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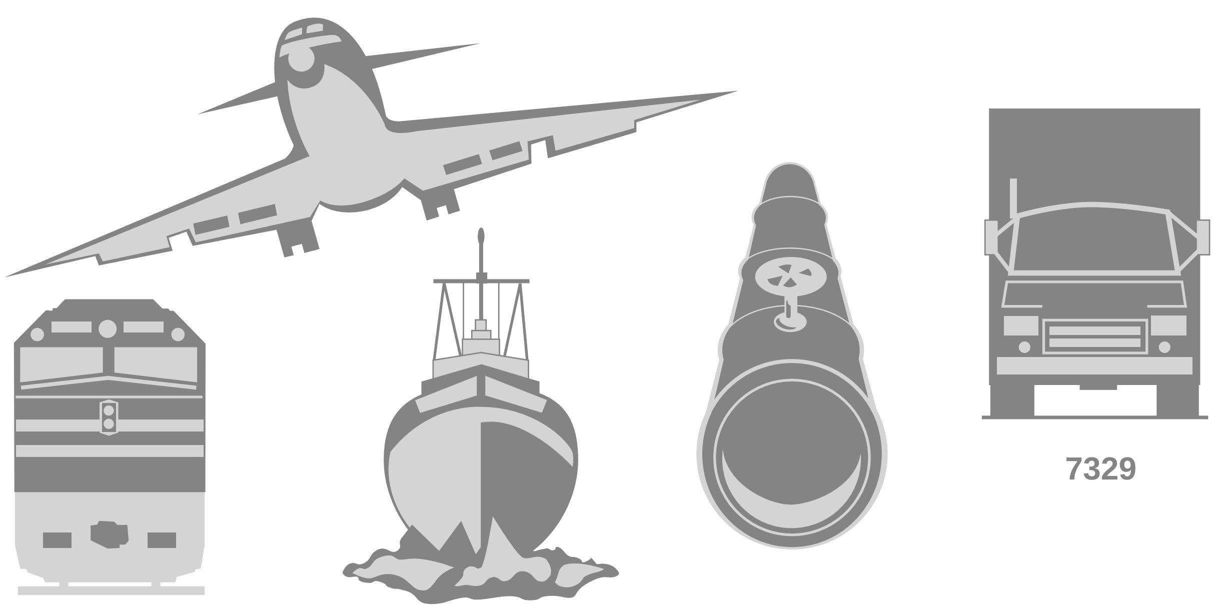
NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

HAZARDOUS MATERIALS ACCIDENT REPORT

RUPTURE OF A RAILROAD TANK CAR CONTAINING HAZARDOUS WASTE NEAR CLYMERS, INDIANA FEBRUARY 18, 1999



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DCA99MZ004
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Notation 7329
Adopted March 5, 2001

National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2001. *Rupture of a Railroad Tank Car Containing Hazardous Waste Near Clymers, Indiana, February 18, 1999.* Hazardous Materials Accident Report NTSB/HZM-01/01. Washington, DC.

Abstract: About 12:05 a.m. on February 18, 1999, railroad tank car UTLX 643593, which was on the west unloading rack at the Essroc Cement Corporation plant near Clymers, Indiana, sustained a sudden and catastrophic rupture that propelled the tank of the tank car an estimated 750 feet and over multistory storage tanks. The 20,000-gallon tank car initially contained about 161,700 pounds (14,185 gallons) of a toxic and flammable hazardous waste that was used as a fuel for the plant's kilns. There were no injuries or fatalities. Total damages, including property damage and costs from lost production, were estimated at nearly $8.2 million.

The safety issues discussed in the report are: sufficiency of safety requirements addressing the procedures used for loading and offloading railroad tank cars and other bulk containers used to transport hazardous materials; adequacy of inspection and testing requirements for pressure relief devices on railroad tank cars; adequacy of provisions addressing changes in product service for railroad tank cars; and adequacy of the U.S. Department of Transportation *Hazardous Materials Regulations* pertaining to the notification and reporting of hazardous materials incidents.

As a result of its investigation, the Safety Board made recommendations to the Federal Railroad Administration, the Research and Special Programs Administration, the Association of American Railroads, the Railway Progress Institute, the Lyondell Chemical Company, the Olin Corporation, the Essroc Cement Corporation, and CP Recycling, Inc., and Affiliated Companies. The Safety Board also reiterated one recommendation to the Research and Special Programs Administration.

Contents

Acronyms and Abbreviations

AAR -- Association of American Railroads

ANPRM -- advance notice of proposed rulemaking

Arco -- Arco Chemical Company

ASTM -- American Society of Testing and Materials

Btu -- British thermal unit

cfm -- cubic feet per minute

CFR -- *Code of Federal Regulations*

cp -- centipoise

CPRIN -- CP Recycling of Indiana

EPA -- Environmental Protection Agency

Essroc -- Essroc Cement Corporation

FRA -- Federal Railroad Administration

ksi -- thousand pounds per square inch

MCB -- monochlorobenzene

Midland -- Midland Manufacturing Corporation

MSHA -- Mine Safety and Health Administration

NPRM -- notice of proposed rulemaking

NRC -- National Response Center

Olin -- Olin Corporation

psia -- pounds per square inch, absolute

psig --pounds per square inch, gauge

RSPA -- Research and Special Programs Administration

RSST -- reactive system screening tool

TDI -- toluene diisocyanate

TSD -- transfer, storage, and disposal

Executive Summary

About 12:05 a.m. on February 18, 1999, railroad tank car UTLX 643593, which was on the west unloading rack at the Essroc Cement Corporation (Essroc) Logansport cement plant near Clymers, Indiana, sustained a sudden and catastrophic rupture that propelled the tank of the tank car an estimated 750 feet and over multistory storage tanks. The 20,000-gallon tank car initially contained about 161,700 pounds (14,185 gallons) of a toxic and flammable hazardous waste that was used as a fuel for the plant's kilns. There were no injuries or fatalities. Total damages, including property damage and costs from lost production, were estimated at nearly $8.2 million.

The National Transportation Safety Board determines that the probable cause of the accident was the failure of Essroc Cement Corporation and CP Recycling of Indiana management to develop and implement safe procedures for offloading toluene diisocyanate matter wastes, resulting in the overpressurization of the tank car from chemical self-reaction and expansion of the toluene diisocyanate matter wastes.

This report discusses the following safety issues:

- Sufficiency of safety requirements addressing the procedures used for loading and offloading railroad tank cars and other bulk containers used to transport hazardous materials;
- Adequacy of inspection and testing requirements for pressure relief devices on railroad tank cars;
- Adequacy of provisions addressing changes in product service for railroad tank cars; and
- Adequacy of the U.S. Department of Transportation *Hazardous Materials Regulations* pertaining to the notification and reporting of hazardous materials incidents.

As a result of its investigation of this accident, the Safety Board makes recommendations to the Federal Railroad Administration, the Research and Special Programs Administration, the Association of American Railroads, the Railway Progress Institute, the Lyondell Chemical Company, the Olin Corporation, the Essroc Cement Corporation, and CP Recycling, Inc., and Affiliated Companies. The Safety Board also reiterates one recommendation to the Research and Special Programs Administration.

Factual Information

Accident Summary

About 12:05 a.m.[1] on February 18, 1999, railroad tank car UTLX 643593, which was on the west unloading rack at the Essroc Cement Corporation (Essroc) Logansport cement plant near Clymers, Indiana, sustained a sudden and catastrophic rupture that propelled the tank of the tank car an estimated 750 feet and over multistory storage tanks. (See figure 1.) The 20,000-gallon tank car initially contained about 161,700 pounds (14,185 gallons) of a toxic and flammable hazardous waste generated from the production of toluene diisocyanate (TDI). TDI is an intermediate product used in the manufacture of polyurethane foam, a material commonly used to produce seat cushions. TDI matter waste was used as a fuel for the Essroc plant's kilns.

In the 5 days before the accident, employees or contract personnel for the hazardous material disposal firm CP Recycling of Indiana (CPRIN)[2] had applied steam to heat the tank car for a total of 28.5 hours. Their goal was to make the material in the tank sufficiently liquid to transfer to the plant piping and kilns for burning. (See figure 2 for an aerial view of the Essroc plant layout.) The attempts to offload the TDI matter waste were unsuccessful due to solidification of the waste in the plant piping to the kilns.

There were no injuries or fatalities. Total damages, including property damage and costs from lost production, were estimated at about $8.2 million.

Preaccident Events

1993 Loading and 1998 Shipment of Tank Car

Railroad tank car UTLX 643593 (see figure 3) was loaded on October 1, 1993, with approximately 161,700 pounds (14,185 gallons) of a TDI mixture designated as "TDI matter waste" at the then-Olin Corporation (Olin) plant in Lake Charles, Louisiana. The loaded tank car remained in storage at the Lake Charles plant until March 31 or April 1, 1998, when it was shipped to the Essroc cement plant, near the towns of Clymers and Logansport in north-central Indiana.[3] At Essroc, the TDI matter waste was to be used as a fuel for the plant's kilns. UTLX 643593 was interchanged at the rail yard in Logansport on April 20, 1998.

[1] All times are eastern standard time.

[2] CPRIN is a subsidiary of CP Recycling, Inc., and Affiliated Companies.

[3] The TDI matter waste stored in UTLX 643593 was classified as a hazardous waste when it was shipped in April 1998 from the Lake Charles plant to Essroc.

Figure 1. Accident location [not to scale]. *(NTSB)*

Figure 2. Aerial view of Essroc plant (preaccident); areas of interest cited in report are labeled. *(Photo provided by Essroc)*

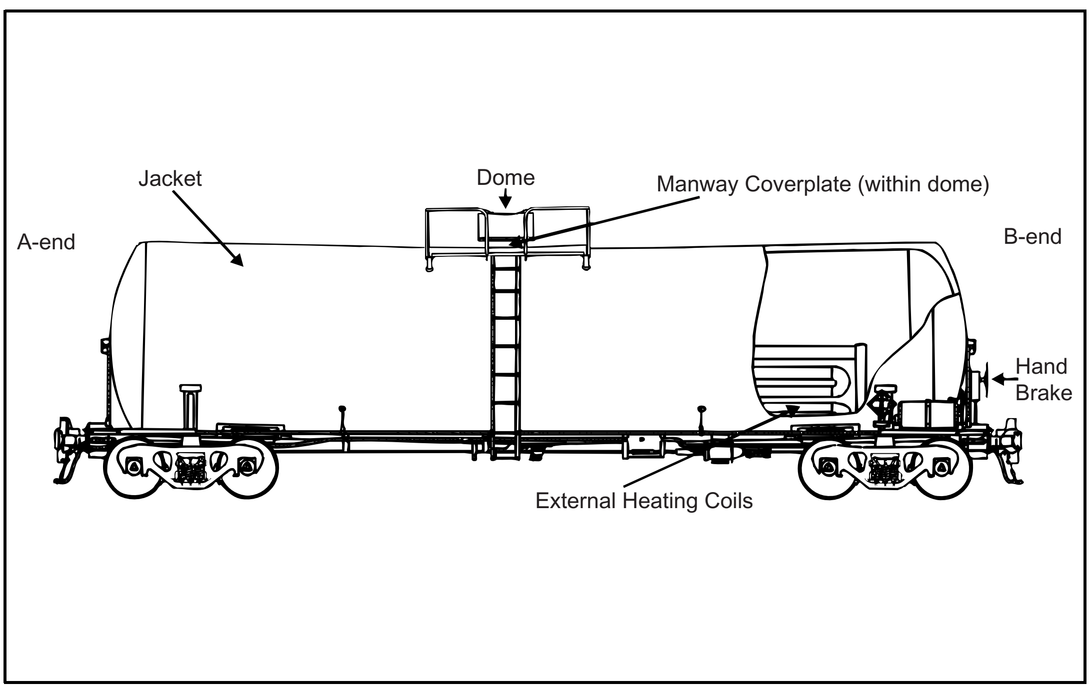

Figure 3. Photo and diagram showing tank cars of same design as UTLX 643593. *(NTSB)*

UTLX 643593 remained in the Logansport rail yard until December 7, 1998, when it was delivered to the Essroc plant. UTLX 643593 was positioned on the west offloading rack at the Essroc plant about 2:00 p.m. on February 12, 1999. The A-end of the tank car was in the direction of "plant north."[4] Essroc daily rail car inspection records from December 7, 1998, through February 17, 1999, show no problems with the tank car.

Heating and Offloading Attempts

Before the TDI matter waste could be offloaded from UTLX 643593, it had to be heated by circulating steam through the tank car's external heating coils to ensure that the waste mixture was sufficiently fluid to be pumped to the plant's kilns, where it was to be burned. (Essroc used the TDI matter waste and other hazardous wastes to fuel the plant's kilns for cement production.)

On February 13, 1999, the Essroc transfer, storage, and disposal (TSD) facility[5] supervisor, who supervised the plant's waste fuel technicians (the Essroc employees who offload waste fuels) and oversaw the transfer of all waste fuels to the plant's kilns, met with the customer service manager for CPRIN at the plant to discuss the steam heating of the tank car. CPRIN was Essroc's on-site contractor for steam heating tank cars containing waste fuels. In that capacity, either the CPRIN service manager or CPRIN contract employees made the steam connections to the tank car and operated the boiler system that produced the steam. Essroc employees made all the offloading connections to the valves on the tank car and operated the pumps, valves, and other equipment to physically offload the tank car and pump the waste to the kilns.

The connections for steam heating UTLX 643593 were completed about 5:00 p.m. on February 13, and steam heating began about 6:00 p.m. At the time the steam connections were made, internal tank pressure was reported to be 0 pounds per square inch, gauge, (psig) and the ambient air temperature was about 30° F.[6]

As a standard practice and quality control measure, Essroc technicians would draw a sample of the TDI matter waste before offloading any tank car. A contract laboratory with on-site facilities would then analyze the sample to ensure that the waste was within prescribed parameters before offloading commenced. One technician stated that he and a second technician drew the quality control sample from UTLX 643593 before the end of their shift at 11:30 p.m. on February 13. They left the sample with the facility supervisor. The technician described the waste sample as being "somewhat thicker" than normal. The sample was taken to the contract laboratory with on-site facilities at 12:20 a.m. on February 14. The analysis was completed and the results reported to Essroc at 1:23 a.m. on February 14.

[4] The true direction of "plant north" is north to northwest. Directional references in this report will be referenced to "plant north" rather than true directions unless otherwise specified.

[5] A *TSD facility* transfers, stores, or disposes of hazardous wastes.

[6] Essroc stated that its waste fuel technicians monitored the internal pressure of the tank car and the temperature of the matter waste in the tank car between February 13 and the accident, but internal tank pressures and temperatures of the waste mixture were not, as a matter of practice, measured at regular intervals or required to be documented. Consequently, the internal tank pressures and cargo temperatures cited in this report are those recalled by the facility supervisor and the waste fuel technicians.

The lab tested the sample for the presence of specific constituents, including chlorine and water, and measured the heating value and density of the waste mixture. It did not indicate the waste's viscosity.[7] The testing indicated that no water was present. The sample had a density of 11.4 pounds per gallon and a heating value of 119,880 British thermal units (Btu) per gallon.

About the time the sample was drawn, the internal tank pressure was 0 psig. The temperature of the matter waste mixture was 80° F at 12:30 a.m. As the steam heating continued, the temperature of samples drawn from the tank car increased to about 120 to 150° F, at about 2:30 a.m., to 202° F at 6:00 a.m., when the steam heating ended.

About 9:00 a.m. on February 14, the Essroc facility supervisor spoke with a waste fuel technician who was on duty. The technician advised the facility supervisor that the steam heating of UTLX 643593 had ended about 6:00 a.m. that morning. The facility supervisor and the waste fuel technician reviewed the procedures to finish offloading operations from a just-emptied tank car, GATX 42585, on the east offloading rack adjacent to UTLX 643593. The facility supervisor told the waste fuel technician to call him if any problems developed in the offloading.

The waste fuel technician notified the Essroc facility supervisor about 11:00 a.m. that he had attempted to begin offloading UTLX 643593 but was unable to do so because the TDI matter waste was too thick. The waste had plugged the fixed plant piping between the offloading rack and the kilns.[8] The facility supervisor directed the technician to shut down the pumping and piping system and to flush the piping from the kilns back to the loading rack.[9] The internal tank pressure was about 10 psig at 11:00 a.m.; it was 40 psig at 1:00 p.m.

About 4:30 p.m., the Essroc facility supervisor received a telephone call from another waste fuel technician on duty. This technician advised the facility supervisor that the on-duty technicians had again tried to offload UTLX 643593 and pump the TDI matter waste to the kilns, but the waste was too thick and had again plugged the piping. The facility supervisor told the technician to flush the piping to the kilns and to shut down the offloading effort. An on-duty product supervisor at the plant notified the facility supervisor before 6:00 p.m. that it had been shut down. No further attempts to heat or offload UTLX 643593 were made on February 14.

The facility supervisor arrived at the Essroc plant between 6:30 and 6:45 a.m. on February 15. About 6:45 a.m., the internal tank pressure in UTLX 643593 was between 20 and 25 psig, and the temperature of a waste sample was 70° F. The facility supervisor

[7] *Viscosity* is a measure of the resistance of a fluid to deformation or flow. A fluid with a high viscosity, such as heavy syrup, tends to be thick and slow flowing. A fluid with a low viscosity, such as water, is thin and flows easily.

[8] The system of piping and pumps that fed the TDI waste directly from the tank car to the kilns was designated as the *TDI direct burn system*.

[9] Essroc personnel indicated that toluene, a solvent for TDI, was used to flush and unplug the piping to the kilns.

determined that the TDI matter waste was too thick to pump. (After the accident, the facility supervisor stated no temperature was prescribed for offloading; he said the waste product was considered ready for offloading when it was "thin" enough to flow.)

The facility supervisor then contacted the CPRIN manager, told him the temperature of the TDI waste sample, and said that the waste was much too thick to pump from the tank car. The CPRIN manager responded that he would reheat the tank car. The second round of steam heating UTLX 643593 began about noon on February 15 and ended about 4:30 a.m. on February 16. The facility supervisor told the waste fuel technicians to draw samples from the tank car every 30 to 60 minutes to check the waste's temperature and visually monitor its viscosity. The facility supervisor left it to the Essroc technicians to advise the CPRIN personnel when the TDI matter waste was fluid enough to pump.

The Essroc facility supervisor checked the status of UTLX 643593 upon arriving at the plant between 6:30 and 6:45 a.m. on February 16. The waste samples drawn from the tank car at that time were 173° F and were thin and fluid. The facility supervisor also noted that the pressure gauge on the nitrogen line used to measure internal pressure in the tank car read 45 psig, which was higher than Essroc's desired pressure of 20 to 25 psig.

To relieve excess pressure in the tank car, Essroc technicians manually opened the vapor valve on top of the tank car that was connected to a "tee" fitting that allowed the injecting of nitrogen into, or the venting of vapors from, the tank car with the alignment of flow valves at the offloading station. The facility supervisor later told the Safety Board that when the technician went to open the vapor valve on the tank car to relieve the internal pressure, he found the pressure relief valve "whispering" or discharging slightly and not seating tightly. The facility supervisor attributed this condition to saturated carbon filters in the offloading station's vapor emission system.[10] He directed the technicians to clean the carbon filters so that they could absorb the pollutant vapors as intended.[11]

While the technicians cleaned the filters, vapors from the tank car were vented into a water bath, which would absorb any pollutants. A 3/4-inch vent hose (about 100 feet long) was connected to the vapor valve on the tank car and then run to a 300-gallon plastic "tote" tank filled with about 275 gallons of water. The end of the vent hose was resting underwater on the bottom of the tote tank so that vapors from the hose would be absorbed in the water rather than emitted to the atmosphere. According to the facility supervisor, Essroc technicians continued to clean the carbon filters throughout the day on February 16, and vapors from the tank car continued to trickle through the water bath.

About 5:30 p.m. on February 16, the facility supervisor told the 3:30 to 11:30 p.m. shift about the problems with the vent system and the carbon filters and directed the shift to monitor the water bath and the internal pressure in UTLX 643593. He also told the

[10] Saturation of the filters could have caused a back pressure in the tank car, which would have caused the pressure relief valve to open so that "whispering" could be heard.

[11] The carbon filters were designed to absorb pollutants in the vapors from the tank car to satisfy air quality standards.

technicians to reconnect the nitrogen line to the tank car when the internal tank pressure was between 20 and 25 psig and to try to offload the tank car. The facility supervisor also checked the internal pressure in UTLX 643593 and noted that the pressure gauge indicated 40 psig.

The on-duty product supervisor notified the facility supervisor about 9:15 p.m. that the technicians had attempted to offload UTLX 643593, but the product was very thick, "like taffy." The attempt to offload had begun about 7:30 p.m. but was stopped a "very short time" later, after a small amount of the TDI waste had been offloaded. The on-duty product supervisor told the facility supervisor that the technicians had been unable to flush the TDI waste from the pipeline to the kilns and that the TDI waste had "frozen" in the pipeline. They shut down the offloading effort.

