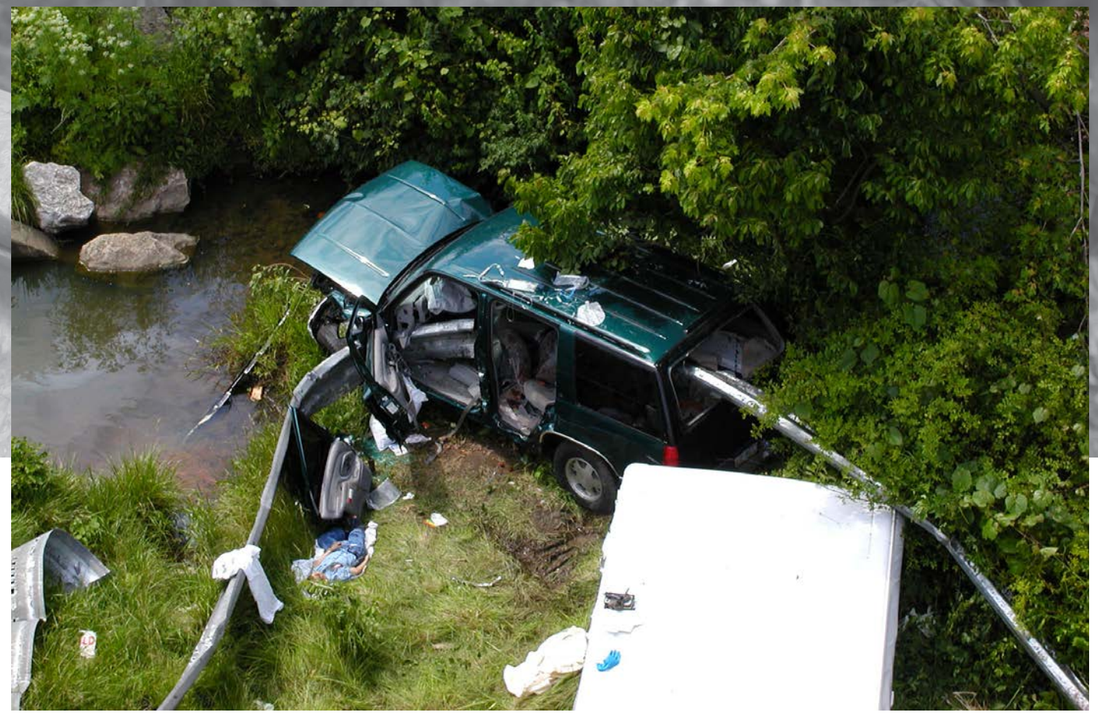
DANGER
ON OUR HIGHWAYS:
GUARDRAILS THAT MAIM AND KILL



BY Kent Emison & Michael Serra

The primary purpose of all guardrails is to reduce the probability of an errant vehicle striking a fixed object off the roadway that is less forgiving than striking the guardrail itself . However, several guardrail end terminals have design defects that cause horrible injuries and deaths.

While these defects are well established, there are still thousands of dangerous guardrail end terminals on our roadways today, and unfortunately more people will be injured. Litigating these cases requires knowledge of the end terminal products and their defects; accident reconstruction; and national standards for testing these critical safety devices.

Design Defects in Guardrail End Terminals

Guardrail designs have evolved since being implemented on U.S. roadways decades ago. Originally, the ends of guardrails did not include safety features, but it was soon discovered that when a vehicle collided with the end of a guardrail, the guardrail pierced the vehicle and caused serious injuries and fatalities. To remedy the problem, early designs added downturned ends on guardrails, which had the unintended consequence of causing deadly rollovers.

In the late 1980s, energy-absorbing end terminals were developed to absorb the impact from a vehicle and allow it to "ride down" the crash without piercing or

overturning the vehicle. One of the most popular energy-absorbing end terminals was the Trinity ET-2000, which had reasonably good results. However, Trinity chose to modify the end terminal to increase profits, which had drastic and deadly consequences.

Development of the ET-2000 and ET-Plus End Terminals

In 1989, Texas A&M Transportation Institute (TTI) developed the ET-2000, an energy-absorbing end terminal system. Trinity Industries obtained the exclusive licensing rights to manufacture and sell the end terminal. During the 1990s, the ET-2000 had a good record of safety. In fact, Trinity conducted an in-service performance evaluation and determined that the ET-2000's injury potential compared to airbags. Trinity reported "no performance problems" with the ET-2000. Despite its good track record, in the late 1990s Trinity decided to replace the ET-2000 end terminal with the ET-Plus.

