National Transportation Safety Board
Washington, D.C. 20594

Railroad Accident Brief

Accident Number:	DCA-01-MR-004
Location:	Baltimore, Maryland
Date and Time:	July 18, 2001, 3:08 p.m.
Accident Type:	Derailment and fire
Companies:	CSX Transportation
Injuries:	5 (minor)
Fatalities:	None
Cost:	$12 million

Synopsis

On Wednesday, July 18, 2001, at 3:08 p.m., eastbound CSX[1] freight train L-412-16 derailed 11 of its 60 cars while passing through the Howard Street Tunnel in Baltimore, Maryland. Four of the 11 derailed cars were tank cars: 1 contained tripropylene, a flammable liquid; 2 contained hydrochloric acid; and 1 contained di(2-ethylhexyl) phthalate, which is a plasticizer and an environmentally hazardous substance. The derailed tank car containing tripropylene was punctured, and the escaping tripropylene ignited. The fire spread to the contents of several adjacent cars, creating heat, smoke, and fumes that restricted access to the tunnel for several days. A 40-inch-diameter water main directly above the tunnel broke in the hours following the accident and flooded the tunnel with millions of gallons of water. Five emergency responders sustained minor injuries while involved with the on-site emergency. Total costs associated with the accident, including response and clean-up costs, were estimated at about $12 million.

The Accident

The train, en route with 31 loaded and 29 empty cars from West Baltimore, Maryland, to Philadelphia, Pennsylvania, departed the CSX West Baltimore Yard, about 6 miles west of the derailment site, at 2:37 p.m. on July 18, 2001. Within its consist, the train had eight fully loaded tank cars containing hazardous materials regulated by the U.S. Department of Transportation (DOT).

On the day of the accident, 11 trains went through the Howard Street Tunnel before the accident train. The crewmembers of the accident train reported that their train

[1] CSX is more formally known as CSX Transportation or CSXT, a subsidiary of CSX Corporation.

entered the west end of the tunnel (Camden end)[2] at a speed of 23 mph. The locomotive event recorders indicated that the locomotives were in throttle position 5 and that the train's speed was less than the timetable speed of 25 mph as the train entered the tunnel.

About 1,343 feet into the 8,700-foot-long tunnel (station 73+57),[3] the track grade changes from a slight descending grade to a slight ascending grade. The event recorders showed that at the dip, the train's speed was 24 mph in throttle position 4. As the train passed through the dip, the engineer gradually increased the throttle to position 8 as the train started the ascending grade. While the train was moving about 21 mph, the locomotive tractive effort increased, and the train slowed to 18 mph. At 3:08 p.m., an uncommanded emergency air brake application[4] was recorded, and the lead locomotive stopped in the tunnel about 1,850 feet from the east portal.

Unknown to the crew at the time, the train had derailed. The emergency application of the train air brakes had occurred when the train became uncoupled ahead of the first car to derail, causing the train air brake line to separate.

The derailment also resulted in the puncturing of a derailed tank car carrying tripropylene and the subsequent ignition of this product. The puncture was a 2-inch-diameter hole located near the bottom of the tank on the B-end (the leading end), left side, and on line with the interior end of the stub sill. Postaccident inspection of the tank car indicated that a braking system linkage bar had disconnected and that the disconnected end of the linkage bar, when lifted upward, aligned with the hole in the tank. The fire spread to cargo in adjacent cars, which included paper and wood products, and generated heavy smoke and fumes that quickly filled the tunnel. Additionally, 2,554 gallons of hydrochloric acid were released from another derailed tank car. (See figure 1 for a diagram showing the positions of the derailed cars.)

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[2] For identification purposes, the timetable tunnel orientations are used. The geographic south end (Camden) of the tunnel is designated as the west end in the timetable, and the geographic north end (Mt. Royal) is designated as the east end.

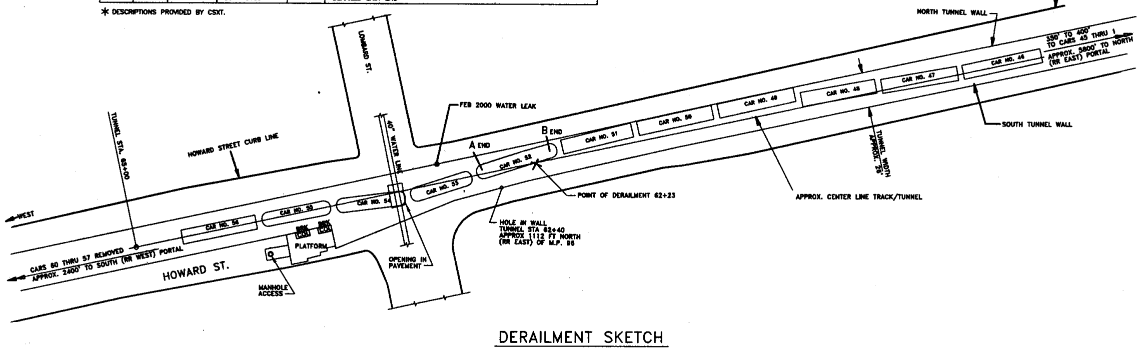
[3] CSX uses station numbers to identify specific locations within the Howard Street Tunnel. Each station represents a distance of 100 feet measured from the east end (Mt. Royal portal) of the tunnel. Locations in the tunnel are identified by indicating the number of feet they are west of the nearest station marker. For example, station 73+57 is about 7,357 feet from the east portal of the tunnel.

[4] Railroads typically refer to any emergency brake application not specifically initiated by the engineer as an "undesired" emergency brake application.

DERAILED CAR INFORMATION *

CAR NUMBER	WEIGHT (TONS)	CAR LENGTH (FT.)	CAR DESCRIPTION	HAZ. MAT. CODE	DERAILED STATUS
46	106	58	CSXT140140		DERAILED TO SOUTH SIDE
47	110	58	CSXT140092		DERAILED TO SOUTH SIDE
48	106	57	AN 5701		DERAILED, NOT SURE OF POSITION OF TRUCKS, TRAILING END STARTING TO LEAN TO NORTH WALL.
49	108	59	CSXT136353		DERAILED LEANING ON NORTH WALL
50	111	58	CSXT140341		DERAILED LEANING ON NORTH WALL
51	104	55	CSXT158745		DERAILED LEANING ON NORTH WALL
52	123	63	SRIX 30015	2057	DERAILED, B END TRUCK BACK UNDER CAR ABOUT 1/3 OF CAR LENTH. A END TRUCK MOVED BACK 12 TO 18 INCHES
53	129	49	RCRX 1345	1789	DERAILED
54	131	53	RCRX 1072	1789	DERAILED
55	130	55	ETCX823504	8082	DERAILED
56	86	55	RBOX 43199		DERAILED EAST END

* DESCRIPTIONS PROVIDED BY CSXT.



NOTES:
DIMENSIONS SHOWN ARE APPROXIMATE.
THE TRAIN POSITION, AS REPORTED ON THE CSXT TRAIN DOCUMENTATION, INCLUDES THREE LOCOMOTIVES, 60 CARS TOTAL.
TUNNEL STA. 0+00 AT NORTH (RR EAST) PORTAL.

SOURCE: NTSB AND CSX TRANSPORTATION

Figure 1. Positions of derailed cars.

