Utility Vehicle Rollover Cases

Understanding the Defect

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The National Highway Traffic Safety Administration (NHTSA) is again considering a Federal Motor Vehicle Safety Standard (FMVSS) associated with rollovers of utility vehicles, pickup trucks, vans, and passenger cars.[1] Citing statistics that show rollover fatalities in utility vehicles and pickup trucks have risen more than 29 percent since the mid-1980s, NHTSA asked for comment from the public and from motor vehicle manufacturers on several proposed rollover standards.

Why the need for regulation? The present disastrous trend in rollover accidents is proof that the automotive industry "forgets" safe design in order to win an increased share of the utility vehicle market.

Back in the Roaring Twenties, steering a car around a sharp corner sometimes resulted in overturn. By 1941, however, a General Motors engineer could brag that "there has been consistent improvement from year to year [in stability]."[2] In 1961, the same engineer—now assistant director of the General Motors Proving Grounds—wrote, "The relative stability of the current cars has been achieved largely by virtue of low center of gravity height."[3]

Several studies during the 1970s noted that passenger cars generally do not turn over on flat surfaces—even with extraordinary steering and braking maneuvers.[4] NHTSA was sufficiently confident of the ability of manufacturers to avoid rollover on flat surfaces that it incorporated "overturning immunity" in its experimental safety vehicle (ESV) program. This standard stated, "To demonstrate overturning immunity, the vehicle carrying a minimum load shall not overturn under any combinations of braking and/or steering at any velocity on a level paved track."[5]

Complying with the ESV, several auto companies developed rollover immunity tests. The J-turn, originally developed as a maneuver to test tires,[6] was used by Volkswagen. Volkswagen defined the J-turn as a 180-degree steering wheel input, applied at no less than 500 degrees per second while the vehicle was traveling at speeds of 30, 50, and 70 miles per hour (mph).[7]

Ford Motor Company used a reverse-steer maneuver conducted as an unmanned test. The test vehicle was towed down a guide rail, which forced it into a standardized left turn; when released from the rail, the front wheels were quickly turned right by a hydraulic steering device. The procedure was repeated at progressively higher speeds until a one-G lateral acceleration was reached in the left turn or until the vehicle spun out or rolled over.[8]

In 1973, NHTSA, looking at the ESV experience, proposed a rollover standard for passenger cars.[9] Many auto companies conceded the safety value of stability, but they opposed the new standard as unnecessary. Typical was Ford Motor Company's statement in August 1973:

> Passenger cars must be "forgiving" of all manner of "unskilled" driver situations that precipitate wild, panic motivated, evasive maneuvers of drivers of widely varying abilities. Ford passenger cars are designed to "forgive" or, in the extreme, to "slide-out" rather than roll over on flat, level pavement.[10]

Market forces since the early 1970s have changed matters. In 1970, American Motors Corporation (now merged into Chrysler) purchased Kaiser Jeep Corporation and began aggressively marketing the Jeep CJ-5. That product line was augmented by 1976 by the CJ-7 model, which had a 10-inch-longer wheelbase and automatic transmission. Television commercials conveyed images of rugged, aggressive vehicles that could climb hills and enter woodlands. Riding in a Jeep looked like fun. Sales zoomed.

