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16. Abstract

This study was conducted by the University of Michigan Transportation Research Institute (UMTRI) to collect and analyze crash data on rear underride in fatal truck crashes in 2008. The underride data was collected as a supplement to the 2008 Trucks Involved in Fatal Accidents (TIFA) survey, which in turn supplements NHTSA's Fatality Analysis Reporting System file.

Data was collected on the rear geometry of the rear-most unit of all trucks in the 2008 TIFA file. In addition, for all collisions in which the rear of the truck was struck, data was collected on the extent of underride, damage to the underride guard, if any, and whether the collision was offset. In addition, international rear underride protection standards were surveyed and summarized.

Overall, accounting for the rear geometry of the vehicles and exemptions for certain cargo body types, it is estimated that about 39 percent of straight trucks in the crashes were required to have underride guards, and about 64 to 66 percent of trailers pulled by tractors were required to have them.

Rear underride was noted in about 63 percent of rear-end-struck (RES) crash involvements. The underride was to the windshield or beyond in 26 percent of RES involvements. Vehicles with lower front geometry tended to experience more underride than vehicles with a higher front geometry. Offset impact was not associated with greater damage to the underride guard, but did tend to result in more extensive underride.

There were 532 fatalities to the occupants of vehicles that struck the rears of trucks. There was some underride reported in 59 percent of the fatalities. Considering light passenger vehicles only, 403 fatalities occurred in RES involvements, with some underride in 260, or 65 percent of the cases.

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Executive Summary

As part of data collection for the 2008 Trucks Involved in Fatal Accidents (TIFA) survey, the University of Michigan Transportation Research Institute (UMTRI) collected a set of data related to rear underride protection and rear underride in the crashes. The information covered two areas. The first is the physical dimensions of the rearmost units of all the trucks in the crashes. For straight trucks, this is the rear of the truck itself; for combination vehicles, it is the last trailer in the combination. The information collected characterizes the physical structure of the rear of the vehicle, to determine the opportunity for underride. In a case where the rear of the truck was struck in the crash, the nature and the extent of underride was determined.

This report provides results from the survey of underride in fatal truck crashes. It includes a discussion of existing underride guard standards; a description of the survey methodology and data collected; results of the survey in terms of a detailed description of the rear dimensions of trucks; and a description of the outcomes of fatal crashes in which trucks were struck in the rear, including whether underride occurred and the extent of underride, offset impacts, and an accounting of the fatalities and injuries in the striking vehicles.

Underride guards on medium and heavy trucks are controlled under two standards in the United States. The first standard was issued in 1953 by the Bureau of Motor Carriers, and applied to motor vehicles manufactured after December 31, 1952, covering straight trucks and trailers. The rule required underride guards with a minimum guard height of 30 inches from the ground, on trucks with cargo beds 30 or more inches off the ground and rear tires 24 or more inches from the rear of the cargo bed. Certain vehicle/body types were exempted. The underride guard standard for trailers and semitrailers was updated and strengthened in 1998. Guard height was lowered to 22 inches, and the wheel setback dimension was shortened to 12 inches. Strength and testing standards were also added.

Recent crash studies on underride have focused on the incidence of underride, primarily in rear impacts on trucks, and the effectiveness of rear underride protection standards. The studies generally agree that underride occurs in a significant fraction of rear impacts on trucks, with estimated percentages ranging from about 65 to almost 80 percent, and one found evidence of underride in 90 percent of rear impacts. (Side underride is generally not studied.) Effectiveness is difficult to assess because of problems in determining the applicable standard, in judging if underride occurred, and in determining if crash forces are beyond design limits.

For the present project, underride data was collected as a supplement to UMTRI’s TIFA survey, by means of a telephone survey. Interviewers used the same respondents, identified from police reports, as for the main TIFA data. Each survey was reviewed by an experienced data editor and cases that needed clarification were returned to the interviewers for more calls. A wide range of data were collected, including rear overhang, cargo bed height, the presence of an underride

guard, and if the truck was struck in the rear, whether there was underride, and how far the vehicle underrode the truck.

The structure of the rear protection standards naturally leads to an analytical distinction between straight trucks and tractor combinations. In the crash year analyzed here, straight trucks accounted for a bit less than a third (28.4%) of the trucks in fatal crashes, and tractor combinations for almost two-thirds (64.1%). Straight trucks were struck in the rear at just about the same rate as tractor combinations. The percentage was slightly higher for straight trucks, at 13.9 percent, than for tractors, at 13.1 percent, but the difference is not great.

The supplemental data collected as part of the current project was used to classify the status of each truck with respect to the 1953 and 1998 standards. (Trailer year is not available so the trucks cannot be classified directly.) Ignoring missing data, under the 1953 rule underride guards are required on 38.6 percent of straight trucks and 56.9 percent of tractor combinations. The "wheels back" exemption accounts for most of the cases not required to have underride protection, for both straight trucks and tractor combinations. Under the 1953 standard, about 32 percent of straight trucks and 36 percent of tractor combinations are exempted. About 10 percent of straights and 1 percent of tractor combinations are exempted because the cargo bed was reported lower than 30 inches. Under the 1998 standard, the percentage of tractor combinations required to have a guard increased to 68.2 percent. While trailer manufacture year is not known (and therefore it cannot be known which standard applies to each vehicle), bounds, based on a realistic distribution of trailer year, can be put on estimates for the percentage of the tractor/trailer population that would be required to have an underride guard. It is estimated that 64 to 66 percent of tractor combinations in fatal crashes should mount underride guards, though there is some uncertainty to that estimate.

In terms of performance in rear-end-struck (RES) crashes, there were 539 fatal crash involvements in 2008 in which a vehicle struck the rearend of a truck. Excluding cases in which underride could not be determined, and including all striking vehicle types, not just light vehicles, at least some underride occurred in over 63 percent of RES fatal crashes. The proportion was very similar for straight trucks and tractor/trailer combinations: 63.4 percent for straights and 62.7 percent for tractor combinations. In 26 percent of the cases, the striking vehicle underrode the truck to its windshield or beyond. For straights that percentage was 20.0 percent and for tractor/trailer combinations it was 27.8 percent.

Overall, there were 532 fatalities in the 539 vehicles that struck the rear of trucks in fatal crashes. (Some of the crashes include more than two vehicles; in some of those the fatality occurred in other vehicles in the crashes, not the vehicles that struck the rear of the trucks.) There was some underride in 312 of the fatalities, no underride for 171 and underride could not be determined for 49. Two hundred fatalities occurred with underride from halfway up the hood to the windshield or beyond. Note that this includes all striking vehicle types, including trucks and buses.

Looking only at light passenger vehicles, the target of the underride standard, there were 403 fatalities in the light vehicles. At least some underride occurred the case of 260, or almost 65 percent of fatalities to light vehicle occupants. Interestingly, the probability of underride by light vehicles was similar regardless of whether the struck truck was a straight truck or a tractor/trailer. At least some light vehicle underride occurred in 67.5 percent of impacts on straight trucks, and in 63.8 percent of impacts on tractor combinations.

Going forward, as the light vehicle population trends toward smaller and lighter vehicles because of fuel economy rules and high fuel prices, light vehicle drivers may be at increased risk in collisions with heavy trucks. Stronger and lower underride guards may be desirable. Changes in the truck population may also raise future issues. Wide-base singles may become more widespread to improve the fuel economy of the truck population. Wide-base singles present a larger gap for smaller, narrower light vehicles, which in turn brings the wheels-back exemption into question.

The present study does not address the issue of side underride. While the literature review found that there has been some attention in many countries to the problem of rear underride (as well as front underride), and there are some designs to provide side underride protection, there has been little focus on the dimensions of the side underride crash problem. In terms of available crash data, it is clear that there is even less information about side underride than rear underride. Expanding the TIFA data collection to include side underride is feasible and would provide valuable new information. The TIFA process provides a readily available and effective tool to monitor truck underride protection and performance.

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1. Introduction

As part of data collection for the 2008 Trucks Involved in Fatal Accidents (TIFA) survey, the University of Michigan Transportation Research Institute (UMTRI) collected a set of information related to underride guards and rear underride in the crashes. The information covered two areas. The first is the physical dimensions of the rearmost unit of all the trucks in the crashes. For straight trucks, this is for the rear of the truck itself. For combination vehicles, the dimensions collected were for the last trailer in the combination. The information collected characterizes the physical structure of the rear of the vehicle, to determine the opportunity for underride. In a case where the rear of the truck was struck in the crash, data was collected about the nature and the extent of any underride that may have occurred.

This report provides results from the survey of underride in fatal truck crashes. It includes

- discussion of existing underride guard standards, including some international standards;
- a description of the survey methodology and discussion of the data collected;
- results of the survey in terms of a detailed description of the rear dimensions of trucks involved in fatal crashes in 2008; and
- a description of the outcomes of rear-end crashes in which the truck was struck. This includes whether underride occurred and the extent of underride, offset impacts, and an accounting of the fatalities and injuries that occurred in the striking vehicles.

2. Recent literature on rear underride and international standards

2.1 Recent literature

Recent literature was reviewed to identify methods that have been used to evaluate underride in truck crashes (i.e., whether or not an underride has occurred); to estimate incidence of underride in rear-end crashes (i.e., the number of underride crashes of all crashes and extent of injuries arising); and to evaluate the effectiveness of underride guards (i.e., whether the presence of an underride protective device mitigates the extent of underride/vehicle deformation or resulting injury). Some international literature is reviewed to characterize the approach to underride guards in other countries and the status of rear underride protection. With respect to the international scoping exercise the following countries were considered: Australia, Brazil, Canada, Europe/United Nations Economic Commission for Europe, Japan, and the United States.

UMTRI conducted a data collection effort paralleling the present study in 1997 and 1998, using a very similar protocol. Those studies found that underride occurred in about 65 percent of fatal impacts on straight trucks and 75 percent of fatal impacts on tractor/trailer combinations. Straight trucks are rear-ended at about the same rate as tractor combinations. One-third of the striking vehicle fatalities in crashes in which a truck is struck in the rear occur in impacts on straight trucks, and two-thirds when the struck truck is a tractor/trailer combination. [1, 2]

A study by Minahan and O'Day of fatal car-truck accidents in Michigan and Texas found evidence of underride in 90 percent of rear-end impacts and 70 percent of side impacts. Underride was found typically to occur at night on straight rural roads. Impact speeds were generally greater than 30 mph. The authors characterized this type of crash as a "surprise event" in which a passenger vehicle came upon a slower or stopped truck unexpectedly. [6]

Braver et al. (1997) attempted to shed light on how reliably underride is coded in the Fatality Analysis Report System (FARS) as well as to improve on estimates of underride in fatal truck crashes. They matched National Automotive Sampling System Crashworthiness Data System (NASS CDS) records with FARS records to compare the identification of underride in the two files. The researchers determined that "[o]f the 275 fatal truck-car crashes included in both data bases between 1988 and 1993, NASS/CDS coded 75 (27%) and FARS coded 18 (7%) as involving underrides. A total of 142 of the 275 fatal truck–car crashes were end-to-end impacts, of which NASS/CDS coded 71 (50%) and FARS coded 8 (6%) as underrides." [4]

A 1998 study by Braver et al. used photographs of fatal truck crashes in Indiana to code underride. Underride was defined as "the passenger vehicle being at least partially underneath the large truck at some time during the crash." The researchers coded underride in 63 percent of 107 fatal impacts overall (front, side, and rear) and in 78.6 percent of rear-end crashes. The rear-end underride rate is consistent with the UMTRI results from 1997-1998. In addition, based on the review of individual cases and the researchers' judgment, the researchers also estimated that preventing underride would reduce the probability of serious injury in about 20 percent of underride cases. [3]

Brumbelow and Blanar used a somewhat similar approach to Braver in 2010, using photographs and other research material available for the Large Truck Crash Causation Study (LTCCS) cases. The goal of their study was to evaluate the performance of current underride protection standards in rear-end struck crashes. They identified 115 cases in the LTCCS in which the rears of trucks were struck by passenger vehicles. The incidence of underride (about78%) was reasonably consistent with prior studies, and severe or catastrophic underride, meaning beyond the base of the windshield, occurred in about half the cases. They found that, of 30 underride guards that appeared to be compliant with FMVSS 224, 2 were at the maximum ground clearance and 26 were actually lower than the maximum ground clearance. They also found that in 8 cases the guards performed well, suffering only minor damage at most, but in 22 the guards sustained enough damage that they may have increased passenger compartment intrusion. [5] Without data on impact forces, it cannot be determined if these impacts were beyond the design specifications of the underride guards or if the guards did not meet the strength standards.

Also in 2010, Allen attempted to estimate the effectiveness of underride guards at reducing deaths and injuries in rear impacts. Allen did not consider underride as such, but instead attempted to estimate the effectiveness of the existing standard in reducing deaths and injuries. The purpose of the standard is to reduce fatalities and injuries in light vehicles striking the rear of combination trucks, so the approach taken was to determine if there was a statistically significant decrease in such injuries after the imposition of the standard. The report analyzed FARS and NASS General Estimates System (GES) crash data, along with a special data collection from Florida and North Carolina. He concluded that there was a decrease in striking vehicle fatalities and injuries in the Florida and North Carolina data, but that the effect was not statistically significant. The North Carolina data showed more passenger compartment intrusion in offset impacts, compared with impacts on the center of the trailers. The national data (FARS and GES) did not show the hypothesized downward trend in any of the measures taken. [7]

Australia has no current rear underride protection requirement as such, though there is a rear bumper standard for semitrailers. Rear underride protection has been considered several times, along with front and side underride protection. [8, 9] However, the general conclusion has been that frontal impacts should be the priority in underride protection, though the most recent evaluation recommended that consideration be given to adopting the European standard. In 2003, Haworth and Symmons updated a statistical profile of heavy truck crashes in Victoria as a basis for estimating the benefits of underride protection. The crash data available does not identify underride directly, but a set of crashes in which underride might have occurred was identified and the assumption was made that underride occurred in half of them. With this assumption, it was estimated that benefit/cost ratios were the largest for impacts with the front of the truck, and the lowest benefit ratio was in rear underride, though the value of the ratio exceeded one for each of front, side, and rear underride protection. [10]

A 2009 Australian regulatory analysis on underride protection considered front, side, and rear underride protection and determined that "there was a good case for the provision of front Underrun Protection for articulated vehicles but marginal Net Benefits from the provision of front UP on rigid vehicles and no Net Benefits for side or rear UP for any vehicle." It was found that 75 percent of trauma related to underride in Australia occurs in frontal impact, while side underride contributes about 15 percent, and rear underride about 10 percent. It was recommended that consideration be given to withdrawing the current rear bumper rule for semitrailers and using the UNECE Regulation No. 58 as an alternative. [10]

In Brazil, the Impact Project—a consortium of a university, General Motors of Brazil, and Mercedes-Benz of Brazil—released a series of reports presenting alternative underride guard designs to improve the effectiveness of the current standard. The reports include little in the way of objective crash analysis to determine the incidence of underride, but assert that existing standards are ineffective, based on the number of fatalities and injuries in collisions with the rear-ends of trucks. The interest of these studies is primarily in the alternative underride guard designs proposed. One is an articulated guard, designed to be lower than any current standard (400 mm ground clearance) but able to swing out to ride over ground obstacles while the truck is in forward motion. The other design is called a “pliers” underride guard. It uses a steel cable net attached to the frame of the truck at the rear and arms anchored on each side of the truck frame, such that a vehicle hitting the steel cable net will cause the arm to swing up and trap the striking vehicle. These designs may allow guards to be designed that are lower and therefore engage the front geometry of passenger vehicles better, as well as reducing the extent of underride. [12, 13, 14]

The European Vehicle Crash Compatibility (VC-Compat) project, 2003-2007, had the goal of developing methods of improving crash compatibility. It addressed both car-car and car-truck crashes. For car-truck collisions, the stated goal was to develop test procedures for underride protection, but it also issued recommendations on guard design. Crash analysis in support of the project identified frontal impact as the top priority. (The data did not identify underride directly.) Collisions with the rears of trucks was about equal with the side in fatality rates. In three of the four countries contributing crash data to the analysis, the rear impact fatality rate was significantly lower than front. However, both testing and crash analysis suggested that current standards were inadequate, and that the guards could fail in relatively low-speed collisions. Alternative underride designs were considered, including the two proposed by the Brazilian team, an Australian design using crush tubes, and an “omnidirectional” space frame design that would protect all sides of a truck/trailer combination. [15, 16, 17, 18]

Based on crash analysis and crash tests, it was proposed to reduce ground clearance of rear underride guards to 400mm, increase the height of the cross member to 200 mm, and require guards to pass test loads significantly higher than current. In a presentation toward the end of the project, Knight predicted the benefit of improved rear-underride guards would be 144 fatalities saved and 1,757 serious injuries averted, in the entire EU. This amounts to 36 percent of fatalities in car into rear of truck crashes, and 52 percent of the seriously injured. [19]

2.2 Selected international standards

2.2.1 Brazil

Brazil implemented their trailer underride regulation in July 1, 2004. The regulation applied to vehicle with gross weight rating above 4,600 kg. The bottom of the horizontal member of the guard must be no more than 400 mm above ground. For tank applications transporting hazardous materials, the face of the horizontal guard member must extend at least 150 mm beyond the tank or rearmost accessory – see Figure 1. The location of point force application is the same as the United States, Canada, and Europe but the test forces vary with vehicle GVW as shown in Table 1. Brazil also included the requirement for diagonal red and white conspicuity stripes on the face of the guard as shown in Figure 2. This marking requirement contains an extensive list of very particular specifications governing the performance characteristics of the reflective materials.

Table 1 Brazilian Test Force Requirements Based on GVW.

	Vehicle GVW (kg)			
Test point	4,600 to 6,500	6,500 to 10,000	10,000 to 23,500	> 23,500 kg
P1	50 kN	60 kN	80 kN	100 kN
P2	75 kN	90 kN	120 kN	150 kN
P3	50 kN	60 kN	80 kN	100 kN

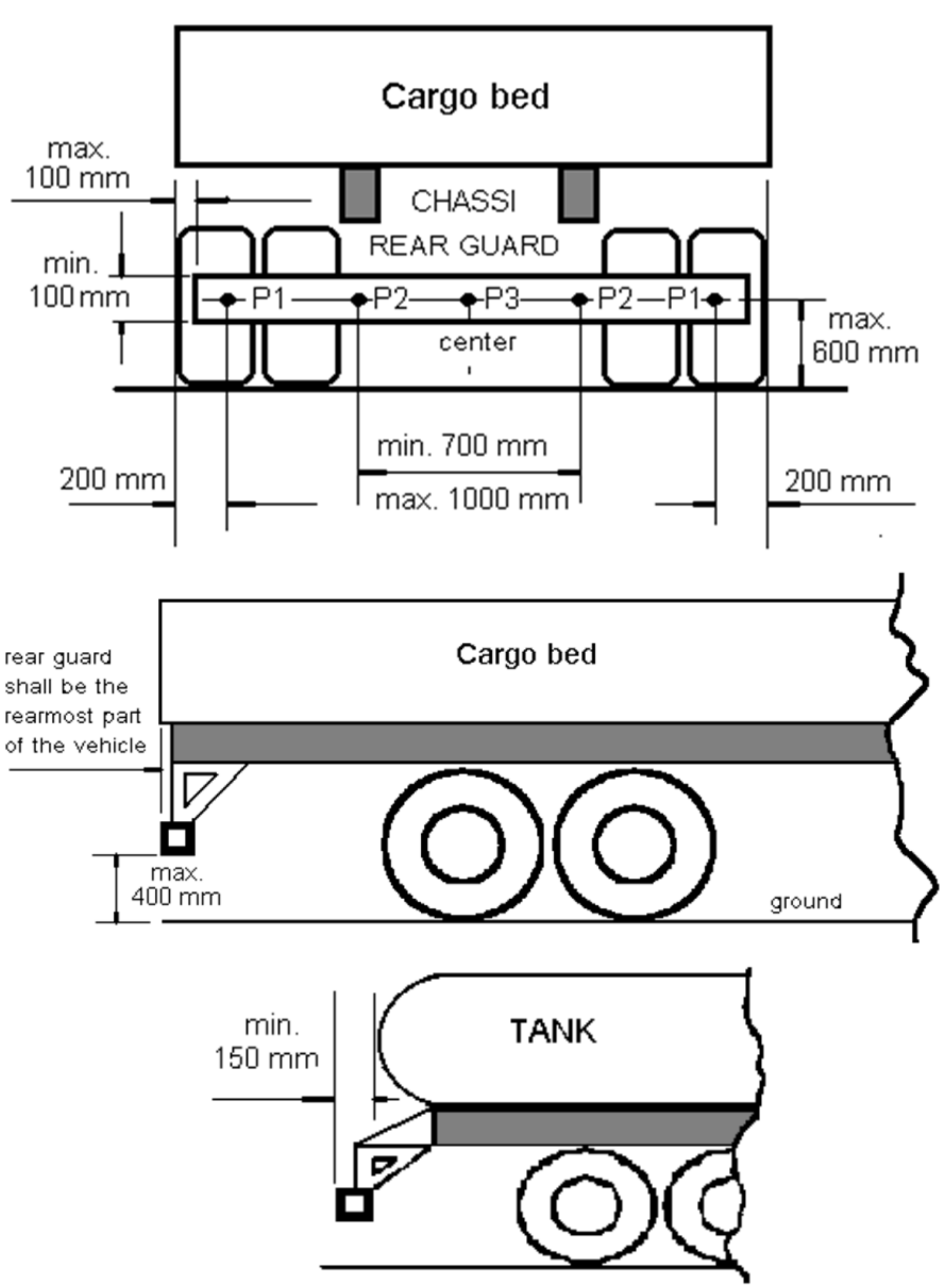

Figure 1 Unique Properties of Brazil's Regulation

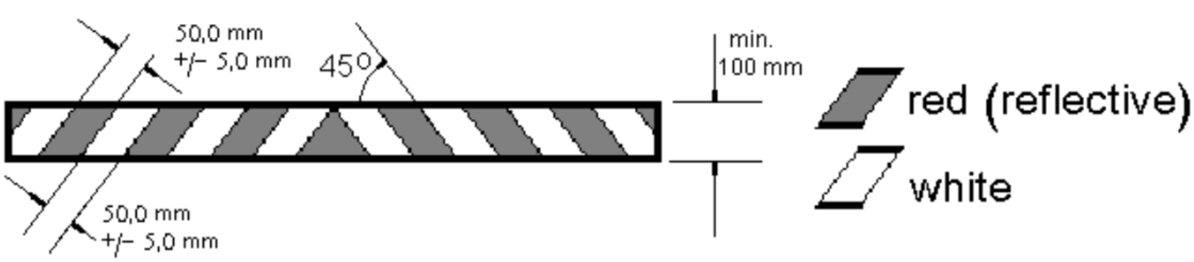

Figure 2 Diagonal conspicuity treatment required in the Brazilian regulation

2.2.2 Canada

The Canadian rear impact protection regulation No. 223 was brought into effect on September 1, 2007. The Canadian Rear Impact Guards (Standard 223) test is consistent with the U.S. requirement for the point load at P1 and P2, however it is generally silent on the point at P3 – see Figure 3 and Table 2. In place of the P3 point load, it requires an evenly distributed load of 350 kN across the face of the horizontal member which encompasses P1, P2, and P3 and that it absorb at least 20,000 J of energy within the first 125 mm of deflection. In the event that the guard demonstrates resistance to a uniform load greater than 700 kN then the regulation states that the energy absorption requirement is no longer required. Finally, after the uniform load test is completed, the ground clearance of the horizontal member shall not exceed 560 mm when measured at each support to which the horizontal member is attached.

