National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: July 20, 2006

In reply refer to: R-06-14 and -15
Reiterate R-04-4 through -7 and R-05-16 and -17

Honorable Joseph H. Boardman
Administrator
Federal Railroad Administration
1120 Vermont Avenue, N.W.
Washington, D.C. 20590

About 5:03 a.m., central daylight time, on Monday, June 28, 2004, a westbound Union Pacific Railroad (UP) freight train traveling on the same main line track as an eastbound BNSF Railway Company (BNSF) freight train struck the midpoint of the 123-car BNSF train as the eastbound train was leaving the main line to enter a parallel siding. The accident occurred at the west end of the rail siding at Macdona, Texas, on the UP's San Antonio Service Unit. The collision derailed the 4 locomotive units and the first 19 cars of the UP train as well as 17 cars of the BNSF train. As a result of the derailment and pileup of railcars, the 16th car of the UP train, a pressure tank car loaded with liquefied chlorine, was punctured. Chlorine escaping from the punctured car immediately vaporized into a cloud of chlorine gas that engulfed the accident area to a radius of at least 700 feet before drifting away from the site. Three persons, including the conductor of the UP train and two local residents, died as a result of chlorine gas inhalation. The UP train engineer, 23 civilians, and 6 emergency responders were treated for respiratory distress or other injuries related to the collision and derailment. Damages to rolling stock, track, and signal equipment were estimated at $5.7 million, with environmental cleanup costs estimated at $150,000.[1]

The National Transportation Safety Board determined that the probable cause of the June 28, 2004, collision of UP train MHOTU-23 with BNSF train MEAP-TUL-126-D at Macdona, Texas, was UP train crew fatigue that resulted in the failure of the engineer and conductor to appropriately respond to wayside signals governing the movement of their train. Contributing to the crewmembers' fatigue was their failure to obtain sufficient restorative rest prior to reporting for duty because of their ineffective use of off-duty time and UP train crew scheduling practices, which inverted the crewmembers' work/rest periods. Contributing to the accident was the lack of a positive train control system in the accident location. Contributing to the severity of the accident was the puncture of a tank car and the subsequent release of poisonous liquefied chlorine gas.

[1] For additional information, see National Transportation Safety Board, *Collision of Union Pacific Railroad Train MHOTU-23 With BNSF Railway Company Train MEAP-TUL-126-D With Subsequent Derailment and Hazardous Materials Release, Macdona, Texas, June 28, 2004,* Railroad Accident Report NTSB/RAR-06/03 (Washington, DC: NTSB, 2006).

The Safety Board's investigation determined that in June 2004, the UP engineer worked at least part of 22 days and that his time on duty ranged from 9 hours to more than 18 hours. Eleven of his work days were longer than 14 hours, with 1 day totaling 22 hours (12 hours on duty and 10 hours of paid limbo time). The engineer's schedule reflected several demanding periods of work, but they were offset by breaks from service. For example, he was off duty for 57 consecutive hours during the first week of June, 69 hours the next week, and 41 hours the third week.

The periods of on-duty and off-duty time for the engineer during the month of June would have put his circadian processes in a state of continuous readjustment. Based on the release-from-duty times shown on the engineer's work schedule, he would have had to obtain much of his post-work recuperative sleep primarily during the daytime. Research has determined that daytime sleep is typically shorter in duration and is degraded in quality as compared with nighttime sleep.[2] For the remainder of the month of June, the engineer's rest would have included nighttime sleep, either when he worked during the day, or when he had multiple-day breaks in service. Such frequent changes in work/sleep patterns have been shown to disrupt circadian rhythms in a way that can degrade work performance.[3]

A complicating factor in the case of the UP engineer was that he did not have a residence of his own. Because he was staying with a fellow engineer but spending all his waking hours elsewhere, he did not have the usual relaxation time preparatory to sleeping that would have contributed to his obtaining recuperative rest. The combined effects of intermittent day and night work and the obstacles the engineer faced in obtaining adequate rest because of his living arrangements likely led to his developing a cumulative sleep loss, or sleep *debt*. Sleep debt occurs when an individual does not obtain sufficient restorative sleep over time.[4] According to one prominent sleep researcher, the tendency of an individual to fall asleep increases progressively in direct proportion to the increase in the sleep debt.[5]