The lead locomotive stopped inside the tunnel about 1,850 feet west of the Mt. Royal portal. For some time, the train crewmembers remained unaware that a derailment had taken place. When the crewmembers attempted to notify the CSX dispatcher while their locomotive was still in the tunnel, they found they could not establish radio contact.[5] About 3:13 p.m., the conductor used his personal cell phone to contact a Baltimore area trainmaster, who relayed information regarding the emergency stop to the train dispatcher. About 3:26 p.m., the crew moved the locomotives eastward out of the tunnel, stopping about 450 feet beyond the east tunnel portal.

Postaccident Events and Emergency Response

At 3:26 p.m., the director of security at a hotel above and adjacent to the derailment site in the tunnel called 911 and reported an unusual disturbance near his facility. The security director then called the Baltimore Department of Public Works to report the disturbance. About 3:34 p.m., he called the CSX communications center to advise them of a strong "rumbling" that had occurred at his building. He told the communications center that he suspected the rumbling had originated in the Howard Street railroad tunnel. About 3:36 p.m., the communications center operator forwarded the call directly to the CSX chief dispatcher.

[5] It was later learned that derailing equipment had rendered the radio relay system inoperable.

The CSX chief dispatcher contacted the Baltimore trainmaster to advise him of the situation and ask if the train was transporting hazardous materials. He was told that the train did include hazardous materials cars. About 3:40 p.m., the CSX chief dispatcher determined that the train likely had a serious problem and had possibly derailed.

At 3:51 p.m., the CSX director of network operations issued a request for assistance to the railroad's hazardous materials team. About 4:00 p.m., Baltimore 911 received a call reporting smoke coming from a sewer near the Howard and Lombard Street intersection. Fire department responders were dispatched, and they traced the smoke to the Camden (west) tunnel portal.

Also about 4:00 p.m., the CSX chief dispatcher telephoned the CSX police communications center to ask that the Baltimore City Fire Department be notified and that emergency response personnel be dispatched to the tunnel. At 4:04 p.m., the CSX police communications center notified the Baltimore 911 operator, who notified the Baltimore City Fire Department. Fire department personnel responded to the site (Mt. Royal Station) about 4:10 p.m., but they could not enter the tunnel because of the fire and smoke. The train crew provided the train consist[6] to the emergency responders.

About 5:07 p.m., the incident commander, after deliberating with the responding technical experts, concluded that the derailment did not pose an immediate threat of a catastrophic explosion or a dangerous vapor release that would require an evacuation of the area. The incident commander thus did not believe a mass evacuation was necessary and instead decided to employ a "shelter-in-place" strategy for the several blocks on either side of the tunnel path along the principal length of the tunnel. Other precautionary measures included evacuating the Camden Yards baseball stadium, activating the public alert siren system, and employing local television and radio outlets for public notifications.

About 6:15 p.m., the water elevation began dropping at the city of Baltimore's Montebello II treatment plant. About 6:19 p.m., the water elevation at the Montebello I water treatment plant also began dropping. At Druid Park Lake, the water flow rate[7] abruptly increased from about 8.5 million to 9 million gallons per day (mgd) to about 18 mgd between about 6:15 p.m. and 6:30 p.m.

A time-stamped security camera (taking a picture every 48 seconds) showed that water had broken through to the street surface at the intersection of Howard and Lombard Streets at 6:19:38 p.m. Water flooded the intersection and flowed south on Howard Street. Water also flowed into the Howard Street Tunnel, which was below the street.

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[6] The *train consist* shows the make-up of the train, including the placement and contents of all cars. If cars containing hazardous materials are part of the train, documentation is attached to the consist list that details emergency response information for those materials.

[7] *Flow rate* is a measurement of the volume of water leaving the reservoir and entering into the water system over a given period of time.

According to city records, notification was received of a water leak about 6:19 p.m., and the city sent a crew to investigate. The crew determined that a failure had occurred in the 40-inch-diameter cast iron water main that passes directly above the Howard Street Tunnel at station 63+15.[8] (See figure 2 showing broken water main.) The crew closed a 40-inch valve at the intersection of Lombard and Paca Streets. They also closed valves on an interconnected 20-inch-diameter water line. A 40-inch valve located 1 block to the east (as well as numerous interconnecting lines) was also closed to isolate the area of the break. The line was shut down by 11:59 p.m., about 5 hours 40 minutes after the appearance of water at street level. The city of Baltimore estimated that about 14 million gallons of water were lost from the water main between the time of the break and the time the line was shut down.

Figure 2. Broken 40-inch-diameter water main.

For the next 2 days, several groups of firefighters and railroad employees equipped with self-contained breathing apparatus ventured into the tunnel to determine the extent of the derailment and the status of burning equipment and cargo. Inside the tunnel, the first 45 railcars in the train consist had not derailed and had been pulled

[8] The city calculated the water pressure of the 40-inch pipe at the point of the tunnel crossing to be about 73 pounds per square inch.

beyond the derailment site. The next 11 railcars had derailed (positions 46 through 56). The remaining four railcars had not derailed.

The fire lasted for about 5 days as smoke emanated from both ends of the tunnel and several manholes at the Howard Street level. On Monday, July 23, at 7:42 a.m., the incident commander declared the scene officially under control. Later that morning, he authorized entry into the tunnel without self-contained breathing apparatus for qualified personnel.

Efforts to Determine Accident Cause

General

Because of the fire in the tunnel and the release of hazardous materials from tank cars, Safety Board investigators were not immediately able to enter the tunnel. By the time Safety Board investigators were able to examine the derailment area in detail, it had been disturbed by the discharge of about 14 million gallons of water from the ruptured water main, by the removal of significant sections of track, and by the use of heavy equipment to pull smoldering cars from the tunnel. Investigators therefore could not document the derailment site as would normally be done in a train derailment accident investigation. The following material considers preaccident data and information, postaccident physical testing and evidence, and statements from people who were in the tunnel during or immediately after the emergency response.

Postaccident examination did not disclose any preaccident defective rail conditions. All the fractures in the north rail initiated from the gage side, and almost all the fractures in this rail were associated with a rail anchor mark. This indicates that the fractures in the north rail were created by a common mechanism. The most likely mechanism was a wheel or wheels dropping off the gage side of the north rail and striking the anchors, driving them in an eastward direction. The anchor marks were likely created when a struck anchor, restrained by a tie, dug into the gage side of the base, creating a depression and, in many cases, initiating a shear crack at the east end of the mark. These shear cracks then propagated and fractured the north rail.

None of the fractures found after the accident contained any features that suggested a defect or a slow-growing crack. Additionally, the investigation did not find any battered rail ends, as would be expected if a rail had broken before the accident. All the fractures found in the rail removed from the accident area were typical of overstress fracture, indicating that a broken or defective rail did not cause the derailment.

Examination of the event recorder data for the accident train did not show any unusual train handling methods, and the engineer and conductor performed their assigned tasks in compliance with the CSX operating rules and special instructions applicable to this train's operation. A review of the crewmen's personnel records showed they were current in the operating rules requirements for their positions, and their medical records did not show restrictions.

Inspections of the train equipment did not reveal any preaccident deficiencies, defects, or missing parts, with the exception of the 52nd car in the consist. The 52nd car, the derailed tripropylene tank car that ruptured, was found de-trucked, with its easternmost (lead) truck near the center of the car and the westernmost truck against the car body bolster. The center pin between the lead truck and car body was missing.[9] The Safety Board and the Association of American Railroads (AAR) used computer models to simulate the movement of this car with the center pin missing between the lead truck and car body. The simulation used the most recent CSX track geometry data for the segment of track with the train entering the west portal of the tunnel at the speed of 23 mph. The simulation did not result in a derailment of the tank car with a missing center pin.