P3 is mentioned under conditions when half of a guard is tested. In this case, there is an option to apply a point load of 175,000 N at one of the P3 locations. The other option allows a uniform load of 175,000 N to be applied to the horizontal member comprising of one half of the rear impact guard. In both cases the allowable deflection can be no more than 125 mm.

These differences in regulation are not insignificant and have implications for performance of the underride guards. The U.S. point load system allows the horizontal bar to contribute to force resistance and energy absorption through bending of the main guard member. The Canadian uniform distributed load prevents deformation of the horizontal bar and therefore negates any contribution of horizontal bending to the force and energy absorption requirements. There is a strong argument that the uniform load scenario is more consistent with rear-end crash kinematics and by requiring a uniform load test, it assures that the source of energy absorption contribution resides in the support structures. The additional option of eliminating the energy absorption requirement if uniform load capacity of the guard is greater than 700 kN provides a robust design target that manufactures can work to which significantly exceed the minimum strength requirements contained in the regulation. Finally the post test guard height requirement of 560 mm ensures that the protective potential of the guard is not diminished by excessive ground clearance during the deformation process. More detail on the Canadian regulation can be found in Appendix F

Table 2 Canadian test load requirements

Test point	Peak forces
P1	50 kN (point load)
P2	50 kN (point load)
P3	175 kN (point or uniform load)

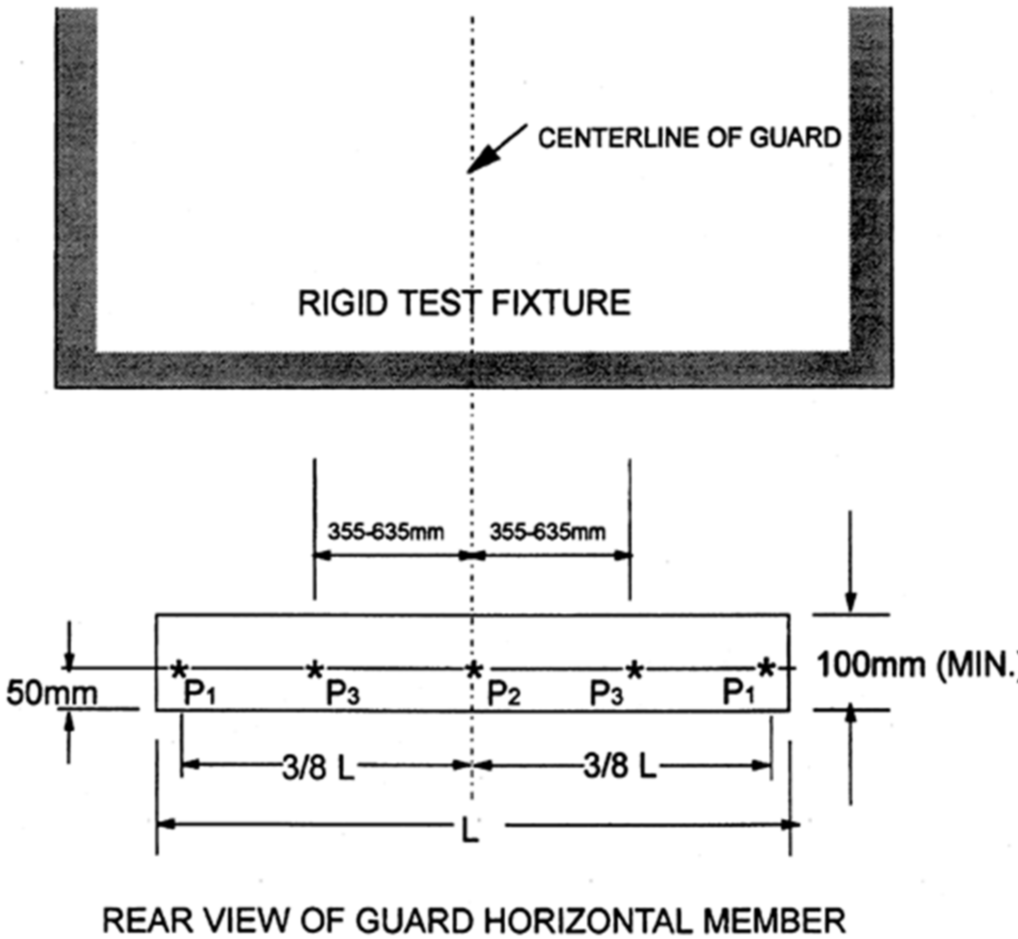

Figure 3 Canadian test loading locations

2.2.3 USA

Regulations FMVSS 223 and 224 were implemented in 1998 and govern rear impact protection and installation of the unit. The regulation 224 applies to trailers 4,359 kg or more. The test forces are applied as independent point loads of 50 kN at locations P1 and P2 and 100 kN at location P3 – see Table 3 and Figure 4. Any given guard need not be tested at more than one location. For loading point P3, there is an energy absorption requirement that the guard absorb by plastic deformation at least 5,650 J of energy within the first 125 mm of deflection. The pre-test vertical distance between the bottom edge of the horizontal member of the guard and the ground is limited to 560 mm. There is no post test height limit requirement. Regulation FMVSS 223 provides installation instructions including an explanation of the method of attachment and detailed testing instructions for rear impact guards. The intent of this regulation was to ensure that independent guard fabricators and installers would be in a position to install rear impact guards to trailers in compliance with regulatory requirements.

Table 3 U.S. test load requirements

Test point	Peak forces
P1	50 kN
P2	100 kN
P3	50 kN

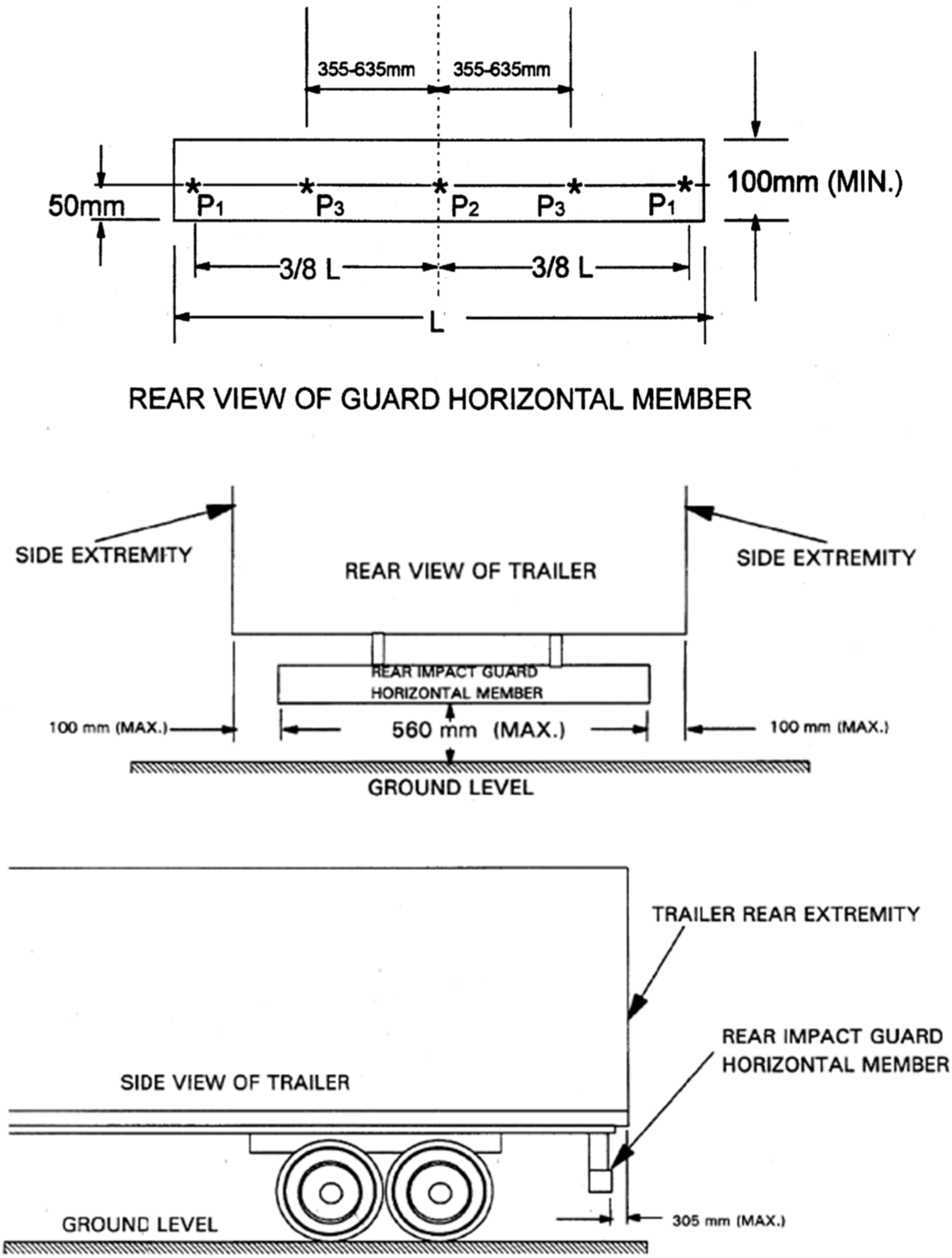

Figure 4 Relevant details pertaining to the U.S. regulation FMVSS 223 & 224

2.2.4 European Union

Council Directive 70/221/EEC is the base regulation covering underride protection. It was initially enacted March 20, 1970, but it has been updated several times since. In its initial form it applied mainly to liquid fuel tank trailers. The bottom of the guard was required to be less than 700 mm from the ground when the vehicle is unloaded. The strength of the device was defined as having a bending strength at least equivalent to that of a steel beam whose cross-section has a bending strength modulus of 20 cm^3.

A significant revision took place with the introduction of Annex II in March 2007. The annex requires point forces to be applied separately as follows: 50 kN at P1, 100 kN at P2 and 50 kN at P3. There is a provision that de-rates the forces applied based on the mass of the vehicle. An example of the regulatory wording follows: "A horizontal force of 100 kN or 50 per cent of the force generated by the maximum mass of the vehicle, whichever is the lesser, shall be applied consecutively to two points situated symmetrically about the centre line of the device or of the vehicle whichever is applicable at a minimum distance apart of 700 mm and a maximum of 1 m. The exact location of the points of application shall be specified by the manufacturer."

The distance between the bottom of the guard horizontal member and the ground must not be more than 550 mm. There is no requirement for energy absorption and there is no post test horizontal member height requirement.

3. History of U.S. underride guard standards

Underride guards on medium and heavy trucks are controlled under two standards in the United States. The first standard was issued in 1953 by the Bureau of Motor Carriers, and applied to motor vehicles manufactured after December 31, 1952. This rule governed straight trucks and trailers and will be referred to throughout this report as the 1953 rule or 1953 standard. The underride guard standard was updated and strengthened in 1998 by a rule that applied to trailers and semitrailers. This rule applied to trailers manufactured after January 26, 1998, and is referred to in this report as the 1998 rule or standard. Each rule is discussed in turn.

3.1 1953 standard

The 1953 rule applied to both straight trucks and trailers. It required a rear underride guard on vehicles in which the vertical distance from the ground to the cargo bed was greater than 30 inches, when the vehicle was empty. Certain vehicle types were exempted, including truck tractors, pole trailers, pulpwood trailers, and trucks in driveaway/towaway operations. In addition, vehicles in which the rear of the tires is less than 24 inches from the end of the cargo body (termed "wheels back"), trucks with the cargo bed lower than 30 inches, trucks with rear mounted equipment that could provide rear-end protection comparable to a rear underride guard, were also exempted. The only strength requirement was that the guard be substantially constructed, and attached by means of bolts or welding. The bottom of the guard must be no more than 30 inches from the ground, within 24 inches of the rear-most extremity of the cargo bed, and must extend within 18 inches of each side of the vehicle.[1]

As stated, the 1953 rule applied to both straight trucks and trailers, and, because the 1998 standard applies only to trailers and semitrailers, continues to be the controlling rule on rear-impact protection for straight trucks. It also applies to trailers and semitrailers manufactured before January 26, 1998.

3.2 1998 standard

The underride guard standard for trailers and semitrailers was updated in Federal Motor Vehicle Safety Standard (FMVSS) 223 and 224. The 1998 standard applies to trailers and semitrailers manufactured after January 26, 1998.

The 1998 standard modifies the 1953 standard primarily in three ways. First, the cargo bed height standard is lowered from 30 inches to 22 inches. Second, the wheels back dimension is reduced from 24 inches to 12 inches. And finally, the guard height standard is lowered to 22 inches. In addition, the underride guard must extend to within four inches of the sides of the truck. Certain trailers types are exempted, including pole trailers, pulpwood trailers, trailers with horizontal discharge (live-bed), special purpose vehicles, and cargo tank trailers with rear end protection conforming with 49 CFR part 178. Special purpose vehicles are defined as those with work performing equipment mounted at the rear or trailers with loading platforms (e.g., liftgates) that deploy through the space where the underride guard would be mounted. FMVSS 223 provides the strength and testing requirements and 224 covers installation.[2]

4. Underride Data collection

The underride data for this project were collected using a form that supplements the 2008 TIFA data collection. The TIFA data come from a survey of all medium and heavy trucks (gross vehicle weight rating (GVWR) over 10,000 lbs.) involved in a fatal traffic crash in the United States. The TIFA data are collected by means of a telephone interview. It is important to note that the TIFA approach differs from many other telephone surveys in that it does not use a prescriptive survey script, in which scripted questions are asked and answers recorded. Instead, the TIFA process is to use highly trained and knowledgeable interviewers to collect the data. The interviewers are trained in trucking and truck operations, and interview respondents until they fully understand the nature of the vehicle and its operations and can complete the survey form. The contacts with respondents are often highly interactive. All data collected is reviewed by an experienced editor, who may request call-backs to clarify the data.

[1] See 49 CFR 393.86(b)(1)
[2] See 49 CFR 571.223, 224.

The TIFA survey proceeds as follows: Medium and heavy trucks are identified in the FARS file, compiled by the National Highway Traffic Safety Administration . Police reports on each crash are acquired from the states. These police reports are used to identify and contact parties with direct knowledge of the truck as it was configured at the time of the fatal crash. Primary sources for this information are the driver of the truck, owner or operator of the truck, safety director, or any other party with direct knowledge of the truck configuration at the time of the crash. If all the data cannot be collected from primary sources, other sources may be contacted, including the reporting police officer, any other crash investigator, or other persons present at the scene, including tow operators and witnesses. The survey data encompass a detailed description of the configuration of the vehicle, including the type of power unit; number, method of attachment, and type of each trailer; cargo body and number of axles on each unit; and type of cargo on each unit. The survey also collects information about the operating authority, the type of trip at the time of the crash, driver hours at the time of the crash, and driver compensation for the trip. The TIFA survey has been operating continuously since the 1980 crash year, and provides a complete and detailed census of all medium and heavy trucks involved in fatal crashes.

4.1 Method

The underride data was collected as a supplement to the TIFA data, so the collection method was a telephone survey. Interviewers used the same respondents as for the main TIFA data and attempted to complete the underride survey form. Each question was asked, along with any clarifying questions that might be needed. Interviewers typically note any information that can help clarify responses on the forms themselves.

Each survey is reviewed by an experienced data editor. The editors examine each data element in the full context of the type of truck and trucking operation, to make sure the responses as a whole are coherent and consistent. Any cases that need clarification are returned to the interviewers for more calls. After another editor review, cases are keypunched and entered into a computer database where automated checks for consistency and outliers are applied.

4.2 Data collected

The underride data collection form is provided in Appendix A. Data collected includes:

- Rear overhang (back of tires to rear of cargo body);
- Cargo overhang (beyond the rear of the cargo body);
- Height of cargo bed;
- Underride guard presence;
- Underride guard height (if present);
- Width of underride guard;
- Presence of equipment mounted below the level of the cargo body;
- Description of the mounted equipment;

- Whether the rear of the combination was struck in the crash.

In cases where the rear plane of the combination was struck during the crash, interviewers asked a series of additional questions to determine whether there was underride or damage to the underride guard. These questions include:

- The level of damage to the underride guard;
- Whether the striking vehicle hit the rear tires of the truck combination;
- The extent of underride, captured in an ordinal variable;
- The extent of underride, estimated in inches.

In addition, case editors identified the vehicle number (which identifies a specific vehicle within a crash) of the striking vehicle so that information about that vehicle could be joined, by vehicle number, to the FARS record. They also entered a code for the state of registration of the truck or trailer, if that could be determined, and recorded any comments about the nature of the crash or anything else that might be of interest. The comment field was used to record whether the rear impact was "offset," defined as an impact to the outer third of the rear plane of the vehicle.

4.3 Methodological limitations

The methodology employed here has a number of limitations. Because the TIFA survey itself supplements the FARS data, it must follow the FARS data in time sequence, and so there is a delay between the crash occurrence and contacting respondents for the TIFA and supplemental underride data. The description of the dimensions of the rear of the trucks is collected primarily from truck operators themselves, so they should be reasonably knowledgeable about most of the items, but some of the dimensions, such as rear overhang and underride guard height, may not be items that they pay much attention to. In most cases, the dimensions are estimated rather than measured.

The limitation of after the fact estimation also applies to the questions related to underride. In some cases, respondents provided estimates from photographs of the crashes (and provided them to us as well), but in many cases they worked from memory. It would, of course, be most reliable to work from on-scene investigation, but in a survey of roughly 4,300 fatal crashes across the U.S., that is clearly not feasible. Instead, the survey relied on police reports, other investigations of the crash, and interviews with the involved parties.

It should be noted the estimates of underride determined by the telephone interview method are certainly consistent with estimates from photographic evidence, cited in Braver et al. and Brumbelow and Blanar above. [4, 5]

5. Results: Underride guards and trucks in fatal crashes

This section provides a description of the trucks involved in fatal crashes in 2008, with primary emphasis on the rear dimensions of the vehicle. The focus is on opportunities for underride, so the description covers cargo bed height, rear overhang, the presence of an underride guard or any other equipment that might serve as an underride guard.

The TIFA survey includes all medium and heavy trucks involved in a fatal crash. This threshold sweeps in some pickups equipped with heavy duty rear axles that raise their GVWR over 10,000 lbs. Some of these pickups are used for personal transportation only, as replacements for light passenger vehicles. Heavy-duty pickups that are used only for personal transportation are excluded from the analysis here. The focus is on medium and heavy trucks in commercial operations. Excluding personal use pickups gives 4,202 vehicles for analysis, out of the original 4,352 in the full 2008 TIFA file.

