Incidence of Rear Underride in Fatal Truck Crashes 1997-1998

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16. Abstract

For the 1997 and 1998 data years, UMTRI's Center for National Truck Statistics collected data on rear underride as part of its Trucks Involved in Fatal Accidents survey. The purpose of the survey was to evaluate the incidence of underride in these fatal crashes. Supplemental data were collected on each rear-end crash involvement. Data collected included whether the truck had a rear underride guard, whether the striking vehicle underrode the truck, and how much underride occurred.

A total of 853 fatal crash involvements occurred in 1997-1998 in which a nontruck vehicle struck a truck in the rear. Underride was reported in 518 of the 853 rear-end crashes. Among 276 straight trucks struck in the rear, there was no underride in 78 involvements, some underride in 152 involvements and underride could not be determined in 46. Among 541 tractors with one or more trailers struck in the rear, no underride occurred in 124 involvements, some underride occurred in 357 in, and underride could not be determined in 60 involvements.

There were 979 fatalities in these rear-end crashes; 900 of the fatalities occurred in the striking vehicle. Of the striking vehicle fatalities, 211 occurred with no underride, 565 when some underride was recorded, and 124 when underride could not be determined.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kpa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
rnL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	**1.8C + 32**	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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Executive Summary

For the 1997 and 1998 data years, the Center for National Truck Statistics at the University of Michigan Transportation Research Institute (UMTRI) collected data on rear underride as part of its Trucks Involved in Fatal Accidents (TIFA) survey. The purpose of the survey was to evaluate the incidence of underride in these fatal crashes. Supplemental data were collected on each rear-end crash involvement. Data collected included whether the truck had a rear underride guard, whether the striking vehicle underrode the truck, and how much underride occurred. A primary goal of the survey was to estimate the incidence of underride in fatal crashes in which straight trucks[1] are struck in the rear.

The present study does not evaluate the effectiveness of present or past rear underride guard standards. Because the new trailer guard standard did not go into effect until 1998, almost all trailer underride guards in the study were under the 1952 standard. Moreover, since the study population was restricted to fatal crashes, any safety effect from either standard is probably masked, because the impact speed likely is often beyond the design limits of both the current and previous standard. Efforts to evaluate the safety effect of guard standards must include nonfatal crashes.

Data for the study was collected through telephone interviews with people who have knowledge of the truck at the time of the crash, such as the driver, owner, safety director of the carrier operating the truck, the reporting police officer, or any other involved party. Questions about whether the truck was underridden and the amount of underride were answered most often by people at the scene of the crash, such as reporting police officers, other official investigators, tow operators, and the like.

The critical rear dimensions of most straight trucks involved in fatal crashes provide little structural impediment to underride. The mean cargo body overhang for all straight trucks involved in a fatal accident was 49.8 inches. In only 6.2% of the straight trucks was the distance from the rear dual tires to the end of the cargo body 12 inches or less. Cargo body overhang was more than 24 inches in 64.2% of the straight trucks. Almost half of the straight trucks had overhangs greater than three feet. Overall, the mean bed height was 41.6 inches, and almost 75% of straight trucks involved in a fatal crash had cargo body bed heights more than 30 inches from the ground. Only 27.1% of straight trucks involved in a fatal crash had a rear underride guard.

Underride was reported in 518 of the 853 rear-end crashes (60.7%). There were 276 straight trucks (with or without a trailer) involved in a fatal rear-end collision where the striking vehicle was a not a truck. In those 276 rear-end crashes, there was no underride in 78 involvements (28.3%), some underride in 152 involvements (55.1%), and underride was unknown in 46 involvements (16.7%). There were 541 tractors with one or more cargo-

[1] A "straight" truck is a truck with a cargo body permanently mounted to the chassis. Examples include dump trucks and delivery vans. A tractor (or truck tractor) is designed to pull semitrailers, and typically has no cargo-carrying capacity itself.

carrying trailers struck in the rear. No underride occurred in 124 involvements (22.9%), some underride occurred in 357 (66.0%), and underride could not be determined in 60 involvements (11.1%).

In the two years covered by the survey, 979 persons were fatally injured in collisions in which a passenger vehicle struck the rear of a truck. Of these fatalities, 900 occurred in the striking vehicle. Almost 25% of the striking-vehicle fatalities occurred with no underride. There was at least some underride in crashes resulting in 565 striking-vehicle fatalities. Of those deaths, almost half (269) involved underride to the windshield or beyond.

Overall, the problem of rear underride is about the same for tractor-trailer combinations and straight trucks. Straight trucks are involved in rear-end collisions at about the same rate as tractor combinations. Straight trucks are underridden at a slightly lower rate that tractor-trailer combinations but the number of fatalities in the striking-vehicle is in proportion to the number of involvements.

Incidence of Rear Underride in Fatal Truck Crashes, 1997-1998

1.0 Introduction

For the 1997 and 1998 data years, the Center for National Truck Statistics at the University of Michigan Transportation Research Institute (UMTRI) collected data on rear underride as part of its Trucks Involved in Fatal Accidents (TIFA) survey. Underride can occur in a number of crash configurations, but the focus of the study was crashes in which the rear of a truck was struck. The purpose of the survey was to evaluate the incidence of underride in these fatal crashes. Supplemental data were collected on each rear-end crash involvement. Data collected included whether the truck had a rear underride guard, whether the striking vehicle underrode the truck, and how much underride occurred.

Most trailers manufactured after January 26, 1998, with a gross vehicle weight rating over 10,000 pounds, are required to be equipped with an underride guard within 12 inches of the rear of the trailer and with a ground clearance of no more than 22 inches. This rule superseded an earlier requirement setting ground clearance at up to 30 inches and permitting offset from the rear of the trailer up to 24 inches.[2] There are no regulations governing underride guards on straight trucks.[3] A primary goal of the survey was to estimate the incidence of underride in fatal crashes in which straight trucks are struck in the rear.

The present study does not evaluate the effectiveness of present or past rear underride guard standards. Because the new trailer guard standard did not go into effect until 1998, almost all trailer underride guards in the study were under the 1952 standard. Moreover, since the study population was restricted to fatal crashes, any safety effect from either standard is probably masked, because the impact speed likely is often beyond the design limits of both the current and previous standard. Efforts to evaluate the safety effect of guard standards must include nonfatal crashes.

1.1 Data

The data collection of underride in rear-end crashes was implemented as a supplement to the TIFA survey. The TIFA file is in turn built on the Fatality Analysis Reporting System (FARS) file, produced by the National Highway Traffic Safety Administration. FARS is a census of fatal motor vehicle crashes on public roadways. Records of medium and heavy trucks involved in a fatal crash are selected from the FARS file, and then additional data

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[2] 49 Code of Federal Regulations, 393.86, "Rear impact guards and rear end protection."