In the 3 days immediately before the accident, the UP engineer engaged in an intense concentration of work followed by time spent in personal activities on Sunday. Work records show that he had only 9 3/4 hours off duty (after his tour) on Friday, June 25, and 9 1/2 hours off duty on Saturday, June 26. Based on his statements to investigators, he obtained only about 1 1/2 hours of bed rest (in addition to napping on a sofa while watching television) in a 31-hour period between his being called for work on Saturday evening, June 26, and the time of the accident. This lack of recuperative sleep would have increased the sleep debt the engineer was already experiencing because of his work schedule and living arrangements. Under these circumstances, the engineer would be expected to experience notably high sleep pressure with a resulting reduction in his ability to resist falling asleep.

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[2] A. J. Tilly, R. T. Wilkinson, P. S. G. Warren, B. Watson, and M. Drud, "The Sleep and Performance of Shift Workers," *Human Factors* Vol. 24, No. 6 (1982): 629-641.

[3] D. Kripke, M. Marler, and E. Calle, "Epidemiological Health Impact," in C. Kushida ed., *Sleep Deprivation, Clinical Issues, Pharmacology, and Sleep Loss Effects* (New York: Marcel Dekker, 2005) 203.

[4] W.C. Dement, *The Sleepwatchers,* 2nd ed. (Menlo Park, CA: Nychthemeron Press, 1996).

[5] Dement, 1996.

The Safety Board therefore concluded that the UP engineer's combination of sleep debt, disrupted circadian processes, limited sleep through the weekend, and long duty tours in the days before the accident likely caused him to start the accident trip with a reduced capacity to resist involuntary sleep.

This is not to say that, despite his intense work schedule in the days before the accident, the engineer did not have ample time to obtain rest. Had he been determined to do so, the engineer could have obtained recuperative rest after his tours on Friday and Saturday before the accident. And with some effort, he could have obtained even more rest on the Sunday before the accident.

The Safety Board notes that when the engineer went off duty on Sunday, he requested 12 hours' uninterrupted rest. But when he left the work site, he did not return to his temporary residence to seek rest. Instead, he drove to the home of his estranged wife where he intended to spend time with his daughter. He said that he did nap on the couch while watching television before his daughter arrived, but such napping would not be expected to fully ameliorate the effects of the engineer's sleep debt. Similarly, when the engineer left his wife and daughter at about 8:30 p.m., he could have gone back to where he was staying to go to bed. This would have given him several hours of additional sleep before his call to work. But instead of going home, he went to visit a friend and played cards for several hours.

The engineer said that he had expected to get more sleep because he did not believe he would be called to work until later on Monday morning. But the engineer was well aware of the unpredictability of work in pool service. As he acknowledged during the public hearing on this accident, "I could be 15 times out and miss calls because they rolled the board and put me first out." He made no calls to the voice response system on Sunday to get up-to-date information on his standing or on job vacancies, although he may have accessed this information through the UP Web site.

A review of the conductor's schedule in the 10 days before the accident showed that he had had 4 days off followed by 6 consecutive work days leading up to the day of the accident. His duty times for the 6 work days would have allowed him to continue the nighttime sleep pattern that he probably had adhered to during the preceding 4 off days. The conductor's call for the accident trip shortly after midnight on June 28 therefore inverted the work/sleep cycle he had developed over the previous 10 days. Such a disruption would be expected to produce "severe effects" for sleepiness and performance.[6]

On Saturday, June 26, after working until 10:50 p.m., the conductor had 26 hours off duty before reporting for the accident trip. His housemate said that the conductor had stayed up until about 4:00 a.m. Sunday morning and slept until about 1:00 p.m. Sunday afternoon. He was then active until some time after 9:00 when he returned from the home of a friend. Based on the statements of his housemate, the conductor apparently did not go to bed immediately after

[6] M. Rosekind, *et al*., in National Transportation Safety Board consulting report "Analysis of Crew Fatigue Factors in AIA Guantanamo Bay Aviation Accident," pp. 3-4, referenced in National Transportation Safety Board, *Uncontrolled Collision with Terrain, American International Airways Flight 808, Douglas DC-8-61 N814CK, U.S. Naval Air Station Guantanamo Bay, Cuba, August 18, 1993*, Aviation Accident Report NTSB/AAR-94/04 (Washington, DC: NTSB, 1994).

returning home. Thus, at the time the conductor was called for the accident train early Monday morning, he had had, at most, only a few hours of sleep in the previous 11 hours. This limited amount of sleep could have exacerbated the effects of the conductor's inverted work/sleep cycle and could have made it more difficult for him to remain alert in the hours before the accident.