The rear dimensions of the trucks relevant to underride and the application of the underride guard standards are described in some detail here. Of course, the population described consists of trucks involved in fatal accidents, rather than a random sample of trucks intended to represent the truck population. However, the population described here is probably not too far from representative of the general population of trucks, at least with respect to the rear of the vehicles. Fatal crashes tend to occur more on high speed roads, so the population here probably includes more trucks that operate on high speed roads, and somewhat fewer of the vehicles such as work trucks that might operate at lower speeds. Yet all road types are represented, so this bias is a tendency rather than a censoring of the population.

5.1 Basic distributions

Table 4 shows the distribution of truck configurations in the 2008 TIFA data. The configurations shown are aggregated from more detailed information on the number of units, types of trailers and types of connections between the units in the combination. This detail is collapsed here to classify trucks in relationship to the regulations controlling the use of underride guards. Straight trucks are shown separately from tractors and all tractors pulling trailers are combined, regardless of the number of trailers. The supplemental underride information was always collected on the rearmost unit in the combination. Bobtails (tractor without a trailer) are not required to have an underride guard. The tractor/other category consists of tractor/saddlemount combinations, where the front axle of trailing tractors rests on the fifth wheel of the tractor in front. Truck combination could not be determined for 60 trucks, or 1.4 percent of the 4,202 truck combinations represented.

Straight trucks with no trailer—which fall under the 1953 rule—account for about 28 percent of the trucks involved in fatal crashes, while tractor-trailer combinations account for almost two-thirds of the trucks in fatal crashes. Most of these vehicles are tractor-semitrailer units. Slightly over four percent of the vehicles are straight trucks pulling a trailer.

Table 4 Truck Configuration, TIFA 2008

Configuration	N	%
Straight	1,192	28.4
Straight & trailer	174	4.1
Bobtail	79	1.9
Tractor/trailers	2,694	64.1
Tractor/other	3	0.1
Unknown	60	1.4
Total	4,202	100.0

In 2008, there were 539 fatal crashes in which the rear of a truck was struck by another vehicle. (Table 5) This amounts to about 12.8 percent of truck fatal involvements. In terms of the primary truck configurations used in this report, the percentage of total fatal involvements that were rear-end struck is about the same, at least for the most common configurations. A slightly higher percentage of straight trucks than tractor combinations: 13.9 percent of straights and 13.1 percent of tractor combinations were struck in the rear. The percentages were lower for straight/trailer combinations and bobtails, but those two configurations accounted for only 14 and 5 rear-end struck fatal crash involvements respectively.

Table 5 Truck Configuration by Rearend Struck, TIFA 2008

	Struck in the rear?			
Configuration	Yes	No	Unknown	Total
Straight	166	1,023	3	1,192
Straight & trailer	14	160	0	174
Bobtail	5	74	0	79
Tractor/trailers	354	2,332	8	2,694
Tractor/other	0	3	0	3
Unknown	0	5	55	60
Total	539	3,597	66	4,202
Row percentages				
Straight	13.9	85.8	0.3	100.0
Straight & trailer	8.0	92.0	0.0	100.0
Bobtail	6.3	93.7	0.0	100.0
Tractor/trailers	13.1	86.6	0.3	100.0
Tractor/other	0.0	100.0	0.0	100.0
Unknown	0.0	8.3	91.7	100.0
Total	12.8	85.6	1.6	100.0

5.2 Crash environment

This section provides a brief account of the environment for rear-end struck crashes. A description is provided that compares environmental conditions of rearend struck (RES) with other fatal crash types (non-RES), to get a better idea of the circumstances in which the crashes occur. Where differences were identified by truck configuration, those differences are noted. In order to avoid incorporating an excessive number of tables in the text, only highlights are discussed. The full set of tables is provided in Appendix B.

RES crash involvements are associated with high-speed, divided roads, both in that a majority of them occur on such roads and in that they are likely to occur there than other fatal crash types. Overall, almost 45 percent of RES crashes occurred on Interstate-signed routes, compared to 24.9 percent of non-RES crashes. RES crashes are significantly more likely on divided roads, where the traffic stream is going in one direction, than the non-RES fatal involvements of trucks. Almost 70 percent of RES involvements occur on divided roads, compared with 54.4 percent of non-RES involvements. Interestingly, RES crashes are more likely to occur away from intersections or interchanges than non-RES crashes, including intersection-related crashes. Over 77 percent of RES crashes occurred on a road segment classified as non-intersection, non-junction, compared with 65.9 percent of non-RES crashes.

Most fatal RES involvements occur in rural areas (55.8%) but there are relatively more in urban areas than non-RES (43.8% to 34.1%). The association of RES crashes with divided highways is true in both urban and rural areas, with an overrepresentation of Interstate, freeway/expressway, and principal arterial roads for RES fatal crash involvements in comparison with non-RES crashes. With respect to posted speed limits, almost 80 percent occur on roads posted at 55 mph or greater, compared with about 71 percent of non-RES involvements. Almost half are on roads posted at 65 mph or greater, compared with only about a third of other crash types.

In terms of local environmental conditions, over 93 percent of RES involvements occur on straight roads, compared with only about 80 percent of non-RES involvements. The road is also more likely to be dry at the time of the crash (86.3% to 80.0% for non-RES), though the distribution of weather conditions is about the same for both RES and non-RES involvements. On the other hand, RES involvements are more likely to occur in dark or dark but lighted conditions (i.e., there were street lights on at the scene), and somewhat less likely in daylight. RES crashes are also more likely to occur in construction or maintenance zones, 11.5 percent to 4.1 percent; and more likely to involve an alcohol-impaired driver, 19.7 percent to 14.0 percent.

Taken together, these factors paint a picture of a crash type that occurs primarily on straight roadways where the traffic stream is one directional. Most of the roads are limited access, so there is no opportunity for crossing traffic. And the crashes are more likely to occur away from interchanges and other junctions. These roads are high-speed, which would be expected since all the crashes include a fatal injury. Adverse weather conditions do not play a role, though RES involvements are more likely to occur in dark or dark/lighted conditions.

The fact that the crashes are more likely in dark or dark/lighted conditions suggests that conspicuity may play a role, but also note the overinvolvement of alcohol-impaired drivers, which is more likely at night. Also, note the overinvolvement of the crashes in construction or maintenance zones, which would represent a sudden obstruction in otherwise free-flowing traffic. Given that the crashes are mostly occurring on limited access, straight roads, that is, on roads with minimal conflicting traffic streams, and in a crash type where the struck vehicle is plainly out in front of the driver, that suggests possible driver distraction, a sudden change in the flow of traffic, and the driver of the striking vehicle coming upon a vehicle that is unexpectedly stopped or driving much slower than expected.

The distribution of RES crashes for straight trucks is somewhat different than for tractor combinations, probably mostly because of operational differences.

Compared with tractor combinations, straight trucks have a lower proportion of fatal RES crashes in rural areas, though the majority of them is still in rural areas. About 52.4 percent of straight truck RES crashes occur in rural areas, compared with 58.2 percent for tractors. A majority of straight truck RES crashes occur on Interstate or principal arterial roads, but the proportion on minor roads is significantly higher than for tractors. About 65.7 percent of straight truck RES crashes occur on Interstate, freeways, or other principal arterials, compared with 82.8 percent for tractors. About 53.0 percent of straight truck RES crashes occur on divided roads, compared with 69.7 percent for tractor combinations. And in terms of speed limit, a somewhat higher proportion occur on roads posted below 55 mph, compared to tractor combinations. But it is still the case that a majority occur on high speed roads. For straight trucks, 72.3 percent occurred on roads posted at 55 mph or above, compared with 79.6 percent for tractor/trailers. And the proportion that occur at non-interchange, non-intersection locals is almost identical: 75.3 percent for straights and 77.7 percent for tractor/trailers.

In terms of transient environmental conditions, both weather and roadway conditions are about the same for the two truck types. Fatal RES crash involvements for straight trucks are somewhat less likely to occur in dark or dark/lighted conditions than for tractors, 34.3 percent to 44.6 percent. This is probably because straight trucks tend to operate more during daylight hours, while tractor/trailer combinations are used for long-haul freight operations which can include more nighttime travel. Tractor RES crashes are also more likely to include alcohol-impaired drivers and to occur in construction/maintenance zones, but the proportions for straight truck RES crashes are still higher than for all non-RES crashes.

Overall, then, the RES crash distributions of straights are similar to those for tractor/trailer combinations, but somewhat less likely to be in rural areas, on the highest speed roads, or in dark/dark-lighted conditions. More occur on minor or local roads, but it is still the case that the majority are on high speed roads, straight roads, and crash sites away from an intersection or interchange. The main difference in crash circumstances between the RES involvements of straights and tractors is that the road location is more likely to be undivided. Otherwise, the circumstances of straight truck RES crashes appear to be reasonably similar to those of tractor combinations. Please see Appendix B for the full set of tables.

5.3 Rear dimensions, guards, and equipment

The proportion of trucks equipped with an underride guard varied widely by truck configuration type. Table 6 shows the distribution of reported underride guard by truck configuration. An underride guard was reported for only about a quarter of straight trucks with no trailers, 20 percent of the trailers pulled by a straight truck, but over three-quarters of the trailers pulled by tractors. (About 4% of bobtails were reported with an underride guard. These normally would not be expected to have a guard, but these units may have been mobile home toters.) Guard presence could not be determined in 8 to 9 percent of each combination type.

Table 6 Truck Configuration by Underride Guard Reported, TIFA 2008

	Underride guard present?			
Configuration	Yes	No	Unknown	Total
Straight	292	788	112	1,192
Straight & trailer	34	126	14	174
Bobtail	3	68	8	79
Tractor/trailer	2,082	393	219	2,694
Tractor/other	0	3	0	3
Unknown	0	0	60	60
Total	2,411	1,378	413	4,202
Row percentages				
Straight	24.5	66.1	9.4	100.0
Straight & trailer	19.5	72.4	8.0	100.0
Bobtail	3.8	86.1	10.1	100.0
Tractor/trailer	77.3	14.6	8.1	100.0
Tractor/other	0.0	100.0	0.0	100.0
Unknown	0.0	0.0	100.0	100.0
Total	57.4	32.8	9.8	100.0

Overall, 57.4 percent of the configurations were reported with an underride guard on the rear-most unit of the truck. About a third of the trucks did not have an underride guard and the presence of a guard could not be determined for just under 10 percent. (Table 7)

Table 7 Underride Guard Present, TIFA 2008

Guard present?	N	%
Yes	2,411	57.4
No	1,378	32.8
Unknown	413	9.8
Total	4,202	100.0

The TIFA supplemental data include a set of questions about the presence of equipment mounted at the back of the unit below the cargo bed. The purpose of these questions was ultimately to help determine whether the gear might be substantial enough to serve as an underride guard, under the 1953 and 1998 rules. The first question just established whether there was anything mounted under the cargo bed at the rear, and the second captured a short description of the equipment, which was used to judge whether the equipment was substantial enough and mounted such that it could serve as an underride guard. Table 8 shows the incidence of rear-mounted equipment by the truck configuration. Some sort of equipment was reported for about 14.3 percent of the trucks, though the percentage varied significantly by truck configuration. As might be expected, straight trucks had the highest proportion with over 35 percent, while only 5.6 percent of tractor combinations were reported with any rear-mounted equipment. Straight trucks are often working vehicles, with tool boxes, ramps, and other equipment mounted for easy access.

Table 8 Reported Rear-Mounted Equipment, TIFA 2008

	Equipment below cargo bed?			
Configuration	Yes	No	Unknown	Total
Straight	423	653	116	1,192
Straight & trailer	18	144	12	174
Bobtail	7	62	10	79
Tractor/trailer	152	2,327	215	2,694
Tractor/other	0	3	0	3
Unknown	0	0	60	60
Total	600	3,189	413	4,202
	Row percentage			
Straight	35.5	54.8	9.7	100.0
Straight & trailer	10.3	82.8	6.9	100.0
Bobtail	8.9	78.5	12.7	100.0
Tractor/trailer	5.6	86.4	8.0	100.0
Tractor/other	0.0	100.0	0.0	100.0
Unknown	0.0	0.0	100.0	100.0
Total	14.3	75.9	9.8	100.0

For the most part, trucks that had rear-mounted equipment that could potentially serve as an underride guard did not also have an underride guard. However, about 125 or 5.2 percent of those with underride guards also had some sort of equipment mounted below. In most cases, the equipment was either a liftgate and the associated machinery, steps, bumpers, or ramps. Table 9 shows the presence of rear-mounted equipment by truck configuration for trucks that were reported as having an underride guard. Straight trucks were most likely to have both equipment and an underride guard. Tractor combinations only rarely had both equipment and a guard.

Table 9 Reported Rear-Mounted Equipment, Underride Guard Present TIFA 2008

Configuration	Equipment below cargo bed?			Total
	Yes	No	Unknown	
Straight	59	225	8	292
Straight & trailer	4	30	0	34
Bobtail	0	3	0	3
Tractor/Trailer	62	1,993	27	2,082
Tractor/other	0	0	0	0
Total	125	2,251	35	2,411
	Row percentages			
Straight	20.2	77.1	2.7	100.0
Straight & trailer	11.8	88.2	0.0	100.0
Bobtail	0.0	100.0	0.0	100.0
Tractor/Trailer	3.0	95.7	1.3	100.0
Tractor/other	0.0	0.0	0.0	0.0
Total	5.2	93.4	1.5	100.0

Table 10 shows the frequency of rear-mounted equipment for trucks that did not have a rear-underride guard. This group is much more likely to have the rear-mounted equipment, for both straight trucks and tractor-combinations. Over 45 percent of straight trucks without an underride guard had some sort of rear-mounted equipment, though rear-mounted equipment is much more rare on the trailers pulled by straight trucks. But almost 23 percent of tractor/trailer combinations had mounted equipment if there was no guard present. This is about four times as high as the rate for all tractor/trailer combinations. Clearly, underride guard is redundant if there is some sort of equipment mounted on the rear of the truck. In some cases, the guard would interfere with the operation of the equipment. But it is also clear that some trucks have both underride guards as well as equipment mounted in the same general area, though this combination is infrequent.

Table 10 Reported Rear-Mounted Equipment, Underride Guard NOT Present TIFA 2008

Configuration	Equipment below cargo bed? Yes	No	Unknown	Total
Straight	360	408	20	788
Straight & trailer	14	108	4	126
Bobtail	6	59	3	68
Tractor/Trailer	89	297	7	393
Tractor/other	0	3	0	3
Total	469	875	34	1,378
Row percentages				
Straight	45.7	51.8	2.5	100.0
Straight & trailer	11.1	85.7	3.2	100.0
Bobtail	8.8	86.8	4.4	100.0
Tractor/Trailer	22.6	75.6	1.8	100.0
Tractor/other	0.0	100.0	0.0	100.0
Total	34.0	63.5	2.5	100.0

Interviewers recorded any equipment reported by the survey respondents. Each response was later reviewed in consultation with the TIFA editors to judge whether the equipment was substantial enough to serve as an underride guard. The full list of reported equipment is tabulated in Appendix C. Table 11 shows the list and count of equipment items that were accepted as likely meeting the standard of "… other parts of the vehicle [that] provide the rear end protection comparable to impact guard(s) conforming to the requirements of paragraph (b)(1) of this section shall be considered to be in compliance with those requirements."[3] It should be emphasized that this is a judgment based on the description of the equipment, the type of vehicle it is mounted on, and the reported cargo bed height. The table does not include any liftgates, which were reported on 116 trucks, because under the regulations those vehicles qualified as special purpose vehicles. Special purpose vehicles are not required to have rear impact guards, but those cases are discussed elsewhere.

[3] 49 CFR 386.86, (b)(3)

Table 11 Substantial Rear-Mounted Equipment, TIFA 2008

Equipment type	N	%
Attenuator	3	1.3
Axles	5	2.1
Bumpers	55	23.5
Bumpers plus other	89	38.0
Conveyor belt; loading mechanism	2	0.9
Forklift	15	6.4
Ramps	11	4.7
Spreaders	13	5.6
Wheel lift	41	17.5
Total	234	100.0

Note that bumpers account for most of the equipment. These are often on delivery or utility vans. "Wheel lifts" are the mechanism on the rear of tow trucks on which the front axle of the towed vehicle rests. There were even three cases where the struck truck had a crash attenuator mounted on the rear. Six hundred trucks were reported with some sort of rear-mounted equipment and for 234 , the equipment was considered to be sufficiently substantial to serve as an underride guard. These 234 cases amount to 5.6 percent of all the trucks involved in a fatal crash reported here.

Rear overhang is also a critical dimension. Rear overhang is defined as the distance from the face of the rear tires to the end of the cargo bed. This dimension forms one aspect of the space available for underride, since striking vehicles that actually contact the rear tires of the truck are usually stopped right there. Under the 1953 rule, underride guards are not required if the rear wheels are within 24 inches of the end of the cargo body; that distance was revised to 12 inches in the 1998 rule. Respondents were asked to estimate the amount of rear overhang. In some cases the distance is measured, but in most cases it is estimated. The values reported varied from zero to one case reported at 210 inches, three at 150 inches and 29 at 144 inches. Rear overhang was unknown in 14.6 percent of the cases and respondents reported long but unknown in 2.1 percent. The cases reported long but unknown were imputed at 81 inches for the purposes of Table 12, the mean value of cases reported between five and 10 feet.

The amount of rear overhang varies with the type of truck configuration and cargo body. Table 12 shows aggregate statistics on rear overhang, organized by the high-level truck configuration and cargo body. Only straight trucks, straights with trailers, and tractor/trailer combinations are relevant and shown in the table. The table shows the number of cases, mean and median overhang, the standard deviation of the distribution, and the minimum and maximum values observed. The statistics for each configuration as a whole include a number of minor cargo body types not shown separately in the table.

Among tractor/combinations, the van cargo body is the dominant type, with a mean overhang of over five and a half feet (67.2 inches) and a median of six feet. But axle placement (and therefore rear overhang) can vary widely. For example, the axles are typically set all the way back on 53 foot trailers with spread axles, or 28 foot trailers, which are often used on pickup and delivery runs or in doubles combinations. Livestock trailers often have axles set back. Among flatbeds, the amount of rear overhang is significantly less for lowboys than for high deck flatbed trailers. The shortest mean and median overhang was reported for dry bulk tank and dump trailers.

Table 12 Rear overhang (inches) by truck configuration and cargo body type

Cargo body	N	Mean	Median	Std Dev	Minimum	Maximum
Tractor-trailer						
Van	1,251	67.20	72	33.40	0	150
Livestock	25	26.16	18	19.56	6	81
Flatbed	303	41.35	36	31.43	0	210
Lowboy	40	26.43	21	23.51	0	96
Tank	238	23.00	12	22.96	0	81
Dry bulk	46	12.65	7	16.50	0	81
Dump	179	16.21	12	18.75	0	81
All	2,315	49.25	48	36.59	0	210
	N	Mean	Median	Std Dev	Minimum	Maximum
Straight truck (no trailer)						
Van	247	59.74	60	23.13	8	135
Flatbed	116	48.31	48	21.06	2	108
Tank	56	43.52	48	26.33	0	81
Dump	223	20.38	12	21.27	0	132
Refuse	104	49.63	48	26.87	0	124
Mixer	42	30.98	15	30.02	0	96
All	1,044	43.60	42	26.75	0	135
	N	Mean	Median	Std Dev	Minimum	Maximum
Straight truck/Trailer						
Van	13	50.77	36	32.00	6	120
Flatbed	56	58.45	57	31.29	0	144
Dump	24	19.38	12	19.17	0	81
All	157	45.90	42	31.98	0	144

The mean and median overhang for straight trucks overall is about six inches less than for tractor/trailer combinations, but as was the case for tractor combinations, overhang varies substantially by cargo body type. Overhang tends to be short for livestock, tank, and dump cargo bodies, but longer for van and some flatbeds. Figure 5, Figure 6, and Figure 7 show box plots for the distribution of rear overhang by cargo body type for tractor/trailers, straights, and straights with trailers, respectively. The boxes within the plot contain the middle quartiles of the distribution, the line bisecting the box is the median, the plus sign shows the location of the mean, and the whiskers encompass the range.