[3] A "straight" truck is a truck with a cargo body permanently mounted to the chassis. Examples include dump trucks and delivery vans. A tractor (or truck tractor) is designed to pull semitrailers, and typically has no cargo-carrying capacity itself.

about the physical configuration of the truck and the type of company operating it are collected. The TIFA data are collected through telephone interviews with people who have knowledge of the truck at the time of the crash such as the driver, owner, safety director of the carrier operating the truck, the reporting police officer, and any other involved party. The TIFA file is a combination of the FARS records and the additional descriptive data collected through the telephone interviews.

Cases in the 1997-1998 TIFA file are actually a sample of FARS truck crash records. Rather than collecting data on each of the more than 5,000 trucks in a typical year of FARS, some sampling is done among the two best-understood truck configurations: straight trucks with no trailers and tractors pulling one trailer. The sampling procedure is simple. First, all cases where the truck driver was killed are taken for the TIFA file, to ensure complete coverage of this group. Next, all cases identified in FARS as a truck configuration other than a straight truck with no trailer or a tractor with one semitrailer are taken. The remaining trucks are all identified in FARS as either a straight truck with no trailer or a tractor pulling one semitrailer. One-half of these cases are selected for the TIFA survey. Sample weights are included in the TIFA file so that correct population estimates can be calculated. The sample weights are equal to one for those cases taken with certainty and two for the group in which only half of the cases were selected for the TIFA file.

Cases for the rear-end underride supplemental survey were selected from the TIFA truck fatal involvements.[4] Rear-end crashes are identified by the editors of the TIFA survey using the narratives and diagrams on police reports. For the purpose of the survey, a rear-end crash was defined as an impact with the rear plane of a truck by a passenger vehicle. Crashes in which a truck was struck in the rear by another medium or heavy truck were flagged, but they are not included as a rear-end crash in the analysis. In this paper, a rear-end crash refers to a passenger vehicle striking the rear of a truck. "Underride" was coded if any part of the passenger vehicle went under the rear of the truck. Underride can occur in both front and side impacts as well, but the focus of the survey was on rear underride.

Interviews for the underride supplement were conducted with the same sources as the rest of the TIFA survey. Information about the physical structure of the rear of the straight truck or trailer was obtained from a safety director, dispatcher, owner, or driver of the vehicle. Questions about whether the truck was underridden and the amount of underride were answered most often by people at the scene of the crash, such as reporting police officers, other official investigators, tow operators, and the like. Police officers often drew on the reports of accident reconstructionists and the commercial motor vehicle inspectors who are sometimes called to the scene of a fatal truck crash. The data were collected by means of telephone interviews. While interviewers tried to contact the most knowledgeable source with photographic or written documentation, often they had to rely on the memories of those on the scene.

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[4] "Truck fatal involvements" is the set of trucks involved in a traffic crash in which at least one person was fatally injured. In this context, an "involvement" is one truck involved in a fatal crash.

To better characterize the whole population of straight trucks and understand the incidence of underride in rear collisions, the survey included data describing the rear of every straight truck in a fatal crash, regardless of whether the truck was struck in the rear. For every straight truck, interviewers filled out the portion of the rear-end supplemental data form that covers vehicle description. Data collected on all straight trucks include cargo body overhang behind the rear duals, cargo overhang, height of cargo bed from the ground, whether the vehicle was equipped with an underride guard, the height of the underride guard from the ground, the width of the underride guard, and any other equipment[5] on the rear of the truck hanging below the cargo body.

2.0 TIFA Underride Survey Results

This section discusses the results of the survey of rear-end collisions and underride in fatal truck crashes. First, survey results are presented for straight trucks in all fatal crashes, not just collisions in which a truck was struck in the rear. The focus is on the rear of straight trucks, especially characteristics of the rear of the vehicle that can affect underride in the event of a rear-end collision. Topics include cargo body overhang, the height of the cargo bed, and the frequency of mounted equipment and underride guards on the rear end. Then results on rear-end crashes are presented, including the frequency of underride guards, and the frequency and amount of underride.

2.1 Straight Trucks Involved in Fatal Crashes

Because one goal of the underride survey was to evaluate the effectiveness of underride guards for straight trucks, an attempt was made to collect data on the rear configuration of all straight trucks, regardless of whether they were struck in the rear end. The back ends of straight trucks can have a variety of configurations that can affect the opportunity for underride to occur when the truck is struck in the rear. For example, there can be large differences in the amount of cargo body overhang, defined as the distance from the rear dual tires to the rear of the cargo body. In dump trucks, this distance is often less than 12 inches, but in dry vans hauling light-weight cargo, cargo body overhang can be 120 inches or more. Similarly, some straight trucks have equipment mounted at the rear of the cargo body, in place of or in addition to underride guards.

Figure 1 shows the distribution of cargo body overhang for all straight trucks in the TIFA survey. Overhang is defined as the distance in inches from the rear tires to the rear of the cargo body. This is the distance a vehicle potentially can underride a truck before it strikes the rear dual wheels. Researchers were unable to determine this distance in about 18% of the cases. The mean overhang for all straight trucks where the distance could be determined was 49.8 inches, with a standard deviation of 32.3. Also, 6.2% of the trucks had either no overhang or an overhang up to 12 inches (the maximum offset distance in the current trailer rear underride guard standard). An additional 11.3% had cargo body

[5] "Equipment" throughout this paper refers to equipment mounted on the rear of the truck that extends below the level of the cargo body.

overhangs from 13 to 24 inches, and 64.2% had cargo body overhangs greater than 24 inches.

