Log H-585E

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

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In Reply Refer To: H-95-49

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About 1:50 a.m. on Monday, January 9, 1995, a multiple-vehicle rear-end collision occurred during localized fog at milepost 118 on Interstate 40 near Menifee, Arkansas. The collision sequence initiated when an uninvolved vehicle and the accident lead vehicle entered dense fog. As the lead vehicle reportedly slowed from 65 miles per hour (mph) to between 35 and 40 mph, it was struck in the rear. Subsequent collisions occurred as vehicles drove into the wreckage area at speeds varying from 15 to 60 mph. The accident eventually involved eight loaded truck tractor semitrailer combinations and one light-duty delivery van. Eight vehicles were occupied by a driver only, and one vehicle had a driver and a codriver. Three truckdrivers, the codriver, and the van driver were killed. One truckdriver received a minor injury, and four truckdrivers were not injured.[1]

This accident involved nine vehicles that entered an area of dense fog at widely varying speeds. According to driver and witness statements, vehicles entered the fog-affected area at speeds between 30 mph and 60 mph. The four vehicles involved in the initial series of collisions were subjected to relatively low-collision forces. When vehicles 6, 8, and 9 entered into the crash, the catastrophic damage, injuries, and fire resulted. The speed vehicle 7, the cargo van, entered into the crash is unknown, but this vehicle was eventually overrun and destroyed by following vehicles. The investigation revealed that a minimum of four separate collisions were involved; however, as many as eight could well have occurred. The collisions probably happened in 2 minutes or more.

[1]For more detailed information, read Highway Accident Report--*Multiple-Vehicle Collision with Fire during Fog near Milepost 118 on Interstate 40, Menifee, Arkansas, on January 9, 1995/Special Investigation of Collision Warning Technology* (NTSB/HAR-95/03).

Once in the fog and as it increased in density, the drivers of the leading five vehicles reduced their speeds of between 30 and 60 mph to as slow as between 10 and 15 mph for vehicle 5. Following the collisions that involved vehicles 1 through 4, wreckage blocked the right lane of the two westbound lanes. After vehicle 6 became involved in the collision sequence, its trailer rotated clockwise toward the median and completely blocked the road. The distance that the trailer rotated, combined with the damage apparent to the vehicle 5 rear, indicates that this collision involved greater speed than the initial collision series. The vehicle 6 tractor was destroyed by the damage and the fire that ensued later. An examination of vehicles 8 and 9 and the vehicle 9 distance of postimpact travel also indicate severe impact forces. A witness described the speed of vehicle 9 entering the impact area as slightly slower than his own speed of 65 mph. From the witness statements and collision damage, vehicles 6, 8, and 9 entered the collision area at faster speeds than vehicles 1, 2, 3, 4, and 5. Additionally, the drivers of vehicles 2, 3, and 4 did not reduce their speed appropriate to their closing velocities with the preceding vehicles. The precrash driving strategy of driver 7 is unknown.

The surviving drivers described the fog as "white out" and "very, very thick, the thickest fog ever." Other drivers, who were not involved in the accident, reported being unable to see the end of the hood (perhaps 8 feet) and to observe the lane markings from the truck cab looking straight down (perhaps 10 feet). Their descriptions indicate severely limited visibility.

In addition, the surviving drivers reported slowing their vehicles from the 65-mph speed limit to speeds between 35 and 40 mph, between 40 and 45 mph, below 30 mph, below 25 mph, and between 15 and 20 mph. Some said they slowed first when they heard a citizens band radio transmission about fog ahead and then again when they actually entered the fog. Each said slowing was the appropriate response. Two drivers had company-sponsored training that had advised to slow for limited visibility. Two drivers turned on their flashers.

The problem in limited visibility is what speed to choose. Should the headway time between your vehicle and the vehicle in front be reduced to less time needed to brake or swerve, the vehicle ahead will be hit. Conversely, should a speed be reduced sufficiently to preclude a following vehicle from reacting, a rear-end collision will occur. One driver believed he could not reduce his speed below 40 to 45 mph because the trucks behind him were closer than trucks in front and, therefore, posed a greater hazard to him. Further complicating the task of choosing an appropriate speed is the sight-distance variability within limited-visibility areas and the divided attention needed to observe lane markings, shoulder edges, and other peripheral cues to remain on the road.

Drivers 1 and 2 chose speeds that were incompatible with each other and too high for the available visibility. Consequently, driver 2 overtook vehicle 1 and the combination of speed and visibility-reduced headway sufficiently so that driver 2 struck the corner of vehicle 1 with about 36 inches of overlap before veering off into the median. If the headway between vehicles 1 and 2 had been slightly greater, the steering maneuver of driver 2 may have been sufficient to avoid collision. Instead, vehicle 1 was disabled and could not be moved. Each succeeding driver then encountered a gross speed differential because the vehicle 1 speed was zero. Collisions between vehicles 1 and 3 and between vehicles 3 and 4 resulted from the incompatibility between speed and visibility that produced a headway time without sufficient reaction time for the drivers.