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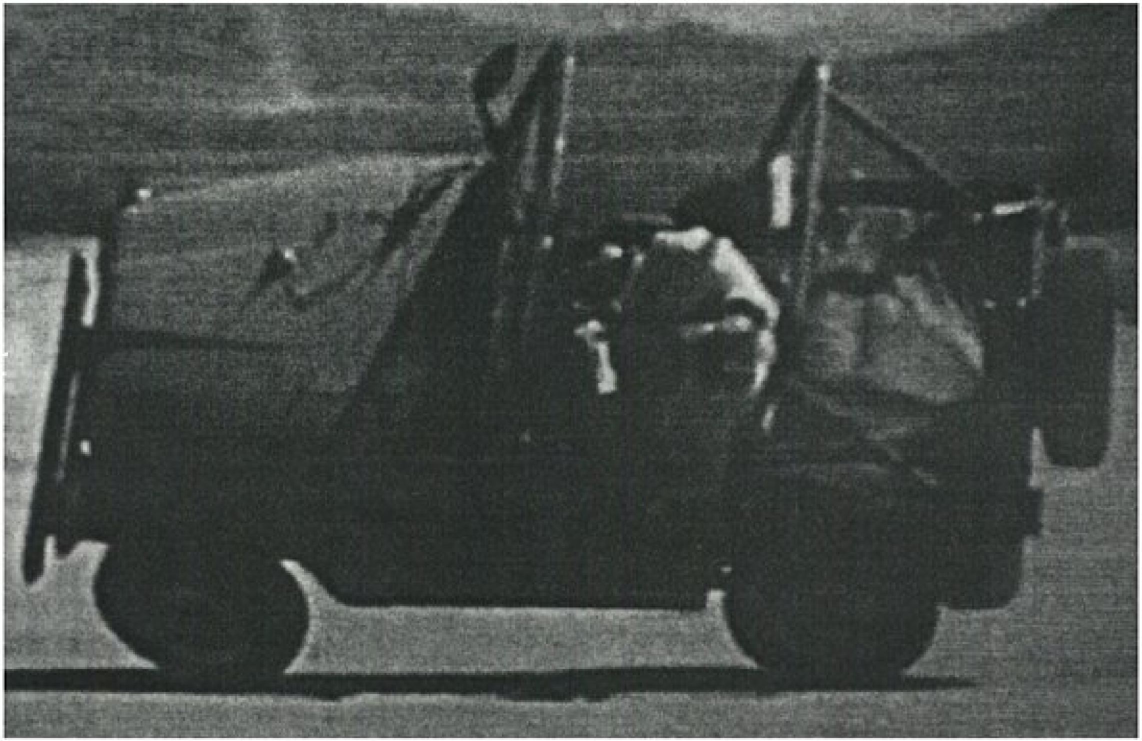

Other companies competed in this market. Volkswagen resurrected its Kubelwagen from World War II and began selling it in the United States as the "Thing" (Type 181). "Things" were not marketed to civilians in Germany or elsewhere in Europe. Volkswagen built a plant in Mexico that distributed primarily to the U.S. market. Other "multi-purpose" or "utility" vehicles marketed during the 1970s were the Ford Bronco, Chevrolet Blazer, International Scout, Toyota Landcruiser, Jeep Cherokee, and Dodge Ramcharger. None had to comply with passenger motor vehicle safety standards because the definition of a passenger automobile at 49 C.F.R. §523.4 exempted multi-purpose vehicles and trucks.

By 1979, the Insurance Institute for Highway Safety had noticed increased rollover accident rates of utility vehicles and sponsored a study by the Highway Safety Research Institute. It noted that utility vehicles "experience rollover at a rate that is at least five times higher . . . than that experienced by the average passenger car."[11] The same report noted that some vehicles fared worse than others. The Jeep and pre-1978 Bronco overturned more than twice as often as the Blazer.

The report also noted that on-road rollover accidents appeared to be directly related to inherent stability deficiencies in utility vehicles. The higher center of gravity combined with relatively narrow track width and very aggressive (high traction) tires resulted in vehicles rolling over rather than skidding to a stop during sharp turns or emergency maneuvers. Rollover accidents, moreover, were very high-risk accidents for serious injury and death.

In December 1980, the CBS program *60 Minutes* broadcast a segment criticizing the Jeep CJ-5 and citing this report. The publicity caused a temporary nosedive in Jeep sales but did not appear to affect the utility-vehicle market overall. Sales climbed throughout the 1980s and into the 1990s, becoming an important segment of an otherwise depressed automobile sales market. Toyota entered the competition with its 4-Runner; Suzuki with its Samurai; Ford with the Bronco II and later the Explorer; General Motors with the S-10 Blazer, Nissan with the Pathfinder; and Isuzu with the Trooper. All these vehicles have rollover death rates much higher than passenger cars.[12]

Interestingly, the Jeep Wagoneer series (which dates from 1962), the Jeep Cherokee series (which dates from the 1970s), and the Jeep Wrangler series (which replaced the Jeep CJ line in 1986) have rollover death rates essentially equivalent to passenger cars.

Why do some utility vehicles appear to be relatively safe? Statistical studies show that the differences are not explained by driver population, type of use, or environmental factors. The answer is physics.