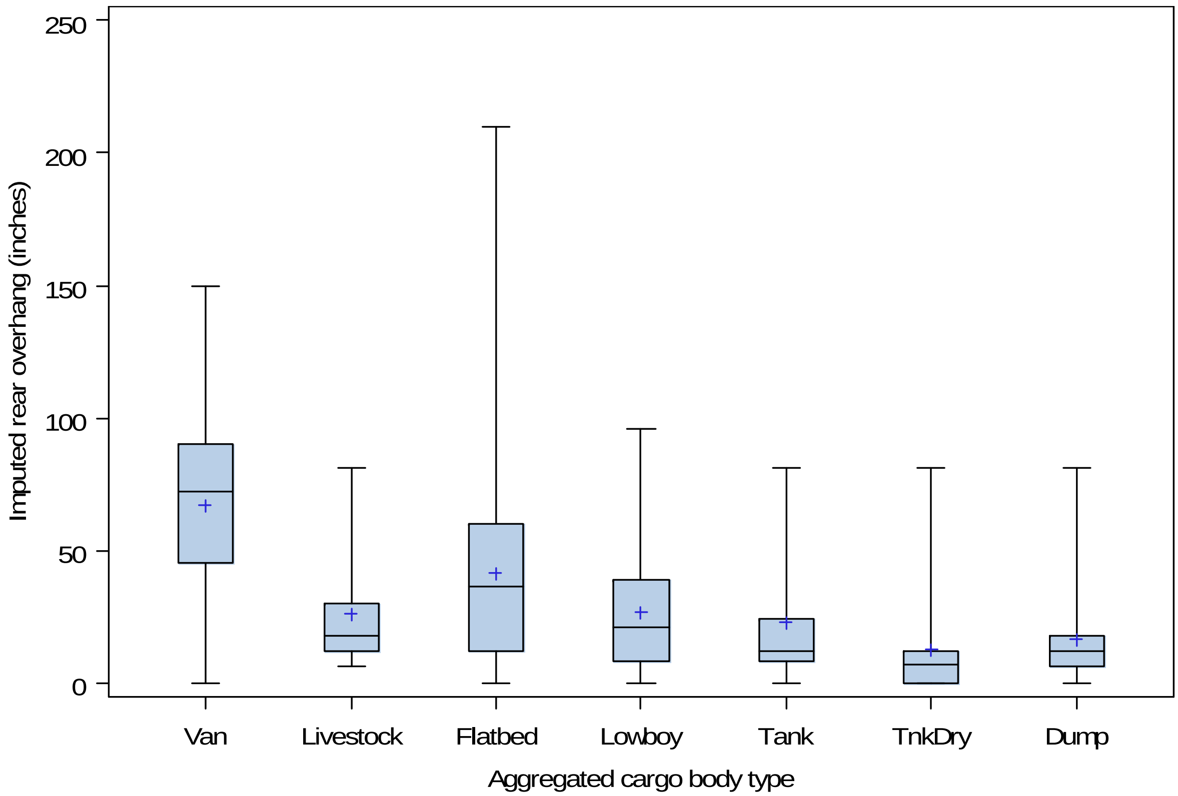

Figure 5 Tractor/Trailers, Rear Overhang by Cargo Body Type, TIFA 2008

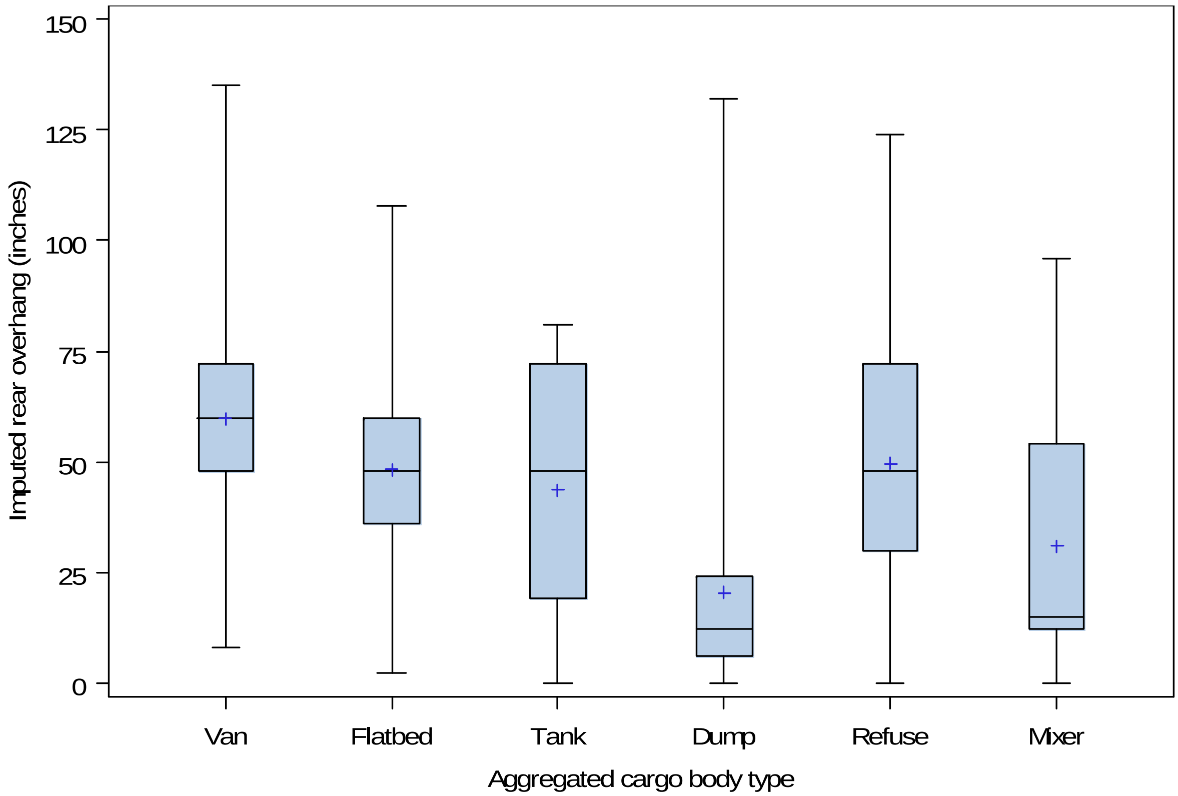

Figure 6 Straight Trucks, Rear Overhang by Cargo Body Type, TIFA 2008

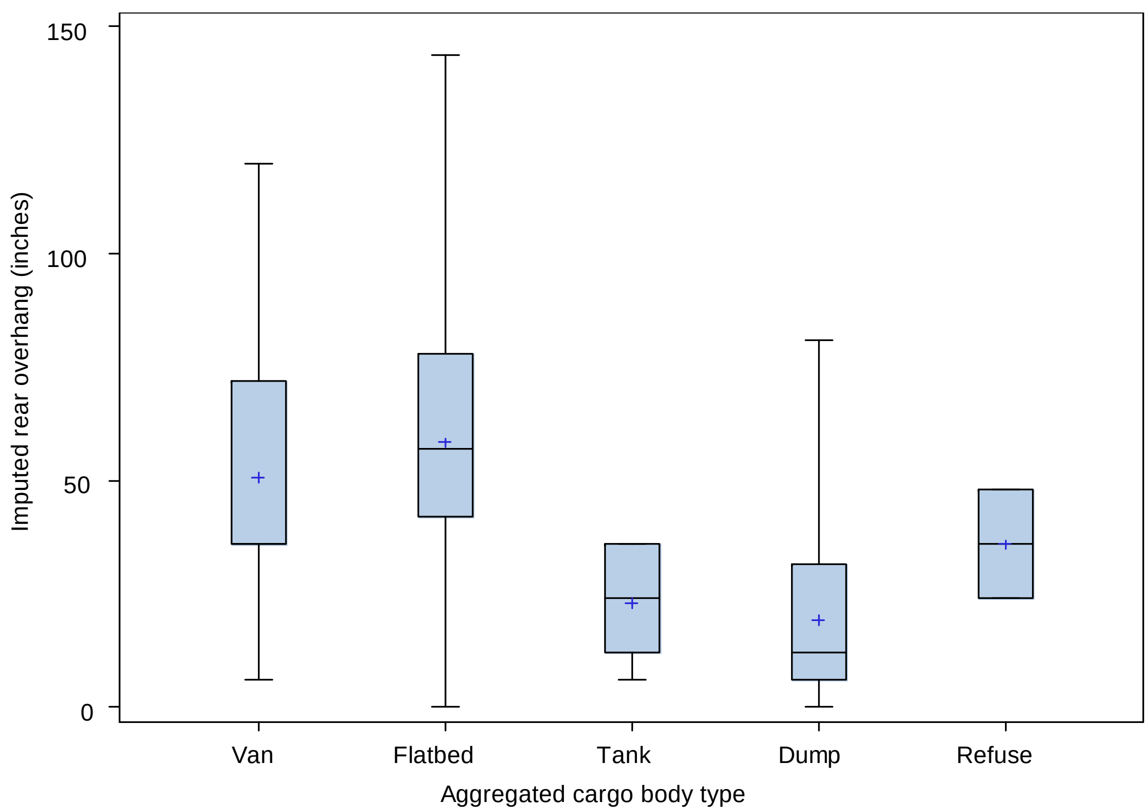

Figure 7 Straight/Trailers, Rear Overhang by Cargo Body Type, TIFA 2008

Guard height, that is the distance from the ground to the underride guard, was reported for 2,263 of the 2,411 trucks reported with underride guards. Table 13 provides the relevant statistics. Guard height was reported "low but unknown" for 17 cases, and "high but unknown" for 15. Values were imputed for each by taking the median value for those with known values less than 22 for "low but unknown," and the median value known values greater than 24 for those coded "high but unknown." The small number of cases imputed did not change significantly the overall mean, median, or mode for guard height. The results in the table are somewhat unexpected. The grand mean is almost precisely 22 inches, and the mean for each of the configurations is about the same. It was expected that the average for straight truck underride guards would be closer to 30 inches, which is the applicable standard for straights. But the mean, median, and mode are almost the same as for tractors with trailers, which should have a substantial number of trailers under the 1998 standard, or 22 inches.

Table 13 Reported guard height (inches) by truck configuration

Configuration	N	Mean	Median	Mode	Std Dev
Straight	267	21.9	22	24	5.23
Straight and trailer	33	20.5	19	18	5.29
Tractor/Trailers	1,960	22.7	22	24	4.19
All guards	2,263	21.7	22	24	4.36

One suspects that the method of collecting the information contributes to this result, compounded by the likelihood that operators generally would have no reason to pay much attention to the height of the underride guard. Respondents are asked to estimate guard height well after the crash took place. Note that for each configuration in Table 13, the mode (most common response) is either 18 or 24 inches, i.e., given in 6-inch increments. Interviewers report some guard heights as measured but in most instances, the respondent is simply estimating a value for a measure that is not a frequent issue for them. However, this result is roughly consistent with the measured (scaled from photographs) result in Brumebelow and Blanar, who found that in almost all the cases where a measurement was possible, guard height was below the minimum 1998 requirement. [5]

There was no cargo overhang in 93.3 percent of the cases, and overhang could not be determined in 4.7 percent. In most cases where overhang could not be determined, cargo body and other essential features of the truck could not be determined. Of cases where overhang could be determined, in 98 percent there was none, and in the 2 percent where there was some overhang, the average overhang was 82 inches, but the distribution is skewed right. The median overhang is 60 inches, and the mode is 48. Very large overhangs (greater than 20 feet) were recorded for logs and a utility pole.

5.4 Development of a guard required indicator.

With the truck configuration, cargo bed height, rear-overhang, equipment mounted below the cargo bed, and knowledge of the cargo body, it is possible to classify each vehicle in relationship to the 1953 and 1998 underride guard standards. The standards are described in section 3.1 and 3.2 above. The 1953 standard applies to all trucks and trailers manufactured after December 1952, effectively all the vehicles in the TIFA data set. In the 2008 calendar year, the oldest power unit was manufactured in 1966. Trailer year is unknown, so it cannot be stated with certainty that none of the trailers were built before 1953, but that is certainly the likelihood. The 1998 revision of the standard is limited to trailers and semitrailers (and not straight trucks) manufactured after January 1998. Thus, the 1953 rules apply to straight trucks, and the ’53 or ’98 rules apply to trailers and semitrailers, depending on the date of manufacture. Trailer model year was not captured in the supplemental data collection for 2008, so it cannot be determined which set of rules apply to trailers. Accordingly, results are shown for the application of each rule in turn. Either one or the other rule applies, so the results shown capture the lower bound and the upper bound of the range of applicability, within the limits of the accuracy of the data collected.

Some insight into the distribution of trailer age can be obtained from the Large Truck Crash Causation Study (LTCCS). Trailer year was captured in those data and a valid age was determined for about 67 percent of the trailers. The LTCCS data cover fatal and serious injury truck crashes, so it is roughly comparable to the TIFA data with respect to crash severity. Analysis of the data shows that about 77 percent of the trailers were 10 years of age or less at the time of the crash, which, applied to the 2008 TIFA data, would mean that the 1998 requirements would apply to that same percentage of the trailers pulled by tractors or by straight trucks. If all the trailers for which trailer year could not be determined are assumed to be older than 10 years, then about 52 percent of the trailers would be 10 years of age or less. Further discussion of theLTCCS evaluation is offered in Appendix E.

Table 14 shows the status of vehicles relative to the 1953 rear impact guard requirement, by the configuration of the truck. Truck configuration is aggregated into categories that map to certain of the fundamental distinctions in the 1953 and 1998 rear impact protection standards. For example, the ’53 standard applied to both straight trucks and trailers, while the ’98 standard applies only to trailers. Thus, straight trucks and bobtails (tractors with no trailers) are shown in separate categories, while straights with a trailer and all tractor/trailer combinations are shown in separate categories. Bobtails are shown separately from straight trucks because they are not required to have an underride guard under either standard, while straight trucks are governed by the 1953 standard. The tractor/other category consists of different saddlemount configurations.

The columns show the status of the cases relative to the rear impact guard requirements. The column headed “Yes” is for cases that seem to be required to have an underride guard under the ’53 standard. In the regulation, there are a number of conditions under which a vehicle would not be required to have rear impact protection. Certain vehicle types were exempted, such as logging or pole trailers, live-bed trailers, and driveaway/towaways (e.g., saddlemounts). Also, trucks with cargo body beds lower than 30 inches from ground level or (low bed in the table) or with the rear wheels less than 24 inches of the rear of the cargo body (wheels back) are exempt. Finally, trucks with rear-mounted equipment below the cargo body that could serve as a guard are not required to have a separate rear impact guard. Note that sufficient information to determine the applicability of the '53 standards could not be obtained for 656 trucks, which amounts to 15.8 percent of all the cases.

Table 14 Classification of Trucks by 1953 Underride Protection Standard, TIFA 2008

	Status relative to 1953 rear impact protection requirements							
Truck configuration	Yes	Exempt type	Low bed	Wheels back	Low bed & wheels back	Mounted equip-ment	Unknown	Total
Straight	397	85	90	308	19	130	163	1,192
Straight & trailer	27	15	53	35	11	2	31	174
Bobtail	0	79	0	0	0	0	0	79
Tractor/Trailer	1,305	126	21	816	16	8	402	2,694
Tractor/other	0	3	0	0	0	0	0	3
Unknown	0	0	0	0	0	0	60	60
Total	1,729	308	164	1,159	46	140	656	4,202

Table 15 shows the result of applying the 1998 standard, which is the current standard, to the same cases. The '98 standard applies only to trailers and semitrailers, so the rows for straight trucks and bobtails are the same as in Table 14. The number of trucks requiring rear impact protection increased by 290, because of the stricter standards of the current rule. The cargo body height exemption was lowered to 22 inches, and the wheel set back exemption was decreased to 12 inches. The cargo body type criteria remained effectively the same, as did the rule regarding equipment mounted below the cargo body. The number of cases exempted because of rear-mounted equipment actually increased in Table 15, but that is an artifact of the classification scheme used here. Vehicles that met both the mounted equipment standard and the '53 wheels back or low bed height standards were included in one of the latter two categories. Those cases that did not meet the '98 rear protection standards moved to the mounted equipment category.

Table 15 Classification of Trucks by the 1998 Underride Protection Standard, TIFA 2008

Truck configuration	Status relative to 1998 rear impact protection requirements: Yes	Exempt type	Low bed	Wheels back	Low bed &wheels back	Mounted equip-ment	Unknown	Total
Straight	397	85	90	308	19	130	163	1,192
Straight & trailer	65	15	28	25	1	7	33	174
Bobtail	0	79	0	0	0	0	0	79
Tractor/Trailer	1,557	126	8	571	2	18	412	2,694
Tractor/other	0	3	0	0	0	0	0	3
Unknown	0	0	0	0	0	0	60	60
Total	2,019	308	126	904	22	155	668	4,202

Because of the amount of missing data, it is informative to examine the proportions calculated after missing data are excluded. If it is assumed that the distribution of missing data is not biased, that is, that cases are not more likely to be unknown if they fall into certain categories, then the distribution excluding missing data provides a reasonable view of the whole population. Table 16 shows the distribution of trucks relative to the 1953 underride protection requirements, excluding missing cases. Almost half of the trucks require an underride guard under the 1953 rule. The most common reason for not needing one is that the wheels (really, the surface of the rear tires) are less than 24 inches from the back of the cargo bed. Almost exactly one-third of the trucks (32.7 + 1.3%) meet that standard. Exempt body types (including the bobtail), low cargo bed, and mounted equipment at the rear of the cargo body that could serve as rear impact protection, each account for about the same proportion of exemptions, ranging from 4.4 to 5.4 percent of the trucks.

Among specific truck configurations, it is somewhat remarkable that almost 39 percent of the straight trucks with no trailers fell into the group needing underride protection under the 1953 standard. This means that the cargo bed was at least 30 inches high, the rear wheels were set back 24 inches or more, and there was no equipment mounted under the cargo bed that could serve as an underride guard. Many of the straight trucks needing a guard are cargo vans, tankers, and flatbeds, which often have long rear overhangs since the cargo is typically light. On the other hand, almost 57 percent of tractors pulling one or more trailers required rear underride protection on the trailer, and, for those that did not, the most common reason was that the wheels on the trailer were set back. Also, only 0.3 percent of tractor combinations are exempt because of rear mounted equipment, compared with 12.6 percent of straights.

Table 16 Application of the 1953 Underride Protection Standard, Excluding Missing Data, TIFA 2008

Truck configuration	Status relative to 1953 rear-impact protection requirements: Yes	Exempt type	Low bed	Wheels back	Low bed &wheels back	Mounted equipment	Total
Straight	397	85	90	308	19	130	1,029
Straight & trailer	27	15	53	35	11	2	143
Bobtail	0	79	0	0	0	0	79
Tractor/Trailer	1,305	126	21	816	16	8	2,292
Tractor/other	0	3	0	0	0	0	3
Total	1,729	308	164	1,159	46	140	3,546
Row percentages							
Straight	38.6	8.3	8.7	29.9	1.8	12.6	100.0
Straight & trailer	18.9	10.5	37.1	24.5	7.7	1.4	100.0
Bobtail	0.0	100.0	0.0	0.0	0.0	0.0	100.0
Tractor/Trailer	56.9	5.5	0.9	35.6	0.7	0.3	100.0
Tractor/other	0.0	100.0	0.0	0.0	0.0	0.0	100.0
Total	48.8	8.7	4.6	32.7	1.3	3.9	100.0

Comparing Table 16 and Table 17 illustrates the impact of the 1998 revision of the rear impact protection standard. Over 57 percent of the trucks in fatal crashes overall require an underride guard (Table 17), compared to only about 49 percent of trucks under the 1953 standard. This is even including the fact that straight trucks are not covered by the 1998 regulation. Almost 70 percent of tractor combinations (primarily tractors pulling one semitrailer) require a guard, and the percentage of straights with a trailer needing a guard more than doubles from about 19 percent to about 46.1 percent.

Table 17 Application of the 1998 Underride Protection Standard, Excluding Missing Data, TIFA 2008

Truck configuration	Status relative to 1998 rear-impact protection requirements						
	Yes	Exempt type	Low bed	Wheels back	Low bed &wheels back	Mounted equip-ment	Total
Straight	397	85	90	308	19	130	1,029
Straight & trailer	65	15	28	25	1	7	141
Bobtail	0	79	0	0	0	0	79
Tractor/Trailer	1,557	126	8	571	2	18	2,282
Tractor/other	0	3	0	0	0	0	3
Total	2,019	308	126	904	22	155	3,534
Row percentages							
Straight	38.6	8.3	8.7	29.9	1.8	12.6	100.0
Straight & trailer	46.1	10.6	19.9	17.7	0.7	5.0	100.0
Bobtail	0.0	100.0	0.0	0.0	0.0	0.0	100.0
Tractor/Trailer	68.2	5.5	0.4	25.0	0.1	0.8	100.0
Tractor/other	0.0	100.0	0.0	0.0	0.0	0.0	100.0
Total	57.1	8.7	3.6	25.6	0.6	4.4	100.0

The alteration of the wheels-back criteria from 24 inches to 12 inches accounted for most of the cases that moved from not requiring rear underride protection under the 1953 standard to needing one under the 1998 standard. There were 290 additional cases that were classified as needing an underride guard, and most of them (241 or 83.1%) came from the wheels-back group. (See Table 18.)

