National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: May 4, 2012

In reply refer to: H-12-1

The Honorable Anne S. Ferro
Administrator
Federal Motor Carrier Safety Administration
Washington, D.C. 20590

On July 15, 2009, about 8:00 a.m., a cargo transfer hose ruptured shortly after transfer of anhydrous ammonia began from a Werner Transportation Services, Inc. (Werner) cargo tank truck to a storage tank at the Tanner Industries, Inc. (Tanner) facility in Swansea, South Carolina. A white cloud of anhydrous ammonia, a toxic-by-inhalation gas,[1] moved from the parking lot of the facility across U.S. Highway 321 to a largely wooded area, where it eventually dissipated. About the same time, a motorist traveling north on the highway drove into the ammonia cloud, apparently tried to get away from the cloud, then got out of her car and died of ammonia poisoning. Fourteen people reported experiencing minor respiratory problems or dizziness as a result of the anhydrous ammonia release and were evaluated by emergency medical services (EMS) on scene. Of those 14, 7 displayed symptoms that required EMS to transport them for further evaluation at an emergency department; they were treated and released the same day. The anhydrous ammonia cloud caused temporary discoloration of vegetation in the area, including the leaves on the trees. Residents in the area sheltered in place, and U.S. Highway 321 was closed until about 2:00 p.m. on the day of the accident. The Lexington County Fire Service arrived on scene about 8:07 a.m. Property damage and losses were limited to the ruptured hose and about 6,895 pounds of the anhydrous ammonia that was released.[2]

The National Transportation Safety Board (NTSB) determined that the probable cause of the accident was Werner Transportation Services, Inc.'s use of a cargo hose assembly that was not chemically compatible with anhydrous ammonia. Contributing to the accident was the lack of explicit requirements by the Pipeline and Hazardous Materials Safety Administration (PHMSA) that the motor carrier and the facility carrier verify that the cargo hose assembly is chemically compatible with the product to be transferred before transfer operations begin.

[1] The U.S. Department of Transportation (DOT) classifies anhydrous ammonia as a Hazard Class 2 nonflammable gas. Anhydrous ammonia is a colorless liquid or gas that is both poisonous and corrosive and that has an intense, pungent, suffocating odor.

[2] See *Cargo Hose Rupture and Release of Anhydrous Ammonia during Offloading of a Werner Transportation Cargo Tank Motor Vehicle at the Tanner Industries Plant near Swansea, South Carolina, July 15, 2009*, Hazardous Materials Accident Report NTSB/HZM-12/01 (Washington, D.C.: National Transportation Safety Board, 2012) on the NTSB website at <http://www.ntsb.gov>.

Accident Hose Assembly

The ruptured transfer hose was manufactured by Durodyne, Inc.,[3] in 2005. The hose, Durodyne product number DD-G-220, was designed for liquefied petroleum gas (LPG) transfer only and was constructed of several different layers of material that are chemically compatible with LPG, but not with anhydrous ammonia. The innermost layer of the hose was made of nitrile rubber, followed by three sequential layers of polyethylene terephthalate (PET) yarn braids encased in chloroprene rubber and an outer layer of neoprene rubber. The PET yarn braids are used to mechanically reinforce the hose, and they provide the hose with the majority of its strength. The hose had been approved by Underwriters Laboratories Incorporated (UL) and met the UL 21[4] standard for LPG hose.

The hose was imprinted with text. One side of the black neoprene cover of the hose featured a blue Mylar stripe extending along the length of the hose with the Durodyne logo and "DD-G-220 LPG TRANSFER ONLY 350 PSI MAX WP" printed in black. The phrases "To prevent serious injury or property damage use for intended purpose only," "Warning: Use of damaged hose could be hazardous; inspect hose and couplings prior to each use," and "Textile reinforcements meet UL21" were also embossed along the imprinted blue Mylar stripe. The opposite side of the hose had "DURODYNE DD-G-220 LPG HOSE UL21 ISSUE E-7874 MH29239 SPEC DD-G-220 TEXTILE BRAID WP 350 PSIG 4Q05 INSPECT HOSE BEFORE USE" embossed on an imprinted stripe extending the length of the hose. (See figure 1.)

Figure 1. Blue Mylar and imprinted stripes on accident hose.

[3] In August 1999, Durodyne was purchased by Argo Tech Costa Mesa. In 2007, Eaton Corporation purchased Argo Tech, including the Durodyne unit.

[4] UL standard 21, for LPG hose, covers hose and hose assemblies in sizes up to and including a nominal internal diameter of 4 inches for conveying LPG.