The Physics of Overturn

Understanding why a vehicle will roll over rather than skid to a stop on a flat surface requires some knowledge of physics. A measure of the likelihood of a vehicle to overturn is derived by the mathematical formula T/2H, where T is the vehicle's track width (measured side to side between the center of the tires) and H is the height of the center of gravity.

In its current rule making announcement, NHTSA has acknowledged the statistical relationship between T/2H and both the number of rollover accidents and the incidence of rollover fatalities. On the other hand, NHTSA rejected using the stability ratio by itself as an indicator of defect "because the agency determined that establishing a minimum stability factor value would neither adequately encompass the causes of vehicle rollover nor satisfactorily ameliorate the problem."[13]

More than 30 years ago, K.A. Stonex reported that experiments conducted at General Motors—dragging cars sideways on different surfaces produced coefficients of friction averaging 0.9 for concrete and from 0.8 to 0.9 for asphalt.[14] The Highway Safety Research Institute has since reported, "Generally speaking, levels of [pavement friction] up to 1.0 can be obtained through tire cornering traction on dry pavements. Levels above 1.0 require other mechanisms, such as sideslipping in soft soil or contact of the sideslipping tire with curbs or other rigid surface irregularities."[15]

A vehicle sliding sideways across an icy bridge and reaching dry pavement will roll over if its dynamic instability allows all of its weight to shift to the outside two tires. Utility vehicles will usually roll over when tire-friction forces (weight on the tires multiplied by coefficient of friction) reach around two-thirds of the value calculated from the T/2H stability ratio. This happens because of the effect of suspension and tires and the higher center of gravity caused by the high seat location of the occupants.[16]

Auto body lean during sharp turns and the "jacking effect" of certain designs of suspension result in both a narrower track width and a higher center of gravity under dynamic conditions.[17] The number and seated height of passengers can cause a significant reduction in the dynamic stability of smaller, lighter utility vehicles.

Imagine a vehicle driving around in a circle, going faster and faster. As it develops body lean, the track width tends to narrow as outside tires are squeezed toward the center. Due to seat height, most of the weight of the people in the vehicle rests above the center of gravity. Assuming the vehicle has enough engine power, it will eventually reach its limit of lateral acceleration and do one of two things: skid out to a safe stop or roll over. A vehicle with dynamically safe design will slide out. A dynamically unstable one will roll over.

The design of the suspension system will affect rollover stability. Engineers from the Ford Truck Engineering Office pointed out in a 1965 article that the twin I-beam suspension used on certain Ford trucks and utility vehicles, for example, "adds to the inertial overturning [likelihood]."[18]

Test results have revealed that the "jacking effect" can raise the center of gravity several inches. It can account for why a Bronco II, for instance, has worse rollover characteristics than an S-10 Blazer, which has similar vehicle dimensions but a different suspension design. In July 1991, NHTSA published a technical assessment paper on the relationship between rollover and vehicle factors that ranked the Bronco II as the worst of 56 vehicles tested during a two-year evaluation period.[19] The same paper noted that the Bronco II flunked the tilt-table test proposed by the United Kingdom (see *Static tests, infra*). The leaf-spring suspension system of the Jeep CJ-5 and CJ-7 also has hazardous rollover characteristics, perhaps because it allows a high angle of body lean.

Manufacturers have ignored the growing rate of rollover accidents, when remedies as simple as proper tires could have made a dramatic difference.

One approach to reducing the rollover tendency in utility vehicles and pickup trucks with narrow track widths and high centers of gravity has been to stiffen the suspension system. This works to an extent. An unstable vehicle capable of 10 degrees of body lean will overturn at slower speeds than one whose suspension system allows only 5 degrees of body lean in sharp turns.

There is a safety trade-off, however, because body lean warns the driver of impending rollover. If the design allows relatively little body lean, drivers are given a false sense of security in a hard turn, until they suddenly finds themselves upside down.[20]

Wheelbase and Tires

For a vehicle to overturn on flat surfaces, it has to develop high lateral forces. The traction or friction developed between the road surface and the tires must be sufficient to overcome the force available to resist overturn. A short wheelbase favors overturn.

