Log H-562

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

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In reply refer to: H-92-1 through -6

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Administrator
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Between January and May 1991, the National Transportation Safety Board investigated seven highway accidents in which Department of Transportation (DOT) specification MC 306 or MC 312 cargo tanks overturned and hazardous materials were released through damaged closures or fittings on top of the tanks. Under DOT regulations, all of the tanks were required to have rollover protection for the fittings on the top of the tanks. All of the tanks were equipped with rails or guards attached to the tank to provide that protection. The failure of the devices to provide adequate rollover protection raised concerns about their performance, and about the adequacy and enforcement of the DOT requirements regarding the structural integrity and the configuration of the rollover protection devices. The Safety Board has addressed these issues in a special investigation on cargo tank rollover protection.[1]

The release of hazardous materials in each of the seven accidents occurred because closure fittings on top of the tanks were either damaged or forced open after striking the ground or objects along the roadway. The closure fittings were vulnerable to damage because the rollover protection guards structurally failed in three of the accidents (Albuquerque, New Mexico; Hamilton, Ohio; and Ethelsville, Alabama), and were not adequately shielded from external impacts in the remaining four accidents (Lantana, Florida; Edenton, North Carolina; Columbus, Georgia; and Bronx, New York).

All of the accidents occurred under conditions and in locations that are common to the transportation environment. Consequently, the Safety Board believes that the seven accidents provide a reasonable measure of the performance of the rollover protection devices on each cargo tank.

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[1] The special investigation report contains more detailed information: "Cargo Tank Rollover Protection," Hazardous Materials Special Investigation Report NTSB/SIR-92/01.

The cargo tanks involved in the accidents were constructed between 1979 and 1991. The applicable DOT design requirements for these tanks and all other specification MC 306 and MC 312 bulk liquid cargo tanks, as well as MC 307 tanks, were contained in Title 49, Code of Federal Regulations (CFR), Sections 178.340 through 178.343. In June 1989, the Research and Special Programs Administration (RSPA) issued comprehensive amendments to the regulations for the design and manufacture of all DOT specification bulk liquid cargo tanks. The amendments included more stringent requirements pertaining to the design, construction, certification, and testing of the cargo tanks, manholes, closure valves, pressure relief devices, and devices for accident damage protection. Because of these extensive changes, cargo tanks constructed under the new regulations given in 49 CFR 178.345 to 178.348 will be designated as specification DOT 406, DOT 407, and DOT 412 cargo tanks, and will supersede the existing MC 306, MC 307, and MC 312 cargo tanks. The effective date of these amendments, and subsequent amendments published in September 1990, became December 31, 1990; however, the RSPA also authorized a transition period between December 31, 1990, and August 31, 1993, during which new MC 306, MC 307, and MC 312 cargo tanks may continue to be constructed under the provisions of 49 CFR 178.340 through 178.343.

Structural Integrity of the Rollover Protection Devices

The regulations require that if guards are used as rollover protection, they must be designed and installed to withstand specified minimum vertical and horizontal loads. Engineers at the RSPA stated that the RSPA expects cargo tank manufacturers, as a minimum, to perform "straightforward" stress calculations to determine if rollover protection guards meet the design loads required by the DOT performance standards.

Because of the structural failure of the rollover protection devices on the cargo tanks involved in the Albuquerque, Hamilton, and Ethelsville accidents, calculations were requested from Acro Trailer Company, New Progress, Incorporated, and Fruehauf Corporation, respectively. According to the manufacturers' calculations, the rollover protection devices on the cargo tanks exceed the minimum design loads that were required under 49 CFR 178.340-8. However, evaluation of Acro's calculations by the RSPA and of New Progress' calculations by a Safety Board metallurgical engineer indicates that the rollover protection on the cargo tanks involved in the Albuquerque and Hamilton accidents did not comply with the minimum design loads: the RSPA determined that the rollover guards that failed on the cargo tank in the Albuquerque accident did not meet the minimum horizontal strength requirements, and calculations of the Safety Board engineer indicate that the rollover protection side rails on the cargo tank in the Hamilton accident did not meet the minimum horizontal strength requirements. Calculations of the Safety Board engineer demonstrated that the rollover protection rails on the Fruehauf-manufactured cargo tank in the Ethelsville accident did meet the minimum horizontal and vertical strength requirements.