Trinity executive, Steve Brown, testified that the company wanted to redesign and replace the ET-2000 because its patent was expiring. In reality, the design changes were strictly meant to increase profits for Trinity Industries and reduce competition.

According to National Cooperative Highway Research Program (NCHRP) 350, the "[d]evelopment of a safety feature from its inception to the time it becomes operational is often a long and arduous process." However, Trinity and TTI completely redesigned the ET-2000 during a single meeting. They made ad hoc design changes without the benefit of any engineering analysis, design calculations or computer simulations. Trinity and TTI redesigned the end terminal's faceplate; shortened its extruder throat; reduced the overall length of the end terminal; made the end terminal asymmetrical; removed internal stiffeners; and removed approximately 100 pounds of steel from the design. These changes became the ET-Plus end terminal.

On October 5, 1999, Trinity Industries conducted a single crash test of the ET-Plus using TTI's test facility, a clear conflict of interest since TTI and its engineers were profiting from the sale of the end terminal pursuant to its licensing agreement with Trinity. In December 1999, Trinity Industries submitted its crash test report for the ET-Plus to the Federal Highway Administration (FHWA), seeking approval for federal reimbursement.

Following FHWA approval, Trinity started aggressively marketing the ET-Plus as a new and "improved" end terminal system. The ET-Plus quickly became one of the most installed end terminals in the United States.

Federal standards outlined in NCHRP 350 specifically state that crash tests are not meant to be "all-inclusive" and that "[i]n-service evaluation is used in the final stage of development of new or extensively modified roadside safety features and has the purpose of appraising actual performance during a broad range of collision, environmental, operational, and maintenance situations for typical site and traffic conditions." However, in the almost two decades that the ET-Plus has been installed on U.S. highways, Trinity has never conducted in-service performance evaluations, a clear violation of applicable standards and good manufacturing practice. Thousands of these defective end terminals remain on our nation's roadways.

Trinity's Undisclosed Modifications to the ET-Plus End Terminal System

In November 2004, Trinity executive, Steve Brown, emailed his superiors pushing modifications to the ET-Plus end terminal. Brown suggested the guide channel on the end terminal could be reduced by one inch, from 5 inches to 4 inches, which would save Trinity $2 per end terminal. The guide channels are the downstream guides of the end terminal that align the end terminal on the guardrail. Trinity intended to make this modification with "no announcement" to the FHWA, a clear violation of the federal regulations.

Here is the email:

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-----Original Message-----
From: Steve Brown
Sent: Tuesday, November 09, 2004 2:38 PM
To: Rodney Boyd; Brian Smith
Cc: Will Burney
Subject: Fw: ET


If Wade's numbers are good, we would save $2/ET.  That's $50,000/ year and $250,000 in 5
years by using the 4" channel for the legs.

For this money we ought to be able to consider some pendulum or sled testing, if that's
what we need to convince TTI that we should roll this out.

I think we'll could get a better ET:

     * it will be a little lighter for side impacts
     * we'll save a few bucks
     * welding will be stronger at the juncture of the head and legs
     * welding, which hasn't been a problem, will be a bit more mistake proof
     * the fit of the head on the guardrail will be much closer.

If TTI agrees, I'm feeling that we could make this change with no announcement.  We did
pretty good with the TRACC changes.
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Brown testified that before implementing the design changes he simply conducted an informal "piece of paper" calculation to determine the difference in weight and cost. Trinity conducted no engineering analysis to determine the effects this modification had on impact performance. In early 2005, Brown requested Wade Malizia – a non-engineer – make a prototype of the 4-inch ET-Plus end terminal.

According to sworn testimony, unidentified shop workers fabricated the prototype 4-inch ET-Plus. They did so with no input or guidance from an engineer. They conducted no engineering or failure mode analysis. They changed the end terminal's welds between the guide channel and end terminal from butt welds to fillet welds. This was done with no analysis as to weld strength. The reduced guide channel size required insertion into the end terminal, which reduced the internal height of the squeezer section and reduced the overall length of the end terminal.

In May 2005, Trinity requested approval for this design modification from TTI's engineers. Within hours, the engineers approved the design modification–a complete lack of due diligence on the part of TTI and Trinity.

On May 27, 2005, Trinity and TTI conducted a single crash test of the modified ET-Plus end terminal. The crash test report contained no mention of the above-referenced design modifications. In its submission of the new design to FWHA, Trinity referred to the 4-inch ET-Plus as a "standard" end terminal. The submission also lacked any detailed drawings or photographs of the end terminal. The FHWA letter highlighted seven design modifications, none of which mentioned the change to 4-inch guide channels.

