Sign retroreflectivity levels will vary
New signs can have different retroreflectivity levels and different degradation rates over time.
Sign sheeting material may degrade over time in different areas of the sign.
ASTM E 1709  Standard Test Method for Measurement of Retroreflective Signs Using a Portable Retroreflectometer

**Coefficient of Retroreflection, \( R_A \)** – the ratio of the coefficient of luminous intensity of a plane retroreflecting surface to its area expressed in candelas per lux per square meter.  \((\text{cd/lx/m}^2)\)
Sign Sheeting Types

Encapsulated Lens Sheeting (Type III – e.g. High Intensity)

- Durable Transparent Plastic Top Film
- Supporting Wall
- Air Space
- Glass Bead
- Adhesive
- Protective Liner
- Plastic Resin

Prismatic Lens Sheeting

- Supporting Wall
- Acrylic Protective Overlay
- Cube Corner
- Reflective Sheet
- Adhesive
- Protective Liner
- Sealing Film
- Air Space
Key Geometry Angles (0.2/-4)
Observation angle = 0.2°  Entrance Angle = -4°

Observation angle (α)
Between source and receptor (red and blue lines)

Entrance angle (β)
Between source and target axis (blue and green lines)

Perpendicular to sign
Technical Terms = Retroreflectivity $R_A = \frac{cd}{lx/m^2}$

Luminance ($cd/m^2$)

Illuminance ($lx$)
Portable Retroreflectometers – Different Types

**Point Instrument** - has a single light detector next to the light source or axis and makes an $R_A$ measurement virtually identical to an $R_A$ measurement made on a lab range system where the light detector is on top of the light source. Like the motorcycle illustration. Typical $R_A$ specifications require making measurements at 0 and 90 degree orientations and averaging the two values.

**Annular Instrument** – has a circular light detector positioned around the light axis and makes an $R_A$ measurement similar to an average of several $R_A$ measurements on a range system or point instrument. No averaging needed.

**Variability of Sign Sheeting $R_A$ at 0 and 90 Degree Orientation** – some sheeting shows greater than 20% difference in $R_A$ at 0 and 90 degree orientations.
Point Instrument – Zero Degree Measurement
Point Instrument – 90 Degree Measurement
Calibrating the Instrument
Example of testing a Quality Control sample (low retro value).
Example of testing a Quality Control sample (high retro value).
When testing sign legend, the aperture size may need to be reduced.
If aperture size is changed, you should recalibrate instrument!
Challenges of making portable instrument measurements

Sign Access

Sign Cleaning?
Challenges in making retroreflective measurements of road signs using portable instruments:

1. Understanding the correct use of the instrument.
   - Correct training is critical.
   - Charging, battery life, calibrations, aperture changes and recalibration and QC checks.

2. Gaining access to road signs
   - Ladders, instrument extensions, safety

3. When to clean signs. Normally we don’t recommend cleaning signs unless they are very dirty.

4. Making measurements of the sheeting – background and legend. Test in several locations and average the results.

5. Documenting sign location, sheeting type, and test results.
<table>
<thead>
<tr>
<th>Observation Angle</th>
<th>Entrance Angle</th>
<th>White</th>
<th>Yellow</th>
<th>Orange</th>
<th>Green</th>
<th>Red</th>
<th>Blue</th>
<th>Brown</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1°&lt;sup&gt;B&lt;/sup&gt;</td>
<td>−4°</td>
<td>300</td>
<td>200</td>
<td>120</td>
<td>54</td>
<td>54</td>
<td>24</td>
<td>14</td>
</tr>
<tr>
<td>0.1°&lt;sup&gt;B&lt;/sup&gt;</td>
<td>+30°</td>
<td>180</td>
<td>120</td>
<td>72</td>
<td>32</td>
<td>32</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>0.2°</td>
<td>−4°</td>
<td>250</td>
<td>170</td>
<td>100</td>
<td>45</td>
<td>45</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>0.2°</td>
<td>+30°</td>
<td>150</td>
<td>100</td>
<td>60</td>
<td>25</td>
<td>25</td>
<td>11</td>
<td>8.5</td>
</tr>
<tr>
<td>0.5°</td>
<td>−4°</td>
<td>95</td>
<td>62</td>
<td>30</td>
<td>15</td>
<td>15</td>
<td>7.5</td>
<td>5.0</td>
</tr>
<tr>
<td>0.5°</td>
<td>+30°</td>
<td>65</td>
<td>45</td>
<td>25</td>
<td>10</td>
<td>10</td>
<td>5.0</td>
<td>3.5</td>
</tr>
</tbody>
</table>