The 40-inch-diameter cast iron water main that ran directly above the Howard Street Tunnel, which ruptured and introduced a large volume of water into the tunnel, was considered as a possible causal factor in the accident. When postaccident examination was made of the ruptured pipe, no indication of third-party damage or significant corrosion damage was found at or near the point of rupture. Metallurgical examination of the fractured pieces of the water main showed that the fractures in the pipe section were brittle, with no evidence of crack arrest positions or slow growth regions, which indicates that a sudden overstress fracture of the cast iron pipe occurred.

A photo from a time-stamped security camera at the intersection of Howard and Lombard Streets indicated that water from the broken main appeared at the street surface at 6:19:38 p.m., about 3 1/4 hours after the derailment. In addition, water elevations at several nearby water treatment plants declined between about 6:15 p.m. and 6:30 p.m. This timing information suggests that the water main broke as a result of the postaccident events, including the fire within the tunnel, rather than prior to the accident.

A finite element analysis[10] of the tunnel and surrounding area in the vicinity of the water main was performed using the ABAQUS[11] code to determine whether the fire within the tunnel could have caused the water main to fracture. The analysis concluded that the postaccident fire was responsible for thermal expansion of the tunnel and that the expansion caused the tunnel walls to heave upwards, displacing the surrounding materials and imparting significant loads upon the water pipe. Further, the unique construction

[9] A center pin does not carry or transmit load during a car's movement.

[10] *Finite element analysis* is the simulation of a physical system (geometry and loading environment) by a mathematical approximation of the real system. Using interrelated building blocks called elements, a real system with infinite unknowns is approximated with a finite number of unknowns.

[11] Hibbitt, Karlsson & Sorensen, Inc., *ABAQUS/Standard User's Manual, Version 6.2* (Pawtucket, RI: 2001).

details of the tunnel, the pipe, and the light rail foundation[12] combined to generate discontinuities in resistance to the thermal heaving, generating significant concentrations of stress within the water pipe. The location of the high stress concentrations predicted by the analysis was consistent with the location of the initiation of the fracture in the pipe, as determined through metallurgical examination. Therefore, the 40-inch water main that ran directly above the Howard Street Tunnel broke after the train had derailed, as a result of the thermal expansion of the tunnel caused by the postaccident fire within the tunnel.

Identifying the Point of Derailment

Wheel marks found on the head of the north rail during the reconstruction of rail recovered from the derailment area indicated that a wheel had moved south toward the inside of the rail about station 62+23. Additional wheel marks were found on the gage side of the base of the north rail; however, no wheel marks were found on the south rail nor were any other wheel marks identified on either rail.

A detailed postaccident examination was conducted of the first several derailed cars. Efforts were concentrated on the first several derailed cars because experience has shown that a derailed car does not cause the derailment of more than two preceding cars on straight track. The inspection of the truck side frame spring seat ribs of the derailed cars showed that the profile of the rail head was worn into the spring seat ribs on the underside of the truck side frame spring seats on one side or the other of the 46th through 48th cars, indicating that they had slid on top of the rail between the body of the side frame and the wheels. The wear varied from car to car; the more wear there was, the longer the car had been derailed before coming to a stop.

The 47th car in the consist showed the most rib wear, indicating that this car had spent the most time derailed, so it was probably the first car to derail. The trucks of the 46th car had the next most rib wear. There was less wear to the B-end (leading end) spring seat ribs of the 48th car and only scrapes to the A-end (trailing end) ribs. Therefore, it appears that the 46th car was the second car to derail (pulled off the track by the 47th car) and that its derailment was followed by the derailment of the 48th and subsequent cars.

Event recorder data showed an increase in the train's tractive effort, followed by an unexpected reduction in train line air brake pressure. Based on this information, the Safety Board determined that derailed cars were on the ground while the train traveled about 300 feet before an air brake line separation between the 45th and 46th cars caused an automatic emergency application of the train's brakes. From the event recorder data and the documented position of the derailed equipment, the 45th and 46th cars came to a stop with about 550 to 600 feet between them. Event recorder data showed that the head

[12] The Maryland Transit Administration operates a double-track light rail service on Howard Street that runs parallel to and above the Howard Street Tunnel.

end of the 47th car was at about station 62+11, about 12 feet past the wheel marks on the north rail, when the emergency application occurred.

Based on the rail reconstruction, the profile of the rail head wear found on the truck side frame spring seat ribs of the car showing the most wear, and the position of the 47th car before the train brakes automatically went into emergency, the point of derailment was near station 62+23.

Derailment Scenarios

Because no clear evidence was found that would point definitively toward a single cause of the derailment, the Safety Board examined several scenarios to determine what factors or combinations of factors may have caused or contributed to this accident.

Sand in the Tunnel. Sand was reported in the derailment area after the accident. Large quantities of sand, if deposited on the track and over the rail, could affect train passage. But none of the 11 train crews that traversed the tunnel before the accident train on the day of the derailment reported seeing unusual quantities of sand on or near the track in the tunnel. Nor did the crew of the accident train report observing any unusual sand deposits. A quantity of sand sufficient to cause a derailment would not likely have gone unnoticed. Furthermore, had such an amount of sand been present, the derailment should have occurred nearer the head end of the train than the 47th car.

Some of the witnesses who entered the tunnel on the day after the accident reported seeing little sand in the derailment area. Other witnesses reported seeing significant amounts of sand. A fire department chief reported that he inspected the undercarriages of the derailed cars and did not notice any sand.

During postaccident examination, a section of the south wall of the tunnel was found to have a bulge projecting into the tunnel near station 62+31. The bulge was about 8 feet above the tunnel floor and about 4 to 6 feet in diameter. It projected into the tunnel less than 1 foot. Within the bulged area was a hole. The hole in the first layer of brick was about 3 bricks wide by 3 bricks high. Deeper in the wall, the hole was about 2 bricks wide and 1 1/2 bricks high. A person working in the tunnel the day after the derailment reported seeing water shooting from this hole, as it was from other locations.

The Safety Board contracted with the U.S. Army Corps of Engineers (USACE) to perform a geotechnical investigation in the area of the tunnel fire and water main break. In its report to the Safety Board, the USACE concluded that any significant quantity of sand in the tunnel was almost certainly carried into the tunnel as a result of the piping action from the ruptured 40-inch water main. Further, the USACE reported that, even if the hole had opened in the south tunnel wall bulge near station 62+31 after the head end of the train had passed, insufficient sand could have been deposited on the track to cause a derailment in the 2 minutes 15 seconds that elapsed from the time the locomotives passed until the first car derailed. The sand on the tunnel floor reported by some observers days after the derailment most likely resulted from the postaccident rupture of the 40-inch water main above the tunnel and the release of 14 million gallons of water.

Wide-gage Track. Wide-gage track can lead to a derailment if the defect is sufficient to allow the train wheels to drop inside the rails. In this accident, wheel markings found after the accident on the north rail could indicate a wide-gage derailment; that is, the markings show that derailed wheels did drop into the gage side of the north track. Other evidence, however, was not consistent with a wide-gage derailment.

Typically, in wide-gage derailments, either the wheels on both sides of the solid axle fall within the gage of the track or the wheels on one side drop in while the opposing wheels remain on the rail. In other cases, a wheel drops in and the opposite wheel forces the other rail to "roll-over" with that wheel then riding along the web of the rolled rail.

Physical evidence did not support any of the wide-gage derailment scenarios. The south wheels of the derailed cars neither fell within the gage of the track nor remained on the rail; they were found derailed to the field side (outside) of the track. Also, the evidence of the profile of the rail head worn into the spring seat ribs on the underside of the truck side frame spring seats on one side or the other of the 46th through 48th cars indicates that neither the north nor south rails immediately rolled during the derailment.