Why the ET-Plus Fails

Where guardrails are concerned, energy absorption means safety. A colliding vehicle can travel a considerable distance, even after impact with the guardrail, which means the more guardrail extruded, the lower the departing vehicle's velocity. As a result, the vehicle is more likely to come to a safe stop and the likelihood of injury is reduced. Some of the main reasons (failure modes) the ET-Plus fails to perform properly include the following:

- **The exit gap is too small.** The exit gap is the available space for the flattened guardrail and splice bolts to exit the terminal head. The exit gap is approximately 1 inch, which is very small for the W-beam and splice bolts to fit through during the extrusion process. Lockup occurs when the end terminal stops extruding if the W-beam gets stuck, or if one of the splice bolts lodges in the exit gap.

•**The splice bolt length is too long for the exit gap.** The length of the splice bolts is 1 5/8 inches. The exit gap is 1 inch. When the bolts get lodged in the exit gap during the extrusion process, lockup occurs, and the guardrail becomes a spear that will go right through a vehicle.

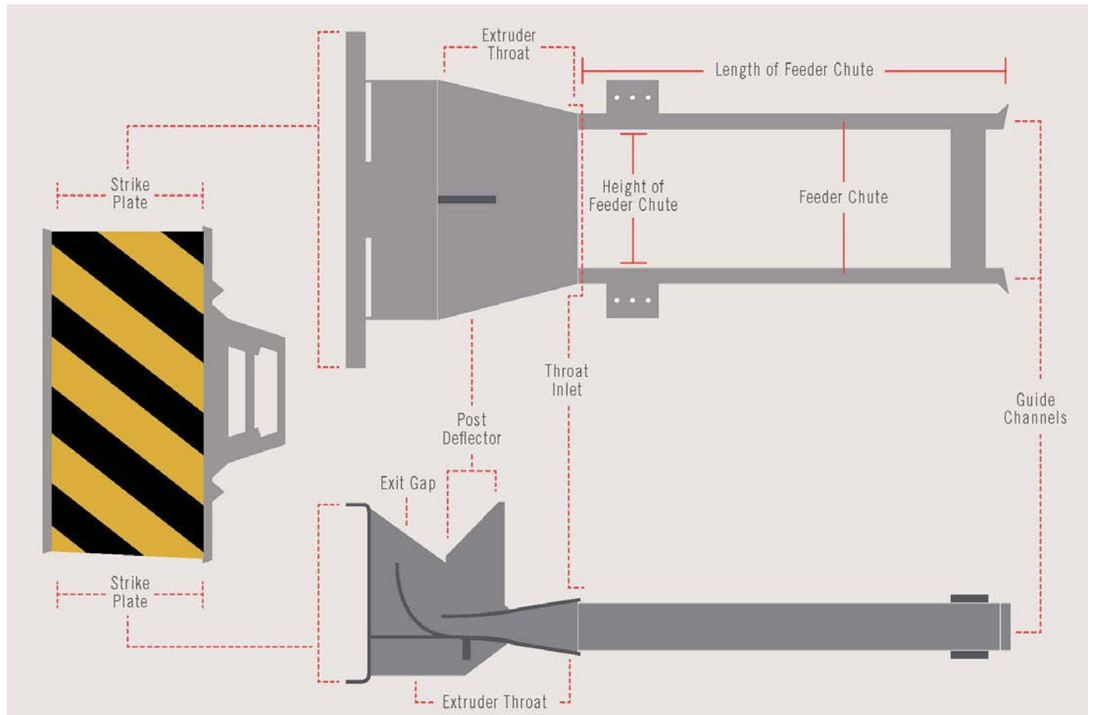
•**The guide channel height is too small, too short and too narrow.** When the W-Beam flattens during the extrusion process, the beam is too wide to fit through the opening and buckling/lockup occurs. Also, the guide channel width is too narrow and too short, which can cause the beam to become locked in the extruder throat. Instead of extruding through the exit gap in a flat ribbon, the beam will fold in half and penetrate the occupant compartment of the striking vehicle.

•**The ET-Plus strike plate is too small (15 inches versus 20 inches in the ET-2000).** A narrow strike will allow the impacting vehicle to rotate more easily about the head, contributing to the potential for lockup.

•**Asymmetry of the end terminal leads to buckling and lockup**. Because the center of the strike plate head is not aligned with the W-beam, the W-beam has potential to buckle at the entrance of the feeder section. This is especially true with low vehicle-to-end terminal impact angles.