Based on the RSPA evaluation and the Safety Board engineer's calculations, the Safety Board concludes that the rollover protection devices on the cargo tanks involved in the Albuquerque and Hamilton accidents failed

to comply with the bending load requirements of 49 CFR 178.340-8(c). The Safety Board is concerned that other Acro and New Progress tanks may not meet the load requirements of 49 CFR 178.340-8(c). Enforcement of the highway cargo tank design and safety standards is the responsibility of the Federal Highway Administration (FHWA); however, FHWA officials indicate that currently no one in the FHWA who is involved with motor carrier safety has the knowledge to review, evaluate, and determine if the cargo tanks comply with the design loading requirements. Thus, the Safety Board believes that the RSPA should assist the FHWA to evaluate all designs of rollover protection devices installed on cargo tanks manufactured by the Acro Trailer Company and by New Progress, Incorporated, to determine if the cargo tanks comply with existing DOT standards.

Acro and New Progress failed to provide sufficiently detailed calculations to demonstrate that the rollover protection devices on their tanks satisfied DOT requirements. Further, they did not consistently interpret the DOT performance standard and did not uniformly apply appropriate formulas to calculate the required loads. The RSPA also indicated that it had difficulties in evaluating Acro's calculations because they were not sufficiently detailed. As a result, the RSPA had to make certain assumptions by using a "best-case" scenario. Also, the Safety Board engineer, who reviewed the calculations submitted by New Progress and made his own calculations, stated that a simple application of the loading formulas was not possible because of the structural complexity of the rollover protection rails. The Safety Board engineer also noted that because the FHWA and the RSPA had no written guidance or interpretations regarding accepted methods and assumptions for calculating the loads, he had to make certain assumptions about the application of the design loads.

A performance standard must be consistently interpreted and uniformly applied to be effective. Therefore, users of a performance standard, such as cargo tank manufacturers, must have sufficient guidance about the factors and assumptions that should be considered before the user can be expected to interpret and apply the standard in a consistent manner. The Truck Trailer Manufacturers Association (TTMA) and several firms involved with the design and construction of cargo tanks have also complained about the lack of written guidance from the DOT on how to calculate the loads and how to determine if the rollover protection devices, as designed, meet DOT performance standards.

Consequently, the Safety Board does not agree with the RSPA that the calculations are necessarily "straightforward" and obvious to all tank manufacturers, or even to the RSPA. Further, the Safety Board concludes that the lack of sufficient guidance from the RSPA about the factors and assumptions that a cargo tank manufacturer must consider when calculating the loads on the rollover protection devices could have contributed to the failure of Acro and New Progress to submit adequate and complete calculations.

The Safety Board notes that the Federal Aviation Administration (FAA) publishes advisory circulars that provide specific guidance to the aviation community regarding acceptable methods for complying with certain FAA

regulations, and that the RSPA's Office of Pipeline Safety published a guidance manual in 1985 for operators of small gas systems.[2] The Administrator of the RSPA noted in an introductory letter to the manual that the manual was "developed to provide a broad and general overview of your compliance responsibilities." The Administrator further noted that the manual "gives specific details for methods of operations and selection of materials which will meet the pipeline safety standards requirements." The RSPA's Office of Pipeline Safety has also endorsed the American Gas Association's written guide[3] to pipeline operators as being of "significant assistance to gas piping system operators in their efforts to comply" with the Federal regulations for the transportation of natural gas and other gases by pipeline (49 CFR Part 192). The Safety Board therefore believes that the RSPA can and should similarly provide cargo tank manufacturers with specific written guidance about the factors and assumptions that must be considered when calculating the loads on the cargo tank rollover protection devices.

Justification of Design Loads

There is no record documenting the basis of the design loads for rollover protection guards or devices for the MC 300 series cargo tanks in the RSPA's "History of Section" files.[4] The RSPA files indicate, however, that the design loads were developed during a 1966 conference. According to the RSPA, it has no records that indicate how the design loads for rollover protection devices were derived. The TTMA stated that the design requirements for these tanks were first published in draft form in 1966 by the Interstate Commerce Commission (ICC), which then had the regulatory responsibilities related to safety requirements for cargo tanks that were later transferred to the DOT. The TTMA also indicated that its members did work with the ICC in the development of these standards. An engineer with Fruehauf Corporation, who was involved with the development of these design requirements, does not recall the justification for the design loads. Further, the director of engineering for the Heil Company, another cargo tank manufacturer, stated that the design loads were not based on testing and that no one could quantify the type or severity of accident to be protected against.

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[2] Research and Special Programs Administration. 1985. Guidance manual for operators of small gas systems. U.S. Department of Transportation, Research and Special Programs Administration, Information Services Division, 400 Seventh St., S.W., Washington, DC 20590. 227 p.

[3] American Gas Association. 1990. Guide for gas transmission and distribution piping systems. American Gas Association, 1515 Wilson Boulevard, Arlington, VA 22209. 351 p.

