Retroreflection

Informed choices for enhanced visibility: the science, the performance, the product options.
Know the terms

1. **Brightness** is a helpful measure of the quality of a retroreflective surface. Brightness helps to characterize luminance, which is the light we observe from an illuminated or reflective surface.

2. **Observation angle** is the angle between the line formed by a light beam striking a surface and the line formed by the retroreflected beam toward the observer’s eye.

3. **Entrance angle** is the angle formed between the light source striking a surface at some point and a line perpendicular to the surface at the same point.

4. **Rotational angle** is the angle at which a retroreflective material is oriented when tests are performed.

**Brightness** is a term used to define the retroreflective performance of a material measured at specified angles. It is a useful value when designing or measuring the quality of retroreflective material. Of course, it is only one piece of information in determining the total visibility of a garment.

**Luminance** is the light we observe from an illuminated or reflective surface. Reflected luminance is the amount of reflected light returned to the driver or equipment operator. (What the driver or operator actually sees.) Total luminance is determined by brightness, amount and placement of retroreflective material, and position relative to the observer.

**Observation angle** is important because retroreflective light is returned as a narrow cone with the inner part of the cone being most intense. Therefore, the light would appear brighter to a sports car driver for example, who sits lower and nearer to the headlights, than to a semi truck driver who sits higher above the headlights. The farther the observing driver is from the reflective garment, the smaller the observation angle becomes.

Retroreflective materials are measured at a wide range of **entrance angles** because workers can be at any angle to a motorist, and their shapes are round, not flat, compounding the angle.

ANSI/ISEA 107-2004 calls for measuring brightness with material oriented at rotational angles of 0° and 90°. As a consequence, additional rotational angles are not needed when a garment is constructed according to the standard garment design requirements.
Retroreflection

Get the facts. See the difference.

With changing performance standards and a flood of new products and claims, it’s never been more important to understand retroreflection from every angle.

Getting clear on the terms, the products and the facts about visibility helps to promote accurate high-visibility apparel specifications and helps enhance personal safety all around.

Retroreflection defined

Retroreflection uses a surface designed to direct light back toward the source. Retroreflectors have either spherical lenses (tiny glass beads) or prismatic (cube corner) elements.

Retroreflective materials appear brightest to observers located near the light source (a car’s headlights and driver, for example). This is true for drivers at almost any viewing angle. 3M pioneered the development of retroreflective sheetings over 50 years ago.

Other kinds of reflectivity

Diffuse reflection scatters light in many directions as it strikes an uneven surface (such as skin, clothing or wood).

Mirror (or specular) reflection occurs when light strikes a smooth or glossy surface and bounces off in an equal but opposite angle — away from the driver’s eyes, unless the surface is at an exact right angle to the vehicle.
Angularity is part of how retroreflective surfaces are measured. The term can be confusing, and is sometimes misused.

**FACT:** All by itself, “angularity” has little meaning because it’s only part of a measurement. Example: if John boasts he ran a race in 5 minutes, that would have little meaning - it’s only part of a measurement. You’d want to know how long the race was: 50 yards? 1 mile?

ANSI/ISEA 107-2004 asks how bright a retroreflective product is at specific entrance, observation and rotational angles.

**TIP:** A good way to get a relevant “apples to apples” comparison of the angularity performance of ANSI/ISEA 107-2004 compliant products is to:

- Compare the brightness of products at specific observation and entrance angles measured at rotational angles of 0° and 90°

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**FACT:** ANSI/ISEA 107-2004 specifications for retroreflective material consider brightness at specified entrance angles (5°, 20°, 30° and 40°) and observation angles (12’, 20’, 1°, 1° 30’) for both 0° and 90° rotational angles.