During a March 2, 1999, interview with officials from the Mine Safety and Health Administration (MSHA), an Essroc laborer who worked this shift stated that he had seen water bubbling and splashing in the tote tank after this last unsuccessful attempt to offload the tank car on February 16. He said that the pressure in the tank car had been holding at 50 psig.

Essroc later estimated that about 750 gallons of the TDI matter waste were offloaded during the three attempts made to offload the tank car.

The facility supervisor arrived at the plant between 6:30 and 6:45 a.m. on February 17, and, as he had the 2 previous days, he checked UTLX 643593. He noted that the pressure gauge measuring the internal pressure in the tank car indicated 40 psig. The facility supervisor opened a valve in the vent line to begin relieving the pressure in the tank car. The pressure was relieved until 10:00 a.m., when the pressure gauge indicated 3 to 5 psig. The vent line valve was closed at that time, and the nitrogen line was opened. Nitrogen was injected into the tank car until about 3:00 p.m., by which time it had increased the internal pressure to between 20 and 25 psig. The facility supervisor said that the tank car was not steam-heated further or otherwise worked on before the explosion.

Accident

The waste fuel technicians and other employees, whose shifts began at 11:30 p.m., February 17, were in an on-site building that housed the technicians' office when UTLX 643593 ruptured. One of the waste fuel technicians was doing paperwork when the accident occurred. About 12:05 a.m. on February 18, the technician heard what he later described as a "small bang." He stated that he was looking out the window, but he did not see any smoke, flame, or flash, and therefore was not sure where the sound originated. Following the bang, he saw an orange fireball, which he estimated was 40 feet high, moving toward the office and engulfing the entire area. According to the technician, the fireball hit the window and was gone. Following the fireball, he felt a concussion. After the fireball and concussion, the technician looked toward the tank car offloading area and saw the entire area in flames. He said that "clumps of fire" were raining down. The technician said he was certain that the source of the explosion was the TDI tank car.

The technician said he heard three other explosions, but he could not estimate the interval between them. He did not know what the first and second explosions were, but he said that the third explosion was the cargo tank truck east of the diesel storage tanks. (See figure 4 for postaccident view of the Essroc plant site.)

Emergency Response

The Logansport Fire Department received the alarm from the Essroc plant at 12:06 a.m. on February 18. The first responding units arrived on the scene at 12:21 a.m. The Clymers Volunteer Fire Department, the Georgetown Fire Department, the Royal Center Fire Department, and the Grissom Air National Guard Base Fire Department also responded. Fire crews extinguished the fires without incident. Because of the potentially hazardous smoke and the loss of area electrical power, residents of about 100 homes were temporarily evacuated to shelters. The emergency had concluded by 7:30 a.m. on February 18.

In addition to the fire departments, the following Federal, State, and local agencies responded to the accident: the Federal Railroad Administration (FRA), MSHA, the Indiana State Emergency Management Agency, the Indiana Department of Environmental Management, the Indiana State Fire Marshal, the Indiana State Police, the Cass County Office of Emergency Management, the Cass County Sheriff's Department and Ambulance, the Carroll County Sheriff's Department, the Logansport Police Department, and the local Red Cross.

The Indiana Department of Environmental Management reported that the containment dike surrounding the offloading area and storage tanks was intact and held fire suppression materials. Solid chunks of TDI matter waste from UTLX 643593 were scattered as a debris field across the plant facility. Essroc confirmed that the following fuels and solvents were released from the damaged storage tanks in the offloading area: 17,000 gallons of diesel fuel; 1,000 gallons of gasoline; 15,000 gallons of HAN 906 solvent; and 2,000 gallons of toluene. In addition to the TDI matter waste remaining in UTLX 643593, the accident released about 4,200 gallons of a flammable and corrosive waste from the nearby cargo tank truck. The Indiana Department of Environmental Management monitored cleanup of the plant facility.

Injuries

No fatalities or injuries were reported.

Figure 4. Essroc plant after the accident; #1 indicates preaccident position of UTLX 643593; #2 indicates location of bulk of tank car after the accident. *(Photo courtesy of Logansport Pharos-Tribune newspaper)*

Damage

General

The Essroc plant is in a rural area with no residences in the immediate vicinity. The cement plant sustained significant property damage and suspended operations for nearly 4 weeks. UTLX 643593 and a cargo tank trailer were destroyed. Two other tank cars (GATX 42585 and UTLX 640738) in the offloading area were also damaged. Total damages and lost business costs were estimated at nearly $3.4 million and $4.8 million, respectively.

At Essroc, two pairs of north-south train tracks led to the two offloading stations for tank cars. The offloading platforms for the two tank car stations, the pipe rack between the two sets of train tracks, and the offloading station for cargo tank trucks on the west side of UTLX 643593 were completely destroyed. Sections of what appeared to be structural steel from the offloading platforms were found on the far east side of the storage tanks and the kilns adjacent to the east side of the offloading area.

Tank car GATX 42585, on the adjacent (east) loading rack, had been blown on its side, away from the west loading station. The cargo tank trailer that had been on the west side of UTLX 643593 had also been blown on its side, away from the west loading station.

Fixed storage tanks along the east and west sides of the offloading area exhibited fire and heat damage, as well as impact damage from flying debris. The damaged areas on all these tanks were directly exposed to the offloading station where UTLX 643593 had been. The four tanks along the west side included two 12,000-gallon fuel oil tanks and two 7,500-gallon tanks containing a blending agent for the TDI matter waste. All four of these tanks were destroyed. A 2,000-gallon tank containing toluene was blown from its original position between UTLX 643593 and the cargo tank trailer into the fuel oil tanks on the west side of the offloading area. Fire had blackened 4 of a group of 10 storage tanks on the east side of the offloading area. The remaining six tanks, although partially shielded, also had some blackening and heat damage. (See figure 5.)

UTLX 643593

Both truck (wheel) assemblies from the tank car had derailed adjacent to the west track in the offloading area, in the approximate location of UTLX 643593 at the time of the accident. Chemical debris and structural components from UTLX 643593 were scattered to the east and west of the offloading station. Investigators did not locate the dome lid from the tank car. Pieces from the metal jacket of the tank car were generally found in the large field west and north of the offloading station.

Most of the UTLX 643593 tank was found in one piece, upside down on the west side of a plant building about 750 feet northeast of the offloading station, with the remaining attached section A-end head next to the building. (See figure 6.) The only section of the tank jacket with burned paint or indication of direct exposure to fire was the jacket section found at this location. A piece of burned rubber hose was found facing and next to the burned area on the jacket.

Figure 5. Essroc loading rack area after accident. *(NTSB)*

Figure 6. Remains of UTLX 643593 tank after accident. *(NTSB)*

There were fractures along the bottom centerline of the tank that had propagated on a shear plane, typical of the shear-face tensile fractures in ductile materials.[12] Toward both head ends of the tank, transverse tearing through the tank plate was observed, creating two sections of the tank barrel that appeared flattened. The fractures observed were not along welds in the tank. The bottom portion of the tank toward the B-end had crumpled and folded over on itself. Measurements of the plate thickness along the fracture surfaces showed that "necking down" deformation had reduced the wall thickness below the nominal thickness of 0.5625 inch.

No pitting, corrosion, blistering, or other visual signs of deterioration were observed on the internal tank surface. No breaches or cracks were observed in the tank, including the area of the tank covered by the external heating coils. The outline of the external heating coils from discoloration of the tank metal was observed on the internal tank surface at both the A- and B-ends. The discoloration was more pronounced at the A-end.

Pieces of solid chemical residue were observed on what had been the interior surface of the section of the A-end tank head. The chemical residue had a solid, glassy, and brittle appearance. Other than this residue, the interior surface of the tank head was clean. The tank head was deformed and dented.

The eduction lines, gauging line, and thermometer well mounted on the manway coverplate were bent at a 45- to 60-degree angle toward the top of the tank, along the longitudinal centerline, and toward the B-end of the tank.

Chemical residue that was dark brown in color and of a solid, glassy appearance filled about half of the dome nozzle. The residue had a top layer of loose chunks. Beneath the chunks, the residue conformed to the shape of the dome nozzle and manway coverplate as if poured into a mold.

Numerous solid chunks of the TDI matter waste material were scattered throughout the large field to the west and north of the offloading station. (See figure 7.) Some pieces of these solids showed indications of burning while others did not. Samples of these solids were obtained for analysis. A retired Olin/Arco employee who had 34 years' experience with the production and handling of TDI and who came to the accident scene as a consultant for Olin told the Safety Board that he was surprised by the number of small chunks of TDI waste on the ground. He identified these chunks as polymeric TDI. He stated that for the polymeric TDI to be in that form, it had to have been a solid block or slab in the tank car when the accident occurred. He further stated that if the polymeric TDI had been in a fluid state in the tank car at the time of the accident, he would have expected the polymeric TDI to have a "stringy" appearance or to be "sort of strung out like you'd throw something out and it'd freeze in the air." He also observed that some of the polymeric TDI appeared to be burned and showed indications of exposure to water, which he attributed to moisture in the air. He stated that he found the offloading

[12] National Transportation Safety Board Materials Laboratory Factual Report No. 99-113, dated May 12, 1999.

lines to UTLX 643593 and noted that they were elongated as "if they was hooked to something" at the time of the accident. He believed that the elongation of these lines indicated they were attached to the tank car when it ruptured.

Figure 7. Solid TDI matter waste gathered from debris field after accident. *(NTSB)*

Meteorological Information

The National Climatic Data Center provided weather data for Lafayette, Indiana, which is about 35 miles southwest of Logansport/Clymers. (Lafayette was the closest weather reporting station to the accident site.) Between February 12 (the date UTLX 643593 was positioned at the loading rack) and February 18 (the accident date), the high temperatures ranged from 32° F on February 13 to 57° F on February 15. The low temperatures ranged from 13° F on February 13 to 35° F on February 16. The average daily temperatures ranged from 23° F on February 13 to 45° F on February 15. No measurable precipitation was recorded in the 7-day period.

The Essroc waste fuel technician who witnessed the February 18 accident said it was cool at the time of the accident, and there was no rain, thunder, or lightning.

Tank Car Information

Union Tank Car Company built UTLX 643593, a U.S. Department of Transportation (DOT) specification 111J100W1 tank car, in late 1992 or early 1993. It was 1 of 52 tank cars (UTLX 643546 through 643597, inclusive) ordered by Olin and designed for TDI product transportation. The certificate of construction for UTLX 643593 and its sister tank cars indicates that these cars were approved for carriage of TDI and

> Non-regulated commodities and commodities authorized in DOT Part 173 [49 *Code of Federal Regulations* (CFR) 173] for which there are no other requirements and which are compatible with this design and class of car.

Each of these tank cars had a capacity of 20,000 gallons. They were approved to carry a maximum of 181,400 pounds of cargo each. The tank was constructed of American Society of Testing and Materials (ASTM) A-516-70 carbon steel. The thickness of the tank shell was 0.563 inch and of the tank heads was 0.603 inch. Under sections 49 CFR 179.201-1 and 179.201-2 of the DOT *Hazardous Materials Regulations*, the minimum required thickness of the tank shell and tank heads for this class of tank car are both 0.438 inch. Union Tank Car calculated the burst pressure of the tank to be between 813 and 844 psia.[13]

The tank car's external heating coils[14] were on the bottom half of the tank and ran the tank's full length. The heating area of the external coils was about 274 square feet of the tank's surface area. The inlet and outlet connections for the heating coils were just to the A-end side of the blind flange covering the sump at the bottom center of the tank. The tank was covered by 6 inches of insulation (1/2 inch of fiberfrax and 5 1/2 inches of fiberglass), a 1/8-inch carbon steel jacket, and 1/2-inch-thick head shields.

All seven valves/fittings on the top of the tank car were mounted on a pressure manway plate, which was bolted to the tank and enclosed in the type of housing used on pressure tank cars that transport liquefied compressed gases. The seven fittings mounted on the manway plate comprised a valve for each of the two liquid loading/offloading lines, the valve to the tank's vapor space, the pressure relief valve, the vacuum relief valve, the gauging device, and the thermometer well. (See figure 8.)

The valves to the two liquid loading/offloading lines were 2-inch Union Tank Car stainless steel ball valves.

The vapor valve was a 1-inch stainless steel Jamesbury ball valve.

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[13] *Psia* stands for pounds per square inch, absolute. For purposes of comparison, 0 psig = 14.696 psia = 1.0 atmosphere.

[14] The external heating coils were welded to the exterior of the tank. The coils were hidden from view by insulation and the metal jacket, which held the insulation in place. (Refer to the figure 3 diagram cutaway.)

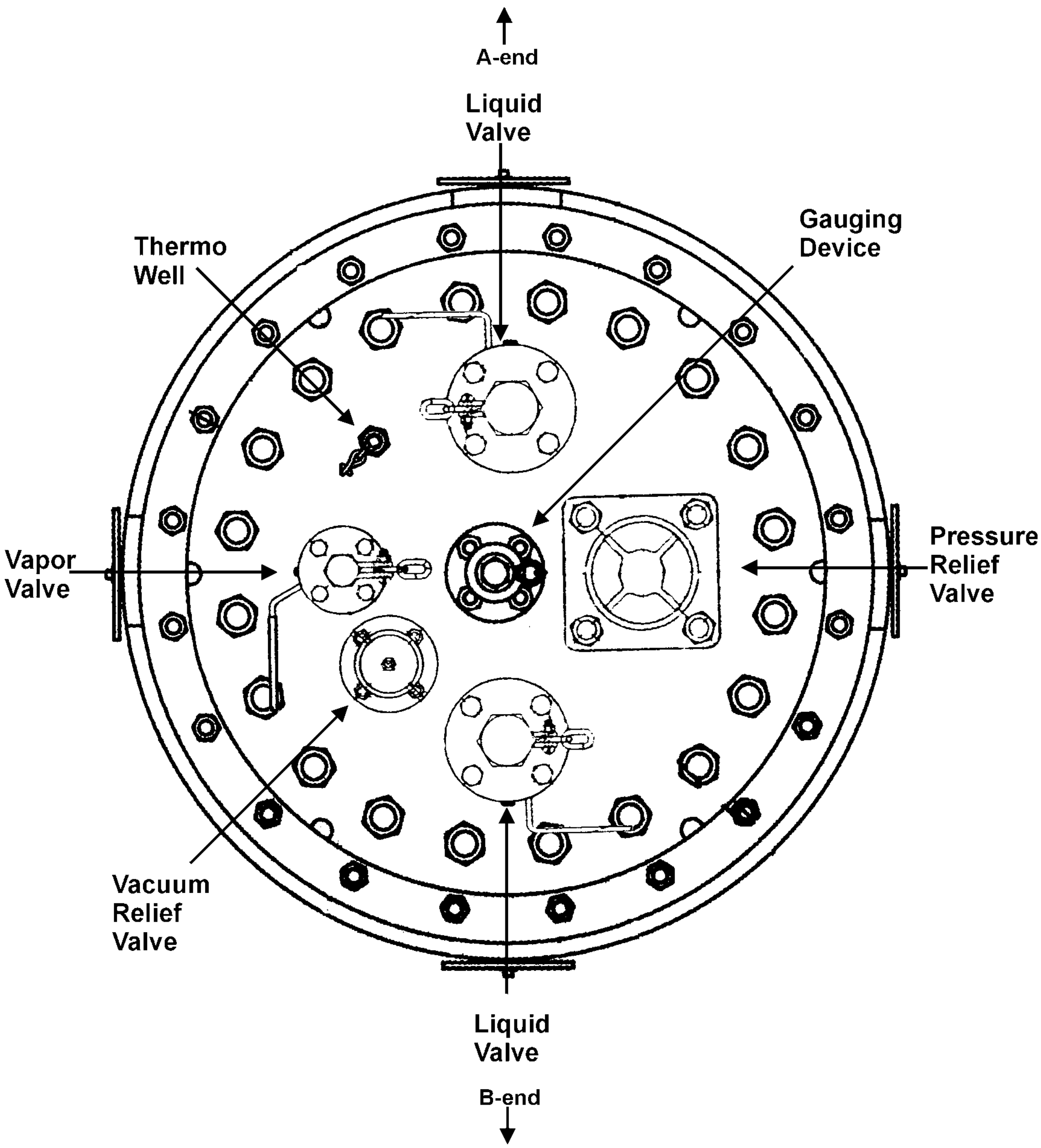

Figure 8. Fittings on UTLX 643593 manway coverplate. *(NTSB)*

The pressure relief valve had been made by the Midland Manufacturing Corporation (Midland). The Midland model A-1479 pressure relief valve had a start-to-discharge pressure of 75 psig. The rated flow capacity of the pressure relief valve was 2,027 cubic feet per minute (cfm). (The DOT minimum flow capacity for this design of tank car was 166 cfm.) The O-rings and gaskets for the pressure relief valve were of ethylene propylene rubber and Teflon, respectively.

The vacuum relief valve was a Midland model A-222W flanged valve made of stainless steel with a standard set point[15] of 0.75 psi vacuum. Midland found no record indicating that the vacuum relief valve on the tank car had a nonstandard set point.

TDI Waste Information

Over the years, the Lake Charles plant shipped to Essroc (and other waste disposal companies) two types of wastes generated from TDI production. The first type, designated as "solvent blend waste," was generated during the final purification and distillation of the TDI product. The second type, designated as "TDI matter waste," was generated from an intermediate product stream removed during the TDI production process. (Generation and shipment of the solvent blend and TDI matter wastes from the Lake Charles plant are discussed in the next section.)

The solvent blend wastes and the TDI matter wastes contained comparable percentages of TDI and TDI polymers. For example, the TDI matter waste mixture in UTLX 643593 (the accident tank car) was approximately (by weight) 42 percent monomeric TDI and 38 percent polymeric TDI.[16] Monomeric TDI is a clear to slightly yellow liquid, and polymeric TDI is a dark brown to black liquid or a glass-like black solid. Both the monomeric and polymeric forms of TDI present high ingestion and inhalation hazards and are combustible, with flash points[17] of 270° F.

Monomeric and polymeric TDI are stable at temperatures below 104° F. At higher temperatures, monomeric TDI can "self-react"[18] in two ways, either by combining to generate polymeric TDI or by reacting to produce carbon dioxide gas and a type of chemical compound known as a carbodiimide. At higher temperatures, the polymeric TDI can decompose and release gaseous byproducts such as carbon dioxide, carbon monoxide, and oxides of nitrogen. Both monomeric and polymeric TDI are reactive with water. TDI will react slowly with water under 122° F; the reaction with water will accelerate rapidly in the presence of alkaline materials and at higher temperatures. Olin's information concerning "TDI product" (TDI in its monomeric form) noted that TDI should not be stored at temperatures above 104° F.

Solvent blend wastes and TDI matter wastes differ with respect to the blending agent present in each that formed the balance of the waste mixture and served to reduce its viscosity. The blending agent typically used for solvent blend wastes was HAN 906, a mixture of flammable petroleum hydrocarbons, such as naphthalene and trimethylbenzene. HAN 906 is combustible and has a flash point of 145° F. Monochlorobenzene (MCB), the blending agent used in the TDI production process and found in the TDI matter wastes, is also a flammable liquid and has a flash point of 82° F. Both HAN 906 and MCB are chemically stable.

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[15] The term *set point* applies to the pressure at which a device, such as the pressure relief valve, which is designed to open at some specific pressure, opens.

[16] A *monomer* is a relatively simple molecule or compound of low molecular weight and simple structure. A *polymer* is a relatively complex compound formed from the combination of some number of molecules or groups of molecules to create a chainlike macromolecule.

[17] A *flash point* is the temperature at which a liquid gives off a vapor sufficient to form an ignitable mixture with the air near the surface of the liquid or within the test vessel.

[18] *Self-reaction* occurs when molecules of a chemical interact with each other (often because of increased temperature) and combine to form a molecular chain.

Lake Charles Plant Shipments of TDI Waste

When UTLX 643593 was loaded in 1993, Olin owned and operated the Lake Charles, Louisiana, plant where the company produced TDI (and generated TDI waste). In December 1996, Olin sold its TDI production business, including the Lake Charles plant, to Arco Chemical Company (Arco). In July 1998, Lyondell Chemical Company (Lyondell) acquired Arco and its assets. Lyondell assumed Arco's responsibilities under the 1996 Olin/Arco purchase agreement and took ownership and operational control of the Lake Charles plant.

Operations Under Olin Ownership

Olin used tank cars to transport and store two distinct chemical streams generated from the production of TDI — solvent blend waste and TDI matter waste.

Solvent Blend Waste. The first stream, solvent blend waste, was generated by the distillation and purification of the TDI product. The waste stream from the distillation process contained monomeric TDI and polymeric TDI that were normally routed to an incinerator on the plant site. When the incinerator's capacity was exceeded or the incinerator was not operable, this waste stream would be pumped into a fixed storage tank where it was mixed (blended) with HAN 906 solvent to reduce its viscosity.

According to the waste profiles for solvent blend waste, after the blending with the HAN 906 solvent, the viscosity of the solvent blend waste was about 150 centipoise (cp).[19] Periodically, when the storage tank was filled, the solvent blend wastes in the fixed storage tank were pumped into rail tank cars or highway cargo tanks for transportation to an off-plant disposal site for thermal destruction.