Table 18 Comparison of Underride Guard Requirements Under the 1953 and 1998 Standards, TIFA 2008

Status applying 1953 rear impact standard	Status applying 1998 rear-impact standard							
	Yes	Exempt type	Low bed	Wheels back	Low bed & wheels back	Mounted equip-ment	Unknown	Total
Yes	1,729	0	0	0	0	0	0	1,729
Exempt type	0	308	0	0	0	0	0	308
Low bed	38	0	121	0	0	5	0	164
Wheels back	241	0	0	896	0	10	12	1,159
Low bed & wheels back	11	0	5	8	22	0	0	46
Mounted equipment	0	0	0	0	0	140	0	140
Unknown	0	0	0	0	0	0	656	656
Total	2,019	308	126	904	22	155	668	4,202

Analysis of the age of semitrailers in LTCCS data showed that between 51 and 77 percent of trailers in serious and fatal crashes are 10 or fewer years old. Trailer age is not known in TIFA, so to produce Table 16 it was assumed, in effect, that all the trailers were manufactured before 1998, so the 1953 standard applied, and Table 17 showed the result if all the trailers were manufactured after 1998, so the 1998 standard applied. Those tables showed that an estimated 56.9 to 68.2 percent of tractor combinations would require an underride guard. If the age distribution from LTCCS is applied to the TIFA data—and between 51 and 77 percent of the trailers were manufactured after 1998, that would mean that the 1998 requirements apply to about 63 to 66 percent of the tractor combinations.[4] However, it should be kept in mind that critical details about the rear of trailers could not be obtained for about 15 percent of the cases. The cases left unknown may be biased toward older vehicles. Moreover, missing data on the rear-end variables would contribute some additional uncertainty.

Table 19 and Table 20 compare reported guard use with whether the truck is required to have one under the 1953 and 1998 standards, respectively. The most striking result is that the percentage of trucks that need an underride guard but do not have one is about the same, regardless of whether the 1953 standard is applied or the 1998 standard. If the 1953 standard is applicable, about 16.9 percent of trucks that should have one do not. Under the 1998 standard, that percentage would rise to 18.3. The number of trucks that are reported to have a rear impact guard even though they are not required is also notable. And almost all of the vehicles reported to have a guard, though not required, are because of the wheels back exemption (438 out of the 904 with wheels back meeting the 1998 standard).

[4] 51 to 77 percent of the interval between 56.9 percent and 68.2 percent.

Table 19 Underride Guards Present by 1953 Standard, TIFA 2008

Guard required under 1953 standard	Guard present			Total
	Yes	No	Unknown	
Yes	1,408	292	29	1,729
Exempt type	112	179	17	308
Low bed	8	154	2	164
Wheels back	650	488	21	1,159
Low bed &wheels back	5	41	0	46
Mounted equipment	14	126	0	140
Unknown	214	98	344	656
Total	2,411	1,378	413	4,202
	Row percentages			
Yes	81.4	16.9	1.7	100.0
Exempt type	36.4	58.1	5.5	100.0
Low bed	4.9	93.9	1.2	100.0
Wheels back	56.1	42.1	1.8	100.0
Low bed &wheels back	10.9	89.1	0.0	100.0
Mounted equipment	10.0	90.0	0.0	100.0
Unknown	32.6	14.9	52.4	100.0
Total	57.4	32.8	9.8	100.0

Table 20 Underride Guards Present by 1998 Standard, TIFA 2008

Guard required under 1998 standard	Guard present			Total
	Yes	No	Unknown	
Yes	1,616	369	34	2,019
Exempt type	112	179	17	308
Low bed	4	122	0	126
Wheels back	438	450	16	904
Low bed &wheels back	2	20	0	22
Mounted equipment	19	136	0	155
Unknown	220	102	346	668
Total	2,411	1,378	413	4,202
Row percentages				
Yes	80.0	18.3	1.7	100.0
Exempt type	36.4	58.1	5.5	100.0
Low bed	3.2	96.8	0.0	100.0
Wheels back	48.5	49.8	1.8	100.0
Low bed &wheels back	9.1	90.9	0.0	100.0
Mounted equipment	12.3	87.7	0.0	100.0
Unknown	32.9	15.3	51.8	100.0
Total	57.4	32.8	9.8	100.0

6. Results: Underride in fatal truck crashes with rear impact

This section discusses the outcomes of fatal rear-end crashes. The outcomes are described in terms of the type of the striking vehicle, the amount of underride, damage to the underride guard (if present), and the number of fatalities and nonfatal injuries. While prior sections discussed all trucks involved in a fatal crash, this section will focus on the 539 trucks that were struck in the rear only.

6.1 Striking vehicle

Table 21 shows the vehicle type of the striking vehicle in rear-end crashes with trucks. The specific vehicle striking the rear of the truck was identified by the editors wherever possible. The vehicle number was transcribed from the police report, and then used to link the interview record to the vehicle record in the FARS file. This enabled the FARS classification of the striking vehicles to be determined. It should be noted that it was not possible to identify the specific vehicle in all cases. Where there were only two vehicles in the crash, the other vehicle is obvious. But when there were multiple vehicles in the crash, particularly in chain reaction crashes, it is not always possible to identify the specific vehicle that struck the rear end of the truck. Moreover, there was a small number of cases in which either the correct vehicle number could not be determined or that vehicle was not captured in the FARS file.

Definitions of the categories used to aggregate vehicle types are provided in Appendix D. The categories combine several similar vehicle types into the types shown in Table 21. The specific categories are selected to group together vehicles that present a similar profile. Note that about 54 percent of the striking vehicles are light passenger vehicles such as automobiles, sport utility vehicles and minivans. Compact pickups are shown in a separate category from large pickups because they typically have a lower front end geometry.

Table 21 Type of Striking Vehicle

Vehicle type	N	%
Auto	184	34.1
Sport utility vehicle	60	11.1
Minivan	39	7.2
Large van	14	2.6
Compact pickup	29	5.4
Large pickup	61	11.3
Bus	2	0.4
Truck	98	18.2
MC/other	41	7.7
Large equipment	0	0.0
Other/unknown	0	0.0
Unknown	11	2.0
Total	539	100.0

Note that 98 of the striking vehicles–18.6 percent of the total–were other medium or heavy trucks. Although not shown here, trucks are overrepresented among vehicles striking the rear of a truck in fatal crashes. In all other (i.e., truck not struck in rear) fatal collisions between a truck and another motor vehicle, that other vehicle was a truck in only 9.1 percent of the cases. The overrepresentation of trucks as the striking vehicle in RES crashes is likely related to the tendency of trucks to platoon—i.e., follow each other closely to gain an aerodynamic advantage.

6.2 Underride extent

Respondents estimated the amount of underride in terms of the amount of the striking vehicle that went under the rear of the truck. The categories were none, less than halfway up the hood, more than halfway but short of the base of the windshield, and at or beyond the base of the windshield. Underride extent could not be determined for 54 cases, or about 10 percent of the 539 fatal involvements in which a truck was struck in the rear.

The distribution of the extent of underride was about the same for straight trucks and tractor/trailer combinations. The percentage of straights and tractor/combinations with no underride was about the same, excluding records that were unknown on extent. (Table 22) Tractor/combinations tended to suffer greater amounts of underride than straights, possibly because straight trucks tend to have slightly shorter rear overhangs, on average.

Table 22 Underride Extent by Truck Configuration, Unknown Extent Excluded

Configuration	Underride extent					Total
	None	Less than halfway	Up to halfway	Windshield or more	Unknown amount	
Straight	53	32	21	29	10	145
Straight & trailer	4	1	1	6	0	12
Tractor/Trailer	121	52	43	90	18	324
Total	179	86	65	126	29	485
Row percentages						
Straight	36.6	22.1	14.5	20.0	6.9	100.0
Straight & trailer	33.3	8.3	8.3	50.0	0.0	100.0
Tractor/Trailer	37.3	16.0	13.3	27.8	5.6	100.0
Total	36.9	17.7	13.4	26.0	6.0	100.0

Table 23 shows the distribution of vehicles and the amount of underride reported for each vehicle type. The top half of the table shows frequencies while the bottom shows row percentages. All vehicle types are shown in this table, though subsequent tables will be restricted to light passenger vehicles only.

Generally, vehicle types with lower front ends tended to experience more underride in fatal collisions with the rears of medium or heavy trucks. Automobiles show more underride than bigger vehicles like pickups and large vans. About 33 percent of striking automobiles experienced underride to the windshield or beyond, compared with only about 14.8 percent of large pickups, and 23.1 percent of minivans. Minivans tend to stand relatively tall. Only about 21 percent of automobiles experienced no underride, compared with about 43 percent of large pickups and 36 percent of minivans.

Table 23 Extent of Underride by Vehicle Type of Striking Vehicle

Other vehicle type	Underride extent						Total
	None	Less than halfway	Up to halfway	Windshield or more	Unknown amount	Unknown	
Auto	38	37	28	60	8	13	184
Sport utility vehicle	15	14	7	17	1	6	60
Minivan	14	6	6	9	0	4	39
Large van	4	5	1	3	0	1	14
Compact pickup	8	4	6	7	1	3	29
Large pickup	26	6	12	9	2	6	61
Bus	1	0	0	0	1	0	2
Truck	47	13	5	16	7	10	98
Motorcycle	20	0	0	5	7	9	41
Unknown	6	1	0	0	2	2	11
Total	179	86	65	126	29	54	539

Other vehicle type	Underride extent						Total
	None	Less than halfway	Up to halfway	Windshield or more	Unknown amount	Unknown	
Row Percentages							
Auto	20.7	20.1	15.2	32.6	4.3	7.1	100.0
Sport utility vehicle	25.0	23.3	11.7	28.3	1.7	10.0	100.0
Minivan	35.9	15.4	15.4	23.1	0.0	10.3	100.0
Large van	28.6	35.7	7.1	21.4	0.0	7.1	100.0
Compact pickup	27.6	13.8	20.7	24.1	3.4	10.3	100.0
Large pickup	42.6	9.8	19.7	14.8	3.3	9.8	100.0
Bus	50.0	0.0	0.0	0.0	50.0	0.0	100.0
Truck	48.0	13.3	5.1	16.3	7.1	10.2	100.0
Motorcycle	48.8	0.0	0.0	12.2	17.1	22.0	100.0
Unknown	54.5	9.1	0.0	0.0	18.2	18.2	100.0
Total	33.2	16.0	12.1	23.4	5.4	10.0	100.0

6.3 Light vehicles

The primary interest in underride focuses on light passenger vehicles, which present the largest risk of underride. The declared purpose of FMVSS standards 223 and 224 is "to reduce the number of deaths and serious injuries occurring when light duty vehicles impact the rear of trailers and semitrailers." Cases where the striking vehicle is a bus, another truck, or a motorcycle are accordingly excluded in the rest of this section. Light vehicles, including the auto, sport utility, minivan, large van, compact pickup, and large pickup, are included in this section.

Many impacts to the rear of a truck are offset, because in some cases the driver maneuvers to avoid the collision. An offset collision was defined as one in which the striking vehicle collided with the outer third of the rear plane of the truck. Figure 8 shows a schematic of the rear of a heavy truck with an underride guard identifying the areas recorded as an offset collision areas. Offset was coded regardless of the angle of impact. For example, a 45 degree angle collision was coded as an offset as long as the contact point was in the offset area. If the impact was to the center of the rear plane, then offset would not be coded. Similarly, a 90 degree collision was coded as offset if the primary impact was in the offset area.

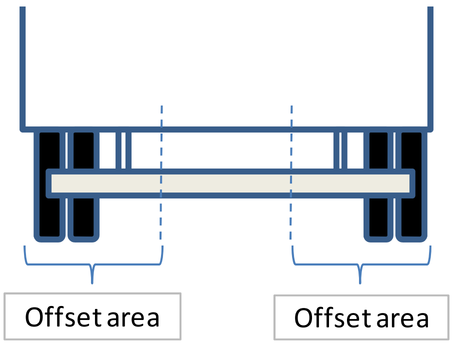

Figure 8 Schematic of rear of heavy truck illustrating offset collision area

In the 2008 TIFA data, guard damage was not strongly related to offset impact. Table 24 shows reported underride guard damage by whether the impact on the rear of the truck was offset. Only cases in which the striking vehicle was a light vehicle are included in the table, and, of course, the table is limited to cases where the truck had a rear underride guard. It had been expected that offset collisions would result in more damage than collisions that were not offset. However, this proves not to be the case. If anything, a higher percentage of major damage was reported in non-offset collision than offset. There are many factors that would affect the severity of damage including, primarily, the speed of impact. It may be that offset collisions follow unsuccessful evasion attempts, which may result in lower impact speeds. This was examined and proved to be the case. The striking vehicle was recorded as maneuvering to avoid the collision in about 30 percent of the crashes where the impact was coded as offset, compared with about 20 percent where there was not offset. The table shows overall that the guards suffer significant damage in a majority (60%) of the crashes.

Table 24 Underride Guard Damage by Offset Impact, Light Vehicle Striking Only, TIFA 2008

Guard damage	Offset impact		Total
	No	Yes	
None	21	11	32
Minor	46	16	62
Moderate	39	14	53
Major	75	16	91
Total	181	57	238
	Column Percentages		
None	11.6	19.3	13.4
Minor	25.4	28.1	26.1
Moderate	21.5	24.6	22.3
Major	41.4	28.1	38.2
Total	100.0	100.0	100.0

However, offset impact was weakly associated with greater underride. Table 25 is restricted to light vehicles; cases unknown on underride extent are excluded. (Underride extent is unknown in about 8.3 percent of light vehicle rear-end, but unknown underride extent is more common where there is no offset [9.5 percent compared with 5.4 percent for offset]). The percentage of impacts that resulted in underride to the windshield and beyond was somewhat higher where the impact was offset, 34.1 percent to 28.2 percent. Exactly half of the offset impacts resulted in underride more than halfway up the hood, compared to 45.5 percent of impacts without offset. Overall, there was some tendency for more underride than not if the collision was offset, but the difference is not marked.

Table 25 Underride Extent by Offset Impact
Light Vehicles Only, TIFA 2008

Underride extent	Offset impact		Total
	No	Yes	
None	82	23	105
< halfway	53	19	72
>= halfway	46	14	60
Windshield+	75	30	105
Unk amount	10	2	12
Total	266	88	354
None	30.8	26.1	29.7
< halfway	19.9	21.6	20.3
>= halfway	17.3	15.9	16.9
Windshield+	28.2	34.1	29.7
Unk amount	3.8	2.3	3.4
Total	100.0	100.0	100.0

Overall, there was somewhat more underride when an underride guard was present, than if there was no guard. This may seem counterintuitive, but there are many trucks that are not required to have a guard, e.g., if the rear wheels are set back, or the cargo body is low, or if the truck is one of the exempt types. Table 26 shows the degree of underride (measured on the striking vehicle) by whether an underride guard was present. In this table, all the striking vehicles were light vehicles, and cases where underride extent could not be estimated are excluded.

Table 26 Underride Extent by Guard Presence
Light Vehicles Only, TIFA 2008

Underride extent	Guard present		Total
	Yes	No	
None	57	47	104
< halfway	41	31	72
>= halfway	43	17	60
Windshield+	78	26	104
Unk amount	5	5	10
Total	224	126	350
None	25.4	37.3	29.7
< halfway	18.3	24.6	20.6
>= halfway	19.2	13.5	17.1
Windshield+	34.8	20.6	29.7
Unk amount	2.2	4.0	2.9
Total	100.0	100.0	100.0

In Table 27, reported underride is shown by the status of the rear of the truck with respect to underride guard requirements. The rears of the struck trucks are classified using the 1998 trailer guard standard. In the table, "no" means no guard and the truck does not qualify for any of the 1998 law exemptions. "Yes" means the truck has a guard and does not qualify for any of the 1998 exemptions. Exempt means the truck is exempt for one or more reasons (chiefly cargo body types). (See section 3 for the types exempted.) "Low or equipment" means the cargo bed was low or there was qualifying mounted equipment. "Wheels back" means the rear wheels were within the qualifying standard. The wheels back condition appears to be the most effective in preventing much underride. Almost 80 percent of the striking vehicles either had no underride or less than halfway up the hood of the striking light vehicle. On the other hand, almost 40 percent of vehicles striking a truck with only a rear guard underrode the truck to the windshield and beyond. This may be interpreted to support strengthening the standard. There were only 36 cases with no guard, and the difference between the amount of underride with no guard and with a guard is not statistically significant.

Table 27 Underride Extent by Underride Guard Status
Light Vehicles Only, TIFA 2008

Underride extent	Underride guard status					Total
	No guard	Underride guard	Exempt	Low bed or rear equipment	Wheels back	
None	11	37	4	12	40	104
< halfway	4	24	4	8	32	72
>= halfway	7	35	7	6	5	60
Windshield+	10	69	4	13	8	104
Unk amount	1	4	1	1	3	10
Unknown	3	5	1	2	3	14
Total	36	174	21	42	91	364
Column Percentages						
None	30.6	21.3	19.0	28.6	44.0	28.6
< halfway	11.1	13.8	19.0	19.0	35.2	19.8
>= halfway	19.4	20.1	33.3	14.3	5.5	16.5
Windshield+	27.8	39.7	19.0	31.0	8.8	28.6
Unk amount	2.8	2.3	4.8	2.4	3.3	2.7
Unknown	8.3	2.9	4.8	4.8	3.3	3.8
Total	100.0	100.0	100.0	100.0	100.0	100.0

6.4 Casualties

In the 539 fatal crashes in which a vehicle struck the rear of a truck, there were 532 fatalities in the striking vehicle.[5] Some of the crashes include more than two vehicles; in some of the crashes, the fatality occurred in another vehicle in the crash, not the vehicle that struck the rear of the truck. Table 28 shows the distribution of injury severity to the occupants of the striking vehicle in these crashes. All striking vehicle types are included, so occupants of striking trucks and buses are included, as well as light vehicles. There were some minor C-injuries, and even some uninjured persons. These may have been in vehicles whose primary collision in the crash was elsewhere, and the impact on the truck was minor. But the very great majority of the occupants were fatally injured, and a large number incurred serious A- or B-injuries.[6]

[5] Counts are adjusted for the 11 cases where the striking vehicle could not be identified with certainty. This adjustment was done by assigning to those cases the average number of deaths and injuries across all vehicle types. The numbers in the tables are rounded to the nearest whole number.
[6] Injuries are classified using the KABCO scale, in which an incapacitating injury is labeled as A-, non-incapacitating but evident as B, and complaint of pain as C-.

Table 28 Severity of Injuries to Striking Vehicle Occupants

Striking vehicle injury severity	N
Fatal	532
A-injury	84
B injury	96
C-injury	33
No injury	51
Total persons	796

Table 29 shows counts of injured persons by injury severity and underride extent. All vehicle types are included. Over half of the fatalities occur with some underride, including 200 fatalities in which the striking vehicle underrode the truck more than halfway up the hood or to the windshield and beyond.

Table 29 Injury Severity by Underride Extent

	Underride extent						
Injuries	None	<halfway	>=halfway	Windshield +	Unk. amount	Unknown	Total
Fatal	171	84	62	138	28	49	532
A-injury	20	10	14	19	11	9	84
B injury	41	13	12	17	3	9	96
C-injury	16	8	4	3	0	1	33
No injury	26	4	6	2	1	12	51

It is also of interest to break out the striking vehicle fatalities by details relative to rear underride guard requirements of the rear of the struck truck. In Table 30, the struck trucks are classified in relation to the 1998 requirements and whether the trucks were reported to have an underride guard. Straight trucks are classified as either having a rear underride guard or not. Tractor/trailer combinations are classified as either having a guard, qualifying as exempt from the guard requirement, or having a low cargo body bed or wheels back, as defined in the 1998 standard. Bobtails are shown separately, as are all other straight combinations (chiefly straights pulling a trailer) and all other tractor combinations. Most of the fatalities occurred in crashes with tractor/trailer combinations with an underride guard, followed by straight trucks with no guard, and tractor/trailer combinations with trailers wheels back, within 12 inches of the rear of the cargo bed.

Table 30 Number of Fatalities by Detailed Truck Configuration and Underride Extent, TIFA 2008

Detailed truck configuration	Underride extent						Total
	None	< halfway	>= halfway	Windshield+	Unk. amount	Unknown	
Straight, guard	8	5	7	6	1	2	29
Straight, no guard	35	25	14	22	7	5	108
Tractor/trailer, guard	54	25	25	80	10	2	195
Tractor/trailer, exempt	8	2	6	3	1	1	21
Tractor/trailer, low bed	3	1	0	1	0	0	5
Tractor/trailer, wheels back	41	18	3	7	3	4	76
Bobtail	0	1	0	1	1	2	5
Straight, other	4	0	1	7	0	13	25
Tractor, other	19	7	6	11	5	20	68
Total	171	84	62	138	28	49	532

Table 31 repeats Table 30, but limited to crashes in which the striking vehicle was a light vehicle. Again, the greatest number of fatalities occurred in collisions with tractor/trailers with underride guards, followed by straight trucks with no guard and wheels back tractor/trailers.

