National Transportation Safety Board
Washington, D.C. 20594

Safety Recommendation

Date: September 2, 2011

In reply refer to: H-11-4 through -6

The Honorable Cynthia L. Quarterman
Administrator
Pipeline and Hazardous Materials Safety Administration
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Washington, DC 20590

On October 22, 2009, about 10:38 a.m. eastern daylight time, a 2006 Navistar International truck-tractor in combination with a 1994 Mississippi Tank Company MC331 specification cargo tank semitrailer (the combination unit), operated by AmeriGas Propane, L.P., and laden with 9,001 gallons of liquefied petroleum gas, rolled over on a connection ramp after exiting Interstate 69 (I-69) southbound to proceed south on Interstate 465 (I-465), about 10 miles northeast of downtown Indianapolis, Indiana.[1]

The truck driver was negotiating a left curve in the right lane on the connection ramp, which consisted of two southbound lanes, when the combination unit began to encroach upon the left lane, occupied by a 2007 Volvo S40 passenger car. The truck driver responded to the Volvo's presence in the left lane by oversteering clockwise, causing the combination unit to veer to the right and travel onto the paved right shoulder. Moments later, the truck driver steered counterclockwise to redirect and return the combination unit from the right shoulder to the right lane.

The truck driver's excessive, rapid, evasive steering maneuver triggered a sequence of events that caused the cargo tank semitrailer to roll over, decouple from the truck-tractor, penetrate a steel W-beam guardrail, and collide with a bridge footing and concrete pier column supporting the southbound I-465 overpass. The collision entirely displaced the outside bridge pier column from its footing and resulted in a breach at the front of the cargo tank that allowed the liquefied petroleum gas to escape, form a vapor cloud, and ignite. The truck-tractor came to rest on its right side south of the I-465 overpasses, and the decoupled cargo tank semitrailer came to rest on its left side, near the bridge footing supporting the southbound I-465 overpass. The

[1] For additional information, see *Rollover of a Truck-Tractor and Cargo Tank Semitrailer Carrying Liquefied Petroleum Gas and Subsequent Fire, Indianapolis, Indiana, October 22, 2009*, Highway Accident Report NTSB/HAR-11/01 (Washington, DC: National Transportation Safety Board, 2011), which is available on the NTSB website at <http://www.ntsb.gov/>.

truck driver and the Volvo driver sustained serious injuries in the accident and postaccident fire, and three occupants of passenger vehicles traveling on I-465 received minor injuries from the postaccident fire.

The National Transportation Safety Board (NTSB) determined that the probable cause of this accident was the excessive, rapid, evasive steering maneuver that the truck driver executed after the combination unit began to encroach upon the occupied left lane. Contributing to the rollover was the driver's quickly steering the combination unit from the right shoulder to the right lane, the reduced cross slope of the paved right shoulder, and the susceptibility of the combination unit to rollover because of its high center of gravity. Mitigating the severity of the accident was the bridge design, including the elements of continuity and redundancy, which prevented the structure from collapsing.

Rollover Prevention Programs

Rollover threshold has been defined as the maximum value of lateral acceleration required to bring a vehicle to the point of initiating roll instability.[2] Rollover threshold for a five-axle articulated vehicle combination unit occurs when the inside wheels of the semitrailer begin to lift off the ground as the combination unit negotiates a curved path. The basic measure of vehicle roll stability is *static rollover threshold*, which is expressed as lateral acceleration in gravitational units (*g*).[3] The typical rollover threshold of a fully loaded five-axle cargo tank motor vehicle is 0.35 *g* for a semitrailer carrying petroleum and 0.26 *g* for a semitrailer with cryogenic[4] product.[5] Drivers usually maneuver cars, light trucks, vans, and sport-utility vehicles below 0.2 *g*,[6] which is well below the calculated rollover threshold of 0.8–1.2 *g* for passenger vehicles. The wide range of maneuvering capability that allows passenger vehicle drivers to recover when errors are made, such as traveling too fast around a curve or introducing a rapid steering input, is not available to commercial drivers because the rollover threshold of loaded heavy trucks extends occasionally into the "normal" maneuvering range and well within the "emergency" maneuvering capability of the vehicle,[7] particularly when rapid, evasive steering maneuvers are executed. Therefore, the NTSB concludes that laden cargo tank motor vehicles provide little tolerance for operator error.

Leaders from three of the largest propane retailers, including AmeriGas Propane, L.P., identified better driver training as the foremost solution for reducing the 120–150 yearly

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[2] T.D. Gillespie and R.D. Ervin, *Comparative Study of Vehicle Roll Stability*, Report No. UMTRI-83-25 (Ann Arbor, Michigan: University of Michigan Transportation Research Institute, 1983).