Postaccident track inspection did not identify any crosstie deficiencies within the undisturbed track leading to the derailment area. Inspection of the undisturbed track crosstie population immediately after the accident and again after completion of a rail renewal project did not show any signs of gage widening for the straight track outside or within the limits of the derailment footprint. No evidence was found to suggest that the condition of the ties that had been destroyed in the fire was significantly different from the condition of the other crossties in the area. The condition of the recovered crossties was also consistent with that of the non-defective resident crosstie population, taking into consideration the damage the recovered crossties received from the derailed equipment. The fasteners and tie plates on the recovered crossties appeared to be affixed solidly on almost every crosstie, indicating that the crossties were likely of sufficient strength not only to sustain the postaccident damage but also to maintain gage within the standards for Federal Railroad Administration (FRA) class 2 track.

Records showed that CSX tested and/or measured the track geometry through the Howard Street Tunnel an average of three times per year. The Safety Board reviewed the seven previous track geometry tests, which took place over a time span of about 2 years.[13] The seven track geometry tests between July 13, 1999, and February 2, 2001, showed that the rate of change in gage during the 2-year period was negligible; during this time, the gage never reached problematic proportions in the area of the straight track,

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[13] The specific test dates were February 2, 2001; January 30, 2001; July 17, 2000; July 12, 2000; March 20, 2000; March 15, 2000; and July 13, 1999.

including the area of the derailment. In addition, preaccident track inspections by both CSX and the State of Maryland did not identify any gage deficiencies within the tunnel.

Track Geometry. A train/track dynamic simulation study was undertaken to examine the interactions of the track, train, and environment within the Howard Street Tunnel. When computer simulations were performed using the most recent preaccident CSX track geometry data (taken on February 2, 2001) and incorporating the condition of the equipment and the dynamic forces applied by the accident train to the track structure, no simulated derailment occurred. But because an actual derailment did occur, and because a broken rail, the mechanical condition of the train, and train operations had not been identified as likely factors in the accident, investigators had to consider whether the derailment could have been caused by one or more deficiencies in the track structure.

The CSX track geometry data for the seven most recent previous tests showed that the gage, cross-level, alignment, profile, and warp measurements were within FRA regulatory thresholds for class 2 track. In fact, the track structure in the straight portion of track in and around the point of derailment consistently met standards for FRA class 5 track (a maximum speed of 80 mph allowable for freight trains),[14] even though CSX elected to operate its trains at 25 mph through the tunnel. Thus, it is unlikely that a train traveling at less than 25 mph, as was the accident train, would have derailed solely due to track geometry as measured before the accident. The track geometry test data reviewed were representative of an approximately 2-year-long period before the derailment. The data show that the track alignment fluctuated within a range of about 0 to 1 1/8 inch during the entire 2-year period. Further, the track in the tunnel underwent maintenance for spot surfacing with crosstie renewal installation. The surfacing of track is consistent with normal crosstie installation, and it is likely that the surfacing helped to maintain or improve the track alignment for the straight stretch of track in the tunnel.

Rail cross-level measurements for the same 2-year period also showed improved measurements, from a 0- to 1-inch range on July 13, 1999, to a 0- to 3/4-inch range for the same portion of straight track on July 17, 2000, almost exactly 1 year before the derailment. The range of the cross-level measurements (0 to 3/4 inch) remained constant for the year preceding the derailment. These measurements do not represent only the actual derailment area but rather the overall area of straight track, beginning east of the curves at station 71+00 and extending eastward on the straight track, through and past the point of derailment.

None of the track warp measurements had exceeded 1 1/8 inch in the previous 2 years. Track warp fluctuated from one test with a range of 0 to 1 1/8 inch in July 1999 to an improved range (a lessening of measurement) of 0 to 1/2 inch for two consecutive test

[14] It should be noted that although this specific portion of track could have been designated as class 5, due to practical engineering considerations concerning physical aspects of the Howard Street Tunnel, trains could not have been safely operated at speeds of 80 mph within the tunnel because of physical characteristics and operational considerations.

dates; then track warp increased to a range of 0 to 3/4 inch and remained constant during the last three tests prior to the derailment. In each case, the track geometry data consistently showed that the higher number in the range of measurements was the exception rather than the rule.

Computer simulations were performed to determine what changes in track geometry would be required to effect a derailment. The simulations were intended to re-create the accident train's movement over the track and, by varying the range of track geometry conditions, to produce a derailment.

Simulations were performed in which only one track geometry anomaly was introduced, without varying the other track geometry parameters. None of these simulations, when based on realistic anomaly data, resulted in a derailment.

Simulations were also performed using various combinations of anomalies in track cross-level, alignment, profile, and warp. These simulations showed that the minimum values necessary to create a wheel lift derailment were 2 1/2 inches of cross-level deviation and 2 1/2 inches of misalignment. But to match these values on the day of the accident, the geometry of the accident track would have to have deteriorated at least 1 3/4 inch vertically and horizontally from the maximum values registered during the most recent track geometry car readings, which had been taken about 5 months before the accident.

The accident train crew and the crew of the train that had traversed the tunnel before the accident train both reported water dripping onto their locomotives and water seepage down the tunnel wall near the derailment area, but neither train crew took exception to the track conditions within the tunnel. The fact that the 46th and 47th cars of the accident train were among the first to derail shows that much of the train had successfully traversed the area of the derailment. Thus, any combination of track anomalies would have had to occur under the passage of the accident train. But the essentially consistent track geometry data recorded during the previous 2 years of testing did not support the likelihood of extreme or rapid track geometry degradation.

The investigation showed that the tunnel had chronic water intrusion, particularly at the east, or Mt. Royal, end. The intrusion of water would be an outside factor affecting the track geometry. CSX was aware of the problem at the Mt. Royal end of the tunnel and performed periodic track maintenance to address it. Water from leaks in water distribution lines, from storm drains, and from naturally occurring groundwater can seep into the tunnel via the various pipeline and electrical conduit paths and accumulate in the voids behind the tunnel walls. However, according to the USACE, the Baltimore area had been suffering from an extended drought at the time of the derailment, and the levels of groundwater were probably lower than normal. There had been rainfall of about 1/4 inch in the early morning of July 18 in downtown Baltimore. The USACE's report stated that this rainfall would not have contributed a significant amount to either the groundwater or the storm water budget in the area.

Track Structure Defects and Foreign Object. In the previously described scenario, a derailment would have required the track at the point of derailment to have deteriorated at least 1 3/4 inch vertically and horizontally from the maximum values registered during the most recent track geometry car inspection. Because such a rapid deterioration would be inconsistent with the inspection history, investigators considered whether a foreign object, when combined with smaller track misalignments, could have induced a derailment.

When a single foreign object was introduced onto the track structure during a computer simulation using the most recent track geometry test data, the wheel climbed the obstruction, but the car returned to the rail without derailing. Simulation data showed that to derail a car, an obstruction on the track would have to be combined with deterioration in the track geometry sufficient to produce a "steering function." The simulated obstruction lengths varied from 6 to 12 inches.

The simulations showed that the combination of a 6-inch obstruction on the inside of the north rail with a 1 1/2-inch cross-level (vertical) deviation of the south rail and 1 1/2-inch alignment (lateral) displacement of the track would derail the lead truck of the car to the south. To obtain the 1 1/2-inch vertical and lateral displacement values, the track geometry would have had to deteriorate only 3/4 inch vertically and horizontally from the maximum values recorded before the accident.