Postmortem toxicological tests of the conductor were negative for drugs but positive for ethanol (alcohol). The alcohol concentrations were 0.013 percent in the blood, 0.051 percent in the urine, and 0.029 percent in the vitreous humor. Although the small concentrations of alcohol in the blood and urine could be explained as natural byproducts of decomposition, the finding of 0.029 percent alcohol in the vitreous humor offers evidence that the conductor had ingested alcohol before reporting for work.[7] This finding was consistent with the housemate's statement that the conductor may have consumed some quantity of beer after he returned from his friend's home.

The Safety Board does not consider the conductor's alcohol use, in and of itself, to be causal to this accident. However, alcohol has been shown to have a sedating effect after use or after the concentration of alcohol in the body has begun to decrease.[8] Thus, the Safety Board concluded that the UP conductor's lack of sufficient rest before reporting to work, the disruption to his previous work/rest pattern that resulted from his change in work schedule, and his alcohol consumption on the evening before the accident likely combined to reduce his capacity to remain awake and alert during the accident trip.

The Safety Board recognizes that work as a train crewmember entails an unpredictable job schedule that can make it difficult for employees to effectively balance their personal and work lives. During those periods when the demand for crews exceeds the supply, the additional pressure on available crewmembers can make achieving such a balance particularly difficult. These conditions make it inevitable that even the most conscientious railroad employees will occasionally find themselves "caught short," without having received adequate rest before being called back to work. Although it cannot be known exactly what the engineer and conductor of the UP train would have done if they had known they would be called for the accident train shortly after midnight, it is clear that they were taking the chance that they would not be called to work when they were. In this case, the unpredictability of their work schedules led them to make what would prove to be imprudent use of their personal time. The Safety Board therefore concluded that the unpredictability of their work schedules may have encouraged the UP engineer and conductor to delay obtaining rest in the hope that they would not be called to work until later on the day of the accident.

The minimum rest periods prescribed by Federal regulations do not take into account either rotating work schedules or the accumulated hours spent working and in limbo time, both of which can affect the ability of an employee to obtain full rest and recuperation between job assignments. While limbo time is most often associated with a crew's travel time to their final

[7] D. Canfield, T. Kupiec, and E. Huffine, "Postmortem Alcohol Production in Fatal Aircraft Accidents," *Journal of Forensic Sciences* July (1993): 914-917. Also D. and V. DiMaio, *Forensic Pathology* (Boca Raton, FL: CRC Press, 1993) 446-450.

[8] T. Roehrs and T. Roth, "Sleep, Sleepiness, and Alcohol Use," *Alcohol Research and Health* Vol. 25, No. 2 (2001): 101-109.

release point after the expiration of their 12-hour service limit, the time spent awaiting transportation can be significant, as the Safety Board documented for the San Antonio Service Unit and the entire UP system during its investigation of the Macdona accident.

During an 8-week period in 1997, UP had three collisions that resulted in five employee fatalities. The Federal Railroad Administration responded by initiating a comprehensive systemwide safety review of the UP's operations seeking ways to correct systemic safety shortcomings. The Federal Railroad Administration concluded that there was:

> significant evidence of ineffective crew utilization, which leads directly to crew fatigue, stress, a lowering of morale, violations of the hours of service act and reduced ability to comply with operating rules. The end effect is train accidents and employee fatalities. *For example: crews being left on trains after the expiration of the Hours of Service. Sometimes in excess of two hours is spent awaiting arrival of crew vans or relief crews. Crews expire under the Hours of service Act approximately 75 percent of the time. This severely adds to crew unavailability and compounds rest and fatigue issues.* [Emphasis added.]