The Jeep CJ-5 and CJ-7 had similar T/2H before 1982. Accident data, however, show that the 10-inch-shorter CJ-5 had a higher rollover death rate than the CJ-7.[21] The shorter CJ 5 turns in a shorter radius and builds up lateral forces more quickly. Vehicles with short wheelbases like the Jeep CJ-5 (83.5 inches from front axle to back axle), CJ-7 (93.5 inches), Bronco II (94 inches), Volkswagen Thing (94 inches), pre-1978 Bronco (92 inches), and Suzuki Samurai (80 inches) yaw sideways more easily than a passenger car would. Therefore, they are more likely to develop the lateral forces necessary to cause overturn during emergency maneuvers.

In a 1990 SAE paper, Ian Jones of Forensic Technologies International and Maria Penny of Resource Planning Corporation wrote, "Rollover increases as this [track width to wheelbase] ratio increases . . . vehicles that are short in length relative to their width have higher rollover odds."[22] NHTSA has also found "significant correlations between rollover accident involvement rates and vehicle wheelbase."[23] NHTSA's recent announcement of rule-making stated—

> Several possible explanations have been put forth to explain this wheelbase-to-rollover accident involvement correlation. For example, the relationship might be due to a correlation of wheelbase with vehicle pre-crash stability, pre-crash condition and/or skid type mentioned above. In other words, wheelbase might be acting as a surrogate for vehicle stability characteristics, and actually the correlation that results is between wheelbase and vehicle loss of stability preceding the rollover.[24]

Some tires are capable of developing more traction than others. Almost all tires have more traction when half worn than they had when new. Auto manufacturers are well aware of this.[25]

At American Motors Corporation, engineer Jim Thornton tested the Jeep CJ-5 and CJ-7 in J-turns and avoidance maneuvers using a variety of tires. AMC found that the CJ could roll over at speeds as low as 18 mph, or skid out at speeds as high as 40 mph, depending on the size and brand of tire used.[26]

Nevertheless, AMC continued marketing the Jeep CJ vehicle with tires that would develop lateral forces (traction) sufficient to cause rollover at 25 mph on flat pavement.

the version proposed by NHTSA, the vehicle

> is placed on the table with the tires on one side against a low curb. The side of the table on the far side from the curb is then slowly lifted while the roll angle of the table is measured. The tilt-table angle is the platform roll angle at which both tires first lift off of the table on the high side. The point of wheel lift is determined using a contact switch to detect when the wheels lose contact with the platform.[31]

NHTSA has found a correlation between tilt-table results and rollover accident rates. In July 1991, it published the results of some testing it had done on a number of vehicles. The following vehicles did *not* reach 40 degrees of angle before the upper tires lost contact with the table: 1989 Aerostar (39), 1981 Jeep CJ-7 (39.5), 1985 E-150 Club (39.2), 1987 Vanagon (39.7), 1981 Jeep CJ 5 (39.2), 1983 S-10 Blazer (39.5), and 1985 Bronco II (39.5).[32]

The side-pull ratio, based on a test developed by General Motors, is defined by NHTSA as

> the ratio of the lateral force acting through the vertical cg [center of gravity] required to lift the opposite side tires off the ground divided by the vehicle weight. The test is performed using wide straps and, in some cases, chains, to apply the pull force to the vehicle body. Extreme care needs to be taken to ensure that the pull force vector passes through the vehicle vertical cg at all times, the force is maintained horizontally to the ground, and adjustments to the pulling mechanism are made as the vehicle rolls on its suspension and deflects laterally and vertically, causing the vertical and horizontal location of the cg to change.[33]

Data obtained from the side-pull test are useful. The ratio obtained is directly related to the friction coefficient of the road surface necessary to cause vehicle rollover. Thus, if the ratio is below the 1.0 coefficient found in many road surfaces, rollover dangers may be inherent in the vehicle. The side-pull test more fully involves tire friction and suspension characteristics than the tilt-table test.

NHTSA has also found a direct correlation between side-pull results and rollover accident rates, although the relationship is not as high as that of the static-stability formula. One difference might be that the test methodology for the side-pull test has not to date required that the vehicle be fully loaded. Utility vehicles have their worst rollover characteristics when fully loaded because of the high seating positions for passengers.