A significant factor in this scenario is that the obstruction accounts for the "suddenness" of the accident. The simulated obstruction lifted the north wheel, and because of the steering mechanism of the 1 1/2-inch vertical and lateral track geometry, the north wheel derailed to the south (the gage side) of the north rail; the solid axle construction also caused the south wheel to lift, and the steering mechanism caused it to pass over the head of the south rail and derail to the south (the field side) of the south rail. This is consistent with the wheel markings on the north rail indicating a departure from the rails and physical evidence indicating that the 47th car (likely the first car to derail) derailed to the south side. However, wheel markings would also be expected on the south rail after the wheels passed the obstruction, but none were identified during the examination of the recovered rail.

Investigators considered possible sources of a foreign object or material that could have caused an obstruction. For example, the postaccident tunnel inspection noted a 2- by 4-foot void about 5 inches deep in the tunnel ceiling at station 63+15,[15] where the 40-inch water line passes directly above the ceiling with a special saddle section. A CSX consultant stated that he believed a previous repair had been made using two layers of wire mesh and a mix of brick and a concrete-like substance and that the repair materials were likely already gone when the fire was burning, because smoke damage was found on the surface underneath the repair. No pieces of a repaired section could be linked to

[15] About 70 to 80 bricks (one brick without mortar measures about 2 1/4 inches by 3 1/2 inches by 7 1/2 inches) could have been contained in the void.

the void during the investigation. Smoke damage within the void can be explained by the fire and smoke that were in the tunnel for several days following the accident.

Previously damaged or deteriorated car parts have been known to fall to the track and cause derailments when a moving train strikes them. No car parts were missing when a postaccident inspection of the first 45 cars of the train was conducted. Additionally, the accident train crew did not report seeing debris on the track.

No convincing evidence was found of a foreign material from the tunnel, a previous train, or other source having been present on the track as the accident train passed. Further, there is no evidence that the train could have derailed solely based on degraded track geometry. Computer simulations indicate that a foreign material between a wheel and the rail, in combination with certain track geometry degradations, could have caused a derailment.

Tunnel Maintenance and Inspections

No CSX records were found that described or defined the extent or nature of the repairs and modifications that had been made to the tunnel over the years. One CSX official told investigators that no records were kept of general maintenance for the Howard Street Tunnel. At least some repairs in the tunnel apparently went unrecorded. For example, there was the previously cited void in the tunnel's arch at station 63+15, immediately below the 40-inch water main. At some time before the accident, the void appears to have been filled with bricks or repair materials, such as concrete patches. However, no records of such repairs could be found.

Water in the tunnel was a common condition. But wet conditions are not unique to the Howard Street Tunnel. A report by the Transit Cooperative Research Program[16] states:

> The number one problem affecting tunnels and underground structures is groundwater intrusion and the subsequent damage caused by the presence of tunnel leaks. This groundwater intrusion is responsible for more problems affecting a tunnel's concrete liners and steel reinforced concrete than all other tunnel structural problems combined.

It is not known how much of the water intrusion in the Howard Street Tunnel comes from water supply lines, storm sewers, and other sources.

The USACE postaccident geotechnical evaluation showed multiple structural anomalies, including voids and delaminations behind the tunnel walls and within the

[16] Transit Cooperative Research Program, *Inspection Policy and Procedures for Rail Tunnels and Underground Structures* (Washington, DC: National Academy Press, 1997).

walls themselves. The timing of the voids' development could not be determined with reasonable certainty.

The CSX tunnel inspection procedures and documentation were neither thorough nor detailed.

On July 23, 2001, a team of about 25 people who were, according to CSX, mostly engineers, entered the Howard Street Tunnel to perform an inspection to determine the tunnel's structural integrity. The team included engineers from CSX and representatives of the city of Baltimore, the Maryland Transit Administration, and other organizations. The team split into smaller groups to examine the sides and ceiling of the tunnel. A lift truck was used to allow close inspection of the tunnel ceiling. After the inspection, CSX determined that the tunnel was structurally sound. A follow-up inspection was performed on August 27, 2001. Again, no structural problems were found.

On July 28, 2001, CSX had an engineering firm conduct two soil borings at the intersection of Lombard and Howard Streets, near the 40-inch water main found broken above the Howard Street Tunnel. To obtain core samples of the tunnel ceiling in the area of the water main, test bores were made through the street above the tunnel and into the brick lining of the tunnel ceiling about 10 feet to either side of the water main. The core samples of the brick lining indicated that the brick and mortar were solid.

Planning and Coordination

CSX and City of Baltimore Coordination

During the course of the investigation, it became apparent that information about modifications and construction in or near the tunnel had not been reliably documented or exchanged among interested parties. For example, there was an opening in the tunnel's arch immediately below the 40-inch water main where a repair had at least been started. Safety Board investigators attempted to obtain information about this void and repair, but neither CSX nor the city of Baltimore knew of or had documentation about when the void was first discovered or who had initiated the repair.

In another instance, information used by the city of Baltimore indicated that a storm sewer was 19 feet below the surface near a test drilling. However, during the drilling project, the drill struck the storm sewer, which was actually only about 8 feet below the surface. Also during the drilling project, it was discovered that a manhole had been moved and the move was not documented.

Documentation and information regarding construction and other alterations to the infrastructure in proximity to the Howard Street Tunnel are unreliable, and the exchange of such information between CSX and the city of Baltimore is inadequate. CSX railroad structures, portions of the Maryland Transit Administration light rail system and the Metro subway, and municipal and private utility lines and structures all coexist within a relatively compact area around the tunnel. Repairs and modifications to structures and utilities near the tunnel could have a significant effect on the tunnel's structural integrity and therefore on the structures of other nearby facilities.

Transportation of Hazardous Materials Through the Tunnel

During the derailment, a tank car released more than 28,600 gallons of tripropylene. The flammable tripropylene was ignited, and the subsequent fire led to the ignition of paper and wood products in adjacent freight cars. The burning wood and paper products sustained the fire over the next several days. The release of the tripropylene initiated the fire and increased the severity of the accident.

Immediately behind the ruptured tripropylene car were two tank cars containing hydrochloric acid and one tank car loaded with di(2-ethylhexyl) phthalate, which is an environmentally hazardous substance. Exposure of the hydrochloric acid tank cars to high temperatures for the duration of the fire resulted in thermal degradation of the cars' rubber linings and corrosive penetration of one of the cars by the acid.

The CSX route through Baltimore and the Howard Street Tunnel is a major rail artery and is a designated hazardous materials key route for all types and classes of hazardous materials. Congress recognized the significance of this rail route when it mandated that the DOT conduct a rail infrastructure study[17] for passenger and freight routes in the Baltimore corridor. Although the FRA had not completed the final report for the study as of August 2004, it has indicated that three options for improving the freight infrastructure through Baltimore have been considered. All three options involve the construction of new, modern tunnels with estimated costs ranging from $1 billion to $3 billion. Because of the scope and expense of these options, replacement of the Howard Street Tunnel is not assured, and at best, several years will be required to complete such a project.

Given these factors, improving the safety of the transportation of hazardous materials through the Howard Street Tunnel and minimizing the potential for more serious hazardous materials incidents in the tunnel will, in the Safety Board's view, depend upon shared communication and coordination between CSX and the city of Baltimore about the volumes and types of hazardous materials that are transported through the tunnel, anticipation of the types of incidents that might occur, and the capabilities and/or limitations of the city to access the tunnel and respond to any hazardous materials incident in it. The desired level of communication and coordination can be achieved through comprehensive emergency preparedness planning, including joint drills and exercises.