Olin contracted Chemical Waste Management, a waste management contractor, to handle the transportation and disposal of its solvent blend waste. In late 1995, Chemical Waste Management, on Olin's behalf, approached CPRIN and Essroc about burning solvent blend waste at Essroc's Logansport cement plant. In a June 5, 1996, letter, CPRIN advised Olin that the solvent blend wastes were acceptable for incineration at the Essroc Logansport plant. Records of tank car shipments and offloading submitted by Olin and Essroc indicate that 70 tank carloads of solvent blend waste were shipped from Olin to Essroc between July 11, 1996, and April 29, 1998.[20] Between July 31, 1996, and July 21, 1998, 67 of these 70 tank cars were successfully offloaded at the Essroc plant, and the solvent blend wastes were burned without incident. According to Essroc records, the company rejected the three remaining tank cars in January and February 1998 because the wastes they contained did not meet Essroc specifications. One of these three cars (GATX 25412) was in the Logansport yard at the time of the February 1999 accident.

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[19] *Centipoise* is the metric measurement unit for viscosity.

[20] Comparison of the shipping records from Olin and Essroc showed minor inconsistencies in the shipment and offloading data. The figures cited in this report are the most accurate numbers that could be obtained from the available data.

TDI Matter Waste. TDI matter waste was an intermediate product stream from Olin's production of TDI. TDI matter waste was a mixture of monomeric TDI, polymeric TDI, and MCB. The MCB in the TDI matter waste acted as a solvent for the substance, which reduced its viscosity. Through reprocessing, Olin could recover both MCB and monomeric TDI from the TDI matter waste.

Beginning in October 1988, at various times, Olin stored the TDI matter waste in tank cars rather than halting the production process when it experienced problems with the processing equipment or the incinerator. Under this practice, Olin would later reintroduce the TDI matter waste stored in the tank cars to the production process to recover the monomeric TDI and MCB. Eventually, Olin's efforts to maximize production resulted in the on-site accumulation of a growing number of tank cars that stored TDI matter waste.

In early 1996, Olin increased its efforts to either reprocess the stored TDI matter waste on-site or ship the tank cars to disposal sites where the TDI matter waste could be incinerated. Olin continued to use tank cars for storing TDI matter waste until late 1996. Olin loaded the last tank car carrying TDI matter waste on November 30, 1996. Olin indicated that it used 144 tank cars for storing TDI matter waste and that it reused an unspecified number of these tank cars for storage after loads of TDI matter waste had been reprocessed at the plant. According to Lyondell, 234 tank carloads of TDI matter waste were stored at the Lake Charles plant during the 8 years Olin followed this practice. Olin and Lyondell both confirmed that the TDI matter waste was stored in tank cars only at the Lake Charles plant.

Operations Under Arco/Lyondell Ownership

On October 9, 1996, Olin and Arco signed a purchase agreement for the Lake Charles plant. Under the terms of the purchase, Arco agreed to assume control and ownership of the TDI matter waste then stored in 128 tank cars at the Lake Charles plant, if the Louisiana Department of Environmental Quality determined that the stored TDI matter waste was in-process material and not a hazardous waste. When this condition was satisfied, on or about December 6, 1996, the sale of the plant was completed.

While purchasing the plant, Arco decided to discontinue the practice of using tank cars for interim storage of the TDI matter waste when the company encountered operation problems with the TDI production equipment. Arco elected to reduce the TDI production rate or shut down production rather than continue to use tank cars for storage. Consequently, the Olin-Arco purchase agreement included terms for processing the 128 tank cars then in storage at the Lake Charles plant. Under these terms, Arco was to either reprocess the TDI matter waste stored in the tank cars at the plant or ship it offsite for thermal destruction by June 30, 1998. This deadline was subsequently extended to October 1, 1998. After October 1, 1998, any remaining tank cars were to be declared "excess TDI matter rail cars." Arco had two options for handling such tank cars. Arco could either (1) ship the tank cars to an off-site disposal facility for thermal destruction of the waste at Olin's expense, subject to monetary conditions, or (2) require Olin to take possession of the tank cars, assume their leases, transport them to an off-site facility for disposal of the waste, and permanently remove the tank cars from the Lake Charles site.

(Olin later indicated that Essroc and two waste disposal companies incinerated the excess TDI matter waste.)

In early 1998, on behalf of Arco, Chemical Waste Management approached CPRIN and Essroc about disposing of TDI matter wastes from the Lake Charles facility at Essroc's Logansport plant. Initial shipment of tank cars carrying the TDI matter wastes to Essroc began in early March 1998, and acceptance of the TDI matter wastes at Essroc was approved in a June 10, 1998, letter from CPRIN to Arco. The waste profile sheet that accompanied CPRIN's June 10 letter stated that the viscosity of the TDI matter waste at 70° F "varies."

Between early March 1998 and early November 1998, Arco/Lyondell shipped 40 tank cars containing TDI matter wastes from the Lake Charles plant to Essroc. Between July 31, 1998, and the date of the accident, 14 of the 40 tank cars were offloaded at the Essroc plant. The wastes from four tank cars were offloaded, blended in a fixed tank, and pumped to the kilns and burned. The wastes from 10 tank cars were offloaded and pumped directly to the kilns, without any blending. (This was termed the "direct injection" process.) The accident tank car, UTLX 643593, would have been the fifteenth tank car to be offloaded at Essroc, and the eleventh offloaded by direct injection. Of the remaining 25 of the 40 tank cars, Essroc was unsuccessful in blending the wastes from 1 tank car; this car was shipped to a transfer facility in Deer Park (Houston), Texas, before the accident. Twenty-four of the original 40 tank cars remaining at Essroc were shipped to the Deer Park facility after the accident.[21]

Lake Charles TDI Waste Offloading and Processing Procedures

Olin

Olin told the Safety Board that it heated the TDI matter waste at the Lake Charles plant by slowly passing low-pressure (around 10 psig) steam through the coils in the rail car. At times, heating the TDI matter waste in this manner took 2 to 3 days. Olin said its procedure was to make sure that there was no back pressure on the steam coil and that the exit line continued to produce warm water and a small amount of steam, ensuring that the steam was not trapped.

Olin stated that during the steam heating, it mixed the TDI matter waste by a process known as "nitrogen sparging" to facilitate even heating. In this process, nitrogen gas was injected through the eduction line at the top of the tank car. When the nitrogen exited the end of the eduction line at the bottom of the tank car, the nitrogen would mix the TDI matter waste, facilitating its even heating. Olin maintained the nitrogen line at a slight positive pressure to avoid suctioning the TDI material from the railcar. Vapors and gases

[21] Olin revised this accounting in August 2000. Thirteen tank cars were shipped directly from Lake Charles and arrived in Deer Park between December 15, 1998, and April 1, 1999. A fourteenth tank car was also shipped from Essroc to Deer Park about 2 weeks before the accident.

vented from the tank car flowed to a vapor emissions system and/or an incinerator. Typically, Olin gradually heated the TDI matter waste in the tank car to 90 to 100° F during the sparging process until the mixture was pumpable. Olin indicated that it never heated the TDI matter waste above 110° F because of possible degradation of the recoverable monomeric TDI.

Olin said it monitored the temperature and pressure on at least an hourly basis during the heating and nitrogen sparging processes. Through nitrogen sparging, the contents of the tank car were gradually heated, mixed, and made less viscous. Olin also added additional MCB to the tank car, if needed, to reduce the viscosity of the TDI matter waste. During this process, Olin drew samples of the TDI matter waste to determine the viscosity of the mixture. When the viscosity of the TDI matter waste was sufficiently reduced, Olin would offload the waste from the tank car and reintroduce it into the TDI production stream.

Olin stated that the on-site blending process with the HAN 906 solvent at the Lake Charles plant for TDI matter waste to be shipped off-site for disposal followed the same procedures for low-pressure steam heating and nitrogen sparging as were followed when the TDI matter waste was offloaded from the tank cars and reintroduced into the plant production stream. The one difference in the procedures was that the TDI matter waste to be shipped off-site was occasionally heated to around 130 to 140° F. The higher temperatures were permitted under the blending procedure because recovery of monomeric TDI was no longer an objective; so heat-caused damage to the substance was not a consideration. Olin also indicated that the temperature of the TDI matter waste in the tank cars never exceeded 140° F. Olin added HAN 906 solvent to the TDI matter waste in the tank cars until the TDI waste mixture met specifications for chlorine content of less than 3 percent and viscosity of 400 to 500 cp, as prescribed by Essroc. The tank cars containing the TDI matter waste were then shipped to Essroc for disposal.

Arco/Lyondell

When Arco assumed ownership of the Lake Charles plant, it determined that it would not reintroduce the TDI matter waste stored in tank cars to the TDI production stream but ship it all offsite for disposal. Arco said it typically blended the TDI matter waste stored in the tank cars with HAN 906 solvent before shipping the waste to a disposal site. According to Lyondell, contractors for Olin blended the stored TDI matter waste with HAN 906 solvent.

Lyondell stated that Arco/Lyondell did not have specific written procedures for on-site blending of the TDI waste mixtures and offloading them from tank cars because Olin or Olin contractors blended and disposed of this TDI waste. Arco/Lyondell said it had written procedures for producing solvent blend wastes in a fixed blending tank at the Lake Charles plant site and then transferring the solvent blend wastes from the blending tank into tank cars. These procedures set the temperature and viscosity limits for the solvent blend wastes in the fixed blending tank. The viscosity of the solvent blend wastes in the blending tank was to be less than 200 cp at a reference temperature of 78° F. The temperature of the solvent blend wastes in the blending tank was to be maintained at

125° F (± 5° F). Further, if the ambient air temperature were below 45° F, the temperature of the solvent blend wastes was to be increased to 145 to 155° F before the solvent blend wastes were transferred to a tank car, to prevent the wastes from plugging the transfer piping.

Apart from these procedures, neither Olin nor Arco/Lyondell had written operating procedures or limitations that addressed the potential for gas generation or product expansion, the maximum temperature and time for heating the TDI wastes, or the maximum product viscosity for offloading tank cars. Lyondell also noted that the company did not conduct any tests on the effects of heating the TDI wastes.

Essroc TDI Waste Disposal Operations

Guidance on Processing TDI Waste Mixtures

Solvent Blend Wastes. During the evaluation of the 1996 proposal to burn solvent blend wastes at Essroc's Logansport plant, Essroc and CPRIN personnel visited the Lake Charles plant to observe Olin's process for handling and incinerating the solvent blend wastes. According to CPRIN, most of the information discussed addressed the risks from exposure to the solvent blend wastes and the necessary equipment to protect Essroc and CPRIN employees who would be involved in processing the solvent blend waste mixtures. Olin also discussed with Essroc and CPRIN the reactivity of the solvent blend wastes with water.

CPRIN stated that it advised Chemical Waste Management that the viscosity of the solvent blend wastes had to be less than 500 cp before they could be shipped to Essroc. According to CPRIN, Olin indicated that, to meet this standard for viscosity, the solvent blend wastes would only have to be heated to about 90 to 100° F for Essroc to offload and pump the wastes directly to the kilns.

Essroc stated that because CPRIN was responsible for heating and delivering the solvent blend wastes in sufficiently fluid states, any operational procedures or limits for heating the waste mixtures were directed toward CPRIN. CPRIN indicated to the Safety Board that Essroc retained ultimate authority over heating, handling, and offloading the wastes; therefore, any change in procedures for heating the wastes would require Essroc approval.

TDI Matter Wastes. In early 1998, Chemical Waste Management approached CPRIN and Essroc about incinerating TDI matter wastes at the Logansport plant. Between March and June 1998, Olin, Chemical Waste Management, CPRIN, and Essroc evaluated the proposal and determined that TDI matter wastes could be processed and incinerated at the Essroc plant. Under this plan, the TDI matter wastes would be offloaded from the tank car to a fixed tank where the wastes were to be blended with HAN 906 solvent. The blended TDI matter wastes would then be pumped to Essroc's kilns and burned.

Before Essroc agreed to accept the TDI matter wastes in spring 1998, a TDI expert who worked at the Lake Charles plant[22] visited the Essroc plant to meet with Essroc and CPRIN personnel and to instruct them about handling and processing the TDI matter wastes. According to the Lake Charles TDI expert, he told the Essroc and CPRIN personnel that the TDI matter wastes would have to be heated to 125° F before they could be offloaded from the tank car and transferred to the blending tank. In response, Essroc and CPRIN expressed concerns about the generation of the poisonous chemical phosgene and the heating of the TDI matter wastes above 110° F, which was the maximum recommended temperature for pure TDI cited in Olin's product literature.

According to CPRIN, the Lake Charles TDI expert advised that the 110° F temperature limit applied only to the pure monomeric TDI product, which, if heated above that temperature, could not be sold as a usable product. Because Essroc never intended to recover the monomeric TDI from the waste materials in the tank cars sent it for disposal, degradation of the monomeric TDI in the wastes was no longer a concern. Essroc and CPRIN both indicated that the Lake Charles TDI expert said that the TDI matter was heated to temperatures as high as 350° F at the Lake Charles plant, and that the concentration of phosgene in the TDI matter at elevated temperatures was not sufficient to present a hazard. As a result, CPRIN stated it was "given the impression that we should not be concerned about how hot we heated the TDI material." CPRIN further stated that Olin provided no guidance or information about the potential for gas generation and/or product expansion during heating, nor did Olin provide a recommended viscosity for offloading.

According to Essroc, Olin advised Essroc personnel that expansion of the TDI matter wastes during heating was "normal" and that phosgene gas would not likely be generated if the wastes were heated over 125° F. Essroc said that the Lake Charles TDI expert also told its personnel that heating the wastes before offloading them was intended to make the wastes sufficiently fluid to be transferred, not to enable the wastes to meet an established viscosity threshold.

Essroc acknowledged that the Lake Charles TDI expert said that a long, slow heating process, possibly taking 2 to 3 days, would sometimes be necessary before the TDI matter wastes would flow. During a December 1999 Safety Board interview, the Lake Charles TDI expert who had met with Essroc and CPRIN personnel stated that he had discussed the various handling and offloading procedures with them. He said that the procedures discussed had included heating the tank car with low-pressure steam, using nitrogen sparging to facilitate even heating of the TDI matter wastes, and keeping the temperature of the TDI matter wastes below 130 to 140° F. The Lake Charles TDI expert also stated that he discussed the chemical properties of the TDI matter waste, including its reactivity with water and the possible generation of phosgene and carbon dioxide, with Essroc and CPRIN personnel.

[22] This employee worked at the Lake Charles TDI plant under the successive managements of Olin, Arco, and Lyondell as the TDI production facility changed ownership between 1993 and 1999. This report will refer to this employee as the "Lake Charles TDI expert."

In response to Safety Board inquiries about the guidance it provided to Essroc and CPRIN, Olin said that it told Essroc and CPRIN (through its company expert) about using low-pressure steam and nitrogen sparging to evenly heat the TDI matter wastes in the tank cars. Olin also stated that it told Essroc and CPRIN to keep the temperature of the wastes from exceeding 130 to 140° F.

Responding to a Safety Board request for copies of any written guidance provided to Essroc and CPRIN, Olin stated in a January 14, 2000, letter that "to the extent that a written policy or procedure exists for heating TDI matter, it was turned over to Arco as part of the business sold to Arco." In response to the same Safety Board request, Lyondell stated in a January 24, 2000, letter that "since Olin interfaced with Essroc, Arco or Lyondell recommended no guidance or operational limits for heating railcars for unloading."

Operational Problems

Soon after Essroc began accepting the TDI matter wastes in May 1998, the company began to experience problems with the on-site blending process. Sediment from the unblended wastes built up in the fixed blending tank. In addition, Essroc was unable to pump the blended waste from the blending tank to the kilns because the blended waste was solidifying in the pipelines that ran from the blending tank to the kilns. According to the Essroc facility supervisor, Essroc stopped using the storage tank for blending in September or October 1998.

In November 1998, the Lake Charles TDI expert again visited the Essroc plant to determine the cause of the problem with the blending system, but he could not pinpoint it. According to the Essroc facility supervisor, the Lake Charles TDI expert advised Essroc during this visit that the TDI matter wastes could be burned by direct injection from the tank cars to the kilns rather than blending the wastes before feeding them to the kilns.

The Lake Charles TDI expert told the Safety Board that, as part of his November 1998 visit to the Essroc plant, he and two CPRIN employees checked the fluidity of the TDI matter wastes in UTLX 643593 (the accident car), UTLX 643560, and possibly one other tank car. They checked the fluidity by lowering a rod into the tank cars and sensing the resistance to withdrawing the rod. The Lake Charles TDI expert stated that UTLX 643593 had retained a "slight" positive pressure in the tank. He described the condition of the wastes in the three tank cars as "pretty stiff." He stated that a sample of the TDI matter waste was normally drawn from each tank car at the Lake Charles plant before the car was shipped from the plant. The viscosity of the sample was routinely measured to ensure that it was within customer specifications. If the viscosity were too high, HAN 906 solvent would be added to bring it within specifications before the tank car was shipped.

The Lake Charles TDI expert acknowledged that, for some unknown reason, the three tank cars he examined at Logansport in November 1998 had been shipped from the Lake Charles plant without samples being drawn or verification being made that the viscosities were within Essroc specifications (400 to 500 cp). Lyondell later confirmed that tank cars UTLX 643593 (the accident car), UTLX 643560, and UTLX 643562 were shipped on the same date from Lake Charles. (Shipping records from Olin and Essroc indicate that UTLX 643562 was offloaded by late September 1998.) In response to Safety Board inquiries about how this occurred, Olin responded that it was their understanding that "Arco decided not to add HAN 906 solvent," based on the original analysis of the TDI matter waste in each tank car at the time of loading. Lyondell responded that 28 tank cars containing TDI matter waste were shipped to Essroc between March and September 1998, including UTLX 643593, UTLX 643560, and UTLX 643562, because blending of the wastes was to be performed on-site at Essroc. Lyondell stated that the tank cars were shipped "unblended at the request of Olin."

Configuration of Essroc Offloading Station

The Essroc plant's offloading area had two stations for tank cars, one on the west side of the kilns and one near the fixed storage tanks. The offloading area also included a station west of the tank car stations; this western station was used to offload cargo tank trucks.

To offload a tank car, connections to the fixed plant piping were made at the tank car's vapor valve and one of its two loading line valves. The connection to the vapor valve on the tank car controlled the nitrogen system and the vapor emissions system. Nitrogen gas was injected into the tank car's vapor space to maintain a positive pressure of 20 to 25 psig and to provide a nonflammable mixture in the vapor space. The vapor emissions system passed the vapors vented from the tank car through a series of filters before any vapors were released to the atmosphere.[23] The single line from the vapor valve on the tank car contained a shutoff valve and a coupler to the tee fitting that was connected to a coupler for the nitrogen system and a coupler for the vapor emissions system. The nitrogen supply line and the vapor emissions line were also equipped with isolation valves. With this configuration, nitrogen could be injected into the tank car or vapors vented from the tank car through the vapor emissions system. (Nitrogen could not be injected while vapors were being vented.)

The nitrogen was stored in a bulk tank located in the offloading area. The nitrogen was cycled through two heaters before it flowed into the tank car. According to the vendor that supplied the nitrogen to Essroc, the specifications for the nitrogen stipulated a purity of 99.999 percent and a maximum water content of 1.5 parts per million (0.00015 percent by volume). The Essroc TSD facility supervisor indicated during a postaccident interview that Essroc had had no problems with the nitrogen system before the accident.

A section of flexible hose equipped with a coupler and a valve was connected to one of two loading line valves on the tank car. The coupler on this flexible hose could be connected to one of three fixed pipelines: (1) a pipeline serving as a direct feed to the kilns, (2) a pipeline from the storage tanks containing HAN 906 solvent, and (3) a pipeline from the storage tanks containing toluene. Cross-connections between the three pipelines and the placement of pumps and valves enabled Essroc to blend the TDI matter wastes

[23] To ensure compliance with air quality standards.

with the HAN 906 solvent in a fixed tank and to flush the plant piping from the kilns back to the tank car.

The facility supervisor also said, in a postaccident interview, that the offloading stations had no water lines. An air line led to the offloading station; the air line could not be cross-connected to the nitrogen line.

The boiler used to generate the steam to heat the wastes in the tank cars was in a truck trailer north of the tank car offloading station. The CPRIN service manager at the Essroc plant said that the boiler was automatic. The main valve on the boiler controlled the amount of steam delivered to the tank car; it was the only valve manipulated in the steam-heating process. The valve was normally open about halfway. The steam flowed through a 75-foot-long feed line from the boiler to the inlet connection on the bottom center of the tank car. The pressure of the steam discharged from the boiler was between 100 and 125 psig; the maximum design pressure of the boiler was 150 psig. After the steam circulated through the heating coils on the tank car, it flowed through a return line to a steam trap or condensate tank located in the same trailer as the boiler. According to the CPRIN manager, the water in the return line was about 180° F.