As many of the authors cited in this article agree, once a vehicle's static-stability ratio falls below 1:2, it has a statistically significant risk of rollover. The accompanying table indicates the additional track width that would be needed by a wide range of current vehicles to reach a T/2H of 1:2.

The fact that vehicles with static-stability ratios above 1:2 have similar rollover records confirms that there is a baseline minimum for safe design. NHTSA's current tilt-table proposal appears to recognize the validity of the stability ratio analysis, despite NHTSA's formal rejection of a petition to set a minimum stability formula.

Once a vehicle's static-stability ratio falls below 1:2, it has a higher risk of rollover accident.

No new technology is needed for manufacturers to design stable utility vehicles. A 1962 Jeep Wagoneer had the same stability as a passenger car. For years, it has been feasible to test any utility vehicle, van, or pickup truck with techniques used to judge "rollover immunity" in the ESV program of the early 1970s. Manufacturers have ignored the growing rate of rollover accidents, when remedies as simple as using the right tires could have made the difference.

NHTSA's late attention to rollover safety should be welcomed. A stability ratio of 1:2, a tilt-table result of at least 45 degrees (loaded), or a side-pull ratio above 1:0 would all be reasonable minimums for utility vehicle stability.

Notes

1 Rollover Prevention, 57 Fed. Reg. 242 (1992).
2 K.A. Stonex, *Car Control Factors and Their Measurement*, SAE TRANSACTIONS, Mar. 1941, at 81.
3 K.A. Stonex, *Roadside Design Safety*, TRAFFIC SAFETY, Dec. 1961, at 26.
4 *See, e.g.*, R.D. ERVIN et al., VEHICLE HANDLING PERFORMANCE, Vol. 1, DOT-HS-800-759, Highway Safety Res. Inst., U. Mich. (Nov. 1972); R. RICE, DEVELOPMENT OF VEHICLE ROLLOVER MANEUVER, DOT-HS-6-01382, Calspan Corporation (June 1978).
5 NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., TECHNICAL SPECIFICATION: U.S. INTERMEDIATE ESV (1970).
6 SOCIETY OF AUTOMOTIVE ENGINEERS, SAE J 918a and SAE XJ 266.
7 H. Willumeit, *The Volkswagen Experimental Safety Vehicle*, REPORT ON THE FOURTH INTERNATIONAL TECHNICAL CONFERENCE ON EXPERIMENTAL SAFETY VEHICLES, U.S. Dep't of Transportation 121 (Mar. 1973).
8 EXPERIMENTAL SAFETY VEHICLE (FAMILY SEDAN), technical proposal submitted by Ford Motor Company to RFP DOT-OS-00050 (Apr. 1970); J.J. KING & D.A. EATON, MILITARY VEHICLE ROLLOVER TEST, ASRO Report No. S-70-13 (May 13, 1970); D.A. EATON et al, LIGHT TRUCK HANDLING: ROLLOVER TESTS, ASAO Report No. S-71-37 (Aug. 16, 1971).
9 NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., ADVANCED NOTICE OF PROPOSED RULEMAKING ON ROLLOVER RESISTANCE, Docket 73-10 (1973).
10 Letter from Ford to NHTSA in response to Advanced Notice of Proposed Rulemaking on Rollover Resistance, Docket 73-10 (Aug. 15, 1973).
11 R.G. SNYDER et al., ON-ROAD CRASH EXPERIENCE OF UTILITY VEHICLES, UM-HSRI-80-14 (Feb. 1980).
12 NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., TECHNICAL ASSESSMENT PAPER: RELATIONSHIP BETWEEN ROLLOVER AND VEHICLE FACTORS (July 1991); E.A. Harwin et al., *Analysis Of The Relationship Between Vehicle Rollover Stability And Rollover Risk Using The NHTSA CARD File Accident Data Base*, 18 J. TRAFFIC MED. 3 (1990).
13 57 Fed. Reg. 242, 245 (1992).
14 Stonex, *supra* note 3.
15 SNYDER *et al.*, *supra* note 11, at 114.
16 W.F. MILLIKEN & R.S. RICE, VEHICLE HANDLING TEST (VHT) PROGRAM OF THE AMERICAN MOTORS 1981 JEEP CJ-5, prepared for vice president and general counsel, American Motors Corporation, Legal Department (July 1981); *see also* W.F. MILLIKEN et al., THE STATIC DIRECTIONAL STABILITY AND CONTROL OF THE AUTOMOBILE, SAE 76-0712 (Oct. 1976).
17 *See, e.g.*, J. E. HEYWOOD et al., THE TWIN I-BEAM A UNIQUE TRUCK INDEPENDENT FRONT SUSPENSION, SAE 65-0153 (1965), at 705.
18 *Id.* at 705.
19 NHTSA, *supra* note 12, at 4-52, 4-53.
20 The U.S. Army training film for the M-151 military truck explained the danger of this lack of rollover warning.
21 *See* L. Robertson, *Static Stability as a Predictor of Overturn in Fatal Crashes*, 29 J. TRAUMA 313 (1989).
22 IAN JONES et al., ENGINEERING PARAMETERS RELATED TO ROLLOVER FREQUENCY, SAE 90-0104 (Mar. 1990), at 76.
23 57 Fed. Reg. 242, 246; *see also* DISCERNING THE STATE OF CRASH AVOIDANCE IN THE ACCIDENT EXPERIENCE, 10 Proc. of Int. Tech. Conf. on Experimental Safety Vehicles (July 1985).
24 57 Fed. Reg. 242 (1992).
25 *See, e.g.*, D.J. BICKERSTAFF, THE HANDLING PROPERTIES OF LIGHT TRUCKS, SAE 76-0710 (Oct. 1976), at 5-10, 19-27; NORDEEN, ANALYSIS OF TIRE LATERAL FORCES AND INTERPRETATION OF EXPERIMENTAL TIRE DATA, SAE 67-0173 (1967), at 969.
26 The "tire testing" documents of Jim Thornton