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[17] U.S. Department of Transportation's *Baltimore, Maryland, Freight and Passenger Infrastructure Study*, per Public Law 107-87.

Emergency Preparedness Documents

Emergency preparedness documents compiled by the Baltimore Office of Disaster Control and Civil Defense that were reviewed by Safety Board investigators do not contain information on hazardous materials discharge response procedures specific to tunnel environments or infrastructure information on the Howard Street Tunnel. Although principals of the Baltimore City Fire Department and of the member organizations of the South Baltimore Industrial Mutual Aid Plan, Inc.,[18] told the Safety Board that their personnel were familiar with response procedures applicable to tunnel environments and with the infrastructure of the Howard Street Tunnel, such information was not in the written plans.

Investigators reviewed the existing *Hazardous Materials Action Plan* for the city of Baltimore. Although the plan had detailed infrastructure response information on virtually all the industrial facilities within the city of Baltimore, it did not have any information on the Howard Street Tunnel, which could easily present situations as dangerous to responders as some of the industrial facilities that are addressed in the plan.

Despite the representations of the Baltimore City Fire Department and the South Baltimore Industrial Mutual Aid Plan, Inc., organizations that their employees were familiar with the Howard Street Tunnel, during the emergency response, the CSX dispatcher had to tell responding fire department personnel where to find a street-level manhole access to the tunnel at the intersection of Howard and Lombard Streets. The fire department later determined this access point to be instrumental to the fire suppression effort.

Baltimore officials told the Safety Board that they had initiated revisions of their Emergency Response Plan and Emergency Operations Plan to address a number of issues that were identified during the tunnel incident. The city has not yet provided the Safety Board specific information on the expected revisions.

It has long been known that emergency responders should be provided with comprehensive information to effectively and efficiently discharge their emergency response duties. This is particularly true for those responding to hazardous materials incidents. The information should include not only specific emergency response protocols for addressing hazardous materials discharges that occur in a conventional (outdoor) environment but also protocols for discharges that occur in an unusual

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[18] The South Baltimore Industrial Mutual Aid Plan, Inc., is an association of private industries and government agencies with the primary purpose of providing "a system of cooperative action whereby assistance to the public sector and other member companies may be available in an emergency…." It has a membership of about 88 active private industrial facilities in the greater Baltimore area. Members provide technical maintenance support for periodically updating the city of Baltimore's *Hazardous Materials Action Plan*, contribute technical expertise, foster emergency preparedness, and render mutual aid in the event of an emergency involving hazardous materials.

environment, such as inside a tunnel or on a long bridge at night, where conventional response protocols might not apply.

Emergency preparedness plans to address incidents within a tunnel environment could include, for example, considerations of the infrastructure, such as ambient ventilation, possible water infiltration, natural drainage, service and emergency lighting, emergency equipment, and personnel access, among other types of information that would not necessarily apply to an outdoor incident. Having such information clearly documented and instantly available is critical not only for experienced emergency responders but also for new emergency response recruits or support personnel unfamiliar with tunnel environment emergency response procedures.

The Baltimore City Fire Department told investigators that the department intended, at some future date, to coordinate with CSX to revise and update the department's *Manual of Preparedness* and training manuals to include infrastructure information on the Howard Street Tunnel and its potential access sites. Department officials also said they plan to revise and update their firefighter recruit training and to include periodic practice drills appropriate to the Howard Street Tunnel.

Environmental Response and Impact

The environmental response by the Maryland Department of the Environment and U.S. Coast Guard Activities Baltimore was timely and effective. The Maryland Department of the Environment quickly mobilized its hazardous materials spill response team to perform a site assessment. Within 3 hours of the accident, Coast Guard Activities Baltimore had dispatched a field response team to assist the State and local incident command and had established two safety zones because of the potential threat from hazardous vapors. Both agencies effectively coordinated with each other and with CSX environmental contractors to ensure that water sampling and air monitoring were conducted in a timely manner.

Following the excavation of slightly more than 1,400 tons of soil and debris from the tunnel, no appreciable amounts of hydrochloric acid or tripropylene residues were found in the soil in the tunnel. Also, following the removal of 3,000 gallons of water and product from the city's storm drains in response to reports of chemical odors during the weekend of August 11 and 12, 2001, no additional chemicals (other than residual traces) were found in the storm drain system.

Probable Cause

The National Transportation Safety Board, after an exhaustive investigative effort, could not identify convincing evidence to explain the derailment of CSX freight train L-412-16 in the Baltimore, Maryland, Howard Street Tunnel on July 18, 2001.

No preaccident equipment defects or rail defects were found. Computer simulations were used to evaluate locomotive event recorder data, train profile data, track profile data, and preaccident track geometry data. These simulations indicated that neither train operations nor changes in track conditions alone likely resulted in a derailment. Available physical evidence and computer simulations also showed that the most likely derailment scenario involved an obstruction between a wheel and the rail, in combination with changes in track geometry. However, postaccident fire, flooding, and necessary emergency response activities, including removing burning freight cars from the tunnel, significantly disturbed the accident site; and, no obstruction was identified that could be convincingly connected to wheel climb and evidence was insufficient to determine changes in track geometry.

Recommendations

As a result of its investigation of the Howard Street Tunnel railroad accident, the National Transportation Safety Board makes the following safety recommendations:

To CSX Transportation, Inc.:

> Maintain historical documentation of maintenance and inspection activities affecting the Howard Street Tunnel. (R-04-13)

> Take action necessary to enhance the exchange of information with the city of Baltimore on maintenance and construction activities within and in the vicinity of the Howard Street Tunnel. (R-04-14)

To the city of Baltimore, Maryland:

> Take action necessary to enhance the exchange of information with CSX Transportation on maintenance and construction activities within and in the vicinity of the Howard Street Tunnel. (R-04-15)

> Update and revise your emergency preparedness documents to include information on hazardous materials discharge response procedures specific to tunnel environments, as well as infrastructure information on the Howard Street Tunnel. (R-04-16)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

Ellen Engleman Conners
Chairman

Mark V. Rosenker
Vice Chairman

Carol J. Carmody
Member

Richard F. Healing
Member

Deborah A.P. Hersman
Member

Adopted: December 16, 2004

Deborah A. P. Hersman, Member, filed the following concurring opinion on December 1, 2004. Richard F. Healing, Member, joined Member Hersman in this opinion.

Mark V. Rosenker, Vice Chairman, concurred in part, filing the following statement on December 16, 2004:

> While I concur in most of the sentiments offered by Member Hersman, I do not believe the need for additional safety recommendations is demonstrated, nor am I convinced that NTSB access to the scene was imprudently delayed.

Notation 7662

Member HERSMAN, concurring:

> Despite having many reservations, I have agreed with my colleagues to release this accident brief without having a Board Meeting because no probable cause was determined and this investigation is now over three years old. Considerable Safety Board resources have been dedicated to this accident investigation and we have little to show for it. While there are several issues I think could have been raised in a public forum, given the tardiness of this brief and the lack of findings, holding a Board Meeting would not likely change the outcome of the brief or our recommendations. Moreover, I have been advised that it would be a drain

on staff resources to prepare for such a Board Meeting. As such, I will instead raise the following issues, which I believe should be acknowledged with respect to this accident investigation:

1.) The four recommendations contained in the brief could have been made within one month of the accident. While there was no probable cause determination in this accident, there were significant issues raised during the investigation. I believe we should have made additional recommendations to the Department of Transportation (DOT) and the Department of Homeland Security (DHS). (See attachment.)