Essroc Offloading Procedures

Essroc's plant procedures manual contained written instructions for moving and unloading any tank car containing any type of waste fuel and standard operating guidelines that applied specifically to the tank cars carrying TDI wastes. The guidelines addressed receiving and positioning such cars, drawing samples from them, offloading the TDI wastes to a fixed tank, and purging the flow lines after the offloading was complete. The Essroc facility supervisor said that Essroc developed these written procedures in 1995 before the company began to burn standard solvent blend wastes. The facility supervisor also stated that Essroc had written procedures on how to blend TDI wastes in the fixed tank after they were offloaded from a tank car and before they were pumped to the kilns for incineration. The waste fuel technicians had no written procedures or checkoff lists for directly feeding TDI wastes from the tank car to the kilns (the process used for offloading UTLX 643593).

The Essroc written procedures that applied to all tank cars and those specific to the tank cars carrying TDI wastes addressed subjects such as the sequence for opening and closing valves, the means of connecting and disconnecting nitrogen lines, and the ways of increasing and decreasing internal tank car pressures to specific limits. The procedures did not address heating the waste cargoes, limiting temperatures, or limiting maximum viscosities (to ensure the cargo was sufficiently fluid for offloading).

The Essroc facility supervisor stated during postaccident interviews that Essroc personnel would not allow CPRIN to heat TDI wastes to more than 200° F because of a concern that phosgene might be released. The facility supervisor also stated that Essroc workers determined that the TDI wastes were ready for offloading when the wastes were thin enough to flow, rather than when they reached some specific temperature.

The CPRIN manager stated that CPRIN had no written procedures or checkoff lists addressing the steam heating of rail tank cars containing TDI wastes or other waste cargoes. He said that the criteria that CPRIN used for steam heating the tank cars was to conduct steam heating until the viscosity of the TDI wastes was reduced and the waste was in a pumpable state. According to the CPRIN manager, it was not unusual to apply two steam cycles to a tank car containing TDI waste fuels. He also indicated that they applied more heat to UTLX 643593 than to other tank cars.

Postaccident Actions

FRA-Ordered Inspections and Tests

When the accident occurred, 24 tank cars containing TDI matter waste either were stored in the Logansport rail yard or had been delivered to the Essroc plant. Olin advised the FRA on March 23, 1999, that an additional 10 cars containing TDI wastes were at the Deer Park transfer facility in Houston, Texas.

Following the rupture of UTLX 643593, Olin and Lyondell determined that the 24 tank cars in the Logansport area should be sent to Deer Park for offloading. Because of the possibility that UTLX 643593 had failed from overpressurization, the FRA ordered the testing of the pressure relief valves from a representative sample of four of the tank cars in the Logansport area to ensure the valves were functioning properly before the tank cars could be moved. The pressure relief valves from tank cars UTLX 643560, UTLX 643588, GATX 36571, and GATX 92907 were removed and tested at the Midland Manufacturing production facility in Skokie, Illinois, on March 18 and 25, 1999. Because UTLX 643560 and UTLX 643588 were sister tank cars of UTLX 643593, they were equipped with the same model pressure relief valve, a Midland model A-1479 ER relief valve. Tank cars GATX 36571 and GATX 92907 were equipped with Midland model A-1775-P and A-2085 (respectively) pressure relief valves.

Federal regulations at 49 CFR 180.509 require that pressure tests be conducted every 10 years for the pressure relief valves on these tank cars. The pressure relief valves on UTLX 643560, UTLX 643588, and UTLX 643593 had last been tested in 1993 and were due for retesting in 2003. The pressure relief on GATX 36571 had last been tested in 1989 and was due for retesting in 1999. The pressure relief valve on GATX 92907 had last been tested in 1993 and was due for retesting in 2003.

The four valves were pressure-tested on March 18, 1999, in accordance with the procedures in appendix D of the Association of American Railroads (AAR) *Specifications for Tank Cars (M-1002)*.[24] The FRA reported that all four valves, which were to have discharge pressures of 75 psig, failed to meet the tolerances for the start-to-discharge

[24] Association of American Railroads, *Specifications for Tank Cars,* In: Manual of Standards and Recommended Practices, Section C - Part III, Specification M-1002, Washington, DC, 1996.

pressure[25] and vapor-tight pressures required under Federal regulations for tank cars transporting hazardous materials.

Although the start-to-discharge pressures recorded for the valves from UTLX 643560 and UTLX 643588 ranged from 83 to 90 psig, each valve began leaking at 2 to 3 psig. Over three test cycles, the model A-2085 valve from GATX 92907 had a start-to-discharge pressure ranging from 84 to 94 psig, and a vaportight pressure of 20 psig. The model A-1775-P valve from GATX 36571 had a start-to-discharge pressure of 250 psig on its first test, and 120 and 130 psig on two subsequent tests. The vaportight pressure could not be determined.

The O-rings from each valve were examined and tested for brittleness. According to Midland representatives, the O-rings should have durometer[26] readings ranging from 70 to 75 for the relief valve to function properly. Durometer readings for the O-rings were generally in the mid-90s. (Durometer readings increase as a substance's brittleness increases.) The O-rings also exhibited varying degrees of brittleness, swelling, hardness, and cracking. The condition of the metallic components varied widely: heavy rust, scale, pitting, and grit were observed on some valve components from GATX 36571 and GATX 92907. The valve components from UTLX 643560 and UTLX 643588 either had light scale and rust or exhibited no visible deterioration.

Based on these test results, the FRA required that Olin and Lyondell either replace the pressure relief valves on the remaining tank cars in Logansport (24 cars) and Deer Park (10 cars) or prove that the pressure relief valves on the remaining tank cars complied with Federal regulations before any of the tank cars could be moved in commerce.

Disposition of TDI Wastes in Other Tank Cars

In response to the FRA directive, Olin and Lyondell had the pressure relief valves replaced on all 24 tank cars in the Logansport rail yard before moving any of the tank cars to Deer Park, Texas, where they were to be offloaded. By June 22, 1999, the 24 tank cars shipped from Logansport had arrived in Deer Park, where they were staged until they were individually offloaded at the terminal.

Olin contracted a waste disposal firm to dispose of the TDI matter wastes in the 24 tank cars shipped from Logansport and the other tank cars sent to Deer Park. The waste disposal firm was to blend the TDI matter waste with HAN 906 solvent as needed to reduce the viscosity of the waste below a prescribed level before transloading the wastes from the tank cars to tank trucks. The blending agent was added to the TDI matter waste to reduce the waste's viscosity to ensure that it would be sufficiently fluid to allow it to be offloaded into tank trucks. The tank trucks delivered the wastes to incineration sites in Houston, Texas, and Baton Rouge, Louisiana.

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[25] The *start-to-discharge pressure* is the pressure at which the spring-loaded valve begins to lift, allowing vapor to flow through the valve and vent from the tank.

[26] Tool for measuring the degree of brittleness or hardness of a gasket.

The blending and offloading of the wastes in these tank cars began on August 2, 1999. Olin reported that by August 9, 2000, five cars remained to be offloaded. Since August 2000, two tank cars have been successfully offloaded. In the three remaining cars, the TDI matter waste has solidified and cannot be successfully pumped from the tanks. An attempt to offload two of the three cars by mechanical extraction (grinding) is planned for 2001. Experts believe that the final car may have to be cut apart to remove the solidified waste.

UTLX 643560, which had a loading history and waste composition most similar to UTLX 643593, had been offloaded on December 2, 1999. The initial viscosity of the TDI matter waste in UTLX 643560 was 2,160 cp at 75° F. Slightly more than 2,500 gallons of toluene were blended with the waste in UTLX 643560 to reduce the viscosity to 325 cp at 75° F. Because of the reduction in the viscosity from blending with the toluene, steam heating of the waste was not required before offloading UTLX 643560. Olin also stated that no problems were encountered with increased pressures or temperatures concerning any of the tank cars offloaded at Deer Park.

Postaccident TDI Matter Waste Offloading Procedures

Following the accident (and before offloading began), Olin, with the assistance of waste disposal companies, developed written offloading procedures for the 24 tank cars that contained TDI matter wastes and had been stored in Logansport and for the 10 tank cars stored at Deer Park. Under these procedures, a sample of the TDI matter waste would first be drawn to determine its viscosity, which had to be less than 400 cp at 120° F before offloading could begin. If the viscosity of the TDI matter waste in an individual tank car exceeded this limit, the amount of HAN 906 solvent needed to lower the viscosity below the 400 cp threshold was calculated.[27]

Before any TDI matter wastes were transferred from the tank car to a cargo tank truck, technicians were required to conduct the following sequence of operations:

- (To prevent overheating from high-pressure steam) Use low-pressure steam to heat the TDI wastes by connecting the steam supply to the inlet pipe for the heating coils on the tank car, leaving the discharge pipeline for the heating coils open;
- Sparge the TDI waste mixture by injecting nitrogen through the eduction line to agitate the TDI waste while heating;
- Continuously steam heat and mix until the temperature of the TDI waste reaches 125° F, at which time the steam heating and sparging are stopped;
- Inject the previously calculated amount of HAN 906 solvent through the eduction line;
- Recommence sparging of the TDI waste with nitrogen for 1 hour;

[27] Although these procedures specified the use of HAN 906, toluene (a hydrocarbon) could be used as a solvent to reduce the viscosity of the wastes. As noted earlier, toluene was used to reduce the viscosity of the wastes in UTLX 643560.

- Draw a sample of the TDI waste from the tank car and measure its viscosity. (If the viscosity were less than 400 cp, the TDI wastes were to be offloaded from the tank car to cargo tank trucks. If the viscosity exceeded 400 cp, the cycle of steam heating, sparging, and adding HAN 906 solvent was to be repeated until the specifications for viscosity were met.)

The written procedures also specified that the temperature of the TDI matter waste should be maintained at 125° F, ± 10° F.

Inspections and Tests

Metallurgical Examination

After the accident, three sections were cut from UTLX 643593 and sent to the Safety Board's materials laboratory for further examination. The sections were: (1) a 35-inch-long section of the fracture surface along the tank's bottom center toward the A-end, (2) a section from the top center that appeared to be unaffected by the tank rupture, and (3) a section from the bottom center containing a tear in the exterior tank wall.

The 35-inch-long section of the fracture surface was taken from a tank location with the lowest wall thickness, based on field measurements. Measurements of the wall thickness along the fracture face ranged from 0.285 to 0.338 inch. Plastic deformation (necking) of the tank wall along the fracture was observed. The fracture face in the area where the tank wall was thinnest contained shear lips on both the exterior and interior surfaces and a small flat fracture region between the shear lips. The fracture features were typical of ductile tensile overload fractures in low-carbon steels. X-ray energy dispersive analysis indicated that the chemical composition of the steel was consistent with the ASTM A516 grade 70 steel specified for the tank material.

The tank wall in the section removed from the top center of the tank (which had appeared to be unaffected by the rupture) had an average thickness of 0.545 inch. According to Union Tank Car, the thickness of the shell plate before it was rolled into the tank cylinder ranged from 0.569 to 0.580 inch. The microstructure of the tank material was typical of ASTM A516 grade 70 steel in a hot-rolled condition. Based on hardness tests, the ultimate tensile strength was about 89,000 pounds per square inch (ksi). The specified tensile strength of the tank plate was 70 to 90 ksi. The reported tensile strength of the plate from which this tank was manufactured was 78.8 ksi.

Plastic deformation was found on the section removed from the bottom of the tank car that had tearing damage on the exterior surface. Hardness tests indicated that this section had an ultimate tensile strength of 89 ksi.

Examination of the Pressure Relief Valve and Other Fittings

The dome assembly, including the manway cover, valves, piping, and surrounding tank shell, was cut from UTLX 643593's tank on February 24, 1999. The dome assembly was taken in April 1999 to Marsh Railcar Services in St. Peters, Missouri. Testing and examination of the pressure relief valve and the other valves mounted on the manway were conducted on May 18, 1999.

Solid TDI waste material filled about half of the interior of the dome nozzle. Loose pieces of the solid waste were removed to expose a portion of the manway coverplate. The remainder of the manway coverplate interior was covered with a layer of solid, glassy-looking TDI matter waste that was molded into the dome nozzle. The thickness of this layer was 4 to 5 inches. This layer was chipped out to expose the complete interior side of the manway coverplate.

Some TDI waste residue was also on the exterior side of the manway coverplate, between the base of the pressure relief valve and the valve for the B-end loading line. An information card about the health hazards of pure TDI and a plastic bag containing an Olin rail car complaint form were also found within the dome housing. These two items had no apparent heat or thermal damage. The pressure relief valve, the vapor valve, the vacuum relief valve, and the two loading line valves were removed and examined. The Teflon gaskets used to seat these valves on the manway coverplate were clean and had no visible deterioration. The condition of each valve is detailed below.

Pressure Relief Valve. The pressure relief valve was unbolted and removed from the manway coverplate. The orifice in the manway coverplate for the pressure relief valve was completely plugged with solid TDI waste. The solid TDI waste had also flowed onto the exterior of the manway coverplate below the base of the pressure relief valve, between the orifice opening and the Teflon seating gasket. TDI waste filled and plugged the throat of the pressure relief valve. (See figure 9.) The vertical alignment of the pressure relief valve was measured. No misalignment was noted or observed. Dirt, grease, and some corrosion were observed on the exterior surfaces. (The pressure tests and teardown are detailed in the next section.)

Vapor Valve. The handle for the 1-inch vapor valve was not in the fully open position. The orifice through the manway coverplate was completely plugged with TDI waste. When investigators removed the valve, they noted that the inlet at the base of the valve was completely plugged with TDI waste. They disassembled the valve. TDI waste was molded to the interior of the valve; the waste completely plugged the valve from the inlet flange to the outlet flange. (See figure 10.)

Vacuum Relief Valve. The orifice through the manway plate was plugged with TDI waste. The waste did not completely fill the orifice and came to within 1 inch of the exterior side of the manway coverplate. (Refer to bottom photo of figure 10.) No waste material was observed in the body of the valve.

Figure 9. Top photo shows plugged opening in UTLX 643593 manway coverplate for pressure relief valve as viewed from the interior of the tank. Bottom photo shows view of plugged valve from the dome side of the manway cover. *(NTSB)*

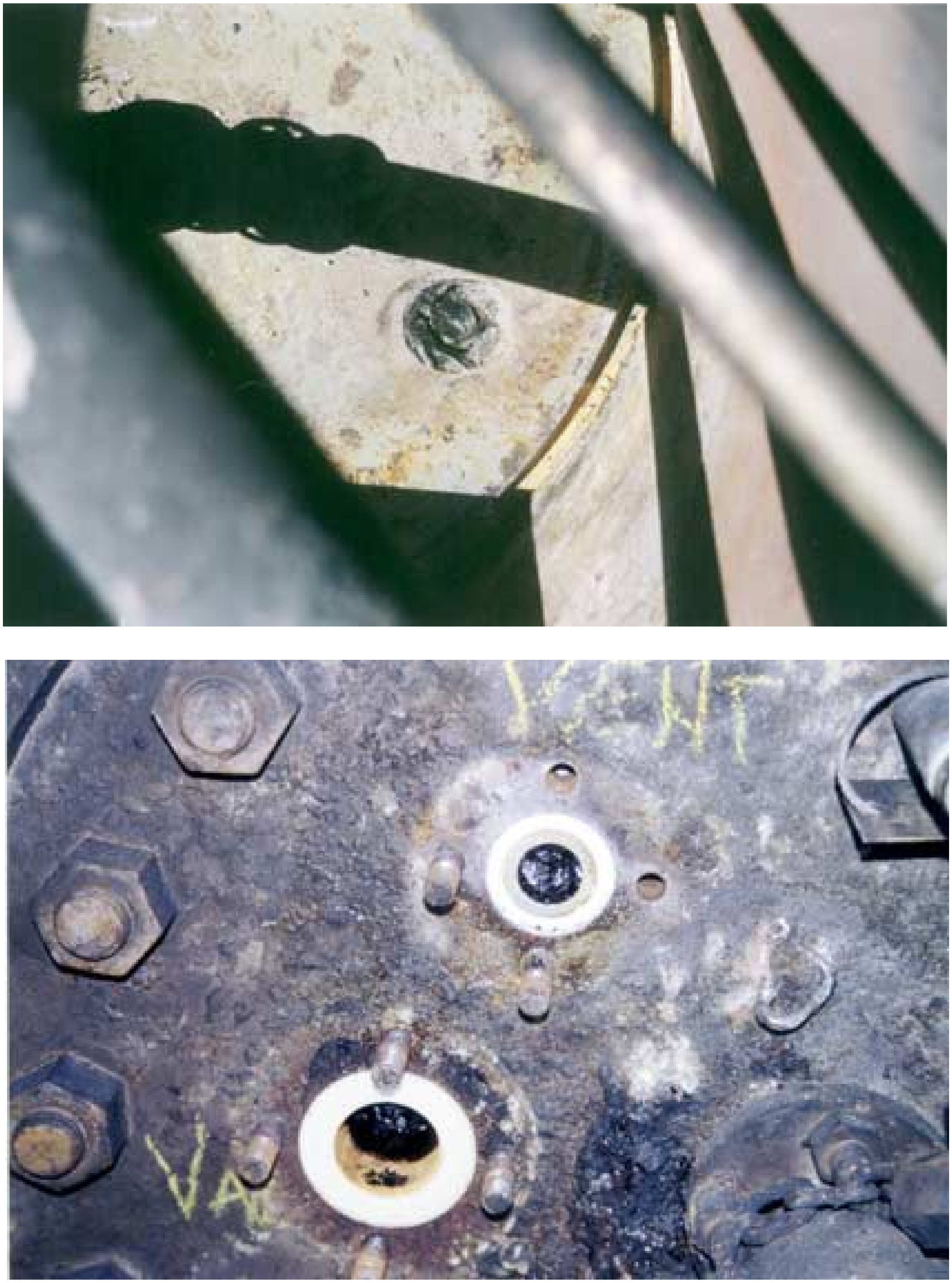

Figure 10. Top photo shows plugged opening in UTLX 643593 manway coverplate for vapor valve as viewed from the interior of the tank. Bottom photo shows plugged openings in manway coverplate for vapor (higher) and vacuum relief (lower) valves from the dome side of the manway cover. *(NTSB)*

A-end Loading Line Valve. The valve handle was in the closed position. The threaded cap used to cover the valve outlet was in place and secure. When the valve was removed from the coverplate, it was seen to contain waste with a taffy-like consistency.

B-end Loading Line Valve. The valve handle was in the closed position. The threaded cap used to cover the valve outlet was unscrewed and dangling from a chain attached to the valve. When the valve was removed from the coverplate, liquid trapped in the valve began to drip. During the inspection, one party representative remarked that the liquid had an odor similar to MCB. (The liquid and other viscous materials trapped in the valve were drained into a glass jar with a screw-on lid. These substances were subsequently sent to an independent laboratory for analysis. See section on "Chemical Analysis and Tests.") The orifice in the manway coverplate was plugged to a depth of about 1 inch below the exterior surface of the coverplate with wet and very soft waste residue. After this residue was removed, a length of pipe was inserted to a depth of 14 inches through the manway plate opening into the loading line to determine whether TDI waste was in the loading line. No waste product was detected using the pipe probe.

Thermometer Well. The cap was off. No other observations were noted.

Pressure Tests and Teardown of Pressure Relief Valve

The pressure relief valve was mounted on a test bench, and air pressure was applied to determine (1) if the start-to-discharge pressure was within the tolerance of ± 3 psi for the 75-psig set point and (2) if the valve, upon closing, was vaportight at not less than 80 percent of the start-to-discharge pressure. Five test runs were conducted. During the first two tests, the valve began to discharge at less than 10 psig and to continuously discharge as the air pressure was increased to 100 psig. For the third test, the TDI waste in the throat of the pressure relief valve was removed, and air pressure was again applied to the valve. The valve began to leak air at less than 10 psig. Before the fourth test, the pressure relief valve was disassembled without changing the spring setting. Debris on the valve seat was observed but left in place. (See figure 11.) After new O-rings were installed, the valve was reassembled, and, without cleaning the debris from the valve seat, air pressure was applied. The valve discharged at 3 psig. For the fifth test, the pressure relief valve was again disassembled and the debris was cleaned from the valve seat and all sealing surfaces. The new O-rings were lubricated, and air pressure was applied. The valve began to discharge at 73 psig, reseated when the air pressure was reduced, and was vaportight at 68 psig. This cycle was repeated twice more with comparable results.