Driver 5 reduced his speed between 15 and 20 mph. He stated that he saw the emergency flashers on the preceding vehicle and managed to stop just short of striking vehicle 4. It is likely his ability to see vehicle 4 and react was enhanced by its hazard flashers. As with the first series of collisions, succeeding drivers behind the stopped vehicle 5 were also faced with a gross speed differential and unable to compensate for the headway resulting from incompatible speed and reduced visibility.

A critical factor in rear-end collisions is the amount of headway time that is maintained between leading and following vehicles. Sufficient headway time is a function of visibility, speed, and reaction time. Reaction time is the time from the onset of a stimulus to the beginning of a response to that stimulus by a simple motor act, such as pressing the brake pedal. A stimulus must be perceived by our senses and transmitted to the brain; a response must be decided, and an action initiated.[2] Research studies of driver braking reaction time to an unexpected stimulus have identified reaction time about 1.5 seconds for the 75th percentile driver.[3] The time available for drivers to react in this accident, based on the visibility and their speeds, was less.

The introduction of a warning in advance of the initiation of a response serves to increase the time available for reaction. In one study,[4] drivers' response times were measured when they were anticipating a certain stimulus within the next 6 miles. The same drivers were then subjected to an infrequently triggered stimulus having intervals of hours to days. The results revealed that drivers reacted 1.35 times faster to the anticipated stimulus than the unexpected stimulus (0.54 to 0.73 seconds). Another study[5] indicated that a warning signal with an optimal lead time of 200 milliseconds could reduce reaction time about 50 milliseconds. Each of these studies indicates the advantage of a warning before a stimulus and response.

Evidence in the Menifee accident indicates that vehicle 1 was traveling in dense fog at a reduced speed when it was struck in the rear by vehicle 2. Assuming driver 1 had reduced his speed to 20 mph and vehicle 2 was behind traveling about 45 mph, a warning system would have activated with a warning light when the vehicles were still approximately 168 feet apart. Considering an appropriate reaction time (1 1\2 seconds to react and apply brakes in this high-

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[2]M. Sivak, P.L. Olson, and K.M. Farmer, "Radar Measured Reaction Times of Unalerted Drivers to Brake Signals," *Perceptual and Motor Skills*, 55, 1985.

[3]Twenty-five percent of drivers would have a longer reaction time. G.T. Taoka, "Brake Reaction Times of Unalerted Drivers," *ITE Journal*, March 1989.

[4]G. Johansson, and K. Rumar, "Drivers Brake Reaction Times," *Human Factors*, Vol. 13, No. 1, 1971.

[5]M.I. Posner, and C.R.R. Snyder, "Facilitation and Inhibition in the Processing of Signals," *Attention and Performance V.*, eds. P.M.A. Rabbitt and S. Dornic (London: Academic Press, 1975).

stress situation) and only moderate braking (0.2 g or 6.44 fps/s) by driver 2, his vehicle would slow to 20 mph while closing on the lead vehicle after 160 feet, and 38 feet of following distance would remain at the time a common speed was reached. Had the driver reacted in a similar manner at the activation of a collision warning system detect light, the vehicles could have reached a common speed while still hundreds of feet apart.

The collision warning system in these scenarios could have provided warning sufficient to avoid the initial collision between vehicles 1 and 2, leaving no road obstructions to be struck by the following vehicles. However, had vehicle 2 been traveling at the highway speed of 65 mph and reacted at an initial warning light, he would probably have been able to swerve around the obstructing vehicle or to brake forcefully, reducing the collision severity. Collision warning systems have the potential for avoidance or reduction in the severity of low-visibility collision conditions such as fog, snow, rain, or darkness.

The National Transportation Safety Board also analyzed the circumstances of the accidents near Weatherford, Texas,[6] (a low-awareness collision), and Fairfax, Minnesota,[7] (a low-visibility/low-awareness collision) to determine whether collision warning system technology can be applied for the avoidance or reduction in the severity of low-awareness collisions common to fatigued and distracted drivers.