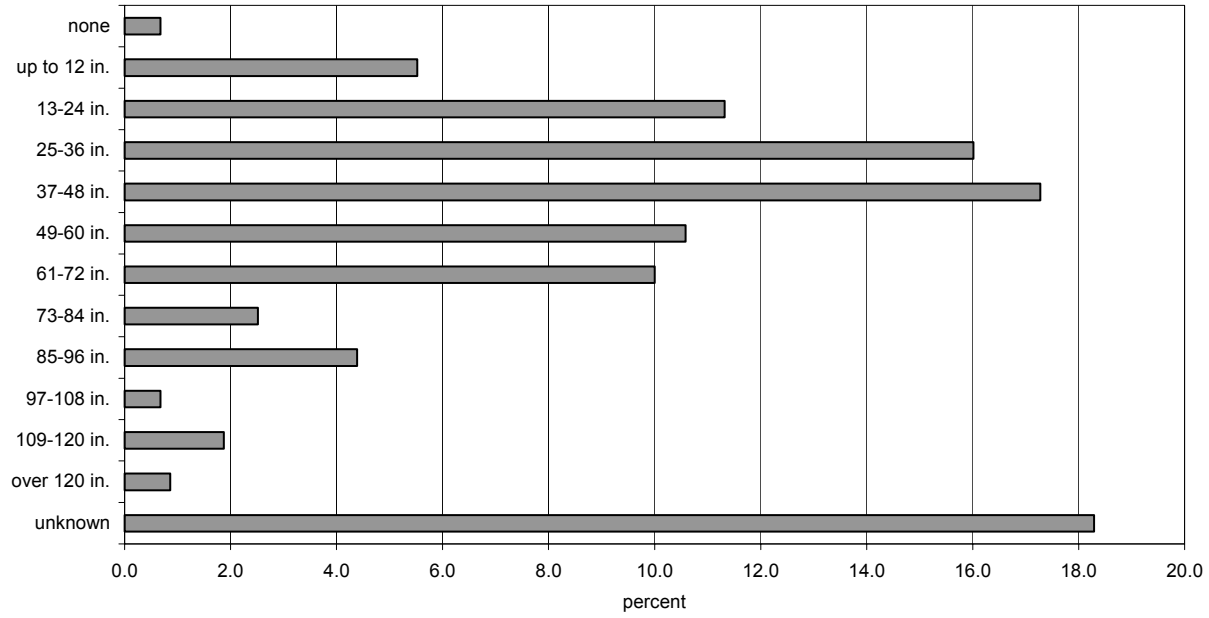

Figure 1 Cargo Body Overhang in Straight Trucks
TIFA 1997-1998

Table 1 shows the average cargo body overhang by cargo body type. Only cases with known cargo body overhang are included. Note that auto carriers are represented by only seven cases. Mean overhang roughly accords with expectations. Vans often have large overhangs because they frequently carry low density cargoes. The cargo body overhang of flatbeds and tanks is substantial, but these vehicles often have equipment mounted at the rear. The average overhang for dumps, at slightly over 34 inches, is longer than expected. But the dump category encompasses a variety of applications. Many of the vehicles with the largest overhangs were used in agriculture; examples include grain bodies and potato bodies which can have rear-unloading equipment that contributes to the overhang.

Table 1
Average Cargo Body Overhang, Straight Trucks
Weighted Frequencies, TIFA 1997-1998

Cargo body type	N	Overhang (inches)	Std. Dev.
Van	638	62.1	31.1
Flatbed	365	53.3	27.9
Tank	158	52.3	27.9
Auto carrier	7	111.4	70.3
Dump	728	34.0	28.4
Refuse	190	60.9	32.6
Other	577	49.0	28.9
All straight trucks	2,663	49.8	32.3

Figure 2 shows the height of the cargo body bed from the ground for all straight trucks. Researchers were unable to determine this distance in 14% of the cases. Respondents were unable to give a precise estimate in some cases, though they were willing to indicate whether the bed was above or below the top of the tires. Overall, the mean bed height was 41.6 inches with a standard deviation of 11.9 inches. The figure shows the distribution in six-inch increments. As might be expected, the largest category is from 43 to 48 inches, but some quite low bed heights were reported, including seventeen cases at 12 inches. Almost 75% of straight trucks involved in a fatal crash in 1997-1998 had cargo body bed heights more than 30 inches from the ground.

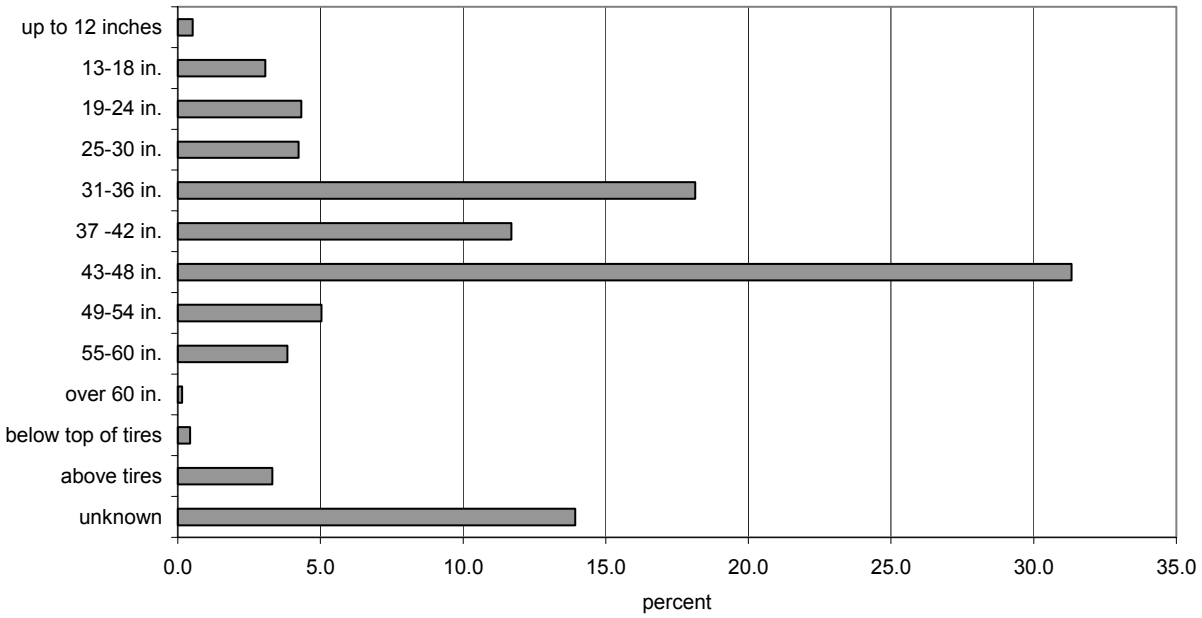

Figure 2 Cargo Body Bed Height from Ground in Straight Trucks
TIFA 1997-1998

Only about 27% of straight trucks were reported to have an underride guard mounted to the rear (Table 2). Over 57% of straight trucks did not have an underride guard, and interviewers were unable to determine if the truck had an underride guard in 15.7% of the cases. Presence of an underride guard varied widely by cargo body style. Over 39% of refuse trucks had an underride guard, compared to no auto carriers and only 15.8% of dumps. Over 36% of vans had an underride guard, as did 41.6% of flatbeds and 36.6% of tanks.