[3] C.B. Winkler and R.D. Ervin, *Rollover of Heavy Commercial Vehicles*, UMTRI-99-19 (Ann Arbor, Michigan: University of Michigan Transportation Research Institute, 1999).

[4] Cryogenic liquids are liquefied gases such as nitrogen, natural gas, oxygen, argon, and methane that are kept in a liquid state at temperatures from -150 to -453° F.

[5] UMTRI-99-19.

[6] American Association of State Highway and Transportation Officials (AASHTO) guidelines for highway curve design result in lateral accelerations as high as 0.17 *g* at the posted advisory speed.

[7] UMTRI-99-19.

rollovers involving single-unit cargo tank trucks that transport liquefied petroleum gas.[8] Training has been provided to "program" drivers not to jerk the steering wheel or attempt to overcorrect when the wheels of the vehicle move off the road.

The rollover segment of the *Vehicle Incident Prevention Training* program provided by AmeriGas Propane, L.P., to its commercial drivers primarily consisted of seven PowerPoint slides containing images and information about the basic considerations for preventing the rollover of cargo tank motor vehicles. The training, which was completed by the accident truck driver on August 15, 2008, emphasized the importance of not "swerving" because it could result in the instability and untripped rollover of a cargo tank motor vehicle. In response to a question on the post-training test about what action should be avoided if an animal darts onto the road, the truck driver correctly responded "swerve." However, contrary to the training he had received to avoid "swerving" to prevent rollovers, the truck driver executed an excessive, rapid, evasive steering maneuver during this accident in response to becoming aware of a passenger vehicle in an adjacent lane.

The truck driver indicated during a postaccident interview with NTSB investigators that he had not received training for preventing or recognizing rollovers, although employee records showed he had attended the *Vehicle Incident Prevention Training* program in August 2008, just over a year before the accident. The NTSB concludes that the rollover training received by the truck driver was not effective in preventing this accident.

Approximately 66 percent of cargo tank rollovers involve drivers with 10 or more years of driving experience.[9] The *Cargo Tank Roll Stability Study*[10] found the main training challenge facing the cargo tank industry was trying to modify human performance by motivating drivers to remain alert and not become distracted. The *Cargo Tank Roll Stability Study* also found that although more "hands on" training using driving simulators has proven cost-effective by reducing training time, no demonstrated business model exists for incorporating simulators for small carriers; further, no long-term studies have been conducted to validate the benefits of simulator training for rollover prevention.

Rollover training should not be limited to commercial drivers but also include action that can be taken by management to reduce schedule-related demands, minimize delivery of loads with partially filled compartments, and identify stragegic steps that could be taken to improve the roll stability of existing and newly manufactured cargo tank motor vehicles. The *Cargo Tank Roll Stability Study* concluded the leading factor for increasing or decreasing cargo tank rollover risk is the dispatcher, who can control the operational demands to comply with tight delivery schedules that often pressure drivers to travel at excessive speeds or drive when drowsy. Dispatchers now more commonly have access to real-time information that can be used to

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[8] "Tipping Point: Bobtail Rollover Frequency Concerns Prompt Push for New Training Remedies," *LPGas* magazine, June 1, 2010.

[9] "Tank Truck Drivers: This Sign's for You!" *Safety News* (Washington, DC: U.S. Department of Transportation, Federal Motor Carrier Safety Administration, May 13, 2008).

[10] D.B. Pape and others, Battelle, *Cargo Tank Roll Stability Study*, final report, contract no. GS23-F-0011L (Washington, DC: U.S. Department of Transportation, Federal Motor Carrier Safety Administration, April 30, 2007).

monitor hours-of-service records and vehicle position history data to identify drivers who may be fatigued or driving faster than posted speed limits.

Similar to the *Heavy Vehicle Rollover Prevention Program* initiated in Australia,[11] rollover prevention programs should include, as a minimum, a detailed and informed discussion about rollover dynamics using truck models and written policies that identify the roles of and reasonable measures to be taken collaboratively by drivers, dispatchers, and management for preventing cargo tank motor vehicle rollovers. These policies should specifically clarify motor carrier actions to reduce the operational demands that may inadvertently be imposed on drivers and contribute to rollover accidents, and stipulate initiatives for improving the roll stability of cargo tank motor vehicles.

