

Understanding Trailer Visibility and Conspicuity Devices

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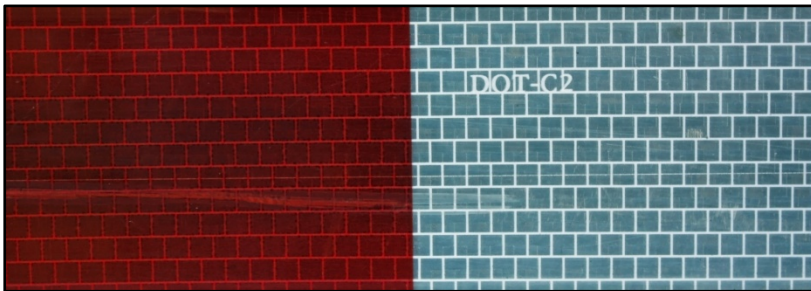
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Introduction

An important method of reducing the number of crashes involving heavy vehicles has been to increase their visibility through the use of additional lighting, reflectors, and conspicuity tape. Specifically with regard to conspicuity tape, the US National Highway Traffic Safety Administration (NHTSA) has estimated that outfitting heavy truck trailers with required conspicuity tape results in a reduction of injury and fatal crashes by 29% - 44% (Morgan, 2001).

The Roles and Benefits of Conspicuity Tape

Conspicuity tape—also known as DOT tape, DOT C2 tape, reflective tape, or retroreflective tape—works by reflecting light back to a source, making it appear to “glow” when light is directed at it.



Close-up image of DOT C2 tape

In a NHTSA study that analyzed data from nearly 11,000 crashes in Florida and Pennsylvania, two things were very clear regarding using the tape.

- Conspicuity tape has a substantial effect on reducing the number of serious crashes between large trucks and other vehicles.
- While conspicuity tape does significantly reduce the number of crashes, it does not eliminate crashes entirely, even for trailers that are properly outfitted with the required tape.

Some more interesting conclusions were drawn by the results of the NHTSA study, including:

- The research showed that serious and fatal crashes were significantly reduced by outfitting trailers with conspicuity tape.
- Very significant benefits of using conspicuity tape were shown when the roadway was dark and unlit.
- The tape appears more effective in reducing the number of impacts into the rear of trailers than the number of impacts into the side of trailers.
- Conspicuity tape was very beneficial in rain, fog, and clear weather conditions, but less benefit was seen in snowy conditions.
- With the addition of conspicuity tape, crashes involving flatbed trailers were reduced more so than crashes involving van-type trailers.
- Conspicuity tape provided the strongest benefit (greatest crash rate reduction) for drivers under the age of 50.
- Even tape that was described by investigating police officers as appearing “dirty” had a significant impact in reducing collisions into the rear of trailers.



In this image of two merged-photos, the two trucks driving side-by-side demonstrate what a dramatic difference it makes for a truck to be outfitted with properly maintained conspicuity tape.

As the NHTSA study shows, conspicuity tape is not only a legal requirement (FMCSR 393.13), but it is also a significant preventative safety measure. The full NHTSA study and a PowerPoint summary of the results are available for free online.

[Full Study](#) | [PowerPoint Summary](#).

Conspicuity Tape and Crash Analysis

When a crash involving a heavy vehicle is being reviewed or analyzed, investigators are often required to consider these questions:

1. Was the heavy vehicle properly outfitted with the legally required conspicuity-enhancing devices (tape, reflectors, and lights)?
2. Were the conspicuity-enhancing devices maintained properly and functioning properly at the time of the crash?

If the answer to either of these questions is “no,” the investigator must attempt to answer the following:

If the devices had been in place / functioning properly, is it reasonable to conclude that the crash would have been less severe, or possibly to have been avoided altogether?

As the results of the NHTSA study show, proper conspicuity tape does not prevent every crash. Sometimes the reason for the tape’s not preventing a crash is obvious, such as when the striking driver is intoxicated. However, in many cases, the answer to whether conspicuity devices were in place and functioning properly is less obvious and will require additional investigation or reconstruction of the crash itself.

Limitations of Conspicuity Tape

The “Degree” of Reflectivity: Conspicuity tape works by reflecting light back to a source. For example, when you shine a flashlight at a mirror, it bounces off the mirror at an angle of about 90°. However, if you shine a light at conspicuity tape (or any other retro-reflector), it shines light back toward you. This makes the tape (like the reflective stripes in your running shoes) appear to “glow” when light hits them.