The Federal Railroad Administration (FRA) has no requirements for the inventory and inspection of tunnels. While railroad tunnels are generally built to last,[1] this seems to be an area where federal guidance is lacking. There are federal requirements to inspect the track, the equipment, and railroad bridges, but nothing addressing tunnels. As major railroad tunnels age, the potential risks of problems increase if maintenance is deferred. Many major tunnels in urban areas are over one hundred years old and still heavily utilized.[2] Following the accident, there were many documented areas of concern in the tunnel, with little information provided on the inspection and maintenance of the tunnel structure.

Accompanying my concerns regarding the condition and maintenance of railroad tunnels is the safe transport of hazardous materials through them. While the transport of hazardous materials has been a principal security concern, it should also be addressed as a safety issue. The Department of Transportation and the Department of Homeland Security are drafting studies and soliciting comments on the transportation of hazardous materials. Generally, the record shows that transporting hazmat is safer on the rails than on the highway. For example, in 1997, the most recent year in which we have data for the transportation of hazardous materials by mode, trucks and trains both moved approximately 75 million ton miles of hazardous materials.[3] However, there were 11,932 incidents and 12 deaths on the highway contrasted with 1,102 incidents and no deaths on the railways.

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[1] As evidenced by the robustness of the Howard Street Tunnel that survived the derailment, explosion, subsequent fire and flooding and remains in service today.

[2] For example, CSX's Howard Street Tunnel was constructed from 1890 to 1895 and is the only north-south freight route east of Hagerstown, Maryland. Amtrak owns the First Street tunnels from the Virginia Avenue interlocking to Union Station in Washington, D.C., which date back to 1904 and are used by Amtrak and the Virginia Railway Express. Amtrak also owns the B & P tunnel in Baltimore built in 1872, which is used by the Maryland Transit Administration, as well as tunnels used by New Jersey Transit commuters and Amtrak intercity passengers under the Hudson and East Rivers between New Jersey and New York.

[3] *Commodity Flow Survey*, U.S. Department of Transportation, Bureau of Transportation Statistics/U.S. Department of Commerce, Economics and Statistics Administration, U.S. Census Bureau (1997).

In short, the consideration of safety and security issues is often inextricably linked. While critical infrastructure and concerns about the transport of hazardous materials are central themes in current public debate surrounding security concerns, the only experience we have to date shows that they should be regarded as important safety issues. Given the long history of expertise at the Federal Railroad Administration in dealing with rail safety issues, including transportation of hazardous materials, it is imperative that any decisions made by DHS with respect to security measures also take into account relevant safety considerations.

2.) Three years have passed since the accident. In an accident investigation, much of what is important to the community, the industry, the employees, and in some cases, the victims, is identifying what happened, and for the parties involved to take actions to prevent such an accident from occurring again. I acknowledge that it is harder and more time consuming to prove all of the things that didn't happen. In this accident, significant time was spent ruling out possible accident scenarios because a probable cause with contributing factors was not determined early in the investigation. While I understand that a backlog of accident investigations has been eliminated in the last several years, there needs to be a renewed focus on timeliness and clear expectations about the process. Three years is simply too long to spend on a brief without making significant progress on the cause or recommendations.

A review of the docket shows that the bulk of the work on this investigation was completed by April of 2003, including much of the written brief. While all of the staff involved in this investigation worked diligently to determine the cause of the accident and make appropriate recommendations, a great deal of time was spent in administrative review, including two months in my office. If the delays are a result of the lack of staff resources, which compromise our ability to launch on accidents and complete our investigations in a timely manner, then a revised timetable ought to be established based on the resources available and all parties should be advised of what to expect.

3.) Lack of access to the accident scene severely compromised our ability to determine the probable cause. This was a unique accident in that much of the evidence was removed or disrupted because of the postaccident fire and subsequent flooding, which resulted in a significantly disturbed accident scene. The emergency response efforts clearly were the first priority in the hours after the accident, as they should be. However, it was almost two days before NTSB personnel entered the tunnel to assess the accident scene. If we do not have access to the scene in a timely manner, then we cannot assess damage and document the evidence. In the future, it is important to be among the first to access the accident scene as soon as it is safe to do so and ensure that other parties do not disturb the evidence.

4.) Lastly, there are general concerns, as there are in any accident investigation, about the resources available to staff. We have only 13 rail investigators at the Safety Board, working on freight rail, passenger rail, and transit accidents. Additionally, as in most of the accidents investigated by the Safety Board, we had to rely on parties to the investigation to provide significant support for our work. In this accident, we had to rely on the Association of American Railroads (AAR) to provide access to simulation software to model the accident. In this case, there was not another option, and to my knowledge, our reliance on the AAR did not pose a problem; however, it is worth noting potential drawbacks that may affect future investigations, i.e. constrained staff resources, a limited number of experts and the necessity of relying on outside sources for technical support.

Attachment to Concurring Opinion of Member Hersman

To the Federal Railroad Administration:

> Work with tunnel owners to assess the safety of major railroad tunnels and provide guidance to tunnel owners and users regarding inspections, maintenance intervals and documentation.

In the aftermath of the CSX freight train derailment and subsequent fire in the Howard Street Tunnel, several important issues need to be addressed regarding the maintenance and repair of railroad tunnels. While maintenance issues may not have been a *causal* factor in the Howard Street Tunnel accident, incomplete and inaccurate information regarding recent construction and repairs to the tunnel's infrastructure represents a serious deficiency in record-keeping as well as an inability to adequately assess the conditions in the tunnel and exchange such information with other interested parties. As indicated in the brief, investigators could not locate any CSX records detailing the extent or nature of recent repairs and modifications to the tunnel over the years. This absence of maintenance and repair documentation highlights the need for comprehensive and systematic assessment and management of railroad tunnels that will accurately and reliably record this information and allow for its exchange between railroad personnel, tunnel owners, emergency response organizations, oversight agencies/administrations, and other interested parties.

Given the current state of information available on railroad tunnels, the inadequacies uncovered in the Howard Street Tunnel accident are not likely an isolated incident of poor record keeping by CSX. After conducting preliminarily searches, including requests to the FRA and the AAR, for the data on the number, age, condition, maintenance, and inspection of railroad tunnels, it appears that this information is not easily accessible or even available. Moreover, access to existing data is further complicated by its dispersion across a number of different sources. In contrast, a good deal of information is provided for road and rail transit tunnels. The Federal Transit Administration (FTA) and the Federal Highway Administration (FHWA) joined forces in March 2001 to create a comprehensive Tunnel Management System[4] for all road and rail transit tunnels in the U.S. With the goal of implementing uniform maintenance and rehabilitation practices to reduce the dangers associated with poor inspection procedures and deferred repairs, a system was implemented that provided for standardized assessments, inspections, and maintenance regulations. Additionally, a computerized database for collecting and

[4] See *Highway and Rail Transit Tunnel Maintenance and Rehabilitation Manual* (FHWA and FTA 2003).

storing all inventory, inspection, and repair data was created. By adopting uniform condition codes and prioritizations for repairs and establishing set frequencies for inspections, the FTA and FHWA have taken the necessary steps to insure adequate reporting, recording, and storage practices for both inventory and maintenance of road and rail transit tunnels.

While still in its infancy, this system promises a number of important advantages. Specifically, an effective management program, "will help tunnel owners and operators all across the country identify potential problems within their tunnels and will provide guidelines for proper maintenance to extend the life of a tunnel and/or to avoid more costly problems later." Furthermore, this system "can minimize damage, disruption of service, and traffic delays caused by typical tunnel problems such as those caused by groundwater and inadequate ventilation."[5] And perhaps most importantly, the creation of a centralized inventory and inspection database will allow for the storage and exchange of tunnel infrastructure information that can aid emergency responders and help reduce the future loss of life and environmental damage associated with these accidents.