<sup>A</sup> Minimum Coefficient of Retroreflection ($R_A$) cd/ft<sup>2</sup> (cd·lx<sup>−1</sup>·m<sup>−2</sup>).  
<sup>B</sup> Values for 0.1° observation angle are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.
Portable Retroreflectometers

Delta
Retrosign
4500

Mechatronic
RC 2000

Zehntner 6060

Road Vista 922
Retroreflectivity Concepts

MEASURING PAVEMENT MARKING RETROREFLECTIVITY
Retroreflectivity Concepts

- ASTM D7585-10 Standard Practice for Evaluating Retroreflective Pavement Markings Using Portable Hand-Operated Instruments
- ASTM WK3833 Test Method for Mobile Pavement Marking Retroreflectivity Measurements
- ASTM E2832-11 Standard Test Method for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Markings in a Standard Condition of Wetness
Retroreflectivity Concepts
Retroreflectivity Concepts

Light rays entering the glass beads are retroreflected back to the driver.

Glass Bead

Paint Binder

Painted Surface

Glass Bead Retroreflection
Retroreflectivity Concepts

Types of Pavement Marking Materials

1. Paint
2. Thermoplastic
3. Preformed Thermoplastic
4. High Performance Tapes
5. Audible & Vibratory Markings
6. Wet Weather Markings
7. Two Component Reactive
Retroreflectivity Concepts

ASTM WK3833 Test method for mobile pavement marking retroreflectivity measurements
Retroreflectivity Concepts

ASTM D7585-10 Standard Practice for Evaluating Retroreflective Pavement Markings Using Portable Hand-Operated Instruments
Retroreflectivity Concepts

CALIBRATION OF TESTING EQUIPMENT
Retroreflectivity Concepts

ASTM E2177 - 11 Standard Test Method for Measuring the Coefficient of Retroreflected Luminance ($R_L$) of Pavement Markings in a Standard Condition of Wetness – Bucket Method
Retroreflectivity Concepts

Questions?
“Standard:
Public agencies or officials having jurisdiction shall use an assessment or management method that is designed to maintain sign retroreflectivity at or above the minimum levels in Table 2A-3”
MUTCD Sign Retro Methods

Assessment Methods

• Visual Nighttime Inspection
  – Calibration Signs
  – Comparison Panels
  – Consistent Parameters
• Measured Sign Retro

Management Methods

• Expected Sign Life
• Blanket Replacement
• Control Signs
Visual Inspection Requirements

- *Trained inspector*
- Nighttime inspection
- Need to tie to minimum values by using one of the following techniques:
  - Comparison panels procedure, or
  - Calibration signs procedure, or
  - Consistent parameters procedure
Visual Inspection Method: Comparison Panel Procedure

- Any vehicle, any inspector age is OK.
- The “initial” inspection occurs at highway speeds.
- When a marginal sign is spotted,
  - Safely pull over to inspect the sign,
  - Install comparison panel on the sign,
  - Evaluate from at least 25 feet,
  - Hold a flashlight near inspector’s ear.
**Visual Inspection Method: Calibration Sign Procedure**

- Any vehicle, any inspector age is OK.
- Before leaving the maintenance yard, the inspectors visually inspects a set of representative signs in an effort to calibrate their eye before starting the nighttime inspections.
- The calibration signs should be viewed at distances from 600 to 100 feet
Visual Inspection Method: Consistent Parameter Procedure

- Model year 2000 or later SUV or truck.
- Inspector needs to be at least 60 years old.
- The inspection occurs at highway speeds.
- No calibration signs or comparison panels are needed.
Retroreflectivity Measurement Method

HANDHELD
Model GR3
by Delta
www.tapconet.com/digital

HANDHELD
Model 922
by Road Vista
www.roadvista.com

MOBILE
AMAC
by DBi Services
www.amacglobal.com
MUTCD Sign Retro Methods

Assessment Methods

• Visual Nighttime Inspection
  – Calibration Signs
  – Comparison Panels
  – Consistent Parameters
• Measured Sign Retro