Table 2
Reported Underride Guard, by Cargo Body Style
Straight Trucks
Weighted Frequencies, TIFA 1997-1998

Cargo body	Yes		No		Unknown		Total	
type	N	%	N	%	N	%	N	%
Van	282	36.2	388	49.7	110	14.1	780	100.0
Flatbed	181	41.6	200	46.0	54	12.4	435	100.0
Tank	70	36.6	87	45.5	34	17.8	191	100.0
Auto carrier	0	0.0	7	16.7	35	83.3	42	100.0
Dump	137	15.8	591	68.2	138	15.9	866	100.0
Refuse	88	39.1	106	47.1	31	13.8	225	100.0
Other	127	18.0	482	68.5	95	13.5	704	100.0
Unknown	0	0.0	0	0.0	16	100.0	16	100.0
Total	885	27.2	1,861	57.1	513	15.7	3,259	100.0

The TIFA survey also determined if there was any equipment mounted on the rear of the truck extending below the level of the cargo body. The purpose of this question was to determine the incidence of rear-mounted equipment that might affect underride. Some equipment, such as liftgates, can be quite substantial and serve as an underride guard, although most of the reported equipment was probably too flimsy to have much effect. Overall, 27.1% of straight trucks involved in fatal crashes in 1997 and 1998 had mounted equipment, and 58.0% did not. The presence of equipment could not be determined in 14.9% of the cases (Table 3). Once again, cargo body style was related to the presence of mounted equipment. Over 36% of vans reported some sort of equipment, compared to about 20% of tanks and flatbeds, and only 17.6% of dumps.

Table 3
Reported Equipment Below Cargo Bed, by Cargo Body Style
Straight Trucks
Weighted Frequencies, TIFA 1997-1998

Cargo body	Yes		No		Unknown		Total	
type	N	%	N	%	N	%	N	%
Van	284	36.4	393	50.4	103	13.2	780	100.0
Flatbed	89	20.5	283	65.1	63	14.5	435	100.0
Tank	39	20.4	124	64.9	28	14.7	191	100.0
Auto carrier	5	11.9	4	9.5	33	78.6	42	100.0
Dump	152	17.6	598	69.1	116	13.4	866	100.0
Refuse	45	20.0	149	66.2	31	13.8	225	100.0
Other	270	38.4	340	48.3	94	13.4	704	100.0
Unknown	0	0.0	0	0.0	16	100.0	16	100.0
Total	884	27.1	1,891	58.0	484	14.9	3,259	100.0

A wide variety of equipment was reported. Of those vehicles with some sort of equipment, steps or bumpers were mentioned for about 36% of the vehicles, hitches were mounted on 17.2%, and liftgates were present on 14.4%. Other items reported were tool boxes, pumps, spreaders, and wheel lifts. Liftgates may be substantial enough to act as surrogate

underride guards, but most of the other items could not on their face help in mitigating underride.

Finally, Table 4 shows the combination of underride guards and rear-mounted equipment. All told, 34.1% of straight trucks in a fatal crash had neither an underride guard nor any rear-mounted equipment. For the most part, trucks either had a guard (20.7%) or mounted equipment (21.2%). Only about 5% were reported to have both an underride guard and some sort of mounted equipment. The unknown category combines cases coded unknown on whether there was an underride guard or any equipment or both.

Table 4
Underride Guard
or Equipment Below Cargo Bed
Straight Trucks Only
Weighted Frequencies, TIFA 1997-1998

	N	%
Guard only	674	20.7
Equipment only	691	21.2
Both	156	4.8
Neither	1,111	34.1
Unknown	627	19.2
Total	3,259	100.0

Table 5 shows the presence of underride guards on the back of straight trucks by cargo body height. Cargo body heights are grouped to reflect the regulations governing the height from the ground of underride guards required on semitrailers. The cut-point at 48 inches is included because that typically corresponds to the top of the tires. Currently, underride guards on semitrailers must be no more than 22 inches from the ground. The prior guard height requirement, dating from 1952, was 30 inches from the ground. There is no requirement for rear underride guards on straight trucks at the present time.

Table 5 Presence of Underride Guard by Cargo Body Bed Height
Straight Trucks Only
Weighted Frequencies, TIFA 1997-1998

	Underride Guard							
	Yes		No		Unknown		Total	
Cargo body height	N	%	N	%	N	%	N	%
<=22 in.	18	13.2	114	83.8	4	2.9	136	100.0
22-30 in.	38	14.6	214	82.3	8	3.1	260	100.0
31-48 in.	642	32.2	1,231	61.8	120	6.0	1,993	100.0
> 48 in.	145	36.1	220	54.7	37	9.2	402	100.0
Below tires	5	35.7	9	64.3	0	0.0	14	100.0
Unknown	37	8.1	73	16.1	344	75.8	454	100.0
Total	885	27.2	1,861	57.1	513	15.7	3,259	100.0

While only 27% of straight trucks were found to have rear underride guards, trucks with higher cargo beds are more likely to be equipped with a guard than those with low cargo beds. Only 13.2% of straight trucks in the 1997 and 1998 TIFA survey with cargo body heights up to 22 inches from the ground had an underride guard, while 83.8% did not. Over

82% of straight trucks with cargo beds between 22 inches and 30 inches off the ground also did not have underride guards, while only 14.6% did. In contrast, 32.2% of trucks with beds between 31 inches and 48 inches off the ground had an underride guard, as did 36.1% of straight trucks with beds over 48 inches from the ground. (Responses indicating that the cargo bed was over the tires are included with the over-48 inch category.)

Table 6 shows the distribution of underride guards by cargo body overhang. Overhang is defined as the distance in inches from the rear dual tires to the rear of the cargo body. It represents the amount of underride available before the underriding vehicle strikes the rear tires. Once again, overhangs are categorized to correspond to the regulations on guard setback for semitrailers. Prior to the 1998 regulation, underride guards could be set no more than 24 inches from the rear of the trailer. In 1998, that distance was shortened to 12 inches. Straight trucks with short overhangs were found to have underride guards much less frequently than straight trucks with large overhangs. Only 10.4% of straight trucks with overhangs of 12 inches or less were equipped with a rear underride guard, compared with almost 34% of straight trucks with overhangs of more than 24 inches.

Table 6 Presence of Underride Guard by Cargo Body Overhang
Straight Trucks Only
Weighted Frequencies, TIFA 1997-1998

	Underride Guard							
Cargo body	Yes		No		Unknown		Total	
overhang	N	%	N	%	N	%	N	%
<=12 in.	21	10.4	169	83.7	12	5.9	202	100.0
13-24 in.	76	20.6	281	76.2	12	3.3	369	100.0
>24 in.	705	33.7	1,268	60.6	119	5.7	2,092	100.0
Unknown	83	13.9	143	24.0	370	62.1	596	100.0
Total	885	27.2	1,861	57.1	513	15.7	3,259	100.0

The rear-end survey also attempted to collect information about the height of the guard from the ground and the width of the guard. These questions proved very difficult to answer. Missing data rates for each variable are 85%.

2.2 Underride in Fatal Rear-End Crashes

This section examines underride in fatal rear-end truck crashes, as identified in the 1997 and 1998 TIFA files. As described above, the underride survey effort collected data describing the rear of trucks, focusing on underride guards, mounted equipment, overhang, and cargo bed height. All of those factors may affect underride in rear-end collisions. Accordingly, the present section will first review the frequency of rear-end crashes and underride, and then present tables examining the association between the rear structures of trucks and underride. Of course, the TIFA file is limited to crashes in which a fatality occurred. Without data on nonfatal crashes, it is not possible to determine whether underride guards decrease the risk of fatality in rear-end crashes. Nevertheless, these data can be used to detect associations between the type of rear-end structure and whether and how much underride occurred, at least for fatal crashes.