Table 31 Number of Fatalities by Detailed Truck Configuration and Underride Extent, Striking Vehicle Is Light Vehicle, TIFA 2008

Detailed truck configuration	None	< halfway	>= halfway	Windshield+	Unk. amount	Unknown	Total
Straight, guard	6	5	7	6	0	1	25
Straight, no guard	25	25	14	21	4	3	92
Tractor/trailer, guard	32	16	22	65	4	2	141
Tractor/trailer, exempt	6	1	4	2	1	1	15
Tractor/trailer, low bed	1	1	0	0	0	0	2
Tractor/trailer, wheels back	28	18	3	6	2	2	59
Bobtail	0	1	0	0	0	2	3
Straight, other	3	0	1	7	0	7	18
Tractor, other	7	6	6	10	2	17	48
Total	108	73	57	117	13	35	403

Table 32 is restricted also to just light vehicle striking, and shows the number of fatalities in each light vehicle type, by the amount of underride. Almost three-quarters of fatal injuries to automobile occupants occurred in crashes with at least some underride. This was the highest proportion for any of the light vehicle types. Moreover, automobiles account for 193 of the 403 light vehicle fatalities, or just about half. In the utility type, primarily sport utility vehicles, almost 70 percent of fatalities occurred with some underride. The proportions were lower for the other light vehicle types. Generally, there were proportionally fewer fatalities associated with underride in rear-end impacts for the larger light vehicles that present a higher front end, such as minivans, large vans, and large pickups. The large pickup vehicle type was the only one in which less than half (41.3%) of the fatalities occurred with underride.

Table 32 Light Vehicle Fatalities by Light Vehicle Type and Underride

Light vehicle type	No underride	Some underride	Unknown	Total
Auto	37	142	14	193
Utility	12	44	7	63
Minivan	14	21	3	38
Large van	5	8	1	14
Compact pickup	9	19	4	32
Large pickup	31	26	6	63
Total	108	260	35	403
Row Percentages				
Auto	18.8	74.0	7.3	100.0
Utility	19.0	69.8	11.1	100.0
Minivan	36.8	55.3	7.9	100.0
Large van	35.7	57.1	7.1	100.0
Compact pickup	28.1	59.4	12.5	100.0
Large pickup	49.2	41.3	9.5	100.0
Total	26.6	64.7	8.7	100.0

Finally, Table 33 shows counts of fatalities to light vehicle occupants by whether there was underride and by the type of truck that was struck. Only three of the 403 light vehicle fatalities occurred in collision with a bobtail tractor. There were 123 fatalities in rear-end collisions with straight trucks, 12 where the truck was a straight pulling a trailer, and 265 where the truck was a tractor combination. Tractor/combinations account for about two-thirds of light vehicle occupant fatalities, while straight trucks with no trailers account for about a third. In terms of underride, the percent of fatalities where there is at least some underride is quite similar for straight trucks with no trailers and tractor/trailer combinations. About 64 percent of the light vehicle fatalities in rear impacts with a tractor combination occurred where there was at least some underride, compared with about 68 percent when the truck was a straight truck.

Table 33 Light Vehicle Fatalities by Truck Type Struck and Underride

Struck truck type	No underride	Some underride	Unknown	Total
Straight	31	83	9	123
Straight/Trailer	3	7	2	12
Bobtail	0	1	2	3
Tractor/Trailers	74	169	22	265
Total	108	260	35	403
Row Percentages				
Straight	25.2	67.5	7.3	100.0
Straight/Trailer	24.4	58.8	16.8	100.0
Bobtail	0.0	33.3	66.7	100.0
Tractor/Trailers	27.9	63.8	8.3	100.0
Total	26.8	64.5	8.7	100.0

7. Summary and discussion

7.1 Key findings:

1. Straight trucks accounted for just under a third (28.4%) of the trucks in fatal crashes, and tractor combinations for almost two-thirds (64.1%).
2. In the 2008 fatal crashes, straight trucks were struck in the rear at about the same rate as tractor combinations. The percentage was slightly higher for straight trucks, at 13.9 percent, than for tractors, at 13.1 percent.
3. Examination of crash circumstances showed that the rear-end struck type typically occurs on high speed, straight, divided roads, in which the traffic streams are separated. There were some differences in the crash environment for straight trucks, but overall, the circumstances of rear-end struck (RES) fatal crashes for straight trucks were reasonably similar to those of tractor combinations.
4. Under the 1953 rule, underride guards are required on 38.6 percent of straight trucks and 56.9 percent of tractor combinations; if it is assumed that all tractor combinations fall under the 1998 standard, the proportion requiring an underride guard increased to 68.2 percent. Based on a realistic assumption about the distribution of trailer manufacture year, we estimate 63 to 66 percent of tractor combinations in fatal crashes should have underride guards.
5. At least some underride occurred in over 63 percent of RES fatal crashes. The proportion was very similar for straight trucks and tractor/trailer combinations: 63.4 percent for straights and 62.7 percent for tractor combinations.
6. Almost a third of automobiles underrode to the windshield and beyond, compared with about 23 percent of minivans and 15 percent of large pickups.

7. Where the striking vehicle was a light passenger vehicle, there were 403 fatalities in the vehicle; at least some underride occurred the case of 260 of the fatalities, or almost 65 percent of fatalities to light vehicle occupants.

This report summarizes data collected on rear underride in fatal truck crashes. Data on the rear geometry of all trucks involved in fatal crashes in 2008 was collected as a supplement to UMTRI's Trucks Involved in Fatal Accidents survey. In crashes in which the rear of the truck was struck, additional information was collected on the type of striking vehicle, whether there was underride, and the extent of underride, if any. In general, underride is difficult or impossible to identify in available computerized crash data files. This is true of the main crash files in the US, and a brief survey of the status of underride research and regulation internationally showed that it is true elsewhere as well. With the supplemental information collected for this project, the TIFA crash data is one of the few sources of real-world data on rear underride.

In the United States, rear underride protection is mandated in two parts. Straight trucks are controlled under a 1953 standard that requires rear guards on vehicles with a cargo bed ground clearance of 30 inches or more, and the rear surface of the tires 24 inches or more from the rear of the cargo bed. There are also other exemptions for certain cargo body types that make installation of a rear underride guard infeasible, as well as for rear-mounted equipment that could serve as a guard. Trailers manufactured before 1998 also are controlled by the 1953 standard, but those manufactured after January 26, 1998, must meet the requirements of FMVSS 223 and 224. Those rules provide strength and installation standards for trailers, as well as reduce the guard height to 22 inches, lower the cargo bed height exemption to 22 inches, and shorten the rear overhang exemption to 12 inches.

The structure of the rules naturally leads to an analytical distinction between straight trucks and tractor combinations. In the crash year analyzed here, straight trucks accounted for a bit less than a third (28.4%) of the trucks, and tractor combinations for almost two-thirds (64.1%). Straight trucks with trailers, bobtails (tractor with no trailer), and other combinations account for only a small percentage of the truck configurations (4.1%, 1.99%, and 0.1% respectively). The great majority of the trucks are either straights, controlled under the 1953 rule, or tractor combinations, controlled under the 1998 rule if the trailer was manufactured in 1998 or later, or the 1953 rule if before.

In the 2008 fatal crashes, straight trucks were struck in the rear at nearly the same rate as tractor combinations. The percentage was slightly higher for straight trucks, at 13.9 percent, than for tractors, at 13.1 percent, but the difference is not of practical significance. Examination of crash circumstances showed that the rear-end struck type typically occurs on high speed, divided roads, in which the traffic streams are separated. Many of these are limited access roads, which reduces the conflicts possible to same direction types. It was found that straight roads were overrepresented, as were alcohol-impaired drivers and construction zones–possibly because they are unexpected interruptions in the traffic flow. Dark conditions are somewhat overrepresented in rear-ends, which may point to conspicuity as a factor.

There were some differences in the crash environment for straight trucks, but overall, the circumstances of RES fatal crashes for straight trucks were reasonably similar to those of tractor combinations. In comparison with tractor combinations, straight truck RES crashes were somewhat more likely to occur in urban areas, on non-principal routes, and on undivided roads. More were on roads posted at 50 mph or below. But this in comparison with the RES involvements of tractor combinations. All of the same overrepresentations of road type, speed, and so on, are true of straight truck RES involvements in comparison with non-RES involvements as they are for tractor combinations. The difference between straight trucks and tractor combinations is simply that the overrepresentations are less well-marked.

Except for trailer manufacture year, the supplemental data collected as part of the current project can be used to classify the status of each truck with respect to the 1953 and 1998 standards. Ignoring missing data, under the 1953 rule, underride guards are required on 38.6 percent of straight trucks and 56.9 percent of tractor combinations. The "wheels back" exemption accounts for most of the cases not required to have underride protection, for both straight trucks and tractor combinations. The 1953 standard was wheels within 24 inches of the rear of the cargo bed, which exempted about 32 percent of straight trucks and 36 percent of tractor combinations. About 10 percent of straights and one percent of tractor combinations qualified because the cargo bed was reported lower than 30 inches. And almost 13 percent of straights had rear-mounted equipment that was judged to provide protection similar to the 1953 underride guard standard.

Note, however, that these percentages were calculated omitting cases that could not be classified because of missing data on one or more items. That amounted to about 15.8 percent of all cases. The UMTRI team believes that there is no significant, relevant bias in the missing data; i.e., that the distribution of cases for which all information was collected reasonably represents the whole population.

In terms of the 1998 standard, the same percentage of straight trucks would be required to have a guard, and the proportion of tractor combinations required increases to 68.2 percent from 56.9 percent. The straight truck percentage does not change because the 1998 standard does not apply to straights. The change for tractor combinations is largely due to reducing the wheels back exemption to 12 inches from 24. That reduced the percentage of tractor combinations exempted under the wheels back rule to 25 percent from 36.

While trailer manufacture year is not known in the 2008 TIFA data (though it is being captured for the 2009), bounds can be put on estimates for the percentage of the tractor/trailer population that would be required to have an underride guard. Based on the distribution of trailer age in the LTCCS data, it is estimated that between 63 and 66 percent of tractor combinations in fatal crashes should mount underride guards. There are at least two sources of uncertainty here. The first is that the estimation method assumes that missing data is randomly distributed with respect to the age of the trailer, but it may be the case that it was more difficult to get the geometric data used to apply the standards on older trailers. And the second source of uncertainty is just that in most cases, the geometric data is based on estimation rather than measurement.

In terms of performance in RES crashes, there were 539 fatal crash involvements in 2008 in which a vehicle struck the rear-end of a truck. A surprisingly large percentage of those vehicles were other trucks. In fact, almost 20 percent of the striking vehicles were trucks or buses, which may be related to the tendency of trucks to form platoons on the highway. Another 7.7 percent were motorcycles. The vehicle could not be identified in 11 cases (2.0%) and the remainder (72%) were light vehicles, which is the vehicle type targeted by underride standards for mitigation.

Overall, underride–where some portion of the striking vehicle goes under the rear of the struck truck–could not be determined in about 10 percent of the cases. This is likely due in part to the method of telephone survey after the fact, because memories can fade. But it is also true that crashes are complex, violent, and disorderly events in which many things may be difficult to establish. In any case, 10 percent missing data is reasonably low. Excluding cases in which underride could not be determined, and including all striking vehicle types, not just light vehicles, at least some underride occurred in over 63 percent of RES fatal crashes. The proportion was very similar for straight trucks and tractor/trailer combinations: 63.4 percent for straights and 62.7 percent for tractor combinations. In 26 percent of the cases, the striking vehicle underrode the truck to its windshield and beyond. For straights that percentage was 20.0 percent and for tractor/trailer combinations it was 27.8 percent.

For light vehicles, the amount of underride varied with the specific vehicle type. Automobiles experienced more underride than light vehicle types that tend to have higher front end geometry. Almost a third of automobiles underrode to the windshield and beyond, compared with about 23 percent of minivans and 15 percent of large pickups. The higher profile of these vehicles may engage more of the rear structure of the truck, including the underride guard or other equipment mounted there, impeding underride.

For many of the light vehicle collisions, the impact on the rear of the truck was offset, defined as to the outer third of the rear plane of the truck. This was the case in almost a quarter of the crashes. Interestingly, an offset collision was not associated with more reported damage to the underride guard, possibly because in offset collisions the driver had braked or steered to avoid the crash and thus reduced the impact speed. Overall, about 60 percent of underride guards were reported with moderate or major damage in light vehicle impacts. About 28 percent of offset impacts were reported with major damage, while major damage was reported in 41.4 percent impacts in which there was no offset. However, offset collisions did tend to result in somewhat more underride, in particular more underride to the windshield and beyond.

Overall, there were 532 fatalities in the 539 vehicles that struck the rear of a truck in a fatal crash. (Some of the crashes include more than 2 vehicles; in some of which the fatality occurred in some other vehicle in the crash, not necessarily the vehicle that struck the rear of the truck.) There was some underride in 312 of the fatalities, no underride for 171 and underride could not be determined for 49. Two hundred fatalities occurred with underride from halfway up the hood to the windshield and beyond. Note that this includes all striking vehicle types, including trucks and buses.

Looking only at light passenger vehicles, again the target of the underride standard, there were 403 fatalities in the light vehicles, and at least some underride occurred the case of 260, or almost 65 percent of fatalities to light vehicle occupants. Interestingly, the probability of underride by light vehicles was similar regardless of whether the struck truck was a straight truck or a tractor/trailer. At least some light vehicle underride occurred in 67.5 percent of impacts on straight trucks, and in 63.8 percent of impacts on tractor combinations. This similarity is consistent with the other comparisons between straight trucks and tractor combinations.

However, it should be noted that in terms of absolute numbers, there were 354 tractor/trailer RES fatal crash involvements and 166 involving straight trucks. A total of 265 light vehicle occupants were killed striking the rears of tractor/trailer combinations, and about 123 when the trucks were straight trucks.

7.2 Future implications

The above analysis is based on one year of TIFA data. The data collection protocol used here, while not ideal, produces results that are consistent with more intensive and costly investigations, which are not feasible on the number of cases represented in the TIFA file. The current protocol has the advantage of providing estimates on the entire census of crashes critical to safety. Based on fatal crashes only, it cannot address the question of effectiveness directly, but it provides a very strong tool to monitor and answer questions about the status of rear underride in the current crash population.

In terms of international standards, the Canadian distributed loading test requirement is more representative of rear-end crash loading than is the point load requirement. The post test guard height requirement and the elimination of the energy absorption requirement where guards demonstrate robust strength are seen as positive requirements that will likely improve the effectiveness of underride guard systems. This is particularly important going forward, as the light vehicle population in the U.S. continues to trend toward smaller and lighter vehicles because of fuel economy rules and persistently high fuel prices, light vehicle drivers may be at increased risk in collisions with heavy trucks. Stronger and lower underride guards may be desirable. The TIFA data provide the best information available when considering the question of strengthening the underride guard standard for straight trucks.

Changes in the truck population may also raise future issues. Wide base singles may become more widespread to improve the fuel economy of the truck population. If so, wide base singles present a larger gap for smaller, narrower light vehicles, which in turn brings the wheels back exemption into question.

In addition, the present study does not address the issue of side underride. While the literature review found that there has been some attention in many countries to the problem of rear underride (as well as front underride), and there are some designs to provide side underride protection for pedestrians and bicyclists, there has been little focus on the dimensions of the side underride crash problem. In the available crash data, it is clear that there is even less information about side underride than rear underride. Expanding the TIFA data collection to side underride is feasible and would provide valuable new information. The TIFA process provides a readily available and effective tool to monitor truck underride protection and performance.

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Appendix A Data Collection Form

TIFA Underride Data Collection Form

1. Case number __ __ __ __ __ __ __ __ (1 2 3 4 5 6 7 8)

2. Rear overhang, back of tires to end of cargo body (inches) __ __ __ (9 10 11)

3. Cargo overhang, end of cargo body to end of cargo (inches) __ __ __ (12 13 14)

4. Height of top of cargo bed (inches) __ __ __ (15 16 17)

5. Was there an underride guard on truck or trailer?

Yes	[ ] 1	
No (go to 8)	[ ] 2	
Unk (go to 8)	[ ] 9	18

6. Height of bottom of underride guard from ground (inches) __ __ __ (19 20 21)

7. Width of underride guard (inches) (less than full width?) (full width?) __ __ __ (22 23 24)

8. Was there anything else that extended below the level of the cargo body? (steps, lift gate, booms, etc.)

Yes	[ ] 1	
No	[ ] 2	
Unknown	[ ] 9	25

9. What was it? (editor only)

__ __ __ __ __ __ __ __ __ __

__ __ __ __ __ __ __ __ __ __

26-45

10. Was the rear of the truck or trailer struck?

Yes	[ ] 1 (continue)	
No	[ ] 2 (stop)	
Unknown	[ ] 9 (continue)	46

11. How much damage to the underride guard?

None	[ ] 1	
Minor	[ ] 2	
Moderate	[ ] 3	
Major	[ ] 4	
No guard	[ ] 8	
Unknown	[ ] 9	47

12. Did the striking vehicle hit the rear tires?

Yes	[ ] 1	
No	[ ] 2	
Unknown	[ ] 9	48

13. Extent of underride?

None	[ ] 1	
Less than halfway up the hood	[ ] 2	
Halfway or more but not to the windshield	[ ] 3	
To the windshield or more	[ ] 4	
Unknown amount	[ ] 7	
Unknown	[ ] 9	49

14. Extent of underride (inches) __ __ __ (50 51 52)

(editor only 15, 16, 17, 18)

15. Comments:

__ __ __ __ __ __ __ __ __ __

__ __ __ __ __ __ __ __ __ __

__ __ __ __ __ __ __ __ __ __

__ __ __ __ __ __ __ __ __ __

53-92

16. FARS vehicle number of striking vehicle: __ __ (93 94)

17. What state/country was truck or trailer registered in? __ __ (95 96)

18. Case type: __ (97)

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Appendix B Tables Describing Rear-end Crash Environment

Table B-1 to Table B-12 include all fatal truck involvements in 2008, from the TIFA 2008 file. They compare environmental distributions for the rearend struck and non-rear-end struck crash types.

Table B-13 to Table B-24 include just fatal crash involvements in which the rear of the truck was struck. They compare environmental distributions for rear-end struck crashes by truck configuration.

Table B-1 Land Use by Crash Type, All Fatal Crash Involvements

	Rear-end Struck Crash			
Land use	Yes	No	Unknown	Total
Urban	236	1,227	39	1,502
Rural	301	2,354	27	2,682
Unknown	2	16	0	18
Total	539	3,597	66	4,202
	Column Percentages			
Urban	43.8	34.1	59.1	35.7
Rural	55.8	65.4	40.9	63.8
Unknown	0.4	0.4	0.0	0.4

Table B-2 Road Functional Class by Crash Type, All Fatal Crash Involvements

	Rear-end Struck Crash			
Road Functional Class	Yes	No	Unknown	Total
Rural-Interstate	142	542	9	693
Rural-Principal Arterial Other	73	743	7	823
Rural-Minor Artery	40	472	3	515
Rural-Major Collector	29	385	5	419
Rural-Minor Collector	4	64	0	68
Rural-Local Road	13	141	3	157
Unknown Rural	0	7	0	7
Urban-Interstate	101	370	19	490
Urban-Freeway/Expressway	38	129	2	169
Urban-other Principal Arterial	63	332	7	402
Urban-Minor Artery	19	187	6	212
Urban-Collector	7	71	2	80
Urban-Local Street	8	136	3	147
Unknown Urban	0	2	0	2
Unknown	2	16	0	18
Total	539	3,597	66	4,202
	Column Percentages			
Rural-Interstate	26.3	15.1	13.6	16.5
Rural-Principal Arterial Other	13.5	20.7	10.6	19.6

Road Functional Class	Rear-end Struck Crash Yes	No	Unknown	Total
Rural-Minor Artery	7.4	13.1	4.5	12.3
Rural-Major Collector	5.4	10.7	7.6	10.0
Rural-Minor Collector	0.7	1.8	0.0	1.6
Rural-Local Road	2.4	3.9	4.5	3.7
Unknown Rural	0.0	0.2	0.0	0.2
Urban-Interstate	18.7	10.3	28.8	11.7
Urban-Freeway/Expressway	7.1	3.6	3.0	4.0
Urban-other Principal Arterial	11.7	9.2	10.6	9.6
Urban-Minor Artery	3.5	5.2	9.1	5.0
Urban-Collector	1.3	2.0	3.0	1.9
Urban-Local Street	1.5	3.8	4.5	3.5
Unknown Urban	0.0	0.1	0.0	0.0
Unknown	0.4	0.4	0.0	0.4
Total	100.0	100.0	100.0	100.0

Table B-3 Route Signing by Crash Type, All Fatal Crash Involvements

Road Functional Class	Rear-end Struck Crash Yes	No	Unknown	Total
US Highway	107	880	10	997
State Highway	131	1082	20	1233
County Road	27	335	0	362
Township	3	57	2	62
Municipality	24	236	6	266
Frontage Rd	2	22	0	24
Other	3	87	0	90
Unknown	0	3	0	3
Total	539	3597	66	4202
	Column Percentages			
Interstate	44.9	24.9	42.4	27.7
US Highway	19.9	24.5	15.2	23.7
State Highway	24.3	30.1	30.3	29.3
County Road	5.0	9.3	0.0	8.6
Township	0.6	1.6	3.0	1.5
Municipality	4.5	6.6	9.1	6.3
Frontage Rd	0.4	0.6	0.0	0.6
Other	0.6	2.4	0.0	2.1
Unknown	0.0	0.1	0.0	0.1
Total	100.0	100.0	100.0	100.0