A limitation of conspicuity tape is that the tape cannot shine light back from every single angle. The tape used on commercial motor vehicles is required to meet a minimum level of reflectance in six conditions:

- The light source is shining on the tape from -4° , 30° , or 45° (horizontal).
- The observer's viewing angle to the tape is 0.2° or 0.5° (vertical).

Federal Motor Vehicle Safety Standard (FMVSS) 108 details the exact amount of light and other conditions needed for testing the performance of conspicuity tape, as well as the performance requirements for both the red and the white sections of the tape. The standards in FMVSS 108 are significant because it means there is no requirement for the tape to appear reflective if the observer is much too high or too low with respect to the tape, or if the tape is angled (with respect to the observer) at more than 30 degrees.

The photos below show the difference between a truck trailer angled at 45° (left) and 20° (right). In these photos, the angle of observation, or vertical angle with respect to the ground, is about 4° —a small SUV—and the headlights are set on low-beam at approximately 200 feet. Although the images are small, it is obvious that the reflective tape is visible in the 45° photo and that the tape is much less visible in the 20° photo.



Trailer at 45°



Trailer at 20°

[You can view a video of this tractor and trailer pulling out here.](#)

When analyzing a crash or an incident, it's important to remember that the most significant angle (for an approaching driver) is not necessarily the angle of impact, but rather the angle between the approaching vehicle and the trailer *during the approach* to impact. These two angles will only be the same if the trailer is stopped (or moving very slowly) and the roadway is very straight. In many cases, the

curvature of the road and the turning maneuver of the tractor and trailer will both influence the visibility of the trailer.

Another implication of the tape's performing differently at different angles of light incidence, and based on the position of the observer, is that photographs taken *after* a crash can be misleading if they attempt to suggest what a driver saw.

For example, suppose that a responding police officer arrives at the crash scene and parks his/her vehicle at a 20° angle to the crashed trailer. The headlights from the squad car probably won't illuminate the tape in a way that shines much light back at an observer, which could lead to the mistaken conclusion that the tape isn't working when, in fact, the problem is that the squad car is shining light at a steep angle to the tape. This illusion can be especially powerful when the officer gets out and walks directly in front of the headlights wearing a reflective vest. It will appear that the vest is reflecting light and the tape is not, leading to the potentially incorrect conclusion that the tape is deficient.

Wear and Tear: Another limitation of conspicuity tape is that, just like any other product, it wears out. As the tape wears out, its reflectance can be reduced to zero. Normal atmospheric conditions, UV rays from the sun, road salt, and sometimes even the type of load being hauled can all cause the tape to wear out more quickly.

One's Ability to Properly Measure Reflectivity: Measuring the reflectivity of conspicuity tape isn't as simple as merely shining a flashlight on it. Actual measurements require a photometer such as the Minolta LS-100 luminance meter, or the Road Vista Model 922 Retroreflectometer. (MSC uses the Minolta LS-100 luminance meter because the tool can be used in many more human factors and crash investigation tasks than the dedicated retroreflectometers.)

Issues Related to Measuring Retroreflectivity

When an investigator is equipped with the ability to take actual measurements of conspicuity tape, it is possible to determine whether the tape in question met the legal requirements for retroreflectivity. This can be of great benefit when questions arise about "dirty" tape. Morgan (2001) found that even tape that was described as appearing "dirty" by investigating police significantly reduced crashes into the rear of trailers.

However, there is a limit to just how dirty tape can get and have it still be effective and meet legal requirements—after all, at some point the tape can become so dirty that it's hardly visible. In fact, in preliminary results of testing conducted in South Carolina, Stopper (2011) found that 40% of trucks measured on Interstate 26 had at least some tape that did not meet the minimum requirements for reflectivity.

Taking actual luminance measurements after a crash can help avoid costly and often unproductive arguments about “how dirty is too dirty?” Or, “how dirty was it?” Like any other product, conspicuity tape wears out and needs to be maintained. Failing to perform proper maintenance and repair can negatively affect an oncoming driver's ability to see the trailer. Therefore, a thorough analysis may include answering the following questions related to the conspicuity and the crash:

- Was the required conspicuity tape (and other devices such as lights and reflectors) present?
- Were the devices placed on the trailer in compliance with FMCSRs?
- Were the devices maintained and repaired in such a manner that they performed up to at least the minimum applicable standards?
- Did the configuration of the vehicles, during the oncoming driver's approach, preclude the tape (or other devices) from being beneficial?