2.2.1 Underride by Truck Configuration

Table 7 shows the number of trucks involved in a fatal rear-end crash by truck configuration. A total of 853 fatal rear-end crash involvements occurred in 1997-1998. These are all crash involvements in which the truck was struck in the rear by a nontruck vehicle. Crash involvements in which the striking vehicle was another truck (truck-truck) are excluded, as are rear-end involvements in which the truck itself was the striking vehicle, regardless of the type of vehicle struck. Overall, about 8.3% of all trucks involved in a fatal crash were struck in the rear by a nontruck vehicle. The proportion of rear-end crash involvements, the rear-end rate, was similar among the primary truck configurations. The rear-end rate was 8.7% for straight trucks with no trailers, 8.4% for tractor-semitrailers, and 7.0% for tractors pulling two or more cargo-carrying trailers.

Table 7
Incidence of Rear-End by Truck Configuration
Weighted Frequencies, TIFA 1997-1998

	rear-end		no rear-end		total	
Truck configuration	N	%	N	%	N	%
Straight only	245	8.7	2,572	91.3	2,817	100.0
Straight + trailer	31	7.0	411	93.0	442	100.0
Bobtail tractor	15	5.6	254	94.4	269	100.0
Tractor-semitrailer	514	8.4	5,600	91.6	6,114	100.0
Tractor, 2 or more	27	7.0	359	93.0	386	100.0
Tractor, other combo	4	8.5	43	91.5	47	100.0
Unknown	17	6.7	236	93.3	253	100.0
Total	853	8.3	9,475	91.7	10,328	100.0

Overall, underride was reported in 518 of the 853 rear-ends (60.7%). Table 8 shows the incidence of underride in fatal crashes when the truck was struck in the rear. There were 276 straight trucks (with or without a trailer) involved in a fatal rear-end collision where the striking vehicle was a not a truck. In those 276 rear-end crashes, there was no underride in 78 involvements (28.3%), some underride in 152 involvements (55.1%), and underride was unknown in 46 involvements (16.7%). There were 541 tractors with one or more cargo-carrying trailers struck in the rear. No underride occurred in 124 involvements (22.9%), some underride occurred in 357 (66.0%), and underride could not be determined in 60 involvements (11.1%).

Table 8
Underride in Rear-End Fatal Crashes by Truck Configuration
Weighted Frequencies, TIFA 1997-1998

	Underride						
Truck configuration	none	Less than halfway to windshield	More than halfway to windshield	to windshield	Some but unknown amount	unknown	total
Straight only	74	52	30	57	11	21	245
Straight + trailer	4	0	0	2	0	25	31
Bobtail tractor	3	3	0	0	3	6	15
Tractor-semitrailer	119	82	55	178	23	57	514
Tractor, 2 or more	5	6	3	7	3	3	27
Unknown	0	0	2	1	0	18	21
Total	205	143	90	245	40	130	853
	Row percentages						
Straight only	30.2	21.2	12.2	23.3	4.5	8.6	100.0
Straight + trailer	12.9	0.0	0.0	6.5	0.0	80.6	100.0
Bobtail tractor	20.0	20.0	0.0	0.0	20.0	40.0	100.0
Tractor-semitrailer	23.2	16.0	10.7	34.6	4.5	11.1	100.0
Tractor, 2 or more	18.5	22.2	11.1	25.9	11.1	11.1	100.0
Unknown	0.0	0.0	9.5	4.8	0.0	85.7	100.0
Total	24.0	16.8	10.6	28.7	4.7	15.2	100.0

Underride occurred at approximately the same rate for straight trucks and tractor-combinations. There was some tendency for straight trucks with no trailers to have a higher proportion of cases reported with no rear underride than tractor-semitrailers in the fatal crashes, but the differences are not significant. Straight trucks with no trailers experienced some underride in 61.2% of fatal crash involvements in which they were struck in the rear, while 65.8% of tractor-semitrailers in such crashes had some rear underride.

2.2.2 Underride and Underride Guards/Mounted Equipment

The TIFA survey collected information on rear underride guards and mounted equipment in the population of trucks that had been rear-ended, including both straight trucks and tractor combinations. Only eighteen (6.5%) straight trucks and seven (1.3%) tractor combinations had both an underride guard and some sort of rear-mounted equipment (Table 9). About half of the trucks involved in a rear-end crash had a guard only, and these were mostly tractor combinations. Tractor combinations tended to have guards only. Over 74% of rear-ended tractor combinations had an underride guard, but very few had mounted equipment. On the other hand, 38.8% of straight trucks had neither an underride guard nor equipment, 28.6% had equipment only, 18.8% had only an underride guard, and 6.5% had both an underride guard and rear-mounted equipment. (Truck configurations are aggregated to power unit type to avoid proliferation of empty cells. Almost 90% of straight trucks pulled no trailer, and 96.6% of tractors pulled at least one trailer. Power unit type could not be determined in 17 cases.)

Table 9
Underride Guard or Equipment Below Ca

no trailers, tractor-semitrailers, and tractors with two or more trailers. In these configurations, the rear structure of the truck, where an underride guard would be mounted, is exposed to impact. No bobtail tractors, that is truck-tractors operating without a trailer, were reported to have an underride guard. Whether there was an underride guard could not be determined for more than half of the bobtails, though it is unlikely that any had a guard, as tractors are designed and purchased to be operated with trailers.