Smart-Hose Technologies of Philadelphia, Pennsylvania, purchased the LPG transfer hose from Durodyne and installed the Smart-Hose safety system to fabricate the complete accident hose assembly as a Lifeline III LPG Transfer Hose. The Smart-Hose safety system consists of an internal cable running through the bore of the hose connected to specially designed unseated flapper valves located on each end of the cable. In the event of hose or coupling separation, catastrophic hose rupture, or excessive hose stretching, the system is designed to shut off the flow of LPG in both directions as the flapper valves release and instantly seat.

The Smart-Hose assembly consisted of a 238-inch-long 1/4-inch 1x19 galvanized steel strand cable with a nylon coating down the bore of a 216-inch-long piece of Durodyne LPG transfer hose. Each end of the cable was connected to a valve flapper made from 316 stainless steel.[5] The flappers were connected to 2-inch-diameter 316 stainless steel female national pipe thread end fittings on each end of the hose. The end fittings were secured to the hose by 2-inch ferrules crimped onto each end of the hose, which completed the Smart-Hose assembly and held the cable in compression. Records indicate that the hose assembly was 222 inches (18 1/2 feet) long. Smart-Hose issued a new hose test certification for this hose assembly, serial number 10573, on October 18, 2005.

Each end of the hose also had a male acme hammer lock coupling made of cast iron and carbon steel that threaded into each end fitting. This type of coupling is not acceptable in LPG applications because of sparking issues, but it is appropriate for anhydrous ammonia applications. According to Smart-Hose Technologies, these couplings were not installed by or purchased from Smart-Hose at the time Smart-Hose completed the hose assembly. Werner purchased the transfer hose assembly from Gas Equipment Company, Inc. of Indianapolis, Indiana, on December 20, 2005. The invoice for the purchase does not include any information about the couplings, such as whether the couplings were purchased from or installed by Gas Equipment Company. Additionally, no other records or receipts were found that identified the company that installed the couplings. As a result, NTSB investigators were unable to determine when the hammer lock couplings were installed and who installed them.

Postaccident Testing and Analysis of Accident Hose Assembly

On September 9, 2009, the LPG transfer hose assembly was examined at the NTSB's Materials Laboratory in Washington, D.C., in the presence of the parties to the investigation. The overall length of the hose assembly was 18 1/2 feet. The measured length of the hose from end fitting to end fitting was 18 feet. At the time of construction, Smart-Hose certified the length of the hose assembly, not including the couplings, as 18 1/2 feet.[6] The rupture in the hose was about 5 1/2 inches long. The centerline of the rupture was located 131 inches from the A end[7] and 91 inches from the B end of the hose assembly.

[5] Type 316 stainless steel is an austenitic chromium nickel stainless steel containing molybdenum. Because of its superior corrosion and oxidation resistance, good mechanical properties, and fabricability, 316 stainless steel has applications in many sectors of industry, including its use for the manufacture of tanks and storage vessels for corrosive liquids.

[6] Smart-Hose literature states that these hoses may contract up to 3 percent when pressurized. Therefore, an 18 1/2-foot hose could contract 6 inches or more (that is, 3 percent of 18 1/2 feet, or 222 inches, is 6.66 inches).

[7] The "A" and "B" ends of the hose assembly were arbitrarily chosen and labeled by the NTSB's Materials Laboratory for reference use only.

The exterior surfaces of the hose assembly contained only superficial abrasions. No gouges, slices, or other defects were noted on the surface of the hose, including the areas adjacent to and abutting the rupture area. The black text on the blue Mylar stripe was abraded in multiple locations so that the stenciling along the length of the hose could not be read; however, several sections of the hose assembly were free of abrasions or stains, and the text could be read. The embossed text on the imprinted line could be read along the length of the hose assembly.

Fractographic[8] evidence indicates that the rupture in the accident hose assembly initiated on the interior wall of the hose and propagated outward. The NTSB's Materials Laboratory identified a definitive fracture origin on the surface of the fracture that was indicative of relatively slow crack growth. Several secondary cracks were noted in the interior wall of the hose near the fracture origin; however, the interior surface did not appear to be degraded from anhydrous ammonia exposure.

The reinforcing fibers in the two innermost PET braid layers of the hose assembly appeared to be severely damaged on both halves of the fracture surface along the entire length of the ruptured area. In some parts of the ruptured area, the fibers were clumped together and appeared to be encased in salt-like particles. Laboratory analysis of the hose assembly revealed that the fibers in the two innermost PET braid layers were degraded to the point that they were brittle and friable when strained or mechanically flexed. (See figure 2.)

[8] *Fractography* is the study of the fracture surfaces of materials.

