with respect to roadway milepost.

10.6 Retroreflectivity is measured with the MRU operating along the pavement marking survey section of a roadway.

10.6.1 During data collection, the MRU must be operated with minimum changes to vehicle dynamics (braking, acceleration, and vehicle wander) and data can only be collected while the vehicle is in motion.

10.6.2 The MRU must be capable of operating at speeds up to 70 mph to ensure sufficient data is collected when testing. A minimum of 30 data points must be collected for every 0.1 mile of travel for the data to be considered reliable.

11. INTERFERENCE AND ENVIRONMENTAL INFLUENCE

11.1 Measurements made with the MRU may be adversely affected by moisture in the air and on the surface of the pavement markings. Standing water, dew, sleet, and snow on the surface of the pavement marking or fog and smoke in the air, decreases the amount of retroreflected luminance due to light reflecting off the water and away from the detector. Environmental factors are difficult to measure and may vary dramatically; therefore, testing must be avoided when these conditions are present.

11.2 Measurements made with the MRU may be adversely affected by surface dirt, debris, and contamination on the pavement marking which decrease the amount of retroreflected luminance. This may cause variability in the retroreflected luminance of the pavement marking and must be noted accordingly. The operator must note when these conditions are present. See **Section 11.5** for additional information.

11.3 The MRU uses advanced optic and electronic devices known to be sensitive to temperature changes. It is important to recognize these issues in the event that the electronic and optic devices are not working properly so that appropriate corrective actions can be applied.

11.4 Background noise from roadway surfaces and high retroreflectivity levels of

RPMs can influence the retroreflected luminance of longitudinal pavement markings. The operator must recognize these issues in the event that the data acquisition system is not working properly so that appropriate corrective actions can be applied.

11.5 Event Codes

11.5.1 A standard nomenclature and data acquisition event codes, as shown in **Table 3**, was implemented to mark roadway events. The roadway events must be recorded to the nearest thousandth of a mile.

11.5.2 The following items describe how the events must be processed.

11.5.2.1.1 Flag event – The data acquisition system must flag the event while continuing data analysis without resetting the interval / average until the event is triggered a second time to flag the event at the end of the roadway conditions (bridges, pavement change, construction, etc.)

11.5.2.2 Reset Data – When triggering a roadway event (pavement change, audible, etc.) the data acquisition system must end the current row of data analysis to the nearest thousandth while beginning a new row of data analysis.

11.5.2.3 Hold Event – The data acquisition system must hold the event code while continuing data analysis until the event is triggered a second time for roadway conditions.

11.5.2.4 Stop Collection – The data acquisition system must stop retroreflective data collection that could cause inaccurate representations of the pavement marking such as the influence of white turn lanes while measuring a yellow centerline as mentioned in **Table 1**.

Table 3 – Data Acquisition System Event Codes

Description*	**Flag Event**	**Reset Data**	**Hold Event**	**Stop Collection**
Pavement Change	X			
Construction	X			
Audible	X			
No Line	X	X		X
Bridge	X			
Rumble Stripe	X			
Line Damage	X	X		X
Debris on Line	X	X		X
Lane Interference	X	X		X
Lane closure	X	X		X
Miscellaneous Event	X	X		X

*Note: Event codes are used to identify roadway characteristics within a pavement marking survey section.

12. REPORTING

12.1 The following information must be reported as described in ***FDOT Form 675-060-15***:

12.1.1 Project information (project ID, beginning/ending mileposts, roadway direction, stripe type, and other relevant information).

12.1.2 Survey date and weather conditions at beginning of the test.

12.1.3 Identification of the pavement stripe (e.g., R1SL, REL, RCL, etc.).

12.1.4 Identification of the MRU ID, equipment serial number, operator, and software used.

12.1.5 Equipment calibration information.

12.1.6 The results must be reported in millicandelas per square meter per lux ($mcd\cdot m^{-2}\cdot lux^{-1}$). Worksheets specific to direction of travel and stripe type must be reported in 0.1-mile intervals unless recommended otherwise.

12.1.6.1 The results must include event codes as necessary mentioned in **Section 11.5**.

12.1.7 Summary statistics of retroreflectivity.

13. PRECISION

13.1 Repeatability- The results of two properly conducted retroreflectivity tests using the same MRU on the same pavement marking test section must not differ by more than 10.0% at a 95 percent confidence level. This test is to be conducted for the retroreflectivity of longitudinal pavement markings and RPMs, as well as for RPM counts in tenth-mile intervals.

13.2 Reproducibility- The results of two properly conducted retroreflectivity tests using different MRUs on the same pavement marking test section must not differ by more than 15.0% at a 95 percent confidence level. This test is to be conducted for the retroreflectivity of longitudinal pavement markings and RPMs, as well as for RPM counts in tenth-mile intervals.