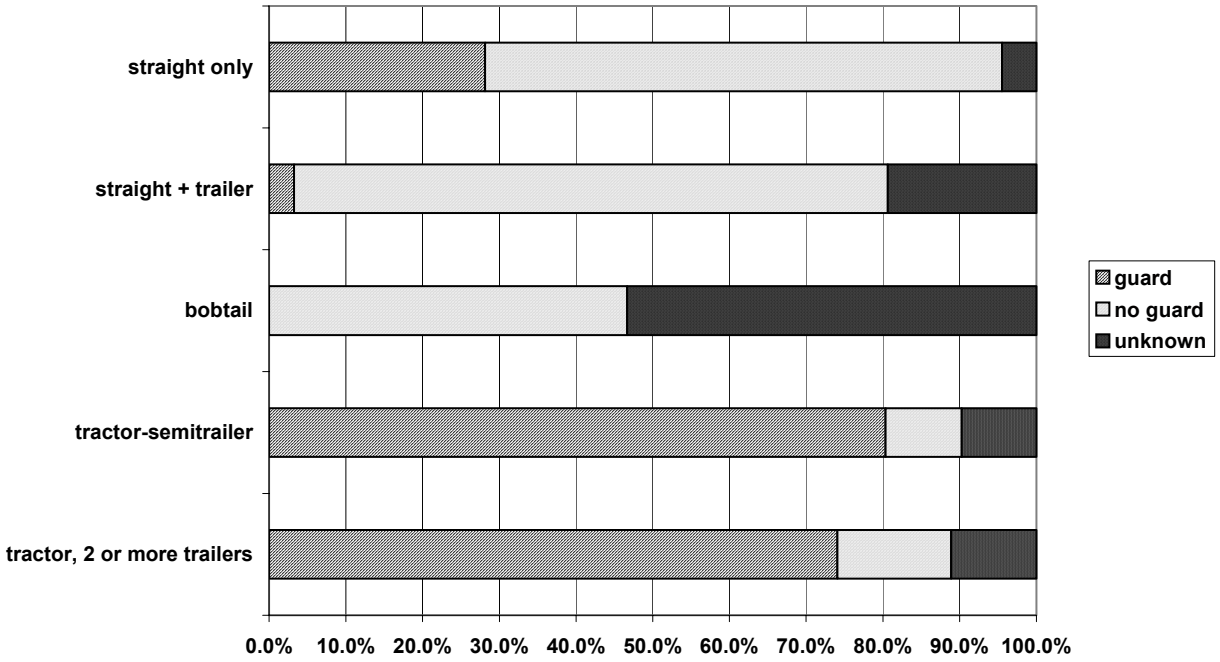

Figure 3 Underride Guard by Truck Configuration
Trucks in Fatal Rear-End Crashes, TIFA 1997-1998

Only about 28% of straight trucks with no trailers involved in a fatal rear-end crash had an underride guard. It is not unexpected that straight trucks generally do not have rear underride guards as there is currently no requirement for them. Tractor-semitrailers and tractors with two or more trailers frequently are equipped with rear underride guards. Over 80% of tractor-semitrailers involved in fatal rear-end crashes had a rear underride guard, and almost 75% of tractors pulling two or more trailers had such guards.

Figure 4 shows the overall relationship of underride guards to rear underride in fatal rear-end crashes. The figure includes all trucks involved in a fatal rear-end crash. No underride was recorded in 25.8% of the involvements in which a truck that was equipped with an underride guard was struck in the rear in a fatal crash. Seventy percent of such trucks were underridden, while underride could not be determined in 4.2%. The rear underride experience was about the same for trucks with no underride guard that were struck in the rear in a fatal crash. Almost 27% had no underride, 60.6% had some underride, and underride could not be determined for 12.7%.

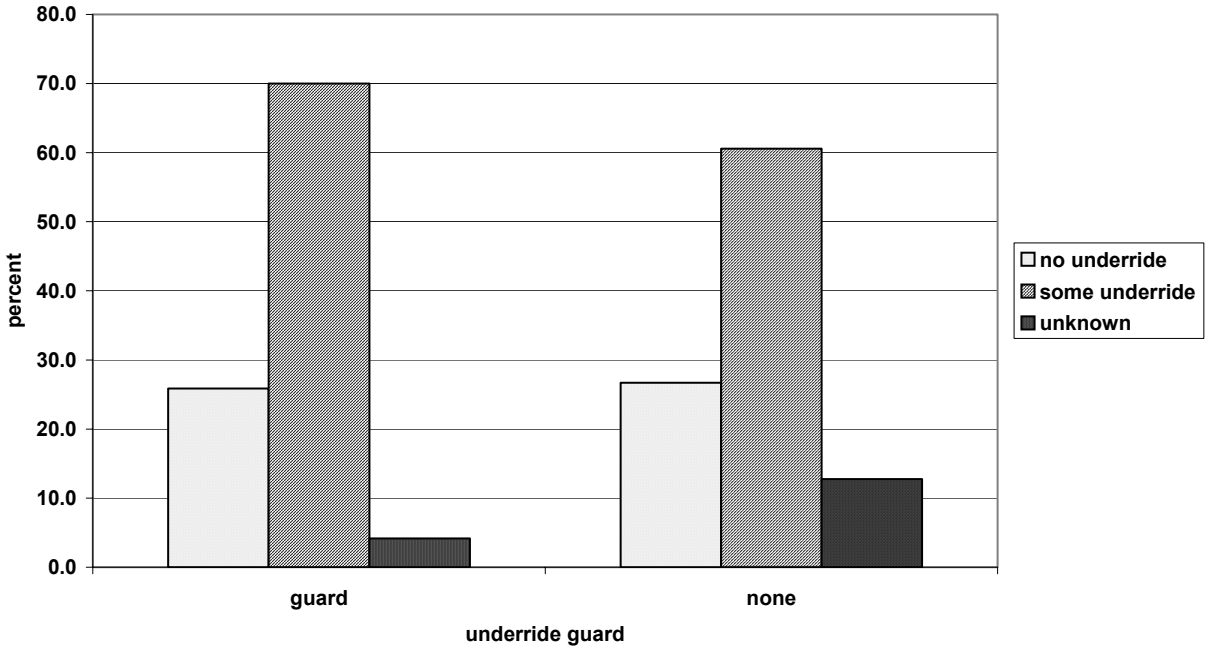

Figure 4 Rear Underride by Presence of Underride Guard
Trucks in Fatal Rear-End Crashes, TIFA 1997-1998

Figure 5 is limited to straight trucks with no trailers. In this configuration, the rear of the truck is exposed to the impact, so the effect of rear underride guards on underride in fatal rear-end crashes can be determined. As in the case of all trucks, it does not appear that the guards limit underride in these crashes. In fact, straight trucks without a guard experienced a lower frequency of underride than straight trucks with an underride guard. Almost 27% of straight trucks with a guard involved in a fatal rear-end crash experienced no underride, compared with almost 33% of straight trucks that had no guard. Over 70% of straight trucks with an underride guard experienced at least some underride, compared with only 60% of straight trucks that had no guard. As Table 5 and Table 6 above show, straight trucks with low cargo body beds and short overhangs tend not to be equipped with an underride guard.