[4] These files, kept with the RSPA's dockets on regulatory rulemakings, trace the development of each section of the hazardous materials regulations. The files have not been updated since 1979.

In its 1985 Notice of Proposed Rulemaking[5] to revise the requirements for cargo tanks, the RSPA noted that the most common highway accident involving loss of cargo tank lading is a rollover. The RSPA also stated in the notice that the top of the cargo tank is one of the "most vulnerable areas" and that "the rollover damage protection system can receive lateral [tangential] loads that equal or exceed the normally applied load." The RSPA, therefore, proposed that the tangential design load for rollover protection devices should be increased to twice the weight of the cargo tank motor vehicle and each device should be capable of supporting at least one-fourth of the load. There is no indication in the notice, however, that the proposed increase in the tangential loading standard was based on testing or on modeling that estimated the dynamic forces acting upon the rollover protection devices during a rollover. A RSPA engineer indicated that the proposed standard for tangential loading was derived from the previous specifications in 49 CFR 178.340-8 without additional research.

The RSPA and the FHWA, however, did jointly sponsor simulated rollover tests in the late 1970s and early 1980s for purposes other than determining rollover protection standards.[6] The results of the tests indicate that the forces that act upon a tank and its rollover protection devices in a typical rollover accident can easily exceed the design loads that were required for the MC 306, MC 307, and the MC 312 specification cargo tanks, and that are now required for the new DOT 406, DOT 407, and DOT 412 specification cargo tanks. Evidence from the Ethelsville, Alabama, accident also indicates that the required design loads were inadequate to provide rollover protection: calculations of the Safety Board engineer indicated that the rollover protection rails met the minimum loading standards; however, the structural failure of these rails contributed to the release of the cargo.

The National Aeronautics and Space Administration (NASA) has used computer programs employing finite element analysis to design cargo tanks to transport rocket fuels and other highly poisonous and reactive materials. Although the NASA-designed cargo tanks are comparable to DOT specification MC 338 cargo tanks that are typically used for cryogenic materials, NASA used the computer models to evaluate the forces and stresses that were likely to be generated during different accident situations, including frontal impacts, side impacts, falls from an overpass onto the tank top, and fire conditions. The RSPA had suggested that NASA consider that the tanks be designed for these accident conditions because of the hazards of the materials being

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[5] Federal Register, Vol. 50, No. 180, dated September 17, 1985, page 37766. The rulemaking action resulted in the amendments that were issued in June 1989.

[6] Tyndall, L. H.; Leananen, D. H.; Gauthier, D. [Dynamic Science, Inc.]. 1980. Cost-effective methods of reducing leakage occurring in overturns of liquid-carrying cargo tanks--overturn integrity of MC-306-type cargo tanks. DOT-FH-11-9494. Washington, DC: U.S. Department of Transportation, Federal Highway Administration, Bureau of Motor Carrier Safety. 2 vol.

transported and to ensure that the tanks would meet the performance standards that the RSPA believed could later be required.

Representatives from the FHWA and the TTMA indicated that they were not aware of any additional research about the types and magnitudes of forces generated in a rollover accident, or of any studies that attempted to characterize the most common damage incurred in a rollover accident. Because of the lack of any subsequent research by the cargo tank manufacturing industry or the DOT, there is inadequate information about the forces that can be encountered in a rollover accident and, therefore, about the extent to which cargo tanks can reasonably be designed to withstand these forces.

The Safety Board believes the DOT and the industry should establish reasonable and effective performance standards based on work similar to that done by NASA to model and analyze forces acting upon a cargo tank under different accident conditions. To be effective, the design loads required in the standards for rollover protection devices must be based on the forces that can be expected to act upon them during a rollover accident. The design loads must, therefore, be based on appropriate engineering modeling and analysis of such forces if a tangible safety benefit is to be realized. Because the design loads specified in 49 CFR 178.340-8(c) for the older MC series specification cargo tanks and the standards of 49 CFR 178.345-8(c) for the new DOT specification 406, 407, and 412 cargo tanks have not been determined from engineering modeling and analysis, the design loads for the rollover protection devices may not be sufficient to adequately protect against the structural failure of the devices during a rollover accident.

The Safety Board, therefore, believes that the RSPA should assist the FHWA to (1) model and analyze the forces that can act upon rollover protection devices on bulk liquid cargo tanks during a rollover accident; (2) promulgate performance standards that are based on the engineering models and analyses of these forces; and (3) establish a program to phase out from hazardous materials service the use of all cargo tanks that fail to meet the new performance standards. Some cargo tanks currently in use may be capable of being modified to meet the new performance standards.