Following the pressure tests, the pressure relief valve was completely disassembled. The interiors of the valve and the spring were free of chemical debris and exhibited no indications of mechanical damage or corrosion. The two O-rings that had been removed from the pressure relief valve were examined and tested for brittleness. The large O-ring had a permanent set or deformation on the sealing surface with the valve. No set or deformation was noted on the small O-ring. Durometer measurements on the new O-rings and the two O-rings removed from the relief valve were taken and compared. Durometer readings for the new O-rings ranged from 70 to 74 (considered normal); the

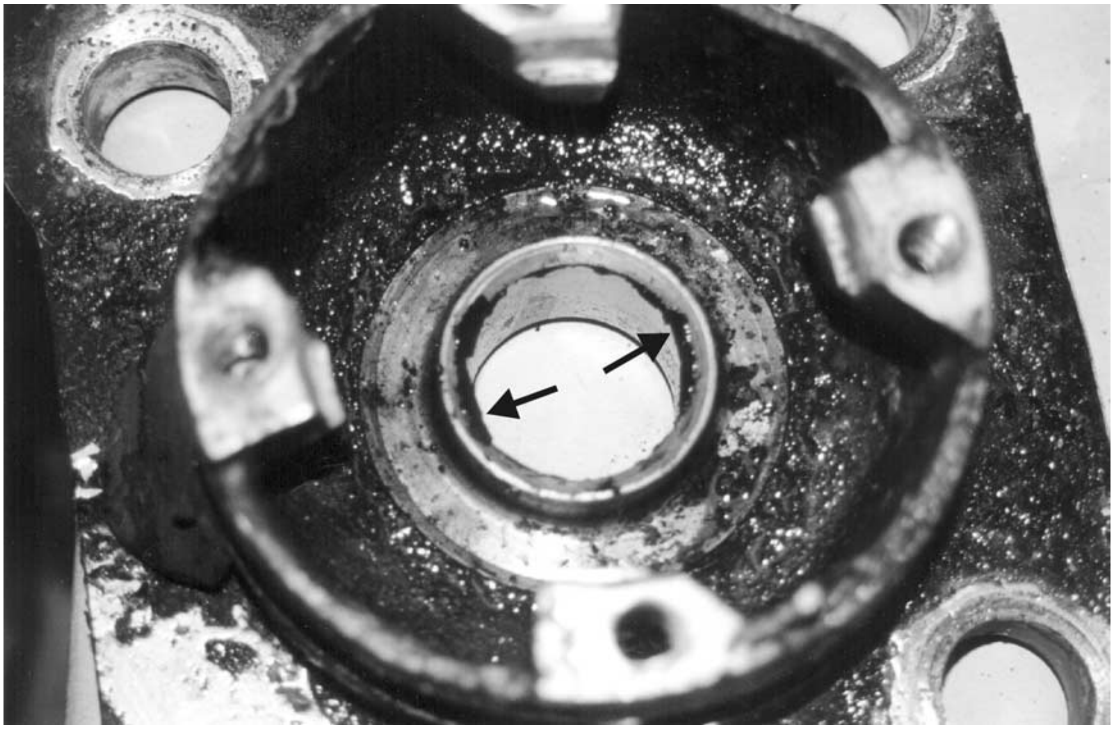

Figure 11. Pressure relief valve fitting. Arrows show debris on the valve seat. *(NTSB)*

reading for the O-rings removed from the pressure relief valve ranged from 80 to 97 (indicating increased hardness and brittleness).

Chemical Analyses and Tests

Samples. Nine chemical samples, including a sample of the TDI waste matter drawn from UTLX 643593 before the accident, were recovered and shipped to the Lake Charles plant for analysis and testing. The other eight samples were recovered after the accident from the remnants of the tank car, debris on the plant grounds, and a cutout section of plugged pipe to the kilns. Heating tests were conducted on the preaccident sample drawn from UTLX 643593 (designated as the "retain" sample), the sample from the plugged pipe section (designated as the "pipe cutting" sample), and a waste sample from the Lake Charles plant. The tests were designed to analyze the effects of heating the samples similarly to the heating of the waste mixture that had been in UTLX 643593.

Testing. The apparatus for the heating tests, known as the reactive system screening tool (RSST), monitored and recorded the temperature and pressure as a 10-cubic centimeter glass vial approximately 2/3 full of each test sample was heated in a closed chamber. The liberation or generation of gas would be indicated in a test run if there were a net increase in the pressure in the test chamber after the chamber had cooled to its initial temperature. The first four test runs were to be conducted following normal RSST methods of increasing the temperature at a controlled rate to the programmed cutoff temperature of 662° F. However, the sample in the first run could not be heated to the cutoff temperature because the glass vial shattered from expansion of the test sample. The sample was heated and held to a temperature range of 428 to 446° F for the maximum test time of 7.3 hours. In the fifth and final run, 10 grams of the preaccident sample drawn from UTLX 643593 were heated to 353° F and held at this temperature for 25.7 hours to approximate the maximum possible temperature of the steam used to heat UTLX 643593 and the total heating time of UTLX 643593. See table 1 for the results of the five test runs.

Table 1. Results of RSST runs on TDI waste matter samples

Run Number	Sample Source	Net Pressure Increase (psi)
1	10.11 g of retain w/200 mg of water	9.4
2	10.10 g of retain	4.4
3	9.10 g of pipe cutting	20.0
4	10.00 g of typical waste	9.9
5	10.20 g of retain	3.5

The sample in each test run exhibited an increase in volume by the conclusion of the test run. The volume increase of the samples in two of the glass vials was sufficient to exceed the volume of the glass vial and cause the vial to break. The volume of the samples from the three remaining test runs expanded from 2/3 of the volume of the vial to fill the vial completely. The test results did not establish whether the volume increase was the result of the expansion of the sample or the entrapment of gas bubbles within the waste.

Gas chromatographic analysis was conducted on the retain sample, the pipe cutting sample, and the typical waste sample to identify specific chemical compounds in each sample. The results of this analysis indicated that each sample contained TDI, chlorinated TDI impurities, and carbodiimides (byproduct of a self-reaction of the monomeric TDI).

An independent laboratory conducted several analytical tests from December 1999 through February 2000 on the waste sample recovered from the B-end loading valve of UTLX 643593 during the inspections at Marsh Railcar Services in May 1999. The sample, when recovered, was a mixture of a viscous material and liquid. Although the sample had been placed in a glass jar and sealed, virtually all the liquid had evaporated when it was delivered to the laboratory for testing. The purpose of these tests was to identify the chemical components of the sample and to test specifically for the presence of toluene and amines. (Toluene was the solvent used by Essroc to flush the plugged piping to the kilns. Amines are a class of chemical compounds that would be byproducts of the reaction of TDI and water.)

Infrared spectrometry and gas chromatography indicated the presence of toluene, amines, and MCB in the sample. Based on additional testing to determine the types of amines detected, the laboratory concluded that the amines present were “primary” amines that would be generated with the reaction of TDI and water.

Approved Cargoes and Components for DOT Specification Tank Cars

Federal Regulations and Oversight

Under 49 CFR 179.15 of the DOT *Hazardous Materials Regulations*, the pressure relief device on a DOT class 111A tank car, such as UTLX 643593 and the four other tank cars tested at Midland in March 1999, must be made of materials that are compatible with the lading transported in the tank car. Paragraph A3.02 of appendix A of the AAR Manual of Standards for tank cars[28] reads, "It is the shipper's responsibility to assure that materials used for gaskets or valve seals are compatible with the lading and the service temperature." The 49 CFR 179.15 compatibility requirement does not reference, or explicitly require conformance with, the AAR standard.

In a February 9, 2000, response to Safety Board inquiries concerning the FRA hazardous materials safety program and issues involved in the Clymers accident,[29] the FRA told the Safety Board that the DOT *Hazardous Materials Regulations* place the responsibility for ensuring that a package is appropriate for transportation on the "offeror" (typically the shipper) of the material. The FRA further stated that the selection should be made with input from the tank car owner, to ensure that the gasket configuration is appropriate for the device and that other entities have similar responsibilities in relation to the tank car's maintenance. The FRA noted that the tank car manufacturer and tank car repair facilities each have a responsibility to ensure that the approved materials are used during the assembly of the tank car and for repairs or replacement. Nevertheless, the FRA stated that the DOT regulations require the offeror to ensure that the components on the tank car are correct before offering the tank car for transportation.

The DOT *Hazardous Materials Regulations* also contain provisions regarding a change in the approved cargoes for a DOT specification tank car. Paragraph 49 CFR 173.31(a)(2) of the *Hazardous Materials Regulations* reads:

> Tank cars and appurtenances may be used for the transportation of any commodity for which they are authorized in this part and specified on the certificate of construction (AAR Form 4-2 or by addendum on Form R-1)... Transfer of a tank car from one specified service on its certificate of construction to another may be made only by the owner or with the owner's authorization. A tank car proposed for a commodity service other than specified on its certificate of construction must be approved for such service by the AAR's Tank Car Committee.

The FRA, in response to Safety Board inquiries, indicated that, under the provisions of 49 CFR 173.31(a)(2), the offeror must secure approval from the tank car owner before making a change in product service. The offeror must also ensure, with the

[28] Association of American Railroads, *Specifications for Tank Cars*. In: Manual of Standards and Recommended Practices, Section C - Part III, Specification M-1002. Washington, DC, 1996.

[29] Letter from FRA Hazardous Materials Staff Director Edward W. Pritchard to the Safety Board, February 9, 2000.

assistance of the tank car owner, that the materials and components that constitute the tank car are appropriate for carriage of a new product. In the case of UTLX 643593 and the other tank cars used to transport the TDI waste mixtures, the FRA stated that the addition of constituents other than TDI would comprise a change in service if the additional constituents substantially changed the chemical makeup of the material or changed its hazard class.[30]

The FRA further stated that no information or guidance regarding gasket and fitting compatibility in conjunction with changes in product service has been issued. The FRA noted, however, that, in an advance notice of proposed rulemaking (ANPRM) published under docket HM-175A in May 1990, the FRA and the Research and Special Programs Administration (RSPA) sought comments regarding performance standards for the gaskets used on tank cars. Because it received numerous comments citing the technical complexities in developing a performance standard for gaskets, RSPA removed the gasket issue from the docket. The FRA stated that it continues to participate in the AAR Tank Car Committee and the North American Non-accident Release Prevention Committee, which have addressed compatibility issues concerning gaskets and fittings in nonaccident releases.

Compatibility of Pressure Relief Device Components with TDI Waste Mixtures

Union Tank Car provided the Safety Board with excerpts from the *Chemical Resistance Guide for Elastomers*, which contains guidance about the resistance of available gasket, O-ring, and sealing materials to degradation upon exposure to various chemicals. According to this guide, ethylene propylene rubber, the material that constituted the O-rings in the pressure relief valves from UTLX 643593 and the four tank cars tested at Midland, offers good to excellent resistance to chemical attack from pure TDI at temperatures up to 70° F and should not exhibit more than minor swelling, softening, or surface deterioration. The guide recommends against using ethylene propylene rubber with either MCB or naphthalene, one of the primary components of the HAN 906 solvent. Teflon is rated as providing excellent resistance to degradation for TDI, MCB, and the naphthalene.

Midland indicated that, because it is the manufacturer rather than the user of the pressure relief valves, the company does not recommend, prescribe, or influence the selection of valve materials. Midland further stated that it is rarely cognizant of the intended service of the valves and fittings it sells. The company provides its customers, in this instance the tank car builder Union Tank Car, with the valves, gaskets, and O-rings specified by the customer. (Olin's construction order to Union Tank Car specified ethylene propylene rubber O-rings for the pressure relief valves on UTLX 643593 and its sister tank cars.)

In response to Safety Board inquiries about the chemical compatibility of the TDI matter wastes with the components of the tank cars used to store them, Olin stated that, at various times since the 1970s, the company had had its tank cars evaluated to ensure their

[30] FRA February 9, 2000, letter.

suitability for storing and transporting TDI, TDI matter wastes, and solvent blend wastes. Olin stated that the results of such evaluations would have been turned over to Arco/Lyondell as part of the sale of the business. Olin indicated that the company has not been able to locate documentation on any such tests and could not provide any additional details. In response to the same inquiry, Lyondell responded that Arco and Lyondell did not conduct any evaluations of the chemical compatibility of the TDI waste mixtures with gaskets, O-rings, and other components on the tank cars used to store these wastes, but "typically" verified the compatibility of the gaskets and O-rings with "vendor-supplied information." Lyondell stated that the company had no reason to investigate use of the gasket materials with the TDI wastes because no in-plant incidents or releases from tank cars had occurred.

Change of Authorized Cargoes

Because of concerns involving the chemical compatibility of the O-rings with the MCB and the HAN 906 solvent in the TDI waste cargoes, the Safety Board also asked Olin and Lyondell whether they considered that the storage and transportation of the TDI matter wastes in UTLX 643593 and the other tank cars constituted a change in product service from the transportation of pure TDI.

Olin responded that it did not consider the storage and transportation of the TDI wastes in these tank cars to constitute a change in product service. Olin acknowledged that the TDI matter (blended and unblended) and the solvent blend wastes differed from pure TDI but considered that UTLX 643593's and the other tank cars' approval for carriage of pure TDI to be sufficient for carriage of the mixtures of monomeric and polymeric TDI, MCB, and HAN 906 solvent. Olin noted that, under the certificate of construction, UTLX 643593 and its sister tank cars were approved for the carriage of "non-regulated commodities and commodities authorized in DOT Part 173 (49 CFR 173) for which there are no other requirements and which are compatible with this design and class of car." Olin considered that the MCB, the polymeric TDI, and the HAN 906 solvent were within the approved commodity service on the certificate of construction. Consequently, Olin did not seek AAR approval for a change in product service.

Lyondell responded to the Safety Board's inquiry that, although the TDI waste mixtures would have to be identified under a new DOT proper shipping name (hazardous waste, toxic liquid, flammable, organic n.o.s. [not otherwise specified]) rather than as pure TDI, the shipment of these TDI waste mixtures did not constitute a change of product service. Lyondell noted that, under the DOT *Hazardous Materials Regulations*, the bulk containers, such as tank cars, authorized to transport pure TDI were the same containers as those authorized to transport commodities under the new proper shipping name, and that no applicable special provisions in the DOT *Hazardous Materials Regulations* precluded the use of the same type of tank car. Consequently, Lyondell did not seek AAR authorization to change the approved cargoes.

Hazardous Materials Incident Reporting

Notification of Accident

The Essroc plant manager notified the National Response Center (NRC) about the accident by telephone shortly after 3:00 a.m. on February 18, 1999, about 3 hours after the accident. The NRC report summarizing the telephonic notification indicated that a rail car containing "hazardous wastes" had ruptured and was on fire.

The Essroc plant manager believed that, in providing telephonic notification to the NRC, he was complying with applicable Environmental Protection Agency (EPA) regulations.[31] According to Essroc, the plant manager and other Essroc personnel are generally aware of applicable DOT requirements. Essroc further stated that the company is not a carrier and is not responsible for submitting a written DOT Hazardous Materials Incident Report. Essroc did not submit a written incident report to the DOT.

The rail carrier that delivered UTLX 643593 to the Essroc plant was the Central Railroad of Indianapolis, which was managed by the Indiana and Ohio Rail Company. The parent company for both the Central Railroad of Indianapolis and the Indiana and Ohio Rail Company is Rail America. The general manager for the Central Railroad of Indianapolis and the Indiana and Ohio Rail Company indicated that the rail carrier did not submit a written incident report to RSPA because the tank car had been delivered to and left at the Essroc plant, the accident occurred on Essroc property, and the railroad was not involved in the accident. To date, no written incident report has been received by RSPA.

Notification Requirements

Immediate Notification. Under section 49 CFR 171.15 of the DOT *Hazardous Materials Regulations*, a carrier must notify the NRC by telephone "at the earliest practicable moment" about incidents that occur during "the course of transportation" in which the release of a hazardous material results in a fatality, injuries requiring hospitalization, property damage exceeding $50,000, evacuations of the general public, and other criteria.

EPA regulations contain multiple requirements throughout 40 CFR for immediate notification following releases of those materials it designates as "hazardous substances,"[32] "hazardous wastes," and oil (both "used" and crude) from vessels, offshore and onshore facilities, and hazardous waste management facilities operating under EPA permits, as well as TSD facilities such as Essroc. Under DOT and EPA regulations, the telephonic or immediate notifications are made to the NRC, which then disseminates the report to the appropriate Federal agencies, including the EPA, RSPA, the FRA, and the

[31] The EPA regulations for TSD facilities (40 CFR 264) include notification requirements in the event of a release of a hazardous waste. The regulations for emergency planning and community right-to-know programs (40 CFR 302) also have notification requirements for chemical releases.

[32] Specific materials or chemicals designated under the Comprehensive Environmental Response, Compensation, and Liability Act (42 USC 9601) as harmful to the environment if released in a quantity exceeding the reportable quantity for the material.

Safety Board. A single notification to the NRC often satisfies the notification requirements of several Federal agencies.

The NRC, in processing all telephonic notifications, regardless of the nature of the release, collects information of a general nature necessary to understanding and responding to a current or recent emergency. The information sought by the NRC typically includes such information as the location of the incident, the date and time it occurred, the type of material released, the source of the release, the quantity of material released, the names of the parties involved, the damage to the area, and other information immediately obtainable. Such reports are preliminary in nature and are not designed to be comprehensive.

Written Reports. Section 49 CFR 171.16 of the DOT regulations requires that each carrier that transports hazardous materials submit a written DOT Hazardous Materials Incident Report to RSPA within 30 days of discovery of each incident that occurs “during the course of transportation” in which there has been an unintentional release of a hazardous material. DOT regulations define a “hazardous material” as including both EPA-designated hazardous substances and hazardous wastes. Section 49 CFR 171.16 also requires that the carrier submit a DOT Hazardous Materials Incident Report for any incident that must be telephonically reported under section 49 CFR 171.15. Both 49 CFR 171.15 and 171.16 specify that “the course of transportation” includes loading, unloading, and temporary storage. The regulations define a carrier as “a person engaged in the transportation of passengers or property by land or water as a common, contract, or private carrier or by civil aircraft.” In response to Safety Board inquiries, the FRA stated that, in letters of clarification concerning these requirements, RSPA has indicated that a carrier has a duty to report releases of hazardous materials in accordance with 49 CFR 171.16 when it has knowledge of such releases. The FRA stated that a rail carrier must “report to the Department” within 30 days of the date of discovery.

The DOT Hazardous Materials Incident Report form (see appendix B), contains 45 specific categories of information, including background facts about the incident (mode of transportation, date and time of incident, description of carrier and materials shipped, etc.) and specific details concerning the type of container involved, conditions at the incident site, packaging of the material released, and sources of packaging failures. RSPA uses the information obtained through these written incident reports as the input for its Hazardous Materials Information System, which serves as RSPA’s accident database, which RSPA uses to conduct accident analyses.

The EPA requires the submission of written reports for certain types of hazardous waste and oil releases, under certain conditions. Under 40 CFR 264.56(j) and 279.52(b) the owner/operator of a TSD facility or a used-oil processing facility must file a written report to the EPA regional administrator within 15 days after a release, fire, or explosion involving a hazardous waste or used oil that could threaten human health or the environment outside of the facility. The written report must include seven categories of information:

1. The name, address, and telephone number of the owner or operator,
2. The name, address, and telephone number of the facility,
3. The date, time, and type of incident,
4. The name and quantity of hazardous waste or oil involved,
5. The extent of injuries (if any),
6. An assessment of the actual or potential hazards to human health or the environment, where this is applicable, and
7. The estimated quantity and disposition of recovered hazardous waste or oil that resulted from the incident.

The EPA also requires a transporter of hazardous waste under 40 CFR 263.30 or used oil under 40 CFR 279.43 to file a DOT Hazardous Materials Incident Report in accordance with 49 CFR 171.16 when hazardous waste or used oil is released during transportation.

With respect to those materials that the EPA designates as "hazardous substances," the EPA does not require that a written report be submitted to the agency when a hazardous substance release occurs.

Essroc submitted a report dated March 4, 1999, concerning the Clymers accident to the Indiana Department of Environmental Management. Essroc forwarded a copy of this report and cover letter to the EPA Region 5 office on March 4, 1999.

Regulatory Initiatives

RSPA issued an ANPRM on March 23, 1999, which concerned revising the incident reporting requirements (49 CFR 171) and the DOT Hazardous Materials Incident Report form.[33] According to RSPA, the purpose of any revisions would be to increase the usefulness of the accident/incident data in evaluating the effectiveness of existing regulations, determining the need for regulatory changes to address changing transportation safety problems, and identifying major problem areas requiring additional DOT resources. The ANPRM sought comments and information about numerous issues, including:

- Should the hazardous materials incident reporting requirements be extended to persons other than carriers (such as freight forwarders, warehouse operators, consignees, etc.)?
- If an incident requiring immediate telephonic notification occurs at the location of an offeror or consignee, should the offeror or consignee be required to provide the notification?

[33] RSPA. March 23, 1999. ANPRM "Revisions to the Incident Reporting Requirements and the Detailed Hazardous Materials Incident Report DOT Form F 5800.1." Docket number RSPA-99-5013 (HM-229). 64 *Federal Register* 13943.

The Safety Board commented on the ANPRM in a July 26, 1999, letter and urged RSPA to:

> Require that undeclared shipments of hazardous materials found in transportation be reported; telephonic and written notification be improved; a report be filed for any hazardous materials container failure; shippers be notified when a release involving their cargo occurs; and information be collected that will help identify patterns of container and equipment failure.

In its comments, the Safety Board cited specific deficiencies in current reporting requirements. Among those problems the Safety Board detailed was that:

> …when failures of DOT specification containers or releases of hazardous materials from such containers occur at either the loading or unloading facility, a carrier may not be directly involved, as the Clymers accident demonstrates, thereby increasing the likelihood that such accidents will go unreported to RSPA.

The FRA made no official comments on the ANPRM but stated that the agency addresses its concerns and recommendations through its participation as an active member of the rulemaking team.