Table B-4 Trafficway Flow by Crash Type, All Fatal Crash Involvements

Trafficway Flow	Rear-end Struck Crash Yes	No	Unknown	Total
Not Divided	137	1,955	24	2,116
Median-No Barrier	234	922	21	1,177
Median w/Barrier	142	552	19	713
One Way Traffic	5	30	0	35
Not Divided 2-way Lft	12	70	2	84
Entr/Exit Ramp	6	49	0	55
Unknown	3	19	0	22
Total	539	3,597	66	4,202
	Column Percentages			
Not Divided	25.4	54.4	36.4	50.4
Median-No Barrier	43.4	25.6	31.8	28.0
Median w/Barrier	26.3	15.3	28.8	17.0
One Way Traffic	0.9	0.8	0.0	0.8
Not Divided 2-Way Lft	2.2	1.9	3.0	2.0
Entrance/Exit Ramp	1.1	1.4	0.0	1.3
Unknown	0.6	0.5	0.0	0.5
Total	100.0	100.0	100.0	100.0

Table B-5 Relation to Junction by Crash Type, All Fatal Crash Involvements

Relation to Junction	Rear-end Struck Crash Yes	No	Unknown	Total
Non-Interchange				
Non-Junction	416	2,372	35	2,823
Intersection	37	843	9	889
Intersection-Related	33	85	2	120
Driveway, Alley	5	50	4	59
Ramp	1	17	0	18
Rail Xing	2	14	0	16
Cross-Over	3	13	1	17
Driveway Access	9	53	1	63
Unk., Non-Interchange	0	1	0	1
Interchange Area				
Intersection	3	29	2	34
Intersection-Related	1	8	0	9
Driveway	0	3	0	3
Ramp	5	37	0	42
Other	23	69	12	104
Unknown Interchange	0	1	0	1
Unknown	1	2	0	3
Total	539	3,597	66	4,202
	Column Percentages			
Non-Interchange				
Non-Junction	77.2	65.9	53.0	67.2
Intersection	6.9	23.4	13.6	21.2

Relation to Junction	Rear-end Struck Crash Yes	No	Unknown	Total
Intersection-Related	6.1	2.4	3.0	2.9
Driveway, Alley	0.9	1.4	6.1	1.4
Ramp	0.2	0.5	0.0	0.4
Rail Xing	0.4	0.4	0.0	0.4
Cross-Over	0.6	0.4	1.5	0.4
Driveway Access	1.7	1.5	1.5	1.5
Unknown	0.0	0.0	0.0	0.0
Interchange Area				
Intersection	0.6	0.8	3.0	0.8
Intersection-Related	0.2	0.2	0.0	0.2
Driveway	0.0	0.1	0.0	0.1
Ramp	0.9	1.0	0.0	1.0
Other	4.3	1.9	18.2	2.5
Unk., Interchange	0.0	0.0	0.0	0.0
Unknown	0.2	0.1	0.0	0.1
Total	100.0	100.0	100.0	100.0

Table B-6 Posted Speed Limit by Crash Type, All Fatal Crash Involvements

Speed limit	Rear-end Struck Crash Yes	No	Unknown	Total
0	0	6	0	6
15	0	5	0	5
20	0	4	0	4
25	3	67	4	74
30	6	80	1	87
35	19	187	2	208
40	16	119	5	140
45	42	363	11	416
50	21	157	0	178
55	125	1,162	19	1,306
60	41	221	1	263
65	138	637	21	796
70	99	427	0	526
75	25	94	1	120
80	1	5	0	6
Unknown	3	63	1	67
Total	539	3,597	66	4,202
	Column Percentages			
0	0.0	0.2	0.0	0.1
15	0.0	0.1	0.0	0.1
20	0.0	0.1	0.0	0.1
25	0.6	1.9	6.1	1.8
30	1.1	2.2	1.5	2.1
35	3.5	5.2	3.0	5.0
40	3.0	3.3	7.6	3.3

Speed limit	Rear-end Struck Crash			Total
	Yes	No	Unknown	
45	7.8	10.1	16.7	9.9
50	3.9	4.4	0.0	4.2
55	23.2	32.3	28.8	31.1
60	7.6	6.1	1.5	6.3
65	25.6	17.7	31.8	18.9
70	18.4	11.9	0.0	12.5
75	4.6	2.6	1.5	2.9
80	0.2	0.1	0.0	0.1
Unknown	0.6	1.8	1.5	1.6
Total	100.0	100.0	100.0	100.0

Table B-7 Roadway Curvature by Crash Type, All Fatal Crash Involvements

Roadway Curvature	Rear-end Struck Crash			Total
	Yes	No	Unknown	
Straight	503	2873	49	3425
Curve	33	707	17	757
Unknown	3	17	0	20
Total	539	3597	66	4202
	Column Percentages			
Straight	93.3	79.9	74.2	81.5
Curve	6.1	19.7	25.8	18.0
Unknown	0.6	0.5	0.0	0.5
Total	100.0	100.0	100.0	100.0

Table B-8 Road Surface Condition by Crash Type, All Fatal Crash Involvements

Surface Condition	Rear-end Struck Crash Yes	No	Unknown	Total
Dry	465	2,878	51	3,394
Wet	51	484	7	542
Snow or Slush	14	102	4	120
Ice/Frost	8	111	4	123
Sand Dirt Gravel	0	5	0	5
Water	1	2	0	3
Oil	0	1	0	1
Other	0	4	0	4
Unknown	0	10	0	10
Total	539	3,597	66	4,202
	Column Percentages			
Dry	86.3	80.0	77.3	80.8
Wet	9.5	13.5	10.6	12.9
Snow or Slush	2.6	2.8	6.1	2.9
Ice/Frost	1.5	3.1	6.1	2.9
Sand Dirt Gravel	0.0	0.1	0.0	0.1
Water	0.2	0.1	0.0	0.1
Oil	0.0	0.0	0.0	0.0
Other	0.0	0.1	0.0	0.1
Unknown	0.0	0.3	0.0	0.2
Total	100.0	100.0	100.0	100.0

Table B-9 Road Surface Condition by Crash Type, All Fatal Crash Involvements

Light Condition	Rear-end Struck Crash Yes	No	Unknown	Total
Daylight	303	2357	41	2701
Dark	146	809	18	973
Dark but Lighted	74	283	5	362
Dawn	13	104	2	119
Dusk	3	40	0	43
Unknown	0	4	0	4
Total	539	3597	66	4202
	Column Percentages			
Daylight	56.2	65.5	62.1	64.3
Dark	27.1	22.5	27.3	23.2
Dark but Lighted	13.7	7.9	7.6	8.6
Dawn	2.4	2.9	3.0	2.8
Dusk	0.6	1.1	0.0	1.0
Unknown	0.0	0.1	0.0	0.1
Total	100.0	100.0	100.0	100.0

Table B-10 Weather Condition by Crash Type, All Fatal Crash Involvements

Weather	Rear-end Struck Crash			Total
	Yes	No	Unknown	
Clear/Cloudy	463	3033	56	3552
Rain	20	299	4	323
Sleet (Hail)	3	31	1	35
Snow/Blow Snow	19	124	4	147
Fog/Smog/Smoke	28	80	1	109
Severe X-winds	1	13	0	14
Blow Sand, et al.	5	4	0	9
Other	0	3	0	3
Unknown	0	10	0	10
Total	539	3597	66	4202
	Column Percentages			
Clear/Cloudy	85.9	84.3	84.8	84.5
Rain	3.7	8.3	6.1	7.7
Sleet (Hail)	0.6	0.9	1.5	0.8
Snow/Blow Snow	3.5	3.4	6.1	3.5
Fog/Smog/Smoke	5.2	2.2	1.5	2.6
Severe X-winds	0.2	0.4	0.0	0.3
Blow Sand, et al.	0.9	0.1	0.0	0.2
Other	0.0	0.1	0.0	0.1
Unknown	0.0	0.3	0.0	0.2
Total	100.0	100.0	100.0	100.0

Table B-11 Work Zone Type by Crash Type, All Fatal Crash Involvements

Work Zone Type	Rear-end Struck Crash			Total
	Yes	No	Unknown	
None	477	3450	61	3988
Construction	46	115	2	163
Maintenance	9	17	3	29
Utility	1	4	0	5
Unk. Work Zone	6	11	0	17
Total	539	3597	66	4202
	Column Percentages			
None	88.5	95.9	92.4	94.9
Construction	8.5	3.2	3.0	3.9
Maintenance	1.7	0.5	4.5	0.7
Utility	0.2	0.1	0.0	0.1
Unk. Work Zone	1.1	0.3	0.0	0.4
Total	100.0	100.0	100.0	100.0

Table B-12 Number of Alcohol-Impaired Drivers by Crash Type, All Fatal Crash Involvements

Number of Alcohol-Impaired Drivers	Rear-end Struck Crash			Total
	Yes	No	Unknown	
0	433	3093	55	3581
1	105	485	11	601
2	1	17	0	18
3	0	2	0	2
Total	539	3597	66	4202
	Column Percentages			
0	80.3	86.0	83.3	85.2
1	19.5	13.5	16.7	14.3
2	0.2	0.5	0.0	0.4
3	0.0	0.1	0.0	0.0
Total	100.0	100.0	100.0	100.0

Table B-13 to Table B-24 include just fatal crash involvements in which the rear of the truck was struck. These tables show distributions by truck configuration.

Table B-13 Land Use by Truck Configuration, Rear-end Struck Crash Involvements Only

Land Use	Straight	Straight/Trailer	Bobtail	Tractor/Trailer	Total
Urban	79	8	3	146	236
Rural	87	6	2	206	301
Unknown	0	0	0	2	2
Total	166	14	5	354	539
	Column Percentages				
Urban	47.6	57.1	60.0	41.2	43.8
Rural	52.4	42.9	40.0	58.2	55.8
Unknown	0.0	0.0	0.0	0.6	0.4
Total	100.0	100.0	100.0	100.0	100.0

Table B-14 Road Functional Class by Truck Configuration, Rear-end Struck Crash Involvements Only

Road Functional Class	Straight	Straight/Trailer	Bobtail	Tractor/Trailer	Total
Rural-Interstate	23	3	1	115	142
Rural-Principal Arterial Other	23	1	1	48	73
Rural-Minor Artery	16	1	0	23	40
Rural-Major Collector	17	1	0	11	29
Rural-Minor Collector	3	0	0	1	4
Rural-Local Road	5	0	0	8	13
Urban-Interstate	23	0	2	76	101
Urban-Freeway/Expressway	16	3	0	19	38
Urban-Other Principal Arterial	24	3	1	35	63
Urban-Minor Artery	10	0	0	9	19
Urban-Collector	1	1	0	5	7
Urban-Local Street	5	1	0	2	8
Unknown	0	0	0	2	2
Total	166	14	5	354	539
	Column Percentages				
Rural-Interstate	13.9	21.4	20.0	32.5	26.3
Rural-Principal Arterial Other	13.9	7.1	20.0	13.6	13.5
Rural-Minor Artery	9.6	7.1	0.0	6.5	7.4
Rural-Major Collector	10.2	7.1	0.0	3.1	5.4
Rural-Minor Collector	1.8	0.0	0.0	0.3	0.7
Rural-Local Road	3.0	0.0	0.0	2.3	2.4
Urban-Interstate	13.9	0.0	40.0	21.5	18.7
Urban-Freeway/Expressway	9.6	21.4	0.0	5.4	7.1
Urban-other Principal Arterial	14.5	21.4	20.0	9.9	11.7
Urban-Minor Artery	6.0	0.0	0.0	2.5	3.5
Urban-Collector	0.6	7.1	0.0	1.4	1.3
Urban-Local Street	3.0	7.1	0.0	0.6	1.5
Unknown	0.0	0.0	0.0	0.6	0.4
Total	100.0	100.0	100.0	100.0	100.0

Table B-15 Route Signing by Truck Configuration, Rear-end Struck Crash Involvements Only

Route Signing	Straight	Straight/Trailer	Bobtail	Tractor/Trailer	Total
Interstate	47	3	3	189	242
US Highway	35	5	2	65	107
State Highway	52	3	0	76	131
County Road	15	0	0	12	27
Township	2	0	0	1	3
Municipality	12	3	0	9	24
Frontage Road	1	0	0	1	2
Other	2	0	0	1	3
Total	166	14	5	354	539
	Column Percentages				
Interstate	28.3	21.4	60.0	53.4	44.9
US Highway	21.1	35.7	40.0	18.4	19.9
State Highway	31.3	21.4	0.0	21.5	24.3
County Road	9.0	0.0	0.0	3.4	5.0
Township	1.2	0.0	0.0	0.3	0.6
Municipality	7.2	21.4	0.0	2.5	4.5
Frontage Road	0.6	0.0	0.0	0.3	0.4
Other	1.2	0.0	0.0	0.3	0.6
Total	100.0	100.0	100.0	100.0	100.0

Table B-16 Trafficway Flow by Truck Configuration, Rear-end Struck Crash Involvements Only

Trafficway Flow	Straight	Straight/Trailer	Bobtail	Tractor/Trailer	Total
Not Divided	72	6	1	58	137
Median-No Barrier	55	6	2	171	234
Median w/Barrier	33	2	2	105	142
One-Way Traffic	2	0	0	3	5
Not Div 2-Way Lft	2	0	0	10	12
Entr/Exit Ramp	1	0	0	5	6
Unknown	1	0	0	2	3
Total	166	14	5	354	539
Not Divided	43.4	42.9	20.0	16.4	25.4
Median-No Barrier	33.1	42.9	40.0	48.3	43.4
Median w/Barrier	19.9	14.3	40.0	29.7	26.3
One-Way Traffic	1.2	0.0	0.0	0.8	0.9
Not Div 2-Way Lft	1.2	0.0	0.0	2.8	2.2
Entr/Exit Ramp	0.6	0.0	0.0	1.4	1.1
Unknown	0.6	0.0	0.0	0.6	0.6
Total	100.0	100.0	100.0	100.0	100.0

Table B-17 Relation to Junction by Truck Configuration, Rear-end Struck Crash Involvements Only

Relation to Junction	Straight	Straight/Trailer	Bobtail	Tractor/Trailer	Total
Non-Interchange					
Non-Junction	125	11	5	275	416
Intersection	16	0	0	21	37
Intersection-Related	12	2	0	19	33
Driveway, Alley	2	0	0	3	5
Ramp	0	0	0	1	1
Rail Xing	0	1	0	1	2
Cross-Over	0	0	0	3	3
Driveway Access	1	0	0	8	9
Interchange Area					
Intersection	2	0	0	1	3
Intersection-Related	1	0	0	0	1
Ramp	1	0	0	4	5
Other	6	0	0	17	23
Unknown	0	0	0	1	1
Total	166	14	5	354	539
	Column Percentages				
Non-Interchange					
Non-Junction	75.3	78.6	100.0	77.7	77.2
Intersection	9.6	0.0	0.0	5.9	6.9
Intersection-Related	7.2	14.3	0.0	5.4	6.1
Driveway, Alley	1.2	0.0	0.0	0.8	0.9
Ramp	0.0	0.0	0.0	0.3	0.2
Rail Xing	0.0	7.1	0.0	0.3	0.4
Cross-Over	0.0	0.0	0.0	0.8	0.6
Driveway Access	0.6	0.0	0.0	2.3	1.7
Interchange Area					
Intersection	1.2	0.0	0.0	0.3	0.6
Intersection-Related	0.6	0.0	0.0	0.0	0.2
Ramp	0.6	0.0	0.0	1.1	0.9
Other	3.6	0.0	0.0	4.8	4.3
Unknown	0.0	0.0	0.0	0.3	0.2
Total	100.0	100.0	100.0	100.0	100.0

Table B-18 Posted Speed Limit by Truck Configuration, Rear-end Struck Crash Involvements Only

Speed Limit	Straight	Straight/Trailer	Bobtail	Tractor/Trailer	Total
25	1	0	0	2	3
30	4	1	0	1	6
35	10	0	1	8	19
40	8	1	0	7	16
45	15	3	0	24	42
50	7	2	0	12	21
55	43	2	2	78	125
60	13	1	1	26	41
65	42	1	0	95	138
70	18	1	1	79	99
75	4	2	0	19	25
80	0	0	0	1	1
Unknown	1	0	0	2	3
Total	166	14	5	354	539
	Column Percentages				
25	0.6	0.0	0.0	0.6	0.6
30	2.4	7.1	0.0	0.3	1.1
35	6.0	0.0	20.0	2.3	3.5
40	4.8	7.1	0.0	2.0	3.0
45	9.0	21.4	0.0	6.8	7.8
50	4.2	14.3	0.0	3.4	3.9
55	25.9	14.3	40.0	22.0	23.2
60	7.8	7.1	20.0	7.3	7.6
65	25.3	7.1	0.0	26.8	25.6
70	10.8	7.1	20.0	22.3	18.4
75	2.4	14.3	0.0	5.4	4.6
80	0.0	0.0	0.0	0.3	0.2
Unknown	0.6	0.0	0.0	0.6	0.6
Total	100.0	100.0	100.0	100.0	100.0

Table B-19 Roadway Curvature by Truck Configuration, Rear-end Struck Crash Involvements Only

Roadway Curvature	Straight	Straight/Trailer	Bobtail	Tractor/Trailer	Total
Straight	153	12	5	333	503
Curve	13	2	0	18	33
Unknown	0	0	0	3	3
Total	166	14	5	354	539
	Column Percentages				
Straight	92.2	85.7	100.0	94.1	93.3
Curve	7.8	14.3	0.0	5.1	6.1
Unknown	0.0	0.0	0.0	0.8	0.6
Total	100.0	100.0	100.0	100.0	100.0

Table B-20 Roadway Surface Condition by Truck Configuration, Rear-end Struck Crash Involvements Only

Surface Condition	Straight	Straight/Trailer	Bobtail	Tractor/Trailer	Total
Dry	139	13	5	308	465
Wet	21	0	0	30	51
Snow or Slush	3	1	0	10	14
Ice/Frost	3	0	0	5	8
Water	0	0	0	1	1
Total	166	14	5	354	539
	Column Percentages				
Dry	83.7	92.9	100.0	87.0	86.3
Wet	12.7	0.0	0.0	8.5	9.5
Snow or Slush	1.8	7.1	0.0	2.8	2.6
Ice/Frost	1.8	0.0	0.0	1.4	1.5
Water	0.0	0.0	0.0	0.3	0.2
Total	100.0	100.0	100.0	100.0	100.0

Table B-21 Light Condition by Truck Configuration, Rear-end Struck Crash Involvements Only

Light Condition	Straight	Straight/Trailer	Bobtail	Tractor/Trailer	Total
Daylight	100	13	1	189	303
Dark	40	1	2	103	146
Dark but lighted	17	0	2	55	74
Dawn	8	0	0	5	13
Dusk	1	0	0	2	3
Total	166	14	5	354	539
	Column Percentages				
Daylight	60.2	92.9	20.0	53.4	56.2
Dark	24.1	7.1	40.0	29.1	27.1
Dark but Lighted	10.2	0.0	40.0	15.5	13.7
Dawn	4.8	0.0	0.0	1.4	2.4
Dusk	0.6	0.0	0.0	0.6	0.6
Total	100.0	100.0	100.0	100.0	100.0

Table B-22 Weather by Truck Configuration, Rear-end Struck Crash Involvements Only

Weather	Straight	Straight/Trailer	Bobtail	Tractor/Trailer	Total
Clear/Cloudy	142	13	5	303	463
Rain	9	0	0	11	20
Sleet (Hail)	0	0	0	3	3
Snow/Blow Snow	5	1	0	13	19
Fog/Smog/Smoke	8	0	0	20	28
Severe X-winds	0	0	0	1	1
Blow Sand, et al.	2	0	0	3	5
Total	166	14	5	354	539
	Column Percentages				
Clear/Cloudy	85.5	92.9	100.0	85.6	85.9
Rain	5.4	0.0	0.0	3.1	3.7
Sleet (Hail)	0.0	0.0	0.0	0.8	0.6
Snow/Blow Snow	3.0	7.1	0.0	3.7	3.5
Fog/Smog/Smoke	4.8	0.0	0.0	5.6	5.2
Severe X-winds	0.0	0.0	0.0	0.3	0.2
Blow Sand, et al.	1.2	0.0	0.0	0.8	0.9
Total	100.0	100.0	100.0	100.0	100.0

Table B-23 Work Zone Type by Truck Configuration, Rear-end Struck Crash Involvements Only

Work Zone Type	Straight	Straight/Trailer	Bobtail	Tractor/Trailer	Total
None	153	12	5	307	477
Construction	8	1	0	37	46
Maintenance	3	1	0	5	9
Utility	0	0	0	1	1
Unk. Work Zone	2	0	0	4	6
Total	166	14	5	354	539
	Column Percentages				
None	92.2	85.7	100.0	86.7	88.5
Construction	4.8	7.1	0.0	10.5	8.5
Maintenance	1.8	7.1	0.0	1.4	1.7
Utility	0.0	0.0	0.0	0.3	0.2
Unk. Work Zone	1.2	0.0	0.0	1.1	1.1
Total	100.0	100.0	100.0	100.0	100.0

