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## VEHICLE SAFETY

## Margin of Safety for Heavy Trucks on Curves

by John M. Goebelbecker, P. E.<sup>†</sup> and S. Carl Uzgiris, Ph. D., P.E.<sup>††</sup>

### Introduction

Speed advisory signs reflect speeds which are considered safe for automobiles. "Tests have shown that trucks with a high center of gravity can roll over at the speed limit posted for a curve."<sup>1</sup> Fortunately, drivers of heavy trucks develop skills for judging safe speeds through curves. Their skill is largely dependent on personal driving history and familiarity with the handling characteristics of their trucks. On curves where margins of safety for heavy trucks are small, exceeding the advisory speed by less than 5 mph or performing abrupt steering maneuvers can cause some trucks to roll over.



### Discussion

A series of field tests of passenger vehicles was conducted in the 1930's and 1940's to determine "safe speeds on curves." (See Figure 1) The results of these tests established levels of lateral acceleration (acceleration to the side) at which drivers experienced some discomfort. It was found that drivers are more tolerant of lateral acceleration at slower speeds (typically in urban settings) than at higher speeds (such as on highways or rural roads). Utilizing driver discomfort as the criterion for judging safe speeds, one study by the Highway Research Board<sup>3</sup> concluded that lateral acceleration levels of .21 g's for speeds less than 20 mph, .18 g's for speeds of 25 to 30 mph and .15 g's for speeds of 35 mph and higher, resulted in safe speeds.

A speed advisory sign placed in advance of a curve is intended to notify approaching drivers of the maximum safe speed for negotiating the curve. The U.S. Department of Transportation has adopted the three-tiered lateral acceleration system cited above for establishing speed advisories.<sup>4</sup> Some other agencies have established more conservative criteria. For example, the State of Illinois specifies a maximum lateral acceleration of .15 g's for all curves, regardless of the design speed.<sup>5</sup>

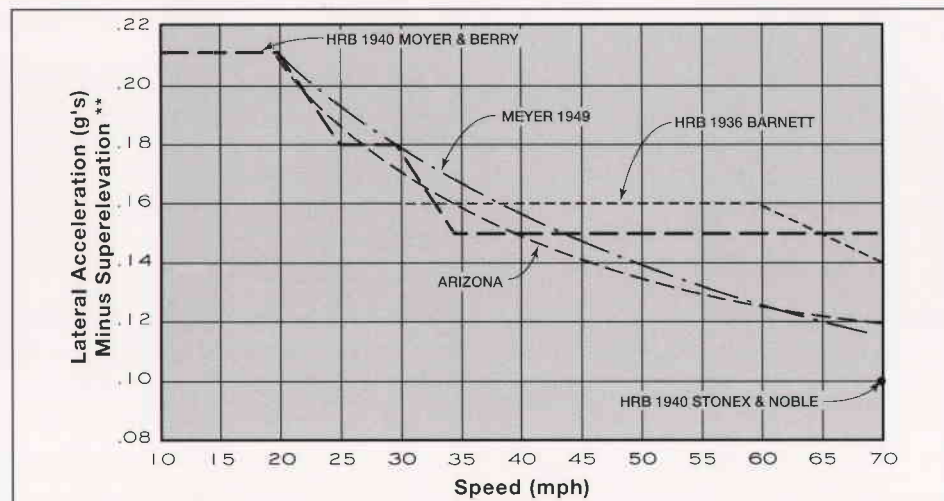


Figure 1 - Recommended Maximum Lateral Acceleration for Safe Speed on Curves<sup>2</sup>

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Table I - Margins of Safety on Curves

VEHICLE TYPE	ROLLOVER THRESHOLD (g's)	LATERAL ACCELERATION CORRESPONDING TO 20 MPH SPEED ADVISORY (g's)	MARGIN OF SAFETY (g's)	AVAILABLE OVERSPEED TO ROLLOVER THRESHOLD *
Tractor with Van Trailer; Full Gross, Medium Density Freight (34 lb/ft <sup>3</sup> )	.34 <sup>b</sup>	.21	.13	6 mph
"Typical" LTL Freight Load	.28 <sup>b</sup>	.21	.07	3 mph
Tractor with Van Trailer; Full Gross, Full Cube, Homogenous Freight (18.7 lb/ft <sup>3</sup> )	.24 <sup>b</sup>	.21	.03	2 mph
Automobile	1.1	.21	.89	26 mph

\* Based on curve with radius of curvature of 130 ft., no superelevation\*\* and 20 mph speed advisory.