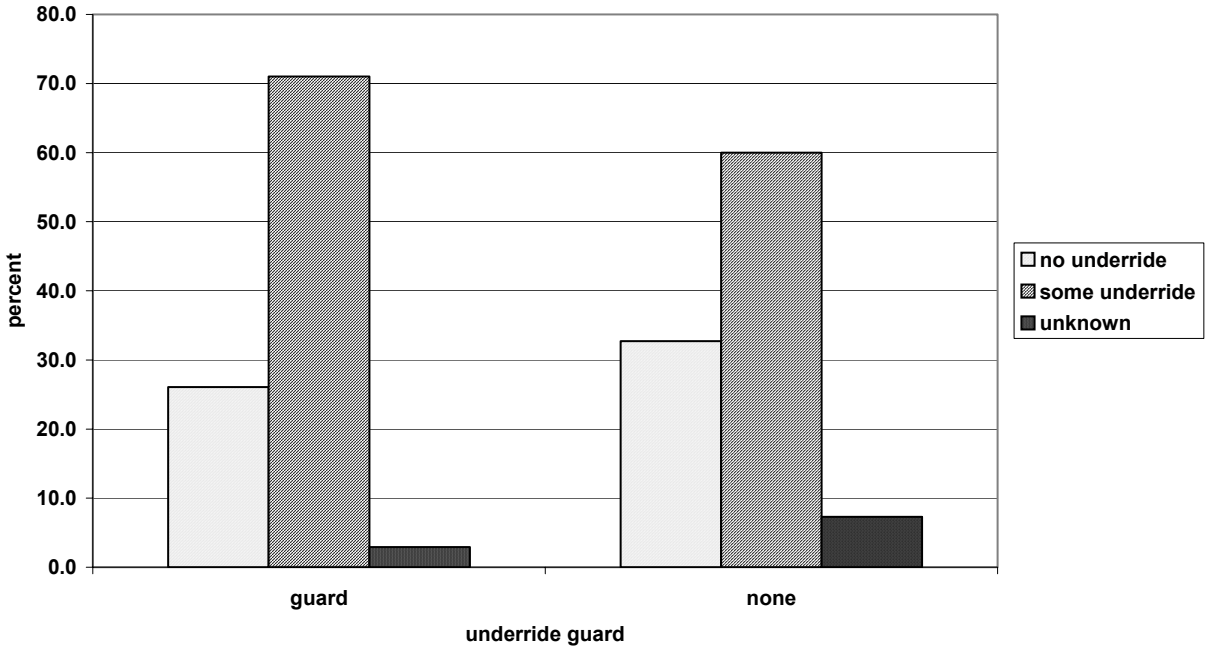

Figure 5 Straight Trucks with No Trailers:
Rear Underride by Presence of Underride Guard
Trucks in Fatal Rear-End Crashes, TIFA 1997-1998

Figure 6 displays a comparable analysis for tractor-semitrailers. Here at least, tractor-semitrailers with a rear underride guard were underridden less frequently in fatal rear-end crashes than tractor-semitrailers with no such guard. Seventy percent of tractor-semitrailers with a guard were underridden in a rear-end crash, compared with over 80% of such combinations not equipped with a guard.

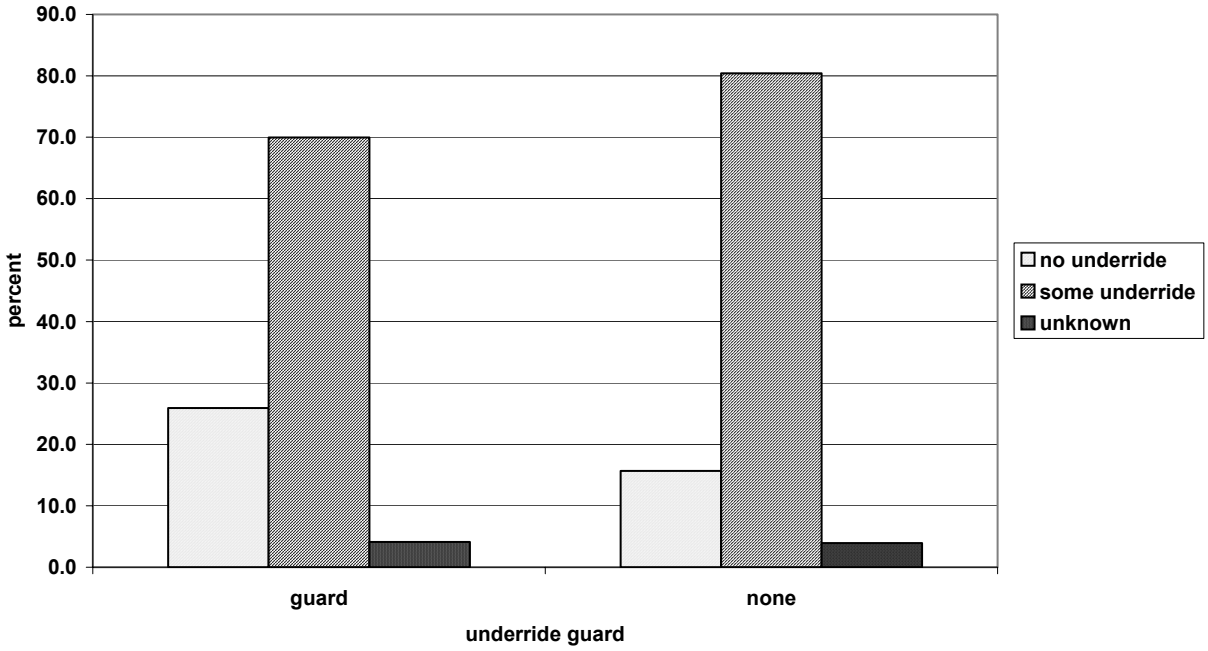

Figure 6 Tractor-Semitrailers:
Rear Underride by Presence of Underride Guard
Trucks in Fatal Rear-End Crashes, TIFA 1997-1998

These results are counter to what would be expected, although this may be due to a host of complicating factors. The severity threshold of the TIFA file may serve to decrease variation in the amount of underride by rear-end structure, since a fatality must occur for the crash to be included in the file. It could be that many of the collisions are beyond the design limits of the guards, and so the guards have no effect. Other complicating factors include the cargo body height, the height and front-end structure of the striking vehicle, overhang of the cargo body, and the height of the underride guard from the ground.

2.2.3 Fatalities in Rear-End Crashes

A total of 979 persons were fatally injured in rear-end crashes in 1997 and 1998 (Table 11). This total includes fatal injuries to any involved party, including the truck driver and any passengers, occupants of the striking vehicle, occupants of any other vehicle, and pedestrians or other nonmotorists. Of the 979 fatalities, 900 (91.9%) occurred in the striking vehicle and 79 were suffered by some other involved party, most often either an occupant of another vehicle in the crash or a pedestrian. (About 16% of the fatal rear-end crashes involved more than two vehicles.) Almost a quarter of the fatal injuries in the striking vehicle occurred in crashes with no underride. A total of 565 fatalities (62.8%) in

the striking vehicle occurred in crashes where there was at least some underride. Of those underride fatalities, almost half involved underride to the windshield or beyond.