Table B-24 Number of Alcohol-Impaired Drivers by Truck Configuration, Rear-end Struck Crash Involvements Only

Number of Alcohol-Impaired Drivers	Straight	Straight/Trailer	Bobtail	Tractor/Trailer	Total
0	139	14	3	277	433
1	27	0	2	76	105
2	0	0	0	1	1
Total	166	14	5	354	539
	Column Percentages				
0	83.7	100.0	60.0	78.2	80.3
1	16.3	0.0	40.0	21.5	19.5
2	0.0	0.0	0.0	0.3	0.2
Total	100.0	100.0	100.0	100.0	100.0

Appendix C Description of mounted equipment

Description	N	Description	N
Air tank	1	Pipe	1
Airbrake connectors	1	Pipes	1
Attenuator	3	Plate + hitch	1
Auger	2	Plates	1
Bars	1	Platform + valves	1
Booster axle	2	Pull-out ramp	1
Bumper	58	Pull-out ramp	2
Bumper & step	1	Pull-out ramps	2
Bumper + hand truck	1	Pump	3
Bumper + hitch	30	Pump box	2
Bumper + levelers	1	Pump housing	1
Bumper + lights	2	Push plate	1
Bumper + outriggers	3	Rails	1
Bumper + pintle hook	1	Ramp	5
Bumper + spare tire	1	Ramp	2
Bumper + step	1	Ramps	1
Bumper + steps	1	Rollers	1
Bumper + valve	1	Salt spreader	4
Bumper, lights+ hitch	1	Skid plate	4
Bumper + pull-out ramp	1	Slide-out ramp	1
Cargo area+ liftgate	1	Slide-out ramp	1
Chute	3	Sliding ramp	1
Conveyor belt	1	Sliding ramps	1
Dock bumpers	1	Sprayer	2
Equipment boxes	1	Sprayer+ folding step	1
Extended bumper	1	Spreader	9
Folding ramp	1	Sprinkler bar	1
Fold-out steps	1	Stabilizers	1
Forklift	10	Steel plate	2
Forklift attachment	5	Step	34
Gearbox	1	Step & hitch	1
Hitch	73	Step & winch	1
Hitch + spreader	1	Step bumper	55
Hitch + taillights	1	Step bumper + fender	1
Hitch + vise	1	Step bumper + hitch	4
Hitch plate	2	Step bumper + lights	1
Hoist component	1	Step bumper + ramp	3
Hose connection	1	Step plates	1

Description	N	Description	N
Hoses	2	Step platform	2
Hydraulics	1	Steps	35
I-beam	1	Steps + bumper	1
Iron bar	2	Stinger bar	10
Ladder	4	Suspension	1
Ladder step	1	Tag axle	2
Lift axle	1	Tailgate	1
Liftgate	90	Taillight mount	1
Liftgate	21	Taillights	3
Liftgate mechanism	4	Tank drain	1
Light bar	1	Tow hook	1
Loading compartment	1	Tube	1
Loading mechanism	1	Tubing	2
Loading ramp	1	Valve cage	1
Metal bar	1	Valve plate	2
Metal plate	1	Valves	1
Outriggers	2	Vehicle loading ramp	1
Outriggers + hitch	1	Wheel lift	40
Pintle hitch	21	Wheel lift + bumper	1

Appendix D Definitions of striking vehicle type

Label	Vehicle type
Auto:	Automobiles and automobile derivatives; typical light passenger vehicles, including convertibles, sedans, station wagons, hatchbacks, coupes, auto-based pickups and panels, limousines
Utility:	Compact and large sport utility vehicles, utility station wagons like Chevrolet Suburban, and unknown type of utility vehicle
Minivan:	Minivans such as Chrysler Town and Country, Plymouth Voyager, Toyota Sienna, GMC Astro, Mercury Villager
Large van:	Vans used often for light commercial purposes, such as Econoliner, E150-E350, Vandura, Tradesman
Compact pickup:	Small pickup trucks such as the S-10, Ranger, Scamp, and Sonoma
Large pickup:	Standard-size pickup trucks, such as F100-350, Ram, Silverado, and Sierra.
Bus:	School buses, other buses including transit, intercity, and bus based motor homes
Truck:	Medium and heavy trucks and truck-tractors
Motorcycle:	Motorcycles, mopeds, ATV, and snowmobiles
Large equipment:	Farm equipment or construction equipment other than trucks
Other/unknown:	Other vehicle type or unknown motorized vehicle type

Appendix E Trailer Age in the LTCCS

The Large Truck Crash Causation Study (LTCCS) captures the manufacture year of each unit. These data were analyzed for insight into the distribution of the age of semitrailers involved in serious crashes.

Semitrailers (as defined in the LTCCS; that definition would include trailers pulled by straights in TIFA) were extracted from the LTCCS TruckUnits data set. The year of manufacture was determined and then trailer age was calculated by subtracting manufacture year from the year of the crash in LTCCS. Trailer manufacture year could not be determined for 32.9 percent of the semitrailers. Even with all the resources available to the LTCCS, in almost one-third of the cases the manufacture year was left unknown.

Figure shows the cumulative distribution of trailer age, excluding records for which manufacture year was unknown. The vertical line is positioned at 10 years, which corresponds to the maximum age of trailers in 2008 that would be subject to the 1998 underride standard. This is 77.1 percent of the records in LTCCS for which trailer age can be calculated. If all the cases for which trailer year could not be calculated are treated as older than 10 years, the cumulative total would be 51.2 percent.

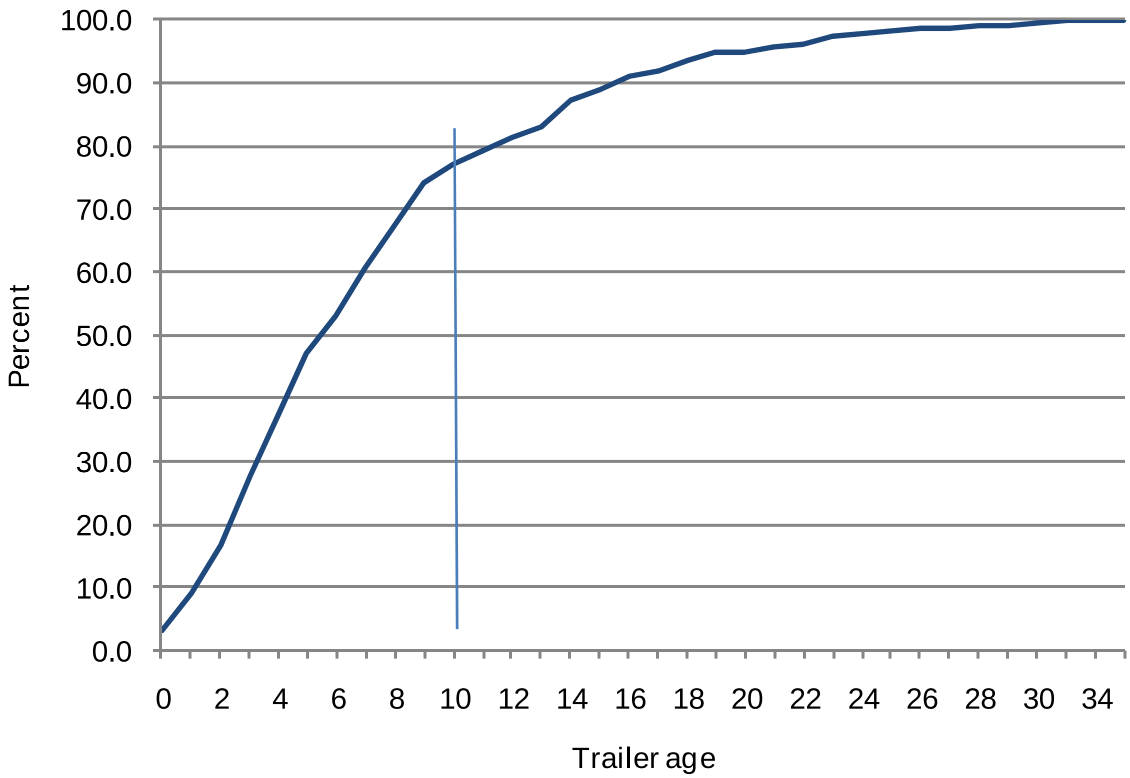

Figure E-1 Cumulative percentage of semitrailers by trailer age in LTCCS

Some experts claim that the useful life of a well-maintained semitrailer is approximately 20 years. It is possible that in recent years, because of the downturn in the economy, carriers try to run their trailers longer than normal. However, the downturn did not begin until 2008, so it would not have had much impact on the distribution of semitrailers in that year.

Appendix F Canadian Underride Protection Regulations

Background on Canadian regulation

The Canadian rear impact protection regulation No. 224 was brought into effect on September 23, 2005. It is based on U.S. Code of Federal Regulations, Title 49, Volume 5, Part 571, Federal Motor Vehicle Safety Standard No. 224, Rear Impact Protection, revised as of October 1, 2000. Canada used a regulatory instrument called Technical Standards Document (TSD) which reproduces an enactment of a foreign government, in this case a Federal Motor Vehicle Safety Standard issued by the U.S. National Highway Traffic Safety Administration, but also provides the ability to override some provisions or specify certain requirements.

This override provision was applied to a section of the Canadian Rear Impact Guards (Standard 223) test requirement which created a unique requirement not present in FMVSS 224. The U.S. requirement calls for independent point loads of 50 kN at locations P1 and P2 and 100 kN at location P3 as illustrated in Figure F-. Any given guard need not be tested at more than one location. For loading point P3, there is an energy absorption requirement that the guard absorb by plastic deformation at least 5,650 J of energy within the first 125 mm of deflection. The Canadian Rear Impact Guards (Standard 223) test is consistent with the U.S. requirement for the point load at P1 and P2, though it is generally silent on the point at P3. In place of the P3 point load, it requires an evenly distributed load of at least 350 kN across the face of the horizontal member which encompasses P1, P2, and P3, and that it absorb at least 20,000 J of energy within the first 125 mm of deflection. In the event that the guard demonstrates resistance to a uniform load greater than 700 kN then the regulation states that the energy absorption requirement is no longer required. Finally, after the uniform load test is completed, the ground clearance of the horizontal member shall not exceed 560 mm when measured at each support to which the horizontal member is attached.

P3 comes into play when half of a guard is tested. In this case, there is an option to apply a point load of 175,000 N at one of the P3 locations. The other option allows a uniform load of 175,000 N to be applied to the horizontal member comprising of one half of the rear impact guard. In both cases the allowable deflection can be no more than 125 mm.

These differences in regulation are not insignificant and have implications for performance of the underride guards. The U.S. point load system allows the horizontal bar to contribute to force resistance and energy abortion through bending of the main guard member. The Canadian uniform distributed load prevents deformation of the horizontal bar and therefore negates any contribution of horizontal bending to the force and energy absorption requirements. There is a strong argument that the uniform load scenario is more consistent with rear-end crash kinematics and by requiring a uniform load test, it assures that the source of energy absorption contribution resides in the support structures. The additional option of eliminating the energy absorption requirement if uniform load capacity of the guard is greater than 700 kN provides a robust design target that manufacturers can work to which significantly exceed the minimum strength requirements contained in the regulation. Finally the post test guard height requirement of 560 mm ensures that the protective potential of the guard is not diminished by excessive ground clearance during the deformation process.

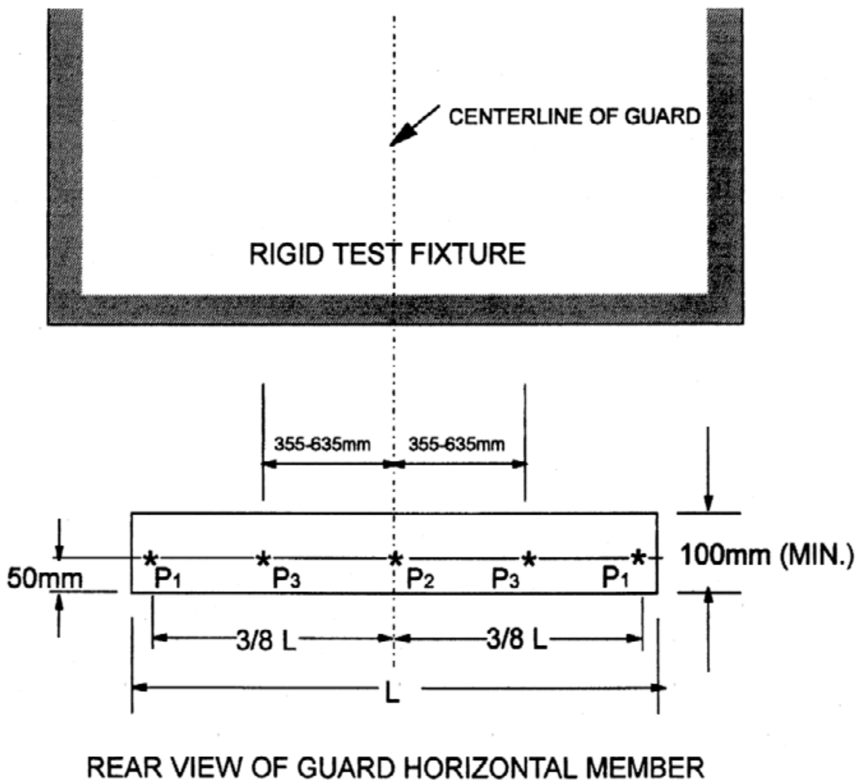

Figure F-1 Performance Requirements

Canada conducted a research project including full scale testing [20] of rigid and deformable rear impact guards. Four guard designs were used in this program. With respect to the guard height above ground, a 560 mm guard, a 480 mm guard, a 480 mm guard with stopper and a 560 mm slanted guard were evaluated. The problem of excessive impact guard deformation resulting in increased effective ground height is illustrated in Figure F-.

Figure F-2 Crash test, Chevrolet Cavalier into 480 mm guard at 65 km/h. Note the highly deformed guard

The 480 mm guard did not provide good protection to the passenger compartment of the Honda Civic, in large part due to the frame of the vehicle sliding under the horizontal member of the guard. By the time the horizontal member was contacted by the engine, it had rotated such that it just struck the top of the intake manifold. The horizontal member then skipped over the engine, contacted slightly the suspension post and came to rest on the A-pillars, deforming those slightly. The driver-side and passenger-side windows shattered, as did a large portion of the windshield. The base of the windshield was pushed inside the passenger compartment.

The tests results revealed that the 560 mm guard worked well for light trucks and vans as the vehicle is large enough that rotation of the underride guard around its supports does not impair its ability to slow the vehicle down and stop it prior to passenger compartment intrusion. However with compact automobiles, the 560 mm did not prevent passenger compartment intrusion at 65 km/h while the 480 mm guard did prevent intrusion but at the expense of higher vehicle declaration (30g).

The guards were least effective on sub compact automobiles. The 560 mm guard could not stop the vehicle; it crashed into the concrete barrier supporting the trailer mock-up structure at approximately 22 km/h. However the 560 mm slanted guard provided good passenger compartment protection at 48 km/h. The 480 mm guard could not offer adequate protection for the crash at 48 km/h. Video of the crash shows the vehicle body structure sliding under the horizontal member of the underride guard, causing it to rotate around its pivot point. The 480 mm guard with stopper provided good passenger compartment protection at both 48 and 56 km/h; in the 56 km/h test.

The National Research Council of Canada under sponsorship from Canadian Transportation Equipment Association (CTEA) conducted a research project to develop a set of cost effective standard design rear impact guards. Separate designs were created for guards fabricated from steel, aluminum and stainless steel [21, 22, 23]. The intent of this development was to supply industry with a set of working drawings that would ensure that the fabricated guard would comply with both CMVSS 223 and FMVSS 223.

The analysis included finite element analysis Figure F-, laboratory testing Figure F-, and development novel design Figure F- and specifications.

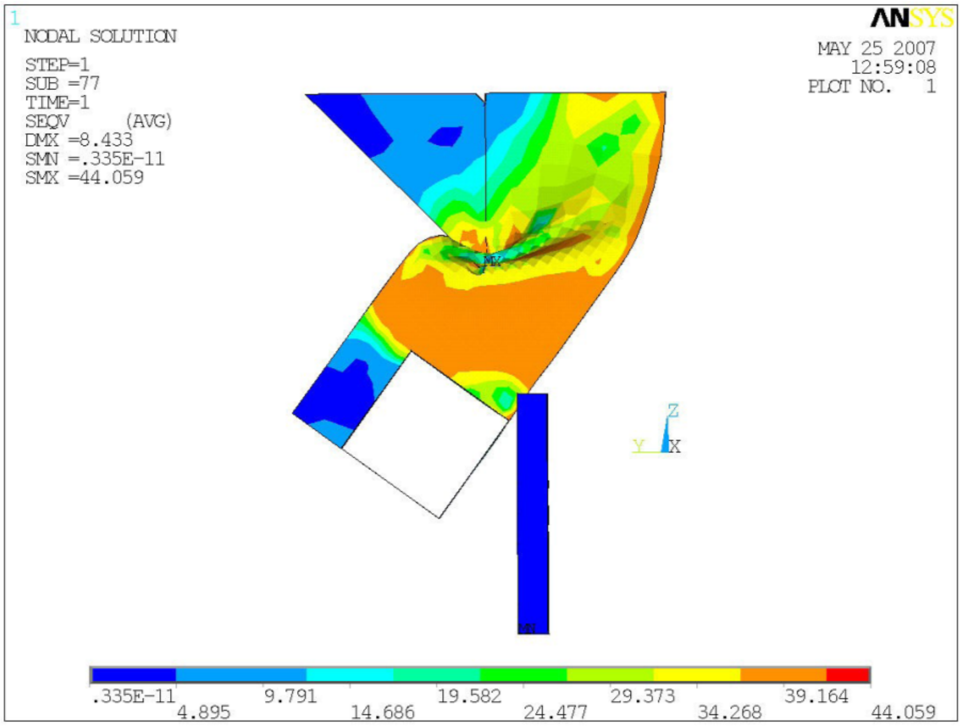

Figure F-3 Example finite analysis representation of final displacement


Figure F-4 View of test rig developed for uniform load application

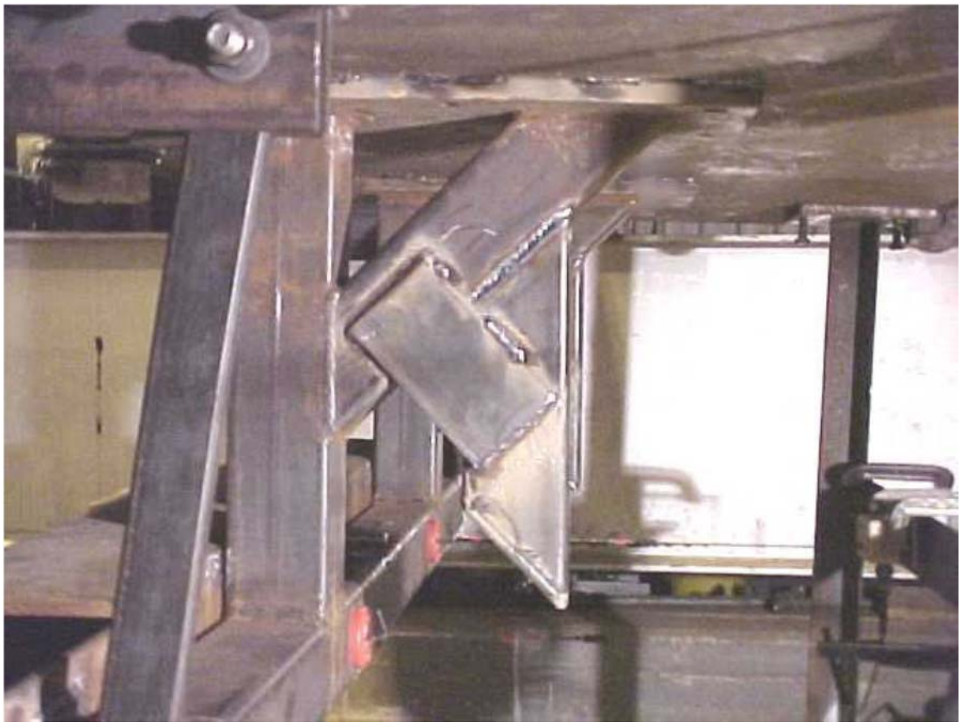

Figure F-5 View of displacement stop feature used to minimize vertical travel of horizontal member.

One of the critical design issues is to ensure that the attachment of the guard to the trailer is sufficiently robust to handle the anticipated forces. The NRC design is such that the upper part of each support is braced, and provides an attachment to the rear-end structure of the trailer that is much stronger than the working part of the rear impact guard, the lower 203.2 mm (8 in) of each support. The braced attachment to the vehicle is designed so that the trailer chassis structure should not yield even if the rear impact guard is fully deformed in a collision. Consequently, the trailer structure should not need repair even if the rear impact guard needs to be replaced after a collision. The strength of the attachment to the trailer should ensure that the rear impact guard will not tear off the trailer, even in a high-speed collision.

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