Road designs, including posted speed advisories, incorporate design specifications established by field tests of *passenger vehicles*. Trucks, however, have different handling characteristics than passenger vehicles and must be driven accordingly. In particular, a truck will roll over more readily than an automobile due to a truck's higher center of gravity. A measure of a truck's ability to resist rollover is given by its *rollover threshold*. The rollover threshold is the lowest value of centrifugal acceleration which causes the truck to tip over when driven steadily in a circular path.

A margin of safety can be viewed as the difference between a vehicle's rollover threshold and the subject curve's lateral acceleration design specification. For example, if a truck's rollover threshold is .28 g's and a curve's design acceleration is .18 g's, the margin of safety is  $.28 \text{ g} - .18 \text{ g} = .10 \text{ g}$ . For a curve with a radius of curvature of 335 feet, no superelevation\*\* and a speed advisory of 30 mph ( $a = .18 \text{ g}$ ), the truck will roll over at 37.4 mph ( $a = v^2/r$ ). If the driver turns the steering wheel abruptly, with sufficient duration, the vehicle may roll over at a lower speed. Table I shows the margins of safety for several typical heavy trucks and an automobile.

Despite the small margin of safety for heavy trucks on curves, many trucks travel at or above the posted speed advisories. Figure 2 illustrates research conducted by Triodyne engineers on highway exit ramp speeds.<sup>7</sup> The histogram shows that although the average speed of exiting trucks was below the posted speed advisory, a substantial number traveled at speeds above the advisory. Automobiles traveled 5 mph faster than trucks, on average.

## Conclusion

Speed advisory signs for curves are not appropriate for heavy trucks. Heavy trucks have unique handling characteristics and their drivers should be aware of the limitations of speed advisory signs. For example, the American Trucking Association recommends that drivers travel 5-10 mph below the posted speed on a curve.<sup>8</sup> Given the nonuniformity of the criteria for establishing the speed advisories and the low margins of safety for trucks on curves, truck drivers must exercise caution and reduce their speed below the posted speed advisories before entering curves.

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\*\* Superelevation - commonly known as the bank in a curve.

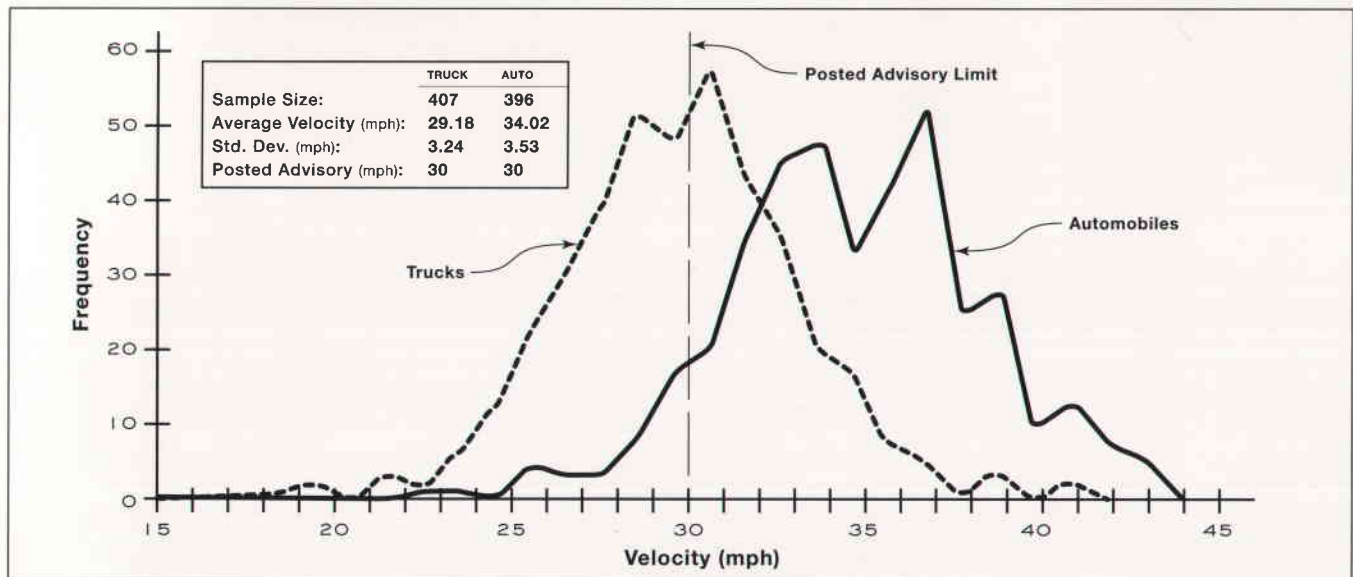


Figure 2 - Exit Ramp Speed Histogram