Management Methods

• Expected Sign Life
• Blanket Replacement
• Control Signs
Expected Sign Life Method

• Use the life of the sheeting in your area
• Replacement based on expected life for individual signs
Blanket Replacement Method

- Divide agency into areas
- Relate number of areas to replacement cycle
- Replace all signs in an area each replacement cycle
- If 12 year life is used, then
  - Area 1 = 2015
  - Area 2 = 2019
  - Area 3 = 2023
  - Area 1 = 2027 ...
Control Signs Method

• Sign life estimated using subset of signs representing agency’s inventory.
  – Subset of signs is the “control signs”

• Control signs can be in-service signs or signs in a maintenance yard.

• Agency monitors (measures) control signs to estimate condition of all signs.

Example of Control Signs
Effectiveness

- Nighttime Visual Inspection
- Measured Retroreflectivity
- Service Life / Blanket Replacement
Nighttime Visual Inspection Studies

**Washington DOT**

**Texas DOT**

**FHWA**
Visual Inspection Accuracy

![Graph showing the relationship between Inspector Accuracy and Retrorreflectivity (cd/lx/sq m)]
**Visual Nighttime Inspection with Trained Inspectors**

<table>
<thead>
<tr>
<th>Measured Retroreflectivity</th>
<th>Number of Signs</th>
<th>Agreement with Measured Retro</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-50</td>
<td>5</td>
<td>5 (100%)</td>
</tr>
<tr>
<td>51-100</td>
<td>6</td>
<td>1 (16.7%)</td>
</tr>
<tr>
<td>101-150</td>
<td>4</td>
<td>4 (100%)</td>
</tr>
<tr>
<td>&gt;150</td>
<td>17</td>
<td>17 (100%)</td>
</tr>
</tbody>
</table>
Mobile Retro Accuracy

![Graph showing comparison of Hand-Held Measurement vs AMAC Van Measurement with different colored markers for Green, White, Yellow, and Red categories.](image-url)
Evaluation of Service Life

Warning sign retro data from a state in the North East

These signs are all OK

Only these signs need replaced
Vehicle Cameras Detect Markings
Highway Safety Statistics

**Roadway Departure Crashes Account for 51 Percent of Fatal Crashes**

- Run off roadway left: 10%
- Run off roadway right: 24%
- Median or center line: 17%
- Non roadway departures: 49%

**Fatalities per Million Miles Traveled (2004-2006)**

- Nighttime
- Daytime

![Image of a car accident]
LDWs have the potential to prevent or mitigate 7,529 fatal and 37,000 injury accidents per year in the US

(Journal of Accident Analysis & Prevention, Vol 43, 2011)
IIHS Findings on LDW (2014)

- Not effective as other vehicle safety technologies
- “we don’t see any evidence that these systems are helping drivers avoid being in crashes”
- Drivers are reported the LDW can be annoying
- “turn signal nanny” effect
TTI Lab studies (2014)

- Objectives
  - Investigated marking properties that would make detection with machine vision more reliable
  - Explored various camera technologies
  - Studied lighting options
    - Visible
    - Infrared
Field Studies (2015)

- Linking machine vision detection to:
  - Contrast (daytime)
  - Retroreflectivity (nighttime)
- What can agencies do to enhance their road to be ready for camera-based vision?

Video demo

Daytime
Nighttime
Preliminary Data

Detection Confidence

Measured Retroreflectivity (mcd)

White Edge Line

Avg = 88
Same Curve
Many Challenging Conditions

- Uniform road marking maintenance thresholds
  - Daytime Contrast & Nighttime Retroreflectivity
- Preventive pavement maintenance treatments
- Horizontal curves
- Roadway lighting
- Tunnels, bridges, shadows
- Wet / snow conditions
- Debris
- Poor marking removal
The objective of the research is to obtain data that can be used to develop correlations between machine vision performance and pavement markings. Factors to be considered are pavement marking presence, contrast, retroreflectivity, pavement uniformity, day and night conditions, and vehicle speed. It is intended that the work include a range of forward-facing cameras and their respective software so that the current technologies and those on the horizon can be accommodated by the new guidelines/criteria.