The NTSB concludes that although a rollover prevention program will not eliminate all rollovers due to driver errors, it can be effective for identifying ways for cargo tank motor vehicle drivers and management to work collaboratively to prevent rollover accidents. The NTSB recommends that the Pipeline and Hazardous Materials Safety Administration (PHMSA) work with the Federal Motor Carrier Safety Administration (FMCSA), as appropriate, to develop and disseminate guidance to assist hazardous materials carriers in implementing comprehensive cargo tank motor vehicle rollover prevention programs, including the active participation of drivers, dispatchers, and management through training, loading practices, delivery schedules, and acquisition of equipment.

Cargo Tank Crash Performance

Federal regulations associated with the structural integrity of U.S. Department of Transportation (DOT) specification cargo tanks require design calculations for the tank shell and heads to account for the load resulting from the design pressure in combination with the dynamic pressure of a longitudinal deceleration.[12] The regulations, however, do not consider the magnitude of accident impact forces imposed on the external surface of DOT specification cargo tanks. Accordingly, while current regulatory requirements account for stresses imposed by a 2 *g* or equivalent force generated by the longitudinal surge of bulk liquid impacting the interior tank head during an abrupt stop, there is no consideration for stresses imposed when accident impact forces are applied to the tank's external structure. PHMSA and industry panelists at the August 2010 NTSB public hearing maintain that this standard is still applicable today because a 2 *g* longitudinal deceleration force generated by product surge represents an extreme condition that could not be achieved by a hard brake application. However, the 2 *g* longitudinal deceleration does not represent all potential impact accident scenarios. For example, a cargo tank initially moving at 60 mph and decelerating at 2 *g* would come to a stop in 1.4 seconds after traveling a distance of 60 feet. In contrast, if a cargo tank traveling at 60 mph were to strike an immovable object and come to a stop by crushing the front head of the tank over a distance of 4 feet, the average deceleration would be 30 *g*, and the tank would come to a stop in less than 0.1 second.

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[11] *Heavy Vehicle Rollover Prevention Program*, VicRoads, Australia <http://www.vicroads.vic.gov.au/truckrollover>, accessed May 1, 2011.

[12] Title 49 CFR 178.338-3(d), Structural Integrity, and 49 CFR 178.345-8, Accident Damage Protection, Specifications for Packaging.

Specification MC331 cargo tanks (the type involved in this accident) are required to be designed to transport compressed liquefied gases under high internal tank pressures that are significantly greater than the dynamic force generated during a 2 *g* deceleration. Consequently, the 2 *g* standard does not affect the design and construction of MC331 cargo tanks but does affect other DOT specification cargo tanks that transport hazardous materials. The NTSB concludes that performance standards for impacts to the external surfaces of all DOT specification cargo tanks, under varying accident conditions, would provide objective guidance for regulators and cargo tank manufacturers in identifying appropriate designs and protective systems for mitigating the release of hazardous materials.

Statistical analysis of accident data provides a starting point for determining which DOT specification tanks are more likely to release product during rollover accidents. A review of additional information—such as the DOT specification of cargo tanks, detailed accident description, tank damage, and type of object that struck the tank—would be instrumental in identifying specific measures to protect cargo tanks and prevent the release of product after rollover accidents. For example, the higher number of shipments carried by DOT specification cargo tanks that transport petroleum may account for their greater frequency of rolling over, and such tanks' thin-wall aluminum shell construction may account for their greater risk of releasing hazardous materials than other DOT specification cargo tanks transporting bulk liquid hazardous materials. A statistical analysis of reportable incidents, for instance, may identify DOT specification tanks that were vulnerable to abrasion. Additionally, modeling impact forces and testing may identify a solution or the development of protective devices for mitigating damage that could result in the release of hazardous materials.

The current 2 *g* longitudinal deceleration standard should be supplemented by accident impact performance standards that provide guidance about how structures could withstand significant impacts under varying accident conditions without the release of hazardous materials. Such performance standards would be more meaningful in predicting the performance and safety of DOT specification cargo tanks in accident situations than the current longitudinal 2 *g* deceleration standard. Therefore, the NTSB recommends that PHMSA conduct a comprehensive analysis of all available accident data on DOT specification cargo tanks to identify cargo tank designs and the associated dynamic forces that pose a higher risk of failure and release of hazardous materials in accidents; and, once such cargo tanks have been identified, study the dynamic forces acting on susceptible structures under varying accident conditions and develop performance standards to eliminate or mitigate these risks. Further, the NTSB recommends that, once the performance standards have been developed, PHMSA require that all newly manufactured cargo tanks comply with the performance standards.