Protection and Shielding

In the accidents that occurred in Lantana, Bronx, Edenton, and Columbus, the cargoes were released because the fittings on top of the tanks were not adequately protected and shielded from impact with the ground or objects along the roadway. The configuration of the rollover protection devices on these four cargo tanks was inadequate to prevent objects along the roadside from striking the top fittings and causing the release of cargo.

The FHWA and the RSPA have not issued any guidance or interpretations that address details about the design of the guards. The specific design of these guards was and is left to the cargo tank manufacturer. The RSPA has indicated that it is not necessary to issue specific guidelines for the design of components on cargo tanks, and that the role of the DOT is to

publish performance requirements and allow the industry the flexibility to meet those requirements.

The performance standard in 49 CFR 178.340-8(c) for the MC 306, 307, and 312 cargo tanks required that top-mounted closures be protected from damage that would result in leakage, whereas the performance standard in 49 CFR 178.345-8(a) for the new DOT specification 406, 407, and 412 cargo tanks requires the tanks to be designed and constructed to minimize the potential for the loss of lading due to an accident. The Safety Board recognizes that the regulations establish performance standards rather than specific design standards for rollover protection devices. Consequently, the regulations do not address details such as the minimum vertical clearances between the rollover protection guards and the fittings, configurations to prevent the intrusion of roadside objects into the area enclosed by the rollover protection guards, or other methods to shield the top fittings. The Safety Board believes, however, that these performance standards should be supplemented by sufficiently detailed guidance and interpretations about acceptable means to comply with the performance standard. For example, details about configurations that provide an acceptable level of shielding and protection, such as the configuration on the NASA-designed cargo tank, could be included in advisory circulars provided to the cargo tank industry. Consequently, the Safety Board concludes that the lack of written guidance, not only about the calculation of the design loads for the rollover devices but also about the protection and shielding of top-mounted fittings on bulk liquid cargo tanks, has resulted in designs and configurations of rollover protection devices that fail to provide an adequate level of protection. The Safety Board, therefore, believes that the RSPA should develop detailed written guidance about acceptable means to shield and protect the top-mounted closure fittings on all bulk liquid cargo tanks.

Accident Data Collection and Evaluation

To determine the frequency of rollover accidents resulting in damage to the top fittings and release of the cargo, the Safety Board compared the accident data from the RSPA and the FHWA computerized data bases for 1987, 1988, and 1989. The RSPA accident data base indicated there were an average of 89 reported rollover accidents involving a cargo tank and release of cargo annually, whereas the FHWA data base indicated an average of 86 such accidents annually. The FHWA data base further indicated an annual average of 74 reported rollover accidents without a release of cargo for this same time period. The FHWA data base does not identify the mode of failure, such as a puncture of the tank shell or a damaged fitting. The RSPA data base does identify damage to fittings but does not document whether the damage was to top-mounted fittings or to other fittings on a tank. The RSPA introduced a revised hazardous materials incident form on January 1, 1990, that distinguishes damage to top-mounted fittings from other fittings. For 1990, the first complete year the revised report forms were in use, the data base identified 96 accidents that involved the rollover of a cargo tank vehicle and some release of the cargo. The top-mounted fittings were damaged in 37 of these accidents.

The University of Michigan Transportation Research Institute (UMTRI) has estimated that for 1984 and 1985, about 1,046 accidents per year occurred in which the rollover of a cargo tank semitrailer combination transporting hazardous materials was either the primary or secondary accident event. Hazardous materials were released in 669 of these accidents; the UMTRI did not specify, however, the number of accidents in which the release occurred through top-mounted fittings. The UMTRI's estimate is based on a comparison of FHWA accident data for 1984 and 1985 with the National Accident Sampling System, which uses a probability-based sampling procedure to estimate all accidents reported to the police, and UMTRI's own data base that documents all truck accidents involving a fatality. The UMTRI acknowledged that the estimates have statistical limitations because there is no existing national accident file that has the detail and coverage to provide a direct estimate of the number of cargo tank rollover accidents.

The FHWA, with the assistance of the National Governor's Association, is implementing a new database that will collect accident data directly from all the State governments. As of December 1991, 20 States are participating in this effort. This file will have some cargo tank rollover data; however, it will not include information needed to precisely identify the type of damage to the cargo tank.