are available to ATLA members who have joined the Attorneys Information Exchange Group.

27 *See, e.g.*, CONSUMER REPORTS (June 1989). Readers may obtain a copy of the Consumers Union's avoidance maneuver by writing Consumers Union at 2561 Washington St., Mt. Vernon, NY 10553.

28 *See, e.g.*, R.D. Ervin, et al., *supra* note 4; TEXAS TRANSPORTATION INSTITUTE, INPUT RESPONSE TESTS OF SELECTED SMALL PASSENGER CARS (Nov. 1971).

29 U.S. DEP'T OF TRANSPORTATION, EVALUATION OF THE 1960-1963 CORVAIR HANDLING AND STABILITY, DOT HS-820-198 (July 1972).

30 Bickerstaff, *supra* note 25, at 5-10, 19-27.

31 57 Fed. Reg. 242, 247. Although NHTSA has proposed a methodology, its proposal does not include a minimum angle. Presumably the minimum angle would be the focus of rulemaking activities if the tilt-table method is selected. According to the notice in Docket No. 91-68, the tilt table is NHTSA's preferred method at the moment.

32 NHTSA, *supra* note 12, at 4-40.

33 57 Fed. Reg. 242, 247.

San Francisco VDT Law Overturned; Appeal Filed

A San Francisco superior court judge recently overturned what was believed to be the nation's strictest regulation of video display terminal (VDT) workstations. The ordinance had required businesses with 15 or more employees to equip workstations with adjustable chairs, proper lighting, and terminals with anti-glare screens. (*See San Francisco Requires VDT Workstation Upgrades and Breaks for Workers*, TRIAL, Mar. 1991, at 91.)

Judge Lucy McCabe issued an oral ruling declaring that the ordinance was preempted by state law. Section 142.3 of the California Code gives sole authority for health and safety regulation to the state's Occupational Safety and Health Standards Board, she held. (*C & T Management Servs. Inc. v. City of San Francisco*, No. 936661 (Cal., San Francisco Cty. Super. Ct. 1992).)

The decision may prompt local governments around the county to think twice before passing VDT laws, said plaintiff's attorney Jeff Tanenbaum. He represents C & T Management Services, Inc., a data processing and accounting company.

Elaine Warren, a deputy San Francisco city attorney, said the city has appealed the decision. She contended that §142.3 was designed to protect workers and does not preclude local regulation. ☐