The Weatherford, Texas, accident evidence indicates that vehicle 1, a passenger van, was traveling approximately 15 mph when vehicle 2, a tractor/semitrailer combination, traveling about 55 mph, struck it in the rear. The driver of vehicle 2 was found to have been fatigued, thus operating in a state of low awareness. Had a collision warning system been operational in vehicle 2, a detect light would have illuminated when the combination approached 500 to 600 feet of headway, and then a warning light and tone alert would have activated when the combination approached 3 seconds of headway (about 242 feet). If the driver had attempted avoidance by fully applying brakes (assuming 1 1\2 seconds reaction and brake application time), the vehicles would have reached a common speed while still 24 feet apart, and this collision would have been avoided. A driver with the same 3 seconds of warning time could have driven around the van with a steering maneuver to either the right or left. With the prompt 1 1\2-second reaction time, the combination would have avoided the passenger van by approximately 62 feet. The fatigued driver would probably not have reacted as quickly as a nonfatigued driver. With a longer reaction time, the vehicle still should have slowed significantly, due to braking, and the collision warning system probably would have reduced the severity of the collision.

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[6]Highway Accident Brief--*Collision of Tractor/Semitrailer and Passenger Van, I-20 near Weatherford, Texas, July 3, 1994* (DCA/94-M/H006).

[7]Highway Accident Brief--*School Bus Loading Zone Accident, S.R. 19 near Fairfax, Minnesota, December 21, 1994* (CRH/95-F/H006).

In the Fairfax, Minnesota, accident, a school bus was stopped in dense fog to load children when a tractor semitrailer combination approached about 55 mph from the rear. If a collision warning system had been operational in the combination, a detect light would have activated at 500 to 600 feet of headway. Had the driver been highly alert in this stressful driving situation and applied heavy braking, he could have brought the vehicle to a stop in 366 feet and 134 feet from the rear of the bus. Given the conditions of this collision and the detect light at 500 feet, the driver should have been much better prepared to take appropriate avoidance maneuvers when the school bus warning lights became visible. If the school bus warning lights did not become visible to the driver before the first warning light provided by a collision warning system, the driver may still have had sufficient time and distance to avoid the collision with a combination of braking and steering action. The heightened level of alertness provided by a collision warning system should have provided the driver more time to consider other avoidance options. Collision warning systems have the potential for avoidance or reduction in the severity of low-awareness collisions common to the fatigued or distracted driver.

The collision warning systems currently available or under development will eventually provide measurable accident reduction benefits. These systems in their current state can be demonstrated effective in preventing or mitigating the circumstances of many rear-end collisions, as well as many of the other classes of collisions that occur during attempts to avoid rear-end type collisions. The current system development may be adequate for the basic needs of passenger vehicles, considering their braking and handling characteristics, and may well serve the needs of commercial vehicles operating at lower than interstate speeds. However, the distance required for the driver of a heavy vehicle traveling 65 mph to react and to stop can be 500 or more feet. Thus, a driver would not have time under many conditions to perceive the signal as an impending hazard and then formulate and initiate a response as well as complete a successful braking maneuver. In many similar situations, a steering input combined with braking action would be most optimistic. Further development of collision warning technology will enhance the ability of these systems to meet the special requirements of commercial vehicles.

The Safety Board understands that new, relatively untested technology cannot be incorporated into day-to-day operations of a business enterprise without significant disruption. The experiences from the early generation of collision warning systems exemplifies the problems encountered when technology precedes user acceptance. Industrywide incorporation of advanced systems must be preceded by intensive practical testing in commercial fleets, extensive demonstration of the system benefits, and comprehensive training of the final operators. These prerequisites can be achieved under the sponsorship of the U.S. Department of Transportation (DOT) Intelligent Transportation System programs. Therefore, the Safety Board believes that the Intelligent Transportation Society of America and the DOT should sponsor, in cooperation, fleet testing of collision warning technology through partnership projects with the commercial carrier industry. Also, they should incorporate the testing results into demonstration and training programs to educate the potential end-users of the systems.

Therefore, the National Transportation Safety Board recommends that the Intelligent Transportation Society of America:

> Sponsor, in cooperation with the U.S. Department of Transportation, fleet testing of collision warning technology through partnership projects with the commercial carrier industry. Incorporate testing results into demonstration and training programs to educate the potential end-users of the systems. (Class II, Priority Action) (H-95-49)

Also, the Safety Board issued Safety Recommendations H-95-44 to the U.S. Department of Transportation; H-95-45 to the National Highway Traffic Safety Administration; H-95-46 to the Federal Communications Commission; H-95-47 to the 50 States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, and the Territories; H-95-48 to the Telecommunications Industry Association; and H-95-50 to the American Association of Motor Vehicle Administrators.

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility "to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any action taken as a result of its safety recommendations. Therefore, it would appreciate a response from you regarding action taken or contemplated with respect to the recommendation in this letter. Please refer to Safety Recommendation H-95-49 in your reply. If you need additional information, you may call (202) 382-6850.

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT and GOGLIA concurred in this recommendation.

By: Jim Hall
Chairman