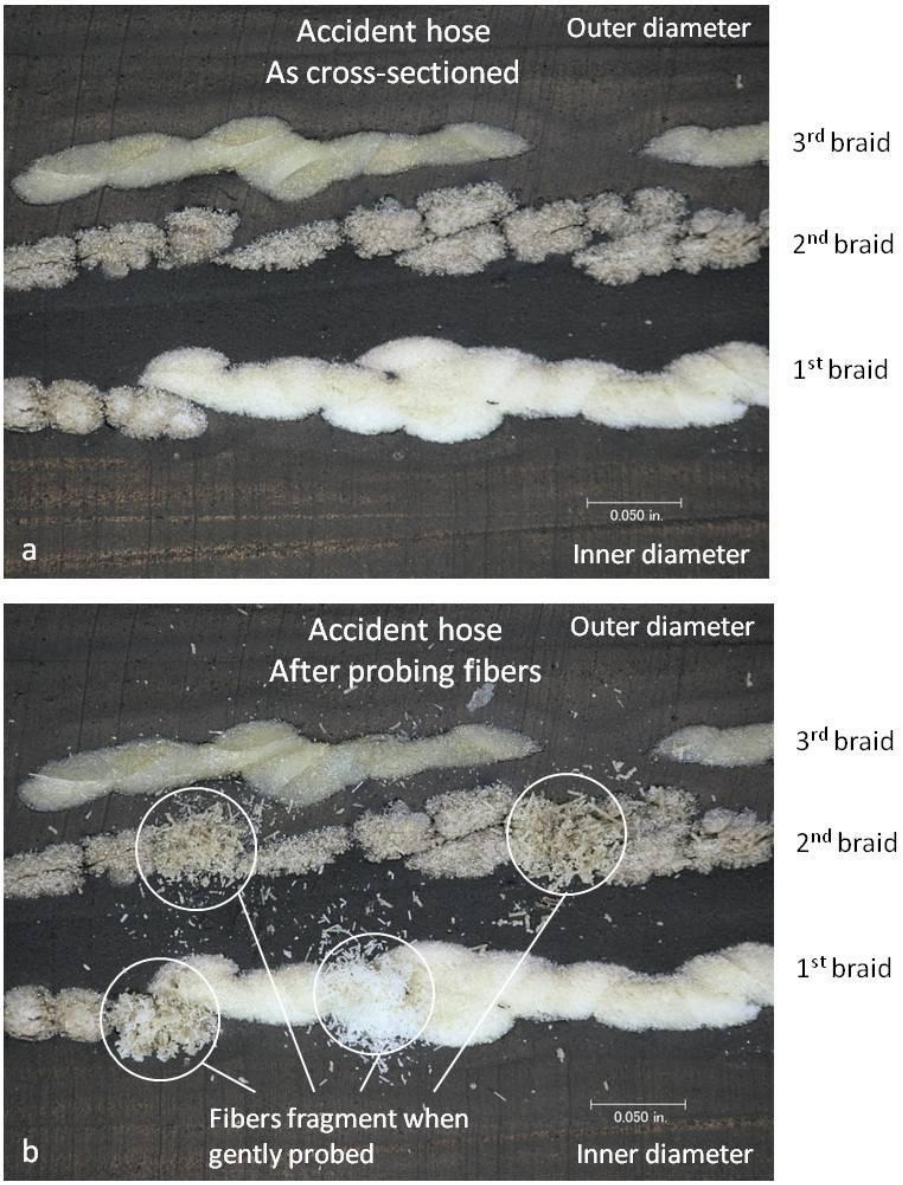

Figure 2. Cross-section of accident hose showing brittleness of fibers in two innermost PET braid layers.

The PET used for the yarn braids is not chemically resistant to anhydrous ammonia or ammonium hydroxide. As documented in several studies,[9] exposure to anhydrous ammonia or ammonia-related compounds results in a chemical reaction (ammonolysis) that can cause PET fibers to degrade and lose strength.

[9] (a) C. Lorenzetti, et. al., "Chemical Recovery of Useful Chemicals from Polyester (PET) Waste from Resource Conservation: A Survey of State of the Art," *Journal of Polymers and the Environment*, vol. 14, no. 1 (2006), pp. 89–101. (b) V. Sinha, et. al., "PET Waste Management by Chemical Recycling: A Review," *Journal of Polymers and the Environment*, vol. 18, no. 1 (2008). (c) M. Khaddaj, et. al., "Processing of New Materials Using Thermal and Thermo-Vaporous Treatment of Terephthalates," *Journal of Physics*, Conference Series 121 (2008). (d) R. Lamparter, et. al., "Process for Recovering Terephthalic Acid from Waste Polyethylene Terephthalate, United States Patent 4542239, September 17, 1985. (e) W. Murdoch, "Production of Terephthalic Acid and Ethylene Glycol from Polyethylene Terephthalate by Ammonolysis," United States Patent 6723873, April 20, 2004.