The Hazardous Materials Transportation Uniform Safety Act, enacted November 16, 1990, requires the DOT to expand the application of its hazardous materials regulations to include intrastate commerce. According to the RSPA and the FHWA, each agency is drafting proposed rulemaking that will address the reporting of hazardous materials accidents and incidents involving intrastate carriers. Because the proposed rulemaking has not yet been released for comments, the Safety Board does not know if all intrastate carriers transporting hazardous materials will be subject to the new requirements.

Despite the statistical limitations of the UMTRI's estimate of the number of rollover accidents involving the release of hazardous cargo during 1984 and 1985, the Safety Board is concerned that this estimate, 669 accidents per year, is more than 7 times greater than the average number of accidents reported per year to the FHWA and the RSPA from 1987 through 1989. Further, an FHWA staff analyst estimates that accidents are underreported to the FHWA by about 50 percent. Evidence from the Safety Board's special investigation on cargo tank rollover protection also demonstrates underreporting. Of the seven accidents that were part of the special investigation, six apparently met the reporting requirements of the FHWA and the RSPA; yet reports for only three of the six accidents (Albuquerque, Lantana, and Bronx) were on file with the FHWA as of December 10, 1991, and reports for four of the six (Ethelsville, Albuquerque, Lantana, and Bronx) were on file with the RSPA as of December 10, 1991.

The seventh accident (Hamilton) involved an intrastate carrier transporting a DOT specification cargo tank. Intrastate carriers are likely to use DOT specification cargo tanks for the transportation of bulk liquids, particularly gasoline and fuel oil, but such carriers are not subject to the

current reporting requirements of the FHWA or the RSPA when transporting these cargoes.

In addition to the underreporting of accidents, inadequately reported and recorded information can also mask trends or a specific pattern of performance. For example, an accident in which a vehicle with a DOT specification cargo tank collides with another vehicle and then overturns may be reported to the FHWA as a collision accident. It may not be identified as a rollover accident in FHWA's data base because the FHWA data base does not identify secondary accident events. Further, if hazardous materials were not released in such an accident, the accident would not have to be filed with the RSPA even though a DOT specification cargo tank was involved. In this example, the cargo tank might have retained its cargo, released a nonhazardous cargo, or might have been empty. The damage to the tank and whether a release of cargo occurred should still be of interest to the RSPA and the FHWA. Consequently, the failure to identify secondary accident events or to record other damage information prevents an accurate evaluation of accident performance.

Because accidents appear to be underreported and current accident data collection and recording procedures can result in the masking of accident trends, the Safety Board concludes that the FHWA and the RSPA cannot rely on their accident data bases to identify important trends and potential problems related to the design and construction of bulk liquid cargo tanks. Consequently, the Safety Board believes that the FHWA and the RSPA should implement a program to collect information necessary to identify patterns of cargo tank equipment failures, including the reporting of all accidents involving any DOT specification cargo tank.

Therefore, as a result of its special investigation, the National Transportation Safety Board recommends that the Research and Special Programs Administration:

> Provide cargo tank manufacturers with specific written guidance about (a) the factors and assumptions that must be considered when calculating the loads on cargo tank rollover protection devices in determining compliance with existing Department of Transportation performance standards; and (b) acceptable means to shield and protect the top-mounted closure fittings on all bulk liquid cargo tanks. (Class II, Priority Action) (H-92-1)

> Assist the Federal Highway Administration to evaluate the design of the rollover protection devices installed on all cargo tanks manufactured by the Acro Trailer Company and by New Progress, Incorporated, to determine if the cargo tanks comply with existing Department of Transportation standards. (Class II, Priority Action) (H-92-2)

Assist the Federal Highway Administration to improve the performance of the rollover protection devices on bulk liquid cargo tanks by:

- Modeling and analyzing the forces that can act upon rollover protection devices during a rollover accident. (Class III, Longer Term Action) (H-92-3)

- Promulgating performance standards for rollover protection devices that are based on the engineering modeling and analysis conducted in response to Safety Recommendation H-92-3. (Class III, Longer Term Action) (H-92-4)

- Phasing out from hazardous materials service the use of all cargo tanks that fail to meet the new performance standards promulgated in response to Safety Recommendation H-92-4. (Class III, Longer Term Action) (H-92-5)

Implement, in cooperation with the Federal Highway Administration, a program to collect information necessary to identify patterns of cargo tank equipment failures, including the reporting of all accidents involving a Department of Transportation specification cargo tank. (Class III, Longer Term Action) (H-92-6)

Also as a result of its special investigation, the Safety Board issued recommendations to the Federal Highway Administration.

Chairman KOLSTAD, Vice Chairman COUGHLIN, and Members LAUBER, HART, AND HAMMERSCHMIDT concurred in these recommendations.

By: Susan M. Coughlin
Acting Chairman