At times, it may be impossible to get precise measurements of conspicuity tape's luminance. In these cases, the investigator should attempt to take comparative photographs or get luminance estimates by taking manually controlled photographs with a digital SLR camera. While these measurements do not offer the precision of measurements taken with a calibrated photometer, if the photos are taken properly with the digital SLR camera, they can be analyzed later to reach a scientific estimate (Messerschmidt 2010).

Limitations of the Striking Vehicle and Driver

Conspicuity tape works by reflecting light back to the observer. Reflective side-markers work in much the same way. It's important to remember that the amount of light that conspicuity tape can reflect depends on the amount of light that actually reaches it, and that this light comes from the headlights of the striking vehicle.

Determining how much light a vehicle's headlamps cast onto the conspicuity tape can present a considerable forensic challenge because when a severe crash occurs, the headlights of the striking vehicle can be completely destroyed. At times, enough of the headlights' filaments may survive for some analysis of hot shock or cold brake. However, checking for proper headlight alignment is almost always impossible. Under these circumstances, it is often important to gather as much information as possible, noting the type of headlight, the appearance or absence of hot shock, hot break, or cold break, and also noting the presence of auxiliary lighting, such as fog lamps. With this information, exemplar headlamps can be tested, or statistical information on headlight beam patterns can be obtained from a source such as [I.DRR](#), a commercially available software package created by Jeffrey Muttart and [Crash Safety Solutions](#).

Another visibility limitation that may be difficult to test because of crash-related damage is that of the striking vehicle's windshield. Excessive dirt or illegal tinting of the striking vehicle's windshield can reduce the amount of light that is transmitted through the glass, making it more difficult to see the reflective tape. This can be most important when a just-noticeable quantity of reflected light is first making its way to the oncoming driver. Under some conditions, the oncoming driver may lose valuable seconds necessary for reacting to the hazard while reflected light from the conspicuity tape is being diffused by their windshield's dirt, haze, or illegal tint.

Another limitation for the oncoming driver is his or her age. Unfortunately, human vision isn't like wine or cheese—instead of getting better with age, it gets worse. One of the first performance decrements that are commonly seen is that older drivers have more difficulty with glare and dark adaptation. This is likely to be the reason that Morgan (2001) found that conspicuity tape was less effective for drivers over 50 than for drivers between 16 and 49 years of age.

Although it should go without saying, inattentive driving—such as driving while text messaging or using a cellular telephone—and/or the use of drugs or alcohol obviously also has a strong negative effect on a driver's ability to detect any hazard, including a trailer.

Even the best, most well maintained reflective devices need light to be cast on them so that light can be reflected back. Once this light is reflected to the oncoming driver, the driver must be able to perceive it.

A thorough analysis of trailer conspicuity may include answering the following questions:

- What evidence can be collected about the striking vehicle's headlights? (This should include type, height, age, original equipment/after-market, and so on.)
- Is there enough evidence remaining to evaluate the striking vehicle's windshield? If so, what was the condition of the windshield (i.e., dirty, covered with bugs, tinted, etc.)?
- Is the striking driver's age such that he/she may have had difficulty adapting to normal glare?
- Is there evidence of alcohol use, cell phone use, or any other signs suggesting that the driver was inattentive to the driving task?

Special Cases

Some crash configurations present unique challenges that can be caused by the presence of additional factors. Two common cases involving heavy trucks and conspicuity are described below.

High Closing Speed: Morgan (2001) found that conspicuity tape was very effective in reducing rear-end crashes (crashes where the rear of the trailer was struck). These types of crashes remain significant, despite the fact that the vast majority of commercial vehicles use reflective tape. One reason that there is still a large number of rear-end crashes even with the use of conspicuity tape is that humans are notoriously bad judges of relative speed, especially when overtaking another vehicle rapidly.

There are several ways that people discern that an object is moving relative to them. Although most of these ways to detect motion and distance rely on binocular vision (seeing with two eyes), not all of them do. For example, if you attend a baseball game and watch a player circle the bases after a homerun, you see him move relative to the background—in this case, the background is the baseball diamond. Even with one eye closed, you can tell if he is running quickly or jogging slowly simply by seeing him cover the distance between the bases and noticing his posture.