As evidenced by the NTSB factual brief on the conditon of the Howard Street Tunnel,[6] the Army Corps of Engineers postaccident study on the structural concerns,[7] and the presence of water around the tunnel, a number of significant safety issues exist.[8] It is generally accepted that the biggest single problem affecting all tunnels is damage caused by water infiltration. According to the Transit Cooperative Research Program report, "Groundwater intrusion is responsible for more problems affecting a tunnel's concrete liners and steel-reinforced concrete than all other tunnel structural problems combined."[9] Concrete spalling and delamination, in turn, trigger a new set of complications that may make the tunnel unusable. Uncontrolled water can potentially cause electrical shorts and other dangerous situations. Therefore, adequate drainage and clearance of water from the tunnel and right-of-way is a major maintenance consideration.[10]

[5] *A Light at the End of the Tunnel*, Frank V. Botelho, (FHWA 2003).

[6] National Transportation Safety Board, Factual Brief on Howard Street Tunnel Construction and Condition, Dr.Joe Kolly, Group Chairman, January 7, 2003.

[7] *Engineering and Geotechnical Report*, U.S. Army Corps of Engineers (December 31, 2002).

[8] These studies address several important structural concerns, e.g., holes in the south wall, brick and mortar conditions, arch damage near Lombard Street, spalled brick lining, etc.

[9] *Inspection Policy and Procedures for Rail Transit Tunnels and Underground Structures*, TCRP Synthesis 23.

[10] See *Highway and Rail Transit Tunnel Maintenance and Rehabilitation Manual* (FHWA and FTA 2003).

Unlike the highway and transit tunnels which are often publicly owned and financed by taxpayer dollars, the private freight railroad industry owns almost all of the railroad infrastructure in the United States. However, all of the railroads' assets coexist with the public, as is evidenced by the impact of the CSX tunnel accident in July 2001 on the city of Baltimore. In many cases, what occurs on a private right-of-way may have significant consequences to the general public.

While the list of activities and expenditures required to keep a tunnel in good, safe working condition is long, at a minimum, the FRA should provide guidance on inspections and record-keeping. While the private sector has long understood the asset management process, the fact that no records exist about inspections, structural damage or repairs made to the Howard Street Tunnel raises significant questions about how determinations could be made to predict future performance and decisions for maintenance activities and capital improvement projects. The FRA should work with the railroad industry to assess the current state of major railroad tunnels and address the inspection and maintenance of tunnels.

To the Department of Transportation and the Department of Homeland Security:

> Complete ongoing studies and rulemaking efforts to address the transportation of hazardous materials and coordinate future activities.

Highlighting the risks associated with the transport of hazardous materials through tunnels, the Howard Street Tunnel accident raises several important safety issues. First, is the need to develop a more comprehensive risk analysis system to assess the dangers associated with the transport of specific materials. Second, is the implementation of detailed emergency preparedness plans and appropriate training for rail employees and emergency responders. Third, is the implementation of standardized regulations for governing the transport of dangerous goods.

There are more than 240,000 tank cars in the North American railroad car fleet and rail shipment of hazardous materials accounts for 18 percent of the ton-miles of all hazardous materials shipped. In 2000, 725 of the reported railroad accidents involved trains transporting hazardous materials. Out of 6,942 cars in those trains, 979 of the cars were damaged and 75 cars released hazmat. This resulted in 5,251 people being evacuated. One fatality (a result of the accident, not due to a hazmat release), 82 injuries, and over $26 million in property damage were reported. Therefore, even with the great safety improvements made to tank cars in the 1970s, 1980s, and 1990s, hazmat is still released during accidents.[11]

Currently, the FRA is undertaking three major projects designed to improve the safe transport of hazardous materials by rail.[12] The first of these projects, *Hazmat Transportation Safety*, has the goal of enhancing the safety and efficiency of transporting dangerous materials by rail. To accomplish this goal researchers are investigating the shipment routing of hazardous materials, specifically considering the confinement of hazmat transport to certain "classes" of tracks and rerouting dangerous shipments around major metropolitan areas. A second project, *Tank Car Structural Integrity*, is charged with the goal of ensuring that the capability of hazmat carriers to maintain structural integrity is understood. Safety issues considered by this ongoing project include the following components and elements related to overall tank car integrity: fatigue damage, welding effects, puncture resistance, steel quality, and thermal protection systems. The third project, *Damage Assessment and Improved Inspection Systems*, is intended to develop, improve, and quantify the capability to assess the condition of tank cars, in repair shops and at accident sites. In particular, the project is designed to increase safety by improving assessment of damaged tank cars and enhancing the existing inspection and repair process. Additionally, it is expected to reduce postaccident risk to emergency responders by providing them with critical information about tank car condition.[13]

In addition to the FRA's efforts to increase safety, recent actions have focused on improving the security of rail transportation, with much remaining to be done. Presidential Decision Directive (PDD) 63, "Critical Infrastructure Protection," requires federal agencies to "take all necessary measures to swiftly eliminate any significant vulnerability to both physical and cyber attacks on our critical infrastructures, including especially our cyber systems." Rail transportation has been determined to be a part of the nation's critical infrastructure. Recently, the DOT's Research and Special Programs Administration and DHS's Transportation Security Administration published a notice in the Federal Register[14] soliciting comments on measures to enhance the security of rail shipments of toxic inhalation hazardous materials. The comment period closed on October

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[11] Federal Railroad Administration Website.

[12] *Railroad Research and Development Program* (Chapter 4, Sec. 4.8) <http://www.fra.dot.gov/us/content/1242>.

[13] By supplying emergency responders with up-to-date, detailed information about the condition of tank cars, the FRA hopes to avoid another tank car accident like the one in Waverly, Tennessee, in the 1970s that resulted in the death of a number of emergency responders when a tank car ruptured unexpectedly due to an undetected crack.

[14] *Federal Register*, Vol. 69, No. 157, Monday, August 16, 2004, Notices, pages 50988-50994.

18, 2004 and the NTSB submitted comments for the record.[15] At this time no further action has been taken on this notice.

A serious incident involving the transport of dangerous goods in a tunnel can be very costly in terms of human lives, the environment, tunnel damage and transport disruption. However, a decision to completely ban the transport of hazmat by rail could increase the overall societal risk of hazmat accidents by diverting the shipment to even less safe modes of transport. Simply redirecting the shipment of hazmat to alternative modes of transport or rerouting it around densely populated areas does not solve the above safety concerns. In many cases, the highest quality of track may go through major metropolitan areas, and unlike roads there are not generally bypass tracks around these areas. Moreover, additional switching and interchanges employed to avoid tunnels and metropolitan areas has inherent risk.

Reducing transportation risk should be the objective; however, quantification of risk is difficult because numerous factors and variables influence probabilities and consequences of incidents involving dangerous goods both inside and outside of tunnels. Even with expert knowledge, it is therefore difficult to assess risk for all circumstances, environments, conditions, etc. In order to rationally evaluate the risks and set regulations, current studies and rulemaking activities need to be completed and evaluated. I would urge the DOT and DHS to complete their ongoing efforts as soon as possible and coordinate their future activities to address security AND safety.

[15] National Transportation Safety Board correspondence, *Hazardous Materials: Enhancing Rail Transportation Security for Toxic Inhalation Hazard Materials*, Notation 7672 (10/13/2004).