Analysis

General

About 12:05 a.m. on February 18, 1999, railroad tank car UTLX 643593, which was on the west unloading rack at the Essroc cement plant near Clymers, Indiana, sustained a sudden and catastrophic rupture that propelled the tank car's tank about 750 feet and over multistory storage tanks. Essroc had been attempting to transfer the substance in the tank car, TDI matter waste, to its kilns, where it was to be burned as a fuel. TDI matter waste is a flammable, toxic, and hazardous substance that must be disposed of in accordance with EPA regulations. This tank car of TDI matter waste had been sent to Essroc by the Arco Chemical Company (later purchased by the Lyondell Chemical Company), which owned the Lake Charles, Louisiana, facility that had generated the TDI matter waste as a byproduct of TDI production.

Lyondell had contracted with Essroc to dispose of the TDI matter waste. The TDI production facility already had a relationship with Essroc for the disposal of hazardous TDI waste, as Essroc had disposed of TDI solvent blend waste from the Lake Charles plant for 2 years before agreeing to take shipment of the TDI matter waste for disposal. When Essroc began accepting TDI matter waste for disposal in May 1998, it initially used a process by which the waste from the rail car tanks was first blended in a fixed tank with solvents (to reduce its viscosity) and then pumped to Essroc's kilns from the fixed tank. When, in fall 1998, Essroc encountered problems with this process, it began using a new procedure to transfer the TDI matter waste from its shipping tank cars directly to the kilns. This was known as the direct injection process. Essroc did not develop, in cooperation with Lyondell, specific written instructions for unloading the waste or disposing of it safely using the direct injection process.

Because of the complex circumstances and nature of the accident, the Safety Board considered several potential causes of the rupture during the investigation. The first section of this analysis will address each of the potential causes of the accident. The succeeding sections will address, in turn, the four major safety issues identified during the investigation, which are:

- Sufficiency of safety requirements addressing the procedures used for loading and offloading railroad tank cars and other bulk containers used to transport hazardous materials;
- Adequacy of inspection and testing requirements for pressure relief devices on railroad tank cars;
- Adequacy of provisions addressing changes in product service for railroad tank cars; and

- Adequacy of the U.S. DOT *Hazardous Materials Regulations* pertaining to the notification and reporting of hazardous materials incidents.

Accident

Rupture of UTLX 643593

The catastrophic rupture of tank car UTLX 643593 was the result of pressurization that exceeded the burst pressure of the tank, which Union Tank Car calculated to be between 813 and 844 psia. The upright position and orientation of both tank car wheel assemblies at the loading station after the accident, the torsion damage to the rails at the loading station, the upward trajectory of the UTLX 643593 tank over the fixed storage tanks, the extended fracture along the bottom centerline of the tank, and the flattening of the tank were all consistent with a failure originating along the bottom centerline of the tank.

Safety Board investigators observed "necking down" deformation in the tank wall at the fracture that extended along the bottom center of the tank. Laboratory measurements of the plate thickness along the fracture indicated that deformation of the plate from "necking" had reduced the plate thickness to as little as 0.285 inch, a 50 percent reduction in the original plate thickness of 0.5625 inch. In addition, metallurgical examination of a 35-inch long section of the fracture along the bottom center of the tank identified features on the fracture surface typical of ductile tensile overload in low-carbon steels. The deformation from necking and the presence of fracture features indicating tensile overload could have resulted only from an overpressurization of the tank.

The absence of pitting, corrosion, and other visual signs of tank deterioration indicated that no structural defects or deficiencies might have caused the tank to rupture, or weakened the tank such that it would have ruptured at pressures within its design limits. Further, based on the results of the laboratory analysis of the steel plate's microstructure and hardness tests, the steel used in the tank's construction met the specifications for ASTM A516 grade 70 steel and had sufficient tensile strength and thickness for the tank car to easily withstand its maximum operating pressure of 100 psig. Consequently, the Safety Board concludes that no evidence indicates that the tank of railroad tank car UTLX 643593 had any structural or material defects that either caused or contributed to the rupture of the tank. Therefore, in the absence of any structural or material defects to weaken the tank, the Safety Board concludes that the internal pressure in tank car UTLX 643593 increased and eventually exceeded the burst pressure of the tank, resulting in the catastrophic rupture of the tank car.

Overpressure Condition

Given the offloading configuration that Essroc employed, internal pressure in UTLX 643593 could be relieved in two ways: (1) controlled venting through the vapor valve on the tank car to the vapor emissions system for the plant and (2) venting through the pressure relief valve on the tank car. The pressure relief valve was designed to discharge when the internal pressure reached 75 psig, but during postaccident testing, it began to discharge at pressures below 5 psig. Consequently, an overpressure and eventual rupture of the tank could have occurred only if the flow of vapor or other material through the vapor valve/vapor emissions system or the pressure relief valve had been completely stopped or if the pressure in the tank had increased at a rate that exceeded the flow capacity of the pressure relief valve to vent.

The Safety Board examined whether the generation of pressure at a rate that exceeded the flow capacity of the pressure relief valve to vent could have caused the overpressure and rupture of UTLX 643593. Essroc employees noted that the pressure relief valve was “whispering” or discharging slightly on the morning of February 16. The Essroc employees attributed the whispering to the saturation of the filters in the vapor emissions system, which prompted them to use a water bath for venting the vapors from the tank car. The facility supervisor described the vapors from the tank car as “trickling” through the water bath on February 16, and a second Essroc employee observed water “bubbling” and splashing in the tote tank on the night of February 16. The Essroc facility supervisor stated that on the morning of February 17, he reduced the pressure in the tank car and then injected nitrogen until the pressure was 25 psig. According to Essroc personnel, no other work was performed on the tank car before the accident.

The trickling of vapors through the water bath and the bubbling of the water bath indicate that only low-pressure venting of vapors was occurring. If pressure in the tank car had been increasing at a rate exceeding the pressure relief valve’s capacity to vent, the venting vapors would have severely agitated the water bath, and such agitation would have been conspicuous. Also, the pressure relief valve would have been fully open, and the vapors passing through the relief valve would have made a loud and noticeable noise. Further, if the capacity of the pressure relief valve had been exceeded, the valve would have remained open, so noise from any escaping vapors would have been continuous and particularly loud. Under such conditions, it would have been virtually impossible for plant employees to fail to notice the severe agitation of the water bath and the continuous noise from the pressure relief valve. However, no Essroc employee mentioned noticing either condition before the accident. Therefore, the overpressure in UTLX 643593 did not result from the pressure’s rate of increase exceeding the flow capacity of the pressure relief valve to vent the tank.

During postaccident examination of the valves and fittings of ULTX 643593, however, investigators found TDI matter waste molded to the interior of the car’s manway coverplate. The TDI matter waste completely plugged the openings through the manway coverplate for the pressure relief, vacuum relief, and vapor valves. The inlet to each of these three valves opens to the vapor space at the top of the tank car. Further, the TDI matter waste was molded into the bodies of the pressure relief and vapor valves.

For the TDI matter waste to completely plug and fill these openings and valves in this manner, it must have flowed into them through expansion of the waste before the tank car ruptured. If the TDI matter waste had been blasted into these openings in the manway coverplate and the valve bodies when the tank ruptured, it would not have been molded to the contours of the openings and valve bodies. Rather, the TDI matter waste would have left void spaces in the openings through the manway coverplate and the valve bodies. Consequently, the Safety Board concludes that the expansion of TDI matter waste that occurred before the accident blocked the vapor and pressure relief valves of tank car UTLX 643593, which effectively removed any means of relieving the build-up of internal pressure.

The Safety Board cannot determine exactly when the vapor and pressure relief valves became plugged. On the morning of February 16, Essroc employees noted that the pressure relief valve was "whispering" (discharging vapors at a low pressure), which they attributed to saturation of the carbon filters in the plant's vapor emissions system. Following the final attempt to offload the tank car on the night of February 16, an Essroc laborer observed water bubbling from the end of the submerged hose in the tote tank. The bubbling indicated that vapors were venting from the tank car at that time.

Although the Essroc facility supervisor and other Essroc employees checked and adjusted the internal pressure on UTLX 643593 throughout the 5 days that UTLX 643593 was at the offloading station, the reliability of these pressures is suspect. The whispering of the pressure relief valve, which was first noted by Essroc personnel on the morning of February 16 and later replicated during postaccident testing of the valve in May 1999, indicates that the pressure relief valve very likely was continuously discharging vapors from the tank until it became plugged by TDI matter waste.

Product Expansion

The initial volume of TDI matter waste in the 20,000-gallon tank car after loading was 14,185 gallons, which was about 71 percent of tank capacity. Therefore, between the loading date in March 1993 and the accident date in February 1999, the TDI matter waste must have expanded to fill the remaining 29 percent of the tank, leading to the rupture.

The Safety Board considered several possible causes for the expansion of the TDI matter waste. These included exposure of the tank car to fire from an unknown external source; gradual instability in the waste material over the 6-year period it was stored in the tank car; chemical reactions initiated from the steam heating of the tank car, resulting in the liberation and entrapment of gaseous byproducts in the waste mixture; and chemical reaction with water that would have liberated gases within the tank.

The Safety Board was able to discount the possibility of the tank car's experiencing direct exposure to fire. The external jacket from UTLX 643593 did not exhibit any evidence of flames affecting it, other than an isolated section found on top of a burned rubber hose.

The Board found no significant evidence that the TDI matter waste's stability had gradually degraded (causing expansion) while the tank car was stored between 1993 and 1999. Essroc personnel working around and with the tank car did not report any usual events or problems with it, apart from the plugging of the plant piping to the kilns. The waste had been stored in the tank car for nearly 6 years with no problems. In addition, chemical data for the monomeric TDI, polymeric TDI, and MCB found in the TDI waste do not indicate that any of these materials were unstable. Nevertheless, the tank car catastrophically ruptured 5 to 6 days after it had been heated with steam on two occasions for a total of 28.5 hours and three attempts to offload the TDI matter waste from it had been made. Therefore, some aspect of the offloading operation most likely led to the rupture.

Heating tests conducted in April 1999 on the TDI matter waste samples drawn from UTLX 643593 before the accident demonstrated that significant expansion of the waste occurred when a waste sample was heated under conditions similar to those experienced by the accident tank car in the days before the accident. Expansion also occurred when a sample was heated and exposed to water. Both these test conditions resulted in the generation of sufficient quantities of carbon dioxide gas to have theoretically increased the pressure in the tank car above its burst pressure.

The most likely means of introducing water into the tank car would have been from the tote tank that was being used as a temporary measure to provide a vapor emissions system while the carbon filters were being cleaned or replaced. No other likely source of water was identified. Essroc employees noted water bubbling in the tote tank throughout the day on February 16, indicating that vapors were venting from the tank car. One Essroc employee also observed water bubbling in the tote tank following the final attempt to offload UTLX 643593 on the evening of February 16. However, no Essroc employee commented on the condition of the tote tank from that time forward.

Based on engineering calculations, water from the tote tank could have been siphoned into the tank car only if a vacuum of 4 to 5 psi (equivalent to a total internal pressure of 10 to 11 psi) had developed in the vapor space within the tank car because of the cooling of the vapors and/or the contraction of the TDI matter waste mixture. The heating tests on samples from UTLX 643593 clearly demonstrate that the waste expanded when it was heated, but it did not contract after cooling. Therefore, the generation of any vacuum would have to have been caused by the vapors cooling in the air space at the top of the tank car. Engineering calculations indicate that vapors initially at 150° F would have to have been cooled to less than -30° F to create a sufficient vacuum in the tank car. More importantly, water drawn into the tank car from the tote tank would have spilled into the TDI matter waste at the point of liquid/vapor interface within the tank car. Any gases from a reaction occurring at the liquid/vapor interface would have entered the vapor space within the tank car and readily been vented. Such venting would have precluded overpressurization of the tank car.

Chemical analyses conducted between December 1999 and February 2000 on the TDI matter waste sample recovered from the B-end loading valve detected the presence of chemical byproducts from the reaction of TDI and water. The analysis could not quantify the amounts of these byproducts. Although the presence of these chemical byproducts suggests that the waste sample from the loading valve reacted with water, it cannot be determined when or how much water came into contact with this sample. Between the accident date and the recovery of the sample in May 1999, the dome assembly from UTLX 643593, including the B-end valve, was kept in indoor storage at Essroc and then at the St. Louis testing facility. After the recovery of the sample in May 1999, the sample was in a glass jar, which, although sealed, proved not to be airtight, as evidenced by the evaporation of the liquid portion of the sample. The waste sample may have been exposed to moist air between the time it was recovered and analyzed, which might have caused the formation of the chemical byproducts detected in the analysis. Nevertheless, the other evidence (as previously discussed) does not support the theory that the overpressurization was the result of a sufficient quantity of water being introduced into the tank car.

Therefore, the overpressurization of the tank car from product expansion and the plugging of the pressure relief and vapor valves most likely occurred as a result of the steam heating of the waste mixture before offloading was attempted. The portion of the TDI matter waste mixture in contact with the tank wall in the bottom half of the tank received the heat from the steam circulating through the heating coils. Because the samples were drawn through one of the eduction lines that extended to the bottom of the tank car, the temperatures of samples drawn by Essroc personnel while the steam heating was performed are good indicators of the temperatures of the waste mixture that was in contact with the heating coils. According to Essroc employees, the temperatures of the samples drawn from UTLX 643593 ranged from 120 to 202° F early on February 14, at the end of the first steam-heating cycle, and reached at least 173° F during the second heating cycle on February 15 and 16. These temperatures are well above the maximum safe temperature range of 130 to 140° F that Olin used for processing the TDI matter wastes at the Lake Charles plant and reported to the Safety Board during the investigation.

In the absence of any means to mix the wastes to facilitate uniform heating throughout the tank, localized overheating of the TDI matter waste in contact with or near the tank wall adjacent to the heating coils most likely caused the TDI to self-react, resulting in the generation of carbon dioxide gas at the bottom of the tank and eventual expansion of the waste. Additionally, because the tank was insulated (and would retain heat), the self-reaction and expansion of the TDI matter waste could have continued after the steam heating was completed. Thus, the TDI matter waste continued to expand until the dome was completely filled and the vapor and pressure relief valves were plugged. Because the tank did not have any room to accommodate continued expansion of the waste or any outlet by which it could relieve the increasing pressure, the tank's burst pressure was exceeded, and the tank car ruptured.

Consequently, the Safety Board concludes that tank car UTLX 643593 was overpressurized from the chemical self-reaction and expansion of the TDI matter waste that was initiated and sustained by localized overheating of the mixture at the bottom of the tank car.

Hazardous Materials Loading and Offloading Practices

TDI Waste Shipments

Essroc Plant Operations. In 1996, Essroc began to accept TDI solvent blend wastes as fuel for its Logansport plant. Blending agents, such as HAN 906 solvent, were added to the TDI solvent blend wastes at the Lake Charles plant before they were shipped to Essroc, to increase the fluidity of the wastes. However, beginning in spring 1998, nearly all the TDI wastes shipped to Essroc were TDI matter wastes. Unlike the solvent blend wastes that had been "thinned" before shipment to Essroc, the TDI matter wastes were to be heated and offloaded from the tank car to a blending tank at the Essroc plant, where the wastes would be mixed with solvents to "thin" them before they were pumped to the kilns and burned. However, problems with the blending tank operation led Essroc to resort to offloading the TDI matter wastes from the tank cars and pumping them directly to the kilns (direct injection process). Essroc was using the direct injection process to offload the TDI matter wastes from UTLX 643593.

Whereas the waste profile for the solvent blend waste specified a maximum viscosity of 500 cp, the profile for the TDI matter waste indicated that its viscosity "varies." Because the TDI matter wastes in UTLX 643593 and the other tank cars were to be blended at the Essroc plant, they typically were more viscous than the solvent blend wastes. Consequently, the TDI matter wastes probably had to be heated for longer periods and to higher temperatures than the solvent blend wastes, to make the TDI matter wastes sufficiently fluid for offloading from a tank car and pumping directly to the kilns.

The heating standard jointly employed by Essroc and CPRIN personnel was to heat the TDI matter waste until it was sufficiently fluid to flow. While CPRIN conducted the steam-heating operation, Essroc personnel drew samples from UTLX 643593 to measure the temperature of the wastes and to determine if the waste mixture was sufficiently fluid for offloading. Although Essroc and CPRIN personnel said they knew that the TDI matter wastes had to be heated to higher temperatures than the solvent blend wastes, Essroc and CPRIN claim they were unaware that Olin recommended a maximum safe temperature range of 130 to 140° F for heating the TDI matter wastes. The Essroc facility supervisor said he was under the impression that the TDI matter wastes could safely be heated to 200° F; whereas CPRIN stated that, although the TDI product should not be heated above 110° F because of possible quality control problems, these concerns did not apply to the TDI matter wastes because no TDI product recovery would be attempted.

Further, the offloading and steam-heating procedures used by Essroc and CPRIN did not include three critical heating and offloading practices that Olin used at the Lake Charles plant: steam heating with low-pressure steam, nitrogen sparging while steam heating, and keeping the temperature of the waste mixture below 140° F. Through steam heating with low-pressure steam, the waste mixtures could be heated more slowly and could more easily be maintained at a temperature below the 130 to 140° F threshold recommended by Olin. Performing nitrogen sparging during the steam-heating process would cause the waste mixture at the bottom of the tank car to agitate, which would facilitate a more even distribution of heat throughout the entire waste mixture. The Safety Board concludes that, if Essroc and CPRIN had employed low-pressure steam to heat the wastes, used nitrogen sparging to facilitate even heating throughout the tank car, and maintained the temperature of the wastes below 140° F, the risk of localized overheating and expansion of the waste mixture would have been minimized, and the accident likely would not have occurred.

Guidance and Instruction on Heating and Offloading Procedures. To determine why Essroc and CPRIN did not employ the procedures used at the Lake Charles plant, the Safety Board asked Olin, Lyondell, Essroc, and CPRIN to describe the information they exchanged about the heating of all TDI waste mixtures, the generation of gas from chemical self-reaction, the expansion of the wastes if overheated, nitrogen sparging, the establishment of temperature limits for the waste mixtures, and other special handling procedures.

Each company provided a different account regarding its responsibilities and the information it either provided or requested. All agreed that the Lake Charles TDI expert met with Essroc and CPRIN personnel at the Essroc plant in spring 1998 to provide instruction on handling and processing TDI matter wastes. The Lake Charles operators, Essroc, and CPRIN agreed that the TDI matter wastes could safely be heated to 125° F, compared to the 90 to 100° F range for the TDI solvent blend wastes. Essroc also acknowledged that the Lake Charles TDI expert had stated that a long, slow heating process was sometimes required to heat the TDI matter wastes. However, neither Essroc nor CPRIN acknowledged that the Lake Charles operators had set a maximum temperature limit or that the Lake Charles operators had recommended using nitrogen sparging and low-pressure steam-heating procedures. The Lake Charles operators, however, maintained that their TDI expert discussed nitrogen sparging, heating with low-pressure steam, and heating limits with Essroc and CPRIN personnel.

As can be seen from this diversity of opinion and recollection as to what was communicated between the producers and receivers in this instance regarding the appropriate procedures for offloading the TDI matter wastes, considerable confusion and misapprehension appears to have been prevalent among those parties that handled the waste mixtures. Given the potentially hazardous nature of TDI matter wastes, such ambiguity is unacceptable.

The investigation also revealed other areas of imprecision. For instance, responsibility for offloading at the Essroc plant seems to have been unclear. Essroc stated that CPRIN was responsible for steam heating the TDI product so that it was sufficiently fluid that it could be pumped to the cement kilns. CPRIN, however, stated that Essroc retained operational authority over the heating and offloading process.

Further, no one at the Essroc plant had comprehensive, written instructions on the offloading procedures to be used. Although Essroc had written procedures for offloading the TDI matter wastes to a fixed blending tank, these procedures did not include details about heating practices, nitrogen sparging, or maximum temperature limits. Then, when Essroc adopted the direct injection procedure in place of blending in a fixed tank, even less information was available. Neither Essroc nor CPRIN had any written procedures for heating and offloading the TDI matter wastes for direct injection of these wastes to the kilns.

Therefore, based on the discrepancies between Essroc's and CPRIN's accounts of their respective roles and responsibilities for handling and disposing of TDI matter wastes and the absence of specific, written procedures for heating and offloading these wastes by direct injection, the Safety Board concludes that Essroc and CPRIN failed to develop and implement appropriate heating and offloading procedures for the TDI matter wastes at the Logansport plant, which resulted in the use of unsafe offloading practices at the plant.

With respect to the Lake Charles operation's procedures, Olin stated, in its response to Safety Board inquiries about whether it had written procedures for heating and offloading TDI wastes, that any written procedures that might have existed had been turned over to Arco (later Lyondell). Lyondell stated that Arco/Lyondell did not have specific, written procedures for on-site blending of the TDI waste mixtures and offloading them from tank cars. Arco/Lyondell had written procedures for blending solvent blend wastes in a fixed tank and then transferring them from the fixed tank into tank cars. These procedures set the temperature and viscosity limits for the solvent blend wastes in the fixed blending tank. However, neither Olin nor Arco/Lyondell had written operating procedures or limitations that addressed the potential for gas generation or product expansion, the maximum temperature and time for heating the TDI wastes, or the maximum product viscosity for offloading tank cars. Therefore, no one at Lake Charles appears to have had comprehensive, written procedures for handling the TDI wastes.