### Minimum coefficient of retroreflection in cd/(lx-m²) for Level 1 retroreflective or combined-performance retroreflective material

<table>
<thead>
<tr>
<th>Observation angle</th>
<th>Entrance angle</th>
<th>5°</th>
<th>20°</th>
<th>30°</th>
<th>40°</th>
</tr>
</thead>
<tbody>
<tr>
<td>12°</td>
<td>250</td>
<td>220</td>
<td>135</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>20°</td>
<td>120</td>
<td>100</td>
<td>75</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>1°</td>
<td>19</td>
<td>11</td>
<td>9</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>1° 30’</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

### Minimum coefficient of retroreflection in cd/(lx-m²) for Level 2 retroreflective or combined-performance retroreflective material

<table>
<thead>
<tr>
<th>Observation angle</th>
<th>Entrance angle</th>
<th>5°</th>
<th>20°</th>
<th>30°</th>
<th>40°</th>
</tr>
</thead>
<tbody>
<tr>
<td>12°</td>
<td>330</td>
<td>290</td>
<td>180</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>20°</td>
<td>250</td>
<td>200</td>
<td>170</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>1°</td>
<td>25</td>
<td>15</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>1° 30’</td>
<td>10</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

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**FACT:** An important part of ANSI/ISEA 107-2004 has to do with placement. Retroreflective material must be placed on a garment to achieve 360° visibility, with at least one retroreflective band encircling the torso.

**TIP:** A good visibility demonstration might be a nighttime demonstration in a parking lot or a simulated work environment — with a retroreflective band encircling a person. Your 3M representative can set up such a demonstration.
Get to know your product options

Retroreflective surfaces direct light back toward the source using spherical lenses (tiny glass beads) or prismatic (cube corner) elements, that are built into retroreflective material and can be protected by a smooth top film. Light reacts to these products in different ways.

Spherical lenses
(tiny glass beads)

An incoming light beam refracts (bends) as it passes through the front surface of a glass bead and bounces off a mirrored surface behind it. The beam then passes back through the front surface, is refracted as it leaves, and returns toward the light source.

3M glass bead technology products meet and exceed ANSI/ISEA 107-2004 guidelines; they also provide:

- Smooth, fabric-like hand
- Multiple formats
- Ease of application
- Wet weather performance
- Home & industrial wash durability

Prismatic (cube corner) elements
(also called ‘high gloss’)

Each cube corner has 3 mutually perpendicular refractive surfaces. An incoming light ray is refracted on each of the 3 surfaces and returned to the source on a parallel path — much like a ball bounced into the corner of a room.

3M prismatic technology products (or high gloss products) meet and exceed ANSI/ISEA 107-2004 guidelines; they also feature:

- Fluorescent colors
- Glossy appearance
- Wet weather performance
- Home wash durability

Other considerations:

- Feel of material
- Ease of use
- Maximum suggested number of wash cycles.
  Materials considered suitable for washing must meet ANSI/ISEA 107-2004 performance requirements after 5 washings; many 3M products far exceed this number. Refer to 3M technical data sheets for specific wash information.
- Flame resistant (FR) properties, measured in char length 2 seconds after flame.

Prismatic tile

Prismatic tile (or tiling) is a type of prismatic retroreflective sheeting that can be proprietary to some manufacturers. 3M also uses this technology to manufacture some traffic control materials. Its design causes it to look different than standard prismatic material in daytime light.

FACT: If you use proprietary product design language in specifications, you may limit the number of manufacturers who can respond to a proposal.

Three examples of compliant technologies:

Typical 3M silver beaded product
Typical brightness of 500 at -4° entrance angle and 0.2° observation angle

Typical 3M prismatic product
Typical brightness of 700 at -4° entrance angle and 0.2° observation angle

Typical prismatic tiled product
Typical brightness of 600 at -4° entrance angle and 0.2° observation angle
Retroreflection

Get the facts
Compare the typical brightness of reflective materials measured at relevant angles as represented in performance standards such as ANSI/ISEA 107-2004.

Understand that ANSI/ISEA 107-2004 placement guidelines call for a 360° placement to achieve definition of the human form, and evaluate retroreflective materials accordingly.

Look for reputable manufacturers you trust
3M retroreflective products exceed ANSI/ISEA 107-2004 minimum standards and maintain a high level of visibility throughout the life of the garment.

Contact your 3M Representative
for more information or to set up a visibility demonstration.

Important Notice to User
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Because of the unlimited variety of potential applications for these products, BEFORE production use, the user (which may be a product designer, product specifier, converter or end product manufacturer or others) must determine that the Products are suitable for the intended use and are compatible with other component materials. User is solely responsible for determining the proper amount and placement of Products. While reflective products enhance visibility, no reflective product can ensure visibility or safety under all possible conditions.

3M may change the product, specifications and availability of the product as improvements are made; therefore, user should contact 3M for latest information before specifying the product.