Cargo Tank Data Collection

A basic requirement for evaluating the accident performance of a particular DOT specification cargo tank (such as the MC331 involved in this accident) is access to data that can be used to quantify both the involvement of those tanks in reportable incidents and the in-service population of those same tanks. While the approximate number of DOT specification cargo tanks involved in accidents may be obtained from the Hazardous Materials Information System or other databases, there is limited access to accurate information on the population of cargo tanks by DOT specification. For example, the most precise number of petroleum-hauling

DOT 406 cargo tank semitrailers cited in the *Cargo Tank Roll Stability Study* appeared to be somewhere between 10,648–60,003 units.

When asked at the August 2010 NTSB public hearing, a PHMSA official acknowledged that the agency did not know the total number of cargo tanks by DOT specification that were currently in service.[13] Further, PHMSA indicated that data analyses for evaluating the performance of DOT specification cargo tanks could be enhanced if the population of cargo tanks by DOT specification were available. The NTSB concludes that the absence of a requirement for motor carriers to periodically provide the number of cargo tanks by DOT specification limits the ability to perform accurate trend analyses.

The limited information currently available for PHMSA to quantify the distribution of cargo tanks by DOT specification differs considerably, for example, from information that can be accessed by the Association of American Railroads (AAR) about tank cars used for transporting bulk liquids by rail. The AAR has used the Universal Machine Language Equipment Register (UMLER) equipment management information system as the industry's central repository for registered railroad and intermodal equipment since 1968. The UMLER system is updated in real time and capable of tracking equipment status, ownership, and inspection history and providing the particular fleet profile.

The population of cargo tanks by DOT specification could be obtained by modifying the *Hazardous Materials Registration Statement* (DOT Form F 5800.2) or the *Motor Carrier Identification Report* (MCS-150). Although the MCS-150 requires carriers to report the classes of hazardous materials transported and the number of cargo tank single-unit trucks and trailers that are owned and leased, no obligation exists to provide the DOT specification, age, or carrying capacity of cargo tanks. Consequently, arrangements could be made to revise the MCS-150 form to regularly require all intrastate and interstate hazardous materials carriers to provide basic information about a cargo tank motor vehicle's manufacture date, carrying capacity, DOT specification, and other pertinent information for conducting risk assessments. Therefore, the NTSB is recommending that DOT require all intrastate and interstate hazardous materials carriers to submit annually the number and types of DOT specification cargo tanks that are owned or leased in addition to data displayed on the specification plates of such tanks and, if necessary, modify the appropriate database to accept additional data fields.

Therefore, the National Transportation Safety Board makes the following recommendations to the Pipeline and Hazardous Materials Safety Administration:

> Work with the Federal Motor Carrier Safety Administration, as appropriate, to develop and disseminate guidance to assist hazardous materials carriers in implementing comprehensive cargo tank motor vehicle rollover prevention programs, including the active participation of drivers, dispatchers, and management through training, loading practices, delivery schedules, and acquisition of equipment. (H-11-4)

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[13] Testimony delivered by Charles H. Hochman, Director, Office of Hazardous Materials Technology, August 4, 2010, at NTSB public hearing concerning the Indianapolis rollover accident.

Conduct a comprehensive analysis of all available accident data on U.S. Department of Transportation specification cargo tanks to identify cargo tank designs and the associated dynamic forces that pose a higher risk of failure and release of hazardous materials in accidents. Once such cargo tanks have been identified, study the dynamic forces acting on susceptible structures under varying accident conditions and develop performance standards to eliminate or mitigate these risks. (H-11-5)

Once the performance standards in Safety Recommendation H-11-5 have been developed, require that all newly manufactured cargo tanks comply with the performance standards. (H-11-6)

The NTSB also issued safety recommendations to DOT, the FMCSA, the National Highway Traffic Safety Administration (NHTSA), the Federal Highway Administration, and AASHTO. Additionally, this report reclassifies previously issued recommendations to NHTSA and AASHTO.

In response to the recommendations in this letter, please refer to Safety Recommendations H-11-4 through -6. If you would like to submit your response electronically rather than in hard copy, you may send it to the following e-mail address: correspondence@ntsb.gov. If your response includes attachments that exceed 5 megabytes, please e-mail us asking for instructions on how to use our secure mailbox. To avoid confusion, please use only one method of submission (that is, do not submit both an electronic copy and a hard copy of the same response letter).

Chairman HERSMAN, Vice Chairman HART, and Members SUMWALT, ROSEKIND, and WEENER concurred in the issuance of these recommendations.

Original Signed By

By: Deborah A.P. Hersman
Chairman