Table 11
Fatalities in Striking Vehicle and Other Fatalities in Crash
Rear-End Crashes by Amount of Underride
Weighted Frequencies, TIFA 1997-1998

	Striking vehicle		Other fatalities		Total	
Amount of underride	N	%	N	%	N	%
None	211	23.4	31	39.2	242	24.7
Less than halfway to windshield	156	17.3	7	8.9	163	16.6
More than halfway to windshield	102	11.3	2	2.5	104	10.6
To windshield	269	29.9	0	0.0	269	27.5
Some but unknown amount	38	4.2	3	3.8	41	4.2
Unknown	124	13.8	36	45.6	160	16.3
Total	900	100.0	79	100.0	979	100.0

Table 12 tabulates the fatalities in the striking vehicle in rear-end crashes by the amount of underride and the power unit type of the truck. The percentages shown in the table are total percents, i.e., the proportion of the cell of all rear-end striking vehicle fatalities. Thus 9.1% of the fatalities involved straight trucks where there was no underride. Over two-thirds of fatalities in striking vehicles occurred in collisions with tractor combinations. Almost half of the fatalities (400 or 44.4%) occurred in collisions with tractor combinations where there was some underride. Straight trucks accounted for about one-third of the fatalities in striking vehicles, and 163 (28.8%) of the 565 fatalities in which underride occurred.

Table 12
Fatalities in Striking Vehicle
Rear-End Crashes by Amount of Underride and Power Unit Type
Weighted Frequencies, TIFA 1997-1998

	All straight trucks		All tractors		Unknown		Total	
Amount of underride	N	%	N	%	N	%	N	%
None	82	9.1	129	14.3	0	0.0	211	23.4
Less than halfway to windshield	59	6.6	97	10.8	0	0.0	156	17.3
More than halfway to windshield	30	3.3	72	8.0	0	0.0	102	11.3
To windshield	64	7.1	203	22.6	2	0.2	269	29.9
Some but unknown amount	10	1.1	28	3.1	0	0.0	38	4.2
Unknown	47	5.2	77	8.6	0	0.0	124	13.8
Total	292	32.4	606	67.3	2	0.2	900	100.0

3.0 Discussion

The critical rear dimensions of most straight trucks involved in fatal crashes provide little structural impediment to underride. The mean cargo body overhang for all straight trucks involved in a fatal accident was 49.8 inches. In only 6.2% of the straight trucks was the distance from the rear dual tires to the end of the cargo body 12 inches or less. The overhang was more than 24 inches in 64.2% of the straight trucks. Almost half of the straight trucks had overhangs greater than three feet. Similarly, cargo bed heights are great enough to allow rear underride in the event of a collision. Overall, the mean bed height was 41.6 inches, and almost 75% of straight trucks involved in a fatal crash in 1997-1998 had cargo body bed heights more than 30 inches from the ground.

Straight trucks are not currently required to have a rear underride guard. Nevertheless, 27.2% of straight trucks involved in a fatal crash in 1997-1998 were so equipped. These guards were slightly more common on straight trucks with high cargo body beds or large cargo body overhangs. Almost 34% of straight trucks with overhangs greater than 24 inches had a rear underride guard. Almost 33% of trucks with cargo bed heights over 30 inches had a guard. Nevertheless, the rear structure of most straight trucks provided ample opportunity for underride in rear-end collisions.

Straight trucks are involved in rear-end fatal crashes (defined here as the impact of a nontruck on the rear plane of a truck) at about the same rate as tractor combinations. A straight truck with no trailer is the predominant straight truck configuration in a fatal crash (86.4%); the most common (93.4%) tractor combination in fatal crashes is a tractor pulling one semitrailer. Rear-end crashes accounted for 8.7% of the fatal crash involvements of straight trucks with no trailers, and about 8.4% of the fatal crash involvements of tractor-semitrailers. Overall, 8.3% of trucks in a fatal crash in 1997-1998 were struck in the rear. Thus the rate of involvement is about the same for straight trucks and tractor combinations. There were about twice as many tractor-semitrailer involvements as straight truck involvements, but the percentage of involvements that were rear-end crashes is about the same for both configurations.

The total number of fatalities in rear-end crashes in 1997-1998 was 979. Of these fatalities, 900 occurred in the striking vehicle. Collisions with straight trucks accounted for 292 of the deaths in the striking vehicle, and 606 occurred in a collision with a tractor combination. (The power unit type could not be determined for two fatalities.) There were thus about twice as many deaths in rear-end crashes involving a tractor combination as a straight truck, but there were about twice as many tractor combinations as straight trucks involved in a fatal accident in 1997-1998.

Underride occurred in 60.7% of fatal rear-end collisions, though underride could not be determined in 15.2% of the crashes. Some underride occurred in 55.1% of straight truck rear-end involvements, and some underride was recorded in 66.0% of tractor rear-end involvements. Straight trucks were reported with underride at a somewhat lower rate than tractor-trailer combinations, but the differences are not substantial. Considering straight trucks with no trailers, where the rear of the truck itself is exposed to impact, straight

trucks were underridden in 61.2% of fatal rear-end crashes while 65.8% of tractor-semitrailers in such crashes had some rear underride. Thus, though tractor-semitrailers were underridden somewhat more often than straight trucks, the differences are not great. Underride occurs in a substantial fraction of all rear-end fatal crashes regardless of power unit type.

In gross terms, then, the problem of rear underride is about the same for tractor-trailer combinations and straight trucks. They are involved in rear-end collisions at about the same rate. Straight trucks may suffer underride at a slightly lower rate than tractor-trailer combinations, but the number of striking vehicle fatalities is in proportion to the number of involvements. The lower number of fatalities in rear-end crashes with straight trucks is apparently explained by exposure, rather than by any safety advantage.

There was no evidence in these data that guards in use in 1997-1998 had any consistent safety effect. The percentage of underride in fatal crashes was essentially unaffected by the presence of underride guards. The primary difference between tractor combinations and straight trucks in rear-end crashes was the higher rate of rear underride guards on tractor combinations. Only about 28% of straight trucks with no trailers (a configuration in which the underride guard is exposed to impact) were equipped with an underride guard. In contrast, over 80% of tractor-semitrailers had such guards. Nevertheless, both combinations were underridden at about the same rate.

However, it must be emphasized that the purpose of the present study was to estimate the incidence of underride in fatal rear-end crashes, not to evaluate the effectiveness of present or past rear underride guard standards. The new trailer guard standard did not go into effect until 1998, so almost all trailer underride guards in the study were governed by the 1952 standard. Collecting information about underride in fatal crashes well after the fact by means of telephone interview with people on the scene probably is not sufficient to accurately measure degrees of underride. The method seems adequate to determine if underride occurred, which was the objective of the current effort. Of course, restricting the study population to fatal crashes probably masks any safety effect, since the impact speed likely is often beyond the design limits of both the current and previous standard. Efforts to estimate the risk of fatality in rear underride must include nonfatal crashes.