The Safety Board also considers that the implementation of comprehensive, written procedures for loading and offloading chemicals or waste materials exhibiting properties that require special handling must incorporate methods that will detect internal tank conditions and accurately reflect the thermophysical state of all of the material in the tank vessel. The written procedures should specify values or ranges for important material properties, such as melting temperature, flash point, maximum allowable product temperature, and viscosity. Further, offloading procedures developed and validated under certain environmental conditions may lead to or cause catastrophic failures or other potential problems in offloading the material when the environmental conditions vary from the baseline conditions.

Partially because there is no written record to which it may refer, the Safety Board cannot decisively determine what information and guidance were provided by the Lake Charles operators to Essroc and CPRIN on heating and offloading TDI matter from tank cars or what consideration, if any, was given to detection of internal tank car conditions that were potentially catastrophic. Nor can the Safety Board be sure what guidance may have been provided by the Lake Charles operators but not implemented by Essroc and CPRIN. Nevertheless, given the differences between the accounts offered by these companies about the guidance given or requested and the lack of comprehensive, written procedures at Lake Charles for handling TDI wastes, the Safety Board concludes that Olin and Arco (now Lyondell) did not provide Essroc with comprehensive, written information about safe handling procedures for TDI matter wastes.

The Safety Board considers that the producer/shipper and the consignee/end-user of any chemical or waste material have joint responsibility for determining and implementing comprehensive, written procedures for the transfer of any chemical or waste material to and from a tank car, highway cargo tank, or other bulk container when the chemical or waste material exhibits properties that require special handling. Such properties would include those identified with the TDI matter wastes involved in this accident, such as temperature and heating effects, means of self-reaction, and the byproducts of reaction, including the generation of gases and product expansion.

In the Safety Board's view, both parties to the transport of a hazardous material have information vital to its safe transfer. The producer/shipper has detailed knowledge about the properties of the chemical or waste material, while the consignee/end-user has specific information about the transfer facilities at the destination. Ideally, the result of the collaboration between the producer/shipper and consignee/end-user should be the development and implementation of specific, written transfer procedures that address each unique property of the chemical or waste material in the context of the physical layout of a given plant or facility.

The importance and effectiveness of such cooperation is evidenced by what happened when the TDI waste materials had to be moved after the Clymers accident took place. Following the accident at the Essroc plant, Olin and the waste disposal companies that were contracted to unload the remaining tank cars at a transfer facility in Deer Park, Texas, jointly developed comprehensive, written procedures that established viscosity and temperature limits and called for nitrogen sparging. Consequently, the transfer and offloading took place without incident. Therefore, the Safety Board believes that Essroc, CPRIN, Olin, and Lyondell should each collaborate with applicable producers, shippers, consignees, and end-users in the development and implementation of specific and written procedures for the loading or offloading of any chemical or waste material from a railroad tank car, highway cargo tank, or other bulk transportation vessel when the chemical or waste material exhibits properties that require special handling or processing during the loading or offloading operation.

Recent Safety Board Actions

The catastrophic rupture of UTLX 643593 in February 1999 at the Essroc plant is the fifth nonaviation accident investigated by the Safety Board since June 1998 in which deficient offloading procedures or operations caused or contributed to an accident and the release of hazardous materials.

The first of the five accidents took place on June 29, 1998, at Stock Island, Key West, Florida.[34] A Dion Oil Company driver was on top of a straight-truck cargo tank checking its contents and preparing to transfer cargo from a semitrailer cargo tank when explosive vapors ignited within the straight-truck cargo tank. The ignition caused an

[34] National Transportation Safety Board, *Fire and Explosion of Highway Cargo Tanks, Stock Island, Key West, Florida, June 29, 1998*, Hazardous Materials Accident Report NTSB/HZM-99/01 (Washington, DC: NTSB, 1999).

explosion that threw the driver from the truck. The fire and a series of at least three explosions injured the driver and destroyed the straight truck, a tractor, the front of the semitrailer, and a second nearby straight-truck cargo tank. Damage was estimated at more than $185,000.

The Safety Board concluded from its investigation that (1) the carrier did not have written procedures to ensure safe cargo handling, (2) the carrier did not adequately train its drivers to ensure safe cargo handling, and (3) Federal training programs for Federal and State motor carrier inspectors did not adequately address the need for inspectors to evaluate the training that motor carriers give their drivers on loading and unloading cargo tanks. Consequently, the Safety Board recommended on October 1, 1999, that the Federal Highway Administration's (FHWA's) Office of Motor Carrier Safety (now the Federal Motor Carrier Safety Administration [FMCSA]):[35]

> H-99-30
>
> Add elements to training programs for Federal and State inspectors that include instruction on determining whether motor carriers have adequate written procedures for and driver training in loading and unloading cargo tanks.
>
> H-99-31
>
> Evaluate the adequacy of cargo-tank loading and unloading procedures of and driver training for hazardous-materials motor carriers and require changes as appropriate.

To date, the Safety Board has not received a response to either recommendation from the FMCSA. On December 14, 2000, the Safety Board sent a follow-up letter to the FMCSA requesting an update on the status of these two recommendations.

Another accident concerning a transfer of hazardous materials took place on August 9, 1998, in Biloxi, Mississippi.[36] A truckdriver was transferring gasoline from a highway cargo tank to underground storage tanks at a gasoline station-convenience store when an underground storage tank containing gasoline overflowed. An estimated 550 gallons of gasoline flowed from the storage tank, across the station lot, and into the adjacent highway and intersection. The gasoline ignited, and fire engulfed three vehicles near the intersection. Five occupants of the vehicles were killed, and one occupant was seriously injured. Property damages were estimated at $55,000.

As a result of its Biloxi investigation, the Safety Board concluded that the carrier's operating manuals for its new employees and driver-trainers lacked the specificity that employees need to ensure that they practice correct and safe cargo unloading procedures.

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[35] The December 9, 1999, enactment of the Motor Carrier Safety Improvement Act of 1999 established a new DOT agency, the FMCSA, to oversee and enforce motor carrier safety regulations, which had previously been handled by the FHWA.

[36] National Transportation Safety Board, *Overflow of Gasoline and Fire at a Service Station-Convenience Store, Biloxi, Mississippi, August 9, 1998*, Hazardous Materials Accident Report NTSB/HZM-99/02 (Washington, DC: NTSB, 1999).

The Safety Board also concluded that to help drivers follow safe loading and unloading procedures, Federal regulations should require carriers that transport hazardous materials in cargo tanks to have specific, written procedures for loading and unloading. Consequently, the Safety Board recommended that RSPA:

> H-99-57
>
> Promulgate regulations requiring motor carriers that transport hazardous materials in cargo tanks to develop and maintain specific written cargo loading and unloading procedures for their drivers.

In a February 24, 2000, response to Safety Recommendation H-99-57, RSPA stated it is evaluating options to amend the general training requirements and the current specialized requirements for motor carriers in the DOT *Hazardous Materials Regulations*. On April 4, 2000, the Safety Board classified Safety Recommendation H-99-57 "Open–Acceptable Response," pending RSPA's development of regulations that meet the intent of the recommendation. On January 5, 2001, the Safety Board sent a letter to RSPA requesting an update on the actions RSPA has taken on this recommendation since February 2000.

Following the Biloxi accident, the Safety Board also recommended that the FHWA:

> H-99-59
>
> Once the Federal regulations requiring motor carriers that transport hazardous materials in cargo tanks to provide written cargo loading and unloading procedures are promulgated, ensure that the motor carriers are in compliance with the regulations.

The FHWA's Office of Motor Carrier Safety stated in a November 23, 1999, response to Safety Recommendation H-99-59 that it would develop procedures to ensure that motor carriers comply with regulations promulgated to address Safety Recommendation H-99-57. The Safety Board classified Safety Recommendation H-99-59 "Open–Acceptable Response" on February 22, 2000. On January 10, 2001, the Safety Board sent a letter to the FHWA requesting an update on the actions taken on this recommendation since February 2000.

On November 19, 1998, at the Ford Motor Company truck plant in Louisville, Kentucky, a cargo tank truck arrived with a delivery of a liquid mixture of nickel nitrate and phosphoric acid. A plant employee inadvertently connected the truck's transfer hose to the wrong connection and then departed the area, leaving the truckdriver to complete the delivery alone. The truckdriver did not check that the connection was correct and began unloading the product into a storage tank that contained a chemically incompatible material. The resulting chemical reaction generated a vapor cloud of toxic gases that forced the evacuation of 2,400 plant employees and caused $192,000 in damages.[37]

Another transfer-related accident occurred in Whitehall, Michigan, on June 4, 1999, after a cargo tank truck arrived at the Whitehall Leather Company with a delivery of sodium hydrosulfide solution. At the direction of a Whitehall shift supervisor, the truckdriver connected the transfer hose from the cargo tank truck to the wrong storage tank; the tank contained a chemical that reacted with the solution in the cargo tank truck. The resulting chemical reaction released hydrogen sulfide gas that resulted in the death of the truckdriver and $411,000 in damages.[38]

The Safety Board's investigation of both the Louisville and Whitehall accidents showed that the companies had significant problems with their loading and unloading processes for hazardous materials. The Whitehall Leather Company did not have written instructions and procedures for unloading hazardous materials from bulk cargo tanks and did not have a training program for those employees who might be involved in loading and unloading such materials. The Ford Motor Company had written instructions and procedures for unloading hazardous materials and maintained a training program on these procedures, but Ford failed to provide the plant employee involved in the Louisville accident with the latest unloading instructions for hazardous materials, which might have prevented the accident.

As a result of its investigations of the Louisville and Whitehall accidents, the Safety Board determined that safety requirements were needed for loading and unloading hazardous materials involved in transport and recommended on June 29, 2000, that RSPA:

> I-00-06
>
> Within 1 year of the issuance of this safety recommendation, complete rulemaking on Docket HM-223, "Applicability of the *Hazardous Materials Regulations* to Loading, Unloading, and Storage," to establish, for all modes of transportation, safety requirements for loading and unloading hazardous materials.

In its July 21, 2000, response to Safety Recommendation I-00-06, RSPA stated that it is drafting a notice of proposed rulemaking (NPRM) under Docket HM-223 and expects to publish the NPRM in early 2001. RSPA anticipates issuance of a final rule by the end of 2001. The Safety Board wrote to RSPA on September 25, 2000, indicating its concern over the slow progress of the rulemaking and urging that a final rule be issued by July 2001. In light of the continuing slow pace of action on this important safety issue indicated by RSPA's letter, the Safety Board classified Safety Recommendation I-00-06 "Open–Unacceptable Response."

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[37] National Transportation Safety Board, *Chemical Reaction During Cargo Transfer, Louisville, Kentucky, November 19, 1998*, Hazardous Materials Accident Brief HZB/00/02 (Washington, DC: NTSB, 2000).

[38] National Transportation Safety Board, *Chemical Reaction During Cargo Transfer, Whitehall, Michigan, June 4, 1999*, Hazardous Materials Accident Brief HZB/00/03 (Washington, DC: NTSB, 2000).

DOT Hazardous Materials Regulations

The rupture of UTLX 643593 at the Essroc plant near Clymers and the accidents in Stock Island, Biloxi, Louisville, and Whitehall can all be attributed to deficient unloading operations that occurred because of inadequate training, or a lack of comprehensive, specific, and written unloading procedures, or both. In the Clymers accident, the failure of the producer/shippers and end-users to collaborate in the development and implementation of comprehensive, written loading and offloading procedures, customized to the characteristics of the TDI matter wastes and the specific facility, resulted in the use of unsafe unloading practices that ultimately caused the tank car to rupture.

Although the DOT *Hazardous Materials Regulations* include general and mode-specific requirements about the loading and unloading of bulk containers such as tank cars, highway cargo tanks, and intermodal tanks, the current requirements only address procedures common to most loading and offloading operations, such as which personnel must attend the transfer, when brakes must be set on the tank car, when tank car wheels must be blocked, and when and how warning signs must be placed. The DOT *Hazardous Materials Regulations* do not include requirements for loading and unloading procedures to be written based on any unique or particular properties of the hazardous materials that would necessitate the implementation of special handling requirements or on the conditions specific to an individual facility. As demonstrated in the Clymers accident, the use of unloading practices that are not based on such thorough and comprehensive standards can have catastrophic consequences. Therefore, the Safety Board concludes that the DOT *Hazardous Materials Regulations* are deficient because they fail to require the development and implementation of comprehensive, written loading and unloading procedures for hazardous materials.

The Stock Island, Biloxi, Louisville, Whitehall, and Clymers accidents all involved the loading and unloading of transport containers carrying hazardous materials. Of the five accidents, however, only the Clymers accident involved rail rather than motor carrier transportation. Recently, therefore, the Safety Board's safety recommendations concerning loading and unloading regulations have focused primarily on highway transportation.

For instance, following the Biloxi accident involving the unloading of a motor carrier's cargo tank containing a hazardous material, the Safety Board recommended that RSPA promulgate regulations requiring motor carriers that transport hazardous materials in highway cargo tanks to develop and maintain specific and written cargo loading and unloading procedures. The Safety Board also recommended that the FHWA ensure that motor carriers comply with the regulations once they are enacted. Both these safety recommendations (H-99-57 and H-99-59) are currently "Open–Acceptable Response."

The Clymers accident, however, showed that swift action is needed to improve the safety of hazardous material loading and unloading operations involving rail tank cars as well as highway cargo tanks. Therefore, to ensure that loading and unloading safety provisions are equivalent throughout transportation modes, the Safety Board considers that action is needed to address the deficiencies in the loading and unloading regulations for rail transport of hazardous materials. Such multimodal action is implicit in Safety Recommendation I-00-06, which the Safety Board issued following the Whitehall and Louisville accidents, which called for RSPA:

> I-00-06
>
> Within 1 year of the issuance of this safety recommendation, complete rulemaking on Docket HM-223, "Applicability of the *Hazardous Materials Regulations* to Loading, Unloading, and Storage," to establish, *for all modes of transportation,* safety requirements for loading and unloading hazardous materials. (Emphasis added.)

Despite the need to carry out this recommendation promptly, as evidenced by the recent Stock Island, Biloxi, Louisville, Whitehall, and Clymers accidents, RSPA has not yet completed action on it or indicated that RSPA intends to accomplish the recommendation before the end of 2001. The Safety Board is concerned that such slow progress on Safety Recommendation I-00-06 could negatively affect the safety of hazardous materials transportation in all modes. Therefore, to ensure that comprehensive, written safety requirements are established without delay for all carriers, including rail carriers, that transport hazardous materials in cargo tanks, the Safety Board reiterates Safety Recommendation I-00-06.

Pressure Relief Valves

Performance

After the Clymers accident, the FRA mandated that the pressure relief valves from 4 of the 24 tank cars containing the TDI matter wastes in storage at the Logansport rail yard be pressure-tested in accordance with the DOT *Hazardous Materials Regulations* before any of the tank cars could be transported for unloading. When these tests were performed in March 1999, three of the four valves were not due for retesting until 2003. Each valve had 4 years remaining of its 10-year test cycle. The fourth valve, also on a 10-year test cycle, was due for a retest in 1999. The pressure relief valve from UTLX 643593 was on a 10-year test cycle and not due for a retest until 2003. This valve was also examined and tested in May 1999. All five pressure relief valves failed to meet the tolerances for the start-to-discharge pressure and vapor-tight pressure as required under the regulations.

Because the valve from UTLX 643593 began to discharge at pressures around 5 psig during the postaccident tests and Essroc personnel heard the valve discharging before the accident, the valve was likely venting vapors whenever a minimal positive pressure developed in the tank. The frequent discharging would have resulted in continual venting of harmful or flammable vapors to the atmosphere and possible exposure of personnel working near the tank car until the valve was plugged from expansion of the TDI matter waste.

Inspection Requirements

The teardown and inspection of the pressure relief valves from these five tank cars (the four cars that the FRA required to be tested and UTLX 643593) demonstrated that the valves were in a deteriorated condition. The ethylene propylene rubber O-rings showed evidence of swelling, hardness, and brittleness, and the metallic components exhibited varying degrees of rust, scale, pitting, and grit. Replacement of the deteriorated O-rings in the pressure relief valve from UTLX 643593 with new O-rings did not, by itself, bring about proper operation of the valve. Even with the new O-rings, the pressure relief valve from UTLX 643953 was within the tolerances for the start-to-discharge and vapor-tight pressures only after all dirt, grit, and other debris had been removed from the sealing surfaces of the valve. Consequently, it appears that the accumulation of rust, scale, and dirt caused the five pressure relief valves to fail to meet the required start-to-discharge and vapor-pressure standards. Therefore, the Safety Board concludes that, based on the deteriorated condition of the pressure relief valves examined in this investigation and the failure of these valves to activate as required, the pressure relief valves on tank cars that transport hazardous materials may require more frequent and rigorous testing to ensure that they remain functional.

The testing interval for a tank car and its components under the *Hazardous Materials Regulations* depends in part upon the types of products that are transported in the tank car. Tank cars that transport corrosive materials must be inspected and retested every 5 to 10 years, whereas tank cars that transport noncorrosive materials must be inspected and retested every 10 years. The regulations also require testing and inspection if there is evidence of damage, corrosion, cracks, dents, or deformation or if the tank car is involved in an accident and is repaired. However, the deterioration of the pressure relief valves from UTLX 643593 and the other four tank cars was only detected when the valves were disassembled and inspected. The Safety Board believes that RSPA and the FRA should, with the assistance of the AAR and the Railway Progress Institute, evaluate the deterioration of pressure relief devices through normal service and then develop inspection criteria to ensure that the pressure relief devices remain functional between regular inspection intervals. They should also incorporate these inspection criteria into the DOT *Hazardous Materials Regulations*.

Changes in Product Service for Railroad Tank Cars

Even when appropriate test intervals are established and followed, carriage of cargoes that chemically attack gaskets and O-rings in valves and fittings can undermine the integrity of valves and fittings. Data provided by Union Tank Car Company indicated that ethylene propylene rubber is subject to chemical attack when it is exposed to MCB and naphthalene, a primary constituent of the HAN 906 solvent. The swelling, hardness, and brittleness of the ethylene propylene rubber O-rings in the pressure relief valves from UTLX 643593 and the four other tank cars that were tested likely resulted from exposure to the MCB in the TDI matter waste.

The addition of a new chemical constituent to a commodity approved for transportation in a tank car changes the chemical composition of that commodity and results in the exposure of gaskets and seals on the tank car to a new mixture. The concentration of a newly added chemical constituent may be sufficiently diluted as to present little or no risk of chemical attack to gaskets and seals, but the risk level can best be ascertained by tests or verification through technical literature that the new chemical constituent is compatible with the gaskets and seals on the tank car.

The AAR Manual of Standards for tank cars clearly places the responsibility on the shipper to ensure that the materials used for gaskets and valve seals are compatible with the lading and the service temperature. Under 49 CFR 173.31(a)(2), a tank car may be transferred from one specified commodity service (listed on the tank car's certificate of construction) to another only by the owner or with the owner's authorization. In addition, under 49 CFR 179.15, the pressure relief device on DOT class 111A tank cars must be made of materials that are compatible with the commodity being transported. Further, the FRA interprets the addition of new constituents to TDI to represent a change in service if the additional constituents substantially change the chemical makeup of the TDI or change the hazard class of the TDI.

Olin and Lyondell did not consider that the presence of MCB and HAN 906 solvents in the TDI waste mixtures might adversely affect the O-rings in the pressure relief valves and other gaskets on the tank cars used to store and transport these wastes. Consequently, Olin and Lyondell did not find that the presence of these chemicals constituted a substantial change in product service from the transport of pure TDI. The investigation, however, showed that the presence of MCB and HAN 906 solvent in the TDI waste mixtures was sufficient to chemically attack the O-rings in the pressure relief valves on tank cars carrying TDI waste mixtures. Therefore, the Safety Board concludes that the transportation of the solvent blend wastes and TDI matter wastes in UTLX 643593 and the other tank cars approved for the transport of pure TDI constituted a change in product service that resulted in the transport of a commodity incompatible with components of the tank car.

The FRA's interpretation that a change in product service occurs when the chemical makeup is substantially changed is subjective and may account for the misinterpretations of Olin and Lyondell that the solvent blend wastes and TDI matter wastes were not "substantially different" from pure TDI. Although the criteria in the AAR Manual of Standards for tank cars and 49 CFR 179.15 seem clear that tank car valves and components must be compatible with the commodity being transported, the mistaken beliefs of Olin and Lyondell suggest that other producers that ship hazardous materials may hold similarly incorrect views regarding the interpretation of these criteria.

The Safety Board knows, for example, that other tank cars used for shipping both solvent blend wastes and TDI matter wastes are equipped with pressure relief valves with ethylene propylene rubber O-rings. The Safety Board does not know, however, whether the shippers using these cars have considered that the MCB and HAN 906 solvents in the TDI waste mixtures might adversely affect the O-rings in the pressure relief valves. Therefore, the Safety Board believes that the FRA should issue an advisory bulletin reminding shippers of hazardous materials that any time a change is made in the chemical constituents of hazardous materials shipped, they should verify the compatibility of all tank car components, such as valves and gaskets, with all of the commodities to be transported.