The Safety Board acknowledges that the amount of limbo time incurred by crews on the UP system or the San Antonio Service Unit is neither causal nor contributory to the Macdona accident. Nevertheless, the Board is concerned that, because minimum rest periods prescribed under the hours-of-service regulations do not take limbo time into account, such time could have cumulative detrimental effects on crewmember fatigue. The Safety Board therefore concluded that limbo time, which is limited neither by Federal regulation nor railroad operating rules, could be a factor in crewmember fatigue in that required rest periods do not take into account the extended hours of wakefulness before the rest period begins. The combination of erratic work schedules and excess limbo time would be expected to have a detrimental impact on crewmember fatigue.

The National Transportation Safety Board therefore makes the following safety recommendations to the Federal Railroad Administration:

> Require railroads to use scientifically based principles when assigning work schedules for train crewmembers, which consider factors that impact sleep needs, to reduce the effects of fatigue. (R-06-14)

> Establish requirements that limit train crewmember limbo time to address fatigue. (R-06-15)

Improving the safety and structural integrity of tank cars, developing necessary operational measures to minimize the vulnerability of tank cars, and equipping train crews with emergency escape breathing apparatus and preparing train crews to use them are other safety issues that emerged during the Macdona, Texas, accident. They are also Safety Board goals reflected in previously issued safety recommendations. The Board remains convinced that the successful and timely completion of Safety Recommendations R-04-4 through -7 and R-05-16 and -17 will help ensure the safety of the railroad industry, train crews, and the public.

Therefore, the National Transportation Safety Board reiterates the following safety recommendations to the Federal Railroad Administration:

R-04-4
Conduct a comprehensive analysis to determine the impact resistance of the steels in the shells of pressure tank cars constructed before 1989. At a minimum, the safety analysis should include the results of dynamic fracture toughness tests and/or the results of nondestructive testing techniques that provide information on material ductility and fracture toughness. The data should come from samples of steel from the tank shells from original manufacturing or from a statistically representative sampling of the shells of the pre-1989 pressure tank car fleet.

R-04-5
Based on the results of the Federal Railroad Administration's comprehensive analysis to determine the impact resistance of the steels in the shells of pressure tank cars constructed before 1989, as addressed in Safety Recommendation R-04-4, establish a program to rank those cars according to their risk of catastrophic fracture and separation and implement measures to eliminate or mitigate this risk. This ranking should take into consideration operating temperatures, pressures, and maximum train speeds.

R-04-6
Validate the predictive model the Federal Railroad Administration is developing to quantify the maximum dynamic forces acting on railroad tank cars under accident conditions.

R-04-7
Develop and implement tank car design-specific fracture toughness standards, such as a minimum average Charpy value, for steels and other materials of construction for pressure tank cars used for the transportation of U.S. Department of Transportation class 2 hazardous materials, including those in "low-temperature" service. The performance criteria must apply to the material orientation with the minimum impact resistance and take into account the entire range of operating temperatures of the tank car.

R-05-16
Require railroads to implement operating measures, such as positioning tank cars toward the rear of trains and reducing speeds through populated areas, to minimize impact forces from accidents and reduce the vulnerability of tank cars transporting chlorine, anhydrous ammonia, and other liquefied gases designated as poisonous by inhalation.

R-05-17
Determine the most effective methods of providing emergency escape breathing apparatus for all crewmembers on freight trains carrying hazardous materials that would pose an inhalation hazard in the event of unintentional release, and then require railroads to provide these breathing apparatus to their crewmembers along with appropriate training.

In addition, Safety Recommendations R-04-4 and -7, previously classified “Open—Unacceptable Response,” were reclassified “Open—Acceptable Response.” Safety Recommendation R-05-16, previously classified “Open—Await Response,” was reclassified “Open—Response Received;” and Safety Recommendation R-05-17, previously classified “Open—Await Response,” was reclassified “Open—Acceptable Response.”

The Safety Board also issued safety recommendations to the Union Pacific Railroad, the Brotherhood of Locomotive Engineers and Trainmen, and the United Transportation Union. In your response to the recommendations in this letter, please refer to Safety Recommendations R-06-14 and -15, R-04-4 through -7, and R-05-16 and -17. If you need additional information, you may call (202) 314-6177.

Acting Chairman ROSENKER and Members HERSMAN and HIGGINS concurred in these recommendations.

[Original Signed]

By: Mark V. Rosenker
Acting Chairman