The outer rubber layer of the accident hose had an array of small pinpricks along its length that was intended to allow the product that it was transferring to permeate through the rubber layers of the hose and escape to the atmosphere. The purpose of this is to prevent gas from becoming trapped in the hose wall and damaging the hose; this pinprick design is standard in rubber hoses for LPG and anhydrous ammonia service. When the anhydrous ammonia permeated through the rubber layers of the accident hose, it collected in the interstitial spaces of the fibers within the PET braids. Also, the accident hose was likely exposed to moisture, including humidity and rain, throughout its life cycle. Any absorbed and dissolved moisture contained in the accident hose likely would have converted the trapped anhydrous ammonia to ammonium hydroxide, leading to chemical degradation of the PET fibers.

Testing completed by both the NTSB's Materials Laboratory and an independent laboratory[10] confirms that the PET fibers in the accident hose had sustained chemical degradation that dramatically reduced the strength of the PET fiber. The NTSB concluded that the accident hose failed because it was not chemically compatible with the anhydrous ammonia in the cargo tank and that caused the chemical degradation, loss of mechanical strength, and ultimate failure of the cargo hose.

Use of Chemically Incompatible Hose

When making deliveries, Werner drivers sometimes used facility-owned hoses instead of the hose on the cargo tank vehicle. It is not known how many times the accident hose assembly was used to transfer anhydrous ammonia before it failed.

Following the accident, a NTSB investigator discovered that the accident hose was the LPG transfer hose that was originally assigned to trailer 2322, not the accident trailer (that is, trailer 3002). Further investigation revealed that an anhydrous ammonia transfer hose manufactured by Goodall Canada Inc. was carried on board trailer 2322 at the time of the accident. According to records and statements from Werner, trailers 2322 and 3002 were stored on the same secure lot in Tampa, Florida, for a several hours on May 17, 2009. Although Werner stated that neither of its drivers had admitted to exchanging the transfer hoses, no other opportunity existed for the LPG transfer hose to be placed on the accident trailer. Based on its records, Werner estimated that the accident hose was used to unload anhydrous ammonia between 2 and 12 occasions.

The physical properties of hazardous materials vary so greatly that cargo hoses are constructed and intended for use with specific products and cannot be used interchangeably. As previously noted, the hose in the accident hose assembly had internal fibers made of PET, which is not chemically compatible with anhydrous ammonia. Therefore, any cargo hose containing PET fibers would not be suitable for anhydrous ammonia service. The need for chemical compatibility applies not only to the hose material, but to all components of the completed hose assembly, including end fittings and couplers. The accident hose assembly had cast iron and carbon steel couplings that were appropriate for anhydrous ammonia service but inappropriate for LPG service, which requires spark-resistant materials such as brass, bronze, and stainless steel.

[10] Trace Laboratories also tested the accident hose.

Therefore, the NTSB concluded that because of the chemical incompatibilities of the hose material with anhydrous ammonia and of the couplers with LPG, Werner Transportation Services, Inc.'s hose assembly was not suitable for use with either anhydrous ammonia or LPG and should not have been carried on the cargo tank motor vehicle that was involved in this accident. The PHMSA Office of Hazardous Materials Safety issues safety advisory notices to help the public understand significant safety risks. PHMSA's safety advisories are published in the *Federal Register* and provide a description of the safety issue and a recommended action to resolve the issue. The Federal Motor Carrier Safety Administration, in conjunction with its duties enforcing rules and regulations, conducting inspections, and licensing hazardous materials carriers, also issues safety advisory notices pertinent to cargo tank safety. The two agencies working together could provide the necessary outreach to assist carriers and facility operators in avoiding the hazards associated with the use of chemically incompatible hoses and couplers during loading and unloading operations.

Therefore, the National Transportation Safety Board makes the following safety recommendation to the Federal Motor Carrier Safety Administration:

> With the Pipeline and Hazardous Materials Safety Administration, jointly issue a safety advisory bulletin to inform cargo tank motor vehicle owners and operators, registered inspectors of these vehicles, and transfer facility operators about the circumstances of this accident and actions needed to prevent the occurrence of a similar accident. (H-12-1)

The NTSB also issued safety recommendations to the Pipeline and Hazardous Materials Safety Administration.

In response to the recommendation in this letter, please refer to Safety Recommendation H-12-1. We encourage you to submit updates electronically at the following e-mail address: correspondence@ntsb.gov. If your response includes attachments that exceed 5 megabytes, please e-mail us at the same address for instructions. To avoid confusion, please do not submit both an electronic copy and a hard copy of the same response.

Chairman HERSMAN, Vice Chairman HART, and Members SUMWALT, ROSEKIND, and WEENER concurred in this recommendation.

[Original Signed]

By: Deborah A.P. Hersman
Chairman