Notification and Reporting of Hazardous Materials Incidents

When the Clymers accident occurred, the Essroc plant manager immediately notified the NRC by telephone, in compliance with Federal regulations, about the releases of hazardous wastes. According to 40 CFR 264.56(j) the owner/operator of a TSD facility that experiences a hazardous waste incident must also submit a written report to the EPA regional administrator within 15 days of the incident. Essroc sent a report concerning the Clymers accident to the EPA Region 5 office on March 4, 1999. However, neither the written report to the EPA required under 40 CFR 264.56(j) nor the immediate telephone report to the NRC comprise the high level of detail regarding a hazardous materials incident reflected in the DOT Hazardous Materials Incident Report form. Neither would contain, as would the DOT Hazardous Materials Incident Report, detailed information concerning the container and packaging used to transport the hazardous material, the specific circumstances of the failure, or the transportation environment in which the incident occurred. Consequently, neither could provide the in-depth information that RSPA needs to maintain its Hazardous Materials Information System, which is crucial to RSPA's ability to carry out meaningful analyses of reported accident data.

The requirements in 49 CFR 171.16 of the DOT *Hazardous Materials Regulations* place the responsibility for submitting the written DOT Hazardous Materials Incident Report on the carrier. The requirements apply to releases of hazardous materials that occur during the course of transportation, which has been defined under 49 *United States Code* Section 5102 to include "the movement of property and the loading, unloading, or storage incidental to the movement."

In the case of the Clymers accident, it seems reasonable that the Central Railroad of Indianapolis, the carrier that delivered UTLX 643593 and the other tank cars to the Essroc plant, assumed it was not responsible for filing a written DOT Hazardous Materials Incident Report with RSPA. The railroad had delivered the tank car to the Essroc plant on December 7, 1998, more than 2 months before the accident took place. The accident occurred on the plant property, and the railroad was not involved in the accident. The Central Railroad of Indianapolis thus had good reason to suppose it was no longer responsible for filing a written report with RSPA. Essroc likewise did not provide a DOT Hazardous Materials Incident Report to RSPA because it is a TSD facility operator, not a carrier.

Consequently, no DOT Hazardous Materials Incident Report has been filed for this accident with RSPA, even though a DOT specification tank car used in revenue service and containing a regulated hazardous waste catastrophically ruptured. The Safety Board concludes that, because the requirements of 49 CFR 171.16 place the responsibility for filing the written DOT Hazardous Materials Incident Report solely upon the carrier, the current requirements do not ensure that RSPA receives the information the Safety Board believes it needs to develop safe practices.

Of the parties involved, the carrier is least likely to have knowledge of or be involved in an accident or incident that occurs at a shipper or consignee facility where loading and unloading operations are carried out, and where hazardous materials containers are temporarily stored. As a result, many loading and unloading accidents may not be reported to the DOT.

The written DOT Hazardous Materials Incident Reports provide the input for the Hazardous Materials Information System, which is RSPA's accident database. Because this database is used (among other things) to carry out trend analyses, the failure to capture data about incidents at loading and offloading facilities may skew accident analyses conducted using these data and obscure industry performance and operational deficiencies. Further, a review of EPA regulations demonstrated that the comprehensive data required are collected only by the written DOT Hazardous Materials Incident Reports.

The Safety Board has previously expressed its concern about this issue to RSPA, most recently through its July 26, 1999, comments on the March 23, 1999, ANPRM that RSPA issued on revising the incident reporting requirements and the DOT Hazardous Materials Incident Report form. Citing reporting deficiencies identified in the Clymers, Louisville, and Biloxi hazardous materials accidents, the Safety Board noted that when accidents involving releases of hazardous materials from DOT specification containers occur at loading or unloading facilities, a carrier may not be directly involved, increasing the likelihood that such accidents will go unreported to RSPA. The Safety Board stated that it believed that "…a complete and accurate accident database requires that incident reports be filed for any failure of hazardous material containers or the unintended release of a hazardous material during any transportation-related operation…."

To repair this gap in the notification and reporting standards, the Safety Board believes that RSPA should develop and implement policies and procedures to ensure that comprehensive reports concerning all significant failures of DOT specification tank cars, highway cargo tanks, and intermodal bulk containers containing hazardous materials are provided in writing to RSPA.

Conclusions

Findings

1. No evidence indicates that the tank of railroad tank car UTLX 643593 had any structural or material defects that either caused or contributed to the rupture of the tank.

2. The internal pressure in tank car UTLX 643593 increased and eventually exceeded the burst pressure of the tank, resulting in the catastrophic rupture of the tank car.

3. The expansion of toluene diisocyanate matter waste that occurred before the accident blocked the vapor and pressure relief valves of tank car UTLX 643593, which effectively removed any means of relieving the build-up of internal pressure.

4. Tank car UTLX 643593 was overpressurized from the chemical self-reaction and expansion of the toluene diisocyanate matter waste that was initiated and sustained by localized overheating of the mixture at the bottom of the tank car.

5. If the Essroc Cement Corporation and CP Recycling of Indiana had employed low-pressure steam to heat the wastes, used nitrogen sparging to facilitate even heating throughout the tank car, and maintained the temperature of the wastes below 140° F, the risk of localized overheating and expansion of the waste mixture would have been minimized, and the accident likely would not have occurred.

6. The Essroc Cement Corporation and CP Recycling of Indiana failed to develop and implement appropriate heating and offloading procedures for the toluene diisocyanate matter wastes at the Logansport plant, which resulted in the use of unsafe offloading practices at the plant.

7. The Olin Corporation and the Arco Chemical Company (now the Lyondell Chemical Company) did not provide the Essroc Cement Corporation with comprehensive, written information about safe handling procedures for toluene diisocyanate matter wastes.

8. The U.S. Department of Transportation *Hazardous Materials Regulations* are deficient because they fail to require the development and implementation of comprehensive, written loading and unloading procedures for hazardous materials.

9. Based on the deteriorated condition of the pressure relief valves examined in this investigation and the failure of these valves to activate as required, the pressure relief valves on tank cars that transport hazardous materials may require more frequent and rigorous testing to ensure that they remain functional.

10. The transportation of the solvent blend wastes and toluene diisocyanate matter wastes in UTLX 643593 and the other tank cars approved for the transport of pure toluene diisocyanate constituted a change in product service that resulted in the transport of a commodity incompatible with components of the tank car.

11. Because the requirements of 49 *Code of Federal Regulations* 171.16 place the responsibility for filing the written U.S. Department of Transportation Hazardous Materials Incident Report solely upon the carrier, the current requirements do not ensure that the Research and Special Programs Administration (RSPA) receives the information the National Transportation Safety Board believes RSPA needs to develop safe practices.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the failure of Essroc Cement Corporation and CP Recycling of Indiana management to develop and implement safe procedures for offloading toluene diisocyanate matter wastes, resulting in the overpressurization of the tank car from chemical self-reaction and expansion of the toluene diisocyanate matter wastes.

Recommendations

New Recommendations

As a result of its investigation, the National Transportation Safety Board makes the following safety recommendations:

To the Federal Railroad Administration

Issue an advisory bulletin reminding shippers of hazardous materials that any time a change is made in the chemical constituents of hazardous materials shipped, they should verify the compatibility of all tank car components, such as valves and gaskets, with all of the commodities to be transported. (R-01-01)

Evaluate, with the assistance of the Research and Special Programs Administration, the Association of American Railroads, and the Railway Progress Institute, the deterioration of pressure relief devices through normal service and then develop inspection criteria to ensure that the pressure relief devices remain functional between regular inspection intervals. Incorporate these inspection criteria into the U.S. Department of Transportation *Hazardous Materials Regulations*. (R-01-02)

To the Research and Special Programs Administration

Evaluate, with the assistance of the Federal Railroad Administration, the Association of American Railroads, and the Railway Progress Institute, the deterioration of pressure relief devices through normal service and then develop inspection criteria to ensure that the pressure relief devices remain functional between regular inspection intervals. Incorporate these inspection criteria into the U.S. Department of Transportation *Hazardous Materials Regulations*. (R-01-03)

Develop and implement policies and procedures to ensure that comprehensive reports concerning all significant failures of U.S. Department of Transportation specification tank cars, highway cargo tanks, and intermodal bulk containers containing hazardous materials are provided in writing to the Research and Special Programs Administration. (I-01-01)

To the Association of American Railroads (R-01-04)
To the Railway Progress Institute (R-01-05)

Assist the Federal Railroad Administration and the Research and Special Programs Administration in the evaluation of the deterioration of pressure relief devices through normal service and the development of inspection criteria to ensure that the pressure relief devices remain functional between regular inspection intervals.

To the Essroc Cement Corporation (I-01-02)
To CP Recycling, Inc., and Affiliated Companies (I-01-03)
To the Olin Corporation (I-01-04)
To the Lyondell Chemical Company (I-01-05)

Collaborate with applicable producers, shippers, consignees, and end-users in the development and implementation of specific and written procedures for the loading or offloading of any chemical or waste material from a railroad tank car, highway cargo tank, or other bulk transportation vessel when the chemical or waste material exhibits properties that require special handling or processing during the loading or offloading operation.

Previously Issued Recommendation Reiterated in this Report

To the Research and Special Programs Administration

I-00-06

Within 1 year of the issuance of this safety recommendation, complete rulemaking on Docket HM-223, "Applicability of the *Hazardous Materials Regulations* to Loading, Unloading, and Storage," to establish, for all modes of transportation, safety requirements for loading and unloading hazardous materials.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

CAROL J. CARMODY
Acting Chairman

JOHN J. GOGLIA
Member

JOHN A. HAMMERSCHMIDT
Member

GEORGE W. BLACK, JR.
Member

March 5, 2001

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Appendix A

Investigation

The National Response Center notified the Safety Board of the accident at 8:30 a.m., February 18, 1999. The Safety Board immediately dispatched a team of two hazardous materials investigators from Washington, D.C., to the scene.

A metallurgist from the Safety Board's D.C. office joined the on-scene investigation several days after the accident occurred. No Board Member participated in the on-scene investigation.

No hearings were held on the accident, and no depositions were filed concerning it.

The Federal Railroad Administration, the Lyondell Chemical Company, the Olin Corporation, the Essroc Cement Corporation, CP Recycling of Indiana, Union Tank Car Company, and Midland Manufacturing Corporation were all parties to the investigation. (The Safety Board also provided information about the investigation on an ongoing basis to the Mine Safety and Health Administration.)

Appendix B

U.S. Department of Transportation Hazardous Materials Incident Report Form

DEPARTMENT OF TRANSPORTATION
HAZARDOUS MATERIALS INCIDENT REPORT

Form Approved OMB No 2137 0039

INSTRUCTIONS: Submit this report in duplicate to the Information Systems Manager, Office of Hazardous Materials Transportation, DHM-63, Research and Special Programs Administration, U.S. Department of Transportation, Washington, D.C. 20590. If space provided for any item is inadequate, complete that item under Section IX, keying to the entry number being completed. Copies of this form, in limited quantities, may be obtained from the Information Systems Manager, Office of Hazardous Materials Transportation. Additional copies in this prescribed format may be reproduced and used, if on the same size and kind of paper.

I. MODE, DATE, AND LOCATION OF INCIDENT

1 MODE OF TRANSPORATION ☐ AIR ☐ HIGHWAY ☐ RAIL ☐ WATER ☐ OTHER

2 DATE AND TIME OF INCIDENT (Use Military Time e g 8 30am = 0830 noon = 1200 6pm = 1800 midnight = 2400) Date TIME

3 LOCATION OF INCIDENT (Include airport name in ROUTE/STREET if incident occurs at an airport)

CITY STATE

COUNTY ROUTE/STREET

II. DESCRIPTION OF CARRIER, COMPANY, OR INDIVIDUAL REPORTING

4 FULL NAME	5 ADDRESS (Principal place of business)

6 LIST YOUR OMC MOTOR CARRIER CENSUS NUMBER, REPORTING RAILROAD ALPHABETIC CODE, MERCHANT VESSEL NAME AND ID NUMBER OR OTHER REPORTING CODE OR NUMBER

III. SHIPMENT INFORMATION (From Shipping Paper or Packaging)

7 SHIPPER NAME AND ADDRESS (Principal place of business)	8 CONSIGNEE NAME AND ADDRESS (Principal place of business)
9 ORIGIN ADDRESS (If different from Shipper address)	10 DESTINATION ADDRESS (If different from Consignee address)

11 SHIPPING PAPER/WAYBILL IDENTIFICATION NO

IV. HAZARDOUS MATERIAL(S) SPILLED (NOTE: REFERENCE 49 CFR SECTION 172.101.)

12 PROPER SHIPPING NAME	13 CHEMICAL/TRADE NAME	14 HAZARD CLASS	15 IDENTIFICATION NUMBER (e g UN 2764, NA 2020)

16 IS MATERIAL A HAZARDOUS SUBSTANCE? ☐ YES ☐ NO
17 WAS THE RQ MET? ☐ YES ☐ NO

V. CONSEQUENCES OF INCIDENT, DUE TO THE HAZARDOUS MATERIAL.

18 ESTIMATED QUANTITY HAZARDOUS MATERIAL RELEASED (Include units of measurement)	19 FATALITIES	20 HOSPITALIZED INJURIES	21 NON HOSPITALIZED INJURIES
22 NUMBER OF PEOPLE EVACUATED			

23 ESTIMATED DOLLAR AMOUNT OF LOSS AND/OR PROPERTY DAMAGE, INCLUDING COST OF DECONTAMINATION OR CLEANUP (Round off in dollars)

A PRODUCT LOSS	B CARRIER DAMAGE	C PUBLIC/PRIVATE PROPERTY DAMAGE	D DECONTAMINATION/ CLEANUP	E OTHER

24 CONSEQUENCES ASSOCIATED WITH THE INCIDENT ☐ VAPOR (GAS) DISPERSION ☐ MATERIAL ENTERED WATERWAY SEWER ☐ SPILLAGE ☐ FIRE ☐ EXPLOSION ☐ ENVIRONMENTAL DAMAGE ☐ NONE ☐ OTHER

VI. TRANSPORT ENVIRONMENT

25 INDICATE TYPE(S) OF VEHICLE(S) INVOLVED ☐ CARGO TANK ☐ VAN TRUCK/TRAILER ☐ FLAT BED TRUCK TRAILER ☐ TANK CAR ☐ RAIL CAR ☐ TOFC/COFC ☐ AIRCRAFT ☐ BARGE ☐ SHIP ☐ OTHER

26 TRANSPORTATION PHASE DURING WHICH INCIDENT OCCURRED OR WAS DISCOVERED ☐ EN ROUTE BETWEEN ORIGIN/DESTINATION ☐ LOADING ☐ UNLOADING ☐ TEMPORARY STORAGE TERMINAL

27 LAND USE AT INCIDENT SITE ☐ INDUSTRIAL ☐ COMMERCIAL ☐ RESIDENTIAL ☐ AGRICULTURAL ☐ UNDEVELOPED

28 COMMUNITY TYPE AT SITE ☐ URBAN ☐ SUBURBAN ☐ RURAL

29 WAS THE SPILL THE RESULT OF A VEHICLE ACCIDENT/DERAILMENT? ☐ YES ☐ NO
IF YES AND APPLICABLE, ANSWER PARTS A THRU C

A ESTIMATED SPEED	B HIGHWAY TYPE ☐ DIVIDED/LIMITED ACCESS ☐ UNDIVIDED	C TOTAL NUMBER OF LANES ☐ ONE ☐ THREE ☐ TWO ☐ FOUR OR MORE	SPACE FOR DOT USE ONLY

FORM DOT F 5800.1 (Rev 6/89) Supersedes DOT F 5800.1 (10/70) (9/1/76)

THIS FORM MAY BE REPRODUCED

VII. PACKAGING INFORMATION: If the package is overpacked (consists of several packages, e.g. glass jars within a fiberboard box), begin with Column A for information on the innermost package.

ITEM	A	B	C
30 TYPE OF PACKAGING INCLUDING INNER RECEPTACLES (e.g. Steel drum, tank car)			
31. CAPACITY OR WEIGHT PER UNIT PACKAGE (e.g. 55 gallons, 65 lbs.)			
32. NUMBER OF PACKAGES OF SAME TYPE WHICH FAILED IN IDENTICAL MANNER			
33. NUMBER OF PACKAGES OF SAME TYPE IN SHIPMENT			
34 PACKAGE SPECIFICATION IDENTIFICATION (e.g. DOT 17E, DOT 105A100, UN 1A1 or none)			
35 ANY OTHER PACKAGING MARKINGS (e.g. STC, 18/16-55-88, Y1.4/150/87)			
36 NAME AND ADDRESS, SYMBOL OR REGISTRATION NUMBER OF PACKAGING MANUFACTURER			
37 SERIAL NUMBER OF CYLINDERS, PORTABLE TANKS, CARGO TANKS, TANK CARS			
38. TYPE OF LABELING OR PLACARDING APPLIED			
39. IF RECONDITIONED OR REQUALIFIED — A REGISTRATION NUMBER OR SYMBOL			
39. IF RECONDITIONED OR REQUALIFIED — B DATE OF LAST TEST OR INSPECTION			
40. EXEMPTION/APPROVAL/COMPETENT AUTHORITY NUMBER, IF APPLICABLE (e.g. DOT E1012)			

VIII. DESCRIPTION OF PACKAGING FAILURE: Check all applicable boxes for the package(s) identified above.

41. ACTION CONTRIBUTING TO PACKAGING FAILURE

	A	B	C	
a.	☐	☐	☐	TRANSPORT VEHICLE COLLISION
b.	☐	☐	☐	TRANSPORT VEHICLE OVERTURN
c	☐	☐	☐	OVERLOADING/OVERFILLING
d	☐	☐	☐	LOOSE FITTINGS, VALVES
e.	☐	☐	☐	DEFECTIVE FITTINGS, VALVES
f.	☐	☐	☐	DROPPED
g.	☐	☐	☐	STRUCK/RAMMED
h	☐	☐	☐	IMPROPER LOADING
i.	☐	☐	☐	IMPROPER BLOCKING
j	☐	☐	☐	CORROSION
k	☐	☐	☐	METAL FATIGUE
l	☐	☐	☐	FRICTION RUBBING
m	☐	☐	☐	FIRE/HEAT
n	☐	☐	☐	FREEZING
o	☐	☐	☐	VENTING
p	☐	☐	☐	VANDALISM
q	☐	☐	☐	INCOMPATIBLE MATERIALS
r	☐	☐	☐	OTHER ____________

42 OBJECT CAUSING FAILURE

	A	B	C	
a	☐	☐	☐	OTHER FREIGHT
b	☐	☐	☐	FORKLIFT
c	☐	☐	☐	NAIL/PROTRUSION
d	☐	☐	☐	OTHER TRANSPORT VEHICLE
e	☐	☐	☐	WATER/OTHER LIQUID
f	☐	☐	☐	GROUND/FLOOR/ROADWAY
g	☐	☐	☐	ROADSIDE OBSTACLE
h	☐	☐	☐	NONE
i	☐	☐	☐	OTHER

43. HOW PACKAGE(S) FAILED

	A	B	C	
a	☐	☐	☐	PUNCTURED
b.	☐	☐	☐	CRACKED
c.	☐	☐	☐	BURST/INTERNAL PRESSURE
d.	☐	☐	☐	RIPPED
e.	☐	☐	☐	CRUSHED
f.	☐	☐	☐	RUBBED/ABRADED
g	☐	☐	☐	RUPTURED
h.	☐	☐	☐	OTHER______________

44 PACKAGE AREA THAT FAILED

	A	B	C	
a	☐	☐	☐	END, FORWARD
b	☐	☐	☐	END, REAR
c	☐	☐	☐	SIDE, RIGHT
d	☐	☐	☐	SIDE, LEFT
e	☐	☐	☐	TOP
f	☐	☐	☐	BOTTOM
g	☐	☐	☐	CENTER
h	☐	☐	☐	OTHER ____________

45 WHAT FAILED ON PACKAGE(S)

	A	B	C	
a	☐	☐	☐	BASIC PACKAGE MATERIAL
b	☐	☐	☐	FITTING/VALVE
c	☐	☐	☐	CLOSURE
d	☐	☐	☐	CHIME
e	☐	☐	☐	WELD/SEAM
f	☐	☐	☐	HOSE/PIPING
g	☐	☐	☐	INNER LINER
h	☐	☐	☐	OTHER

IX. DESCRIPTION OF EVENTS: Describe the sequence of events that led to incident, action taken at time discovered, and action taken to prevent future incidents. Include any recommendations to improve packaging, handling, or transportation of hazardous materials. Photographs and diagrams should be submitted when necessary for clarification. ATTACH A COPY OF THE HAZARDOUS WASTE MANIFEST FOR INCIDENTS INVOLVING HAZARDOUS WASTE. Continue on additional sheets if necessary.

46 NAME OF PERSON RESPONSIBLE FOR PREPARING REPORT	47 SIGNATURE	
48 TITLE OF PERSON RESPONSIBLE FOR PREPARING REPORT	49 TELEPHONE NUMBER (Area Code)	50 DATE REPORT SIGNED