However, when you are overtaking a slow-moving vehicle on the highway (especially at night), you do not have something akin to the baseball diamond to help you gauge the vehicle's speed and distance. Also, unlike the baseball player

who has a different posture based on whether he is sprinting or jogging, vehicles don't move much differently when they are going fast or slow (provided they are not accelerating).

This makes overtaking a very slow-moving lead vehicle especially hazardous for following drivers. When there is very little context (at night, or on a straight, flat roadway, for example), the overtaking driver must rely on how quickly the rear of the lead vehicle appears to be *expanding* in his or her field of view. Research has consistently shown that when the speed difference is 30mph or greater, following drivers can't "appreciate," or perceive, their closing speed until they are dangerously close to the lead vehicle.

Conspicuity tape can help alleviate this problem by providing the following driver a better pattern (or more well defined target) to view, but it does not alleviate the problem altogether. In many cases, a driver may realize that a truck is "up ahead," but at the same time not realize that the truck is stopped or moving very slowly until the driver is dangerously close to the truck (Hoffman & Mortimer, 1996; Muttart, Messerschmidt, & Gillen, 2005).

Oncoming Headlights: When a tractor-trailer combination is making a left-hand turn and a driver is approaching from the tractor's left side, the oncoming driver faces two other challenges. First, the headlights of the tractor appear to be in the proper lane (i.e., the lane adjacent to the oncoming driver's left). Second, these headlights can cause enough glare to obscure the trailer that is behind them (and still blocking the roadway). This problem was described in detail by Badger (1998).

In a case like this, a number of factors may need to be considered. Often, the analysis will begin much the same as a traditional "fail to yield right-of-way" analysis. In other words, the investigator may initially be interested in whether the tractor began to enter the roadway when the oncoming motorist was close enough to be an immediate hazard.

Depending on the time required for the truck driver to safely execute a left-hand turn, the oncoming motorist might have been quite a long distance away when the truck's turn first began. Recent studies of trucks making left turns indicate that these turns are not well modeled by the traditional accident reconstruction method of assuming a constant acceleration (Merela & White, 2010). In this study, which was conducted at a large, well maintained intersection during daylight hours, trucks

took much longer to complete a left turn than most traditional “constant acceleration” models would have predicted.

For example, if a tractor-trailer combination takes 12 seconds to pull out of a side road and reach the area of impact, an oncoming driver traveling at 45mph has the potential for 12 seconds (and 790 feet) to observe the truck and trailer. If the oncoming driver can brake to a stop at 0.7g, he or she needs only about 100 feet to stop after perceiving the trailer being positioned across the lane.

When crashes occur under these circumstances, it becomes necessary to evaluate a number of variables including:

- Did the trailer’s angle prevent the reflective tape from alerting the oncoming driver?
- How were the tractor’s headlights angled during the turn?
- Were the headlights misadjusted and creating excess glare for oncoming driver?
- Were the luminance of the reflective tape and reflective side-markers and the illuminance of the marker lights enough to make the trailer visible behind the tractor’s headlamps?

Especially in side-impact cases, actual measurements of the reflective tape’s luminance, luminance of reflective side-markers, and the illuminance of the side-marker lights can be important. Although it is possible to estimate luminance and illuminance by other means (previous studies, exemplar vehicles, etc.), actual measurements of the crashed vehicles often provide the surest answers the most efficiently and cost-effectively.

Conclusions

Conspicuity-enhancing devices, like lighting, reflectors, and conspicuity tape, as well as reflective side-markers and lights, provide a great benefit to the driving public. Although these devices do not eliminate mishaps all together, conspicuity-enhancing devices have been shown to reduce the number of serious and fatal crashes involving large trucks. However, like all safety devices, they must be used and maintained properly to maximize their benefit. For the crash investigator, the ability to understand the benefits and limitations of conspicuity devices can be of great importance in determining their role in a specific crash.

About the Author

Bill Messerschmidt is the founder of and principal consultant at Messerschmidt Safety Consultants (MSC) in Birmingham, Alabama. Bill began investigating crashes as police officer during college. As a police investigator and private consultant, he has investigated over 1500 motor vehicle crashes and other mishaps, most of which have involved heavy trucks. He is currently completing his graduate studies in Human Factors Psychology through the Engineering Outreach of the University of Idaho, where his areas of interest are human factors in occupational safety and transportation human factors. [Email Bill Messerschmidt.](#)

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