•**The guide channel is too short, which results in the end terminal penetrating the passenger door after lockup.**

ANATOMY OF AN ET-PLUS END TERMINAL



Standards

Two guidance documents establish national standards and recommendations for evaluating the safety and performance of guardrail end terminals and other roadway safety devices:

•NCHRP Report 350.

•American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (MASH).

AASHTO released MASH in 2009 as an updated, tougher standard than NCHRP 350. As of January 1, 2016, all changes to NCHRP 350- tested devices require testing under MASH to receive a federal aid eligibility letter from FHWA. The ET-Plus was tested to the weaker standard but never to MASH.

Virginia DOT Testing of the ET-Plus

Between September 2015 and August 2016, the Virginia Department of Transportation (VDOT) sponsored 12 full-scale crash tests at Karco Engineering in Adelanto, Calif. Half of these crash tests were conducted on the 4-inch ET-Plus. The first four tests were standard NCHRP 350 tests, but the last two were modified versions of an NCHRP 350 test (the usual impact angle of 15 degrees was modified to five degrees).

Modified Test No. 3-33 resulted in catastrophic failure. During this test, only a couple feet of guardrail was extruded before the terminal head gated open. As a result, the vehicle became unstable and rolled after colliding with the backside of the guardrail further downstream. Karco determined that the crash test was a failure, and VDOT subsequently removed the ET-Plus from its qualified products list.

X-LITE Guardrail End Terminals

The X-Lite end terminal is a redirective, gating end terminal manufactured by Barrier Systems, a Lindsay Transportation Solutions Company based in Rio Vista, Calif. The X-Lite is known to have a poor in-service performance record. It is no longer used by at least nine states, some of which have started replacing them amid safety concerns that arose from death and injury crashes.

According to the FHWA, 80 percent of the X-LITE devices are found in seven states– West Virginia, Massachusetts, Tennessee, Maryland, Texas, North Carolina and Virginia. Tennessee, Delaware, Missouri and Virginia have pulled X-LITE off its accepted products lists and will no longer install the end terminal. Tennessee is in the process of removing all X-Lite end terminals on its roadways.

The X-Lite's NCHRP 350 testing shows design problems with the end terminal. In one instance, the impact to a small car test caused the hood to unlatch and fly open. In another test, the car rose up 54 degrees and came back down, a violation of Evaluation Criteria F which states: "The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable." The X-LITE performed poorly and arguably should have failed the structural criteria in the full-size pickup test.

The Transportation Research Board is currently conducting an ongoing in-service study evaluation on the performance of guardrail end terminals. Since May 2016, it has been collecting information from California, Massachusetts, Missouri and Pennsylvania. As of July 31, 2017, the study identified 47 crashes with X-Lite terminals, resulting in 32 property damage incidents; eight minor injury crashes;

four serious injury crashes; and three fatalities. However, a survey of news stories and lawsuits indicates there are 17 incidents in the U.S. since 2016 that resulted in a fatality or serious injury.

Proper installation is an issue cited by several state departments of transportation (DOT) and by Lindsay in defending many of the liability cases. The installation of the X-LITE has been a problem; for example, Tennessee officials complained:

> "Between July and October 2016, TDOT staff conducted field inspections and had discussions with Lindsey Transportation Solutions executives and staff several times attempting to clarify guardrail end terminal installation details. Lindsey Transportation Solutions was unable to resolve our concerns regarding a lack of bolt torque specifications in their installation instructions. We note that in FHWA's September 9, 2011, acceptance letter regarding the X-Lite Terminal, under the standard provisions of acceptance, that 'the manufacturer is expected to supply potential users with sufficient information on design and installation requirements to ensure proper performance.'" (TDOT letter to FHWA, April 4, 2017).

Considerations for Crash Reconstruction

When evaluating a guardrail case, the crash reconstruction is very important. The primary defense to any guardrail case is that the subject collision is outside the testing parameters set forth within NCHRP 350 and MASH. Key elements to consider include:

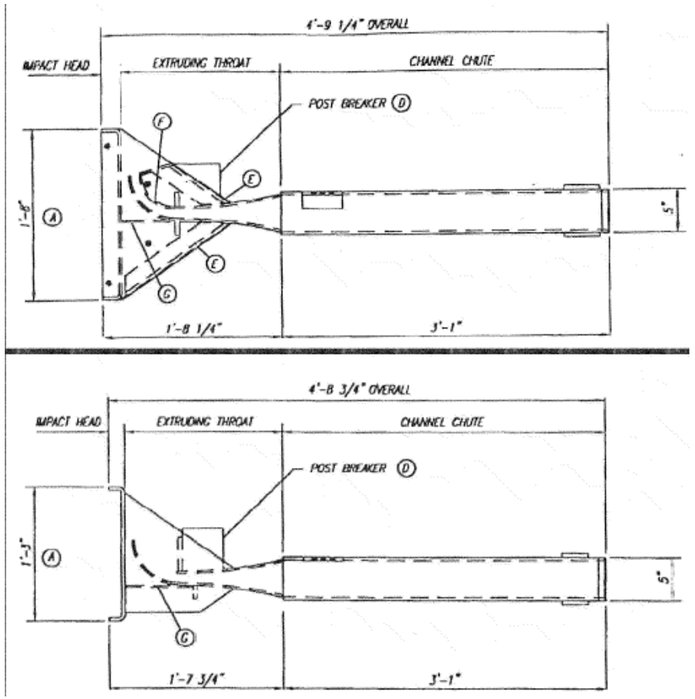
- What part of the vehicle first hit the strike plate of the end terminal (e.g., side impact, frontal impact, frontal offset, front fender).
- Angle of impact.
- Speed.
- Size and weight of the striking vehicle.

The impact speed and size of the vehicle must be sufficient to extrude the W-beam. Alternatively, the speed must not be too high. Tests are done at 62.5 mph.

Alternative Designs

Trinity ET-2000

As discussed above, the ET-2000 had a good performance record. Some of the design differences in the ET-2000 versus the ET-Plus is shown below.



SKT-350

The SKT-350 is an alternative design for a guardrail end terminal that has been approved since approximately 1997. A primary safety feature on the SKT-350 versus the ET-Plus is that the end terminal itself is much longer (83 1/8 inches vs 56 inches for the ET-Plus). This greatly reduces the danger of the folded guardrail impaling the occupant compartment. A comparison of these end terminals is on the next page.

Comparison of Key Performance Parameters

	ET-2000	ET+ (1999)	ET+ (2013)	SKT
Total Length (inch)	57.25	56.75	55.75	83.125
Feeder Chute (inch)	37	37	36	61
Impact Face Width (inch)	20	15	15	20
Weight (lb)	268	175	165	170
Channel Height (inch)	15.5	15 1/8	15 1/8	14
Channel Width (inch)	5	5	4	7 - 4
Exit Gap (inch)	?	1	1	4

ET+ Design in 2005 that had Channel Height at 14 7/8" and Channel Width at 4"?

Installation Claims

All guardrail cases should be investigated for negligent installation claims. It is almost certain that any manufacturer will claim, as a defense, the guardrail was improperly installed. If there are installation problems, it is important to identify what contractor performed the installation. Installation instructions for most guardrails are notoriously bad, and many people installing or repairing guardrails are poorly trained.

SRT Guardrails

The SRT end terminals were developed in the 1990s. SRTs are "slotted rail terminals" and differ from the end terminals discussed above in that they are non-energy absorbing. The SRT design concept involved cutting longitudinal slots in the W-beam rails of the terminal system. This design reduced the buckling strength of the rails in the event of an end-on collision. The patent explains that the reduced buckling strength of the slotted W-beam allows for controlled buckling of the W-beam rail and minimizes some dangers of other end terminals. To function properly, the slot guards must be placed at the downstream end of the slots and away from the di¬rection of traffic; however, the rails are manufactured with the same hole pat¬terns on the rail ends for assembly, which leads to the guardrail being assembled improperly.

As with most guardrails, the instructions are very poor, leading to many instances of improper installation.

ET-2000 and ET-Plus

Installation problems involving the energy-absorbing ET-2000 and ET-Plus end terminals are numerous, but include:

- Improper height of the strike plate.
- Improper installation of the breakaway posts.
- Improper alignment of the beam and exit gap/head.
- Improper installation of the cables.
- Improper distance from the roadway.
- Use of damaged or improperly repaired components.
- Improper alignment of the W-beam.

X-Lite End Terminal

X-Lite end terminals are notoriously difficult to install. As discussed above, state DOTs have complained about the extreme difficulty of installing these end terminals.

Conclusion

Guardrail systems must be designed and installed to protect errant motorists. Unfortunately, motorists on most U.S. interstates will encounter the defective guardrail end terminals discussed in this article. Because of budgeting restraints, these bad guardrails will not be replaced for many years, and more people will be needlessly maimed and killed. It is up to trial lawyers to hold the manufacturers accountable for defective designs and contractors accountable for negligent installation of guardrails.

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