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CALSPAN ON-SITE MOTORCOACH FIRE INVESTIGATION

SCI CASE NUMBER: CA10012

VEHICLE: 2001 MOTOR COACH INDUSTRIES (MCI) MODEL E4500

LOCATION: WISCONSIN

INCIDENT DATE: MARCH 2010

Contract No. DTNH22-07-C-00043

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
Washington, D.C. 20590

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Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety system.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. CA10012	*2. Government Accession No.*	*3. Recipient's Catalog No.*	
4. Title and Subtitle Calspan On-Site Motorcoach Fire Investigation Vehicle: 2001 Motor Coach Industries (MCI) Model E4500 Location: State of Wisconsin		*5. Report Date*: November 2010 *6. Performing Organization Code*	
7. Author(s) Crash Data Research Center		*8. Performing Organization Report No.*	
9. Performing Organization Name and Address Crash Data Research Center Calspan Corporation P.O. Box 400 Buffalo, New York 14225		*10. Work Unit No.* *11. Contract or Grant No.* DTNH22-07-C-00043	
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590		*13. Type of Report and Period Covered* Technical Report Crash Date: March 2010 *14. Sponsoring Agency Code*	
15. Supplementary Note This on-site investigation focused on the origin and severity of a fire that involved a 2001 Motor Coach Industries (MCI) Model E4500 motorcoach.			
16. Abstract This on-site investigation focused on the origin and severity of a fire that involved a 2001 Motor Coach Industries (MCI) Model E4500 motorcoach. The motorcoach was occupied by the 58-year-old male driver and 38 adult passengers. The motorcoach was traveling southbound on an interstate roadway when a fire initiated in the back of the vehicle. The driver was alerted to the fire by a passing truck driver. The motorcoach driver brought the vehicle to a controlled stop on the west shoulder of the interstate. He immediately ordered the evacuation of all passengers from the motorcoach. After safely evacuating all passengers without injury, the driver retrieved the onboard fire extinguisher and contained the fire. A cellular call was placed to the emergency response system to request fire and police support. The responding fire department arrived on-scene and suppressed the fire that was confined to the left rear engine compartment area.			
17. Key Words 2001 MCI Model E4500 Motorcoach Fire Fire Origin		*18. Distribution Statement* General Public	
19. Security Classif. (of this report) Unclassified	*20. Security Classif. (of this page)* Unclassified	*21. No. of Pages* 12	*22. Price*

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BACKGROUND

This on-site investigation focused on the origin and severity of a fire that involved a 2001 Motor Coach Industries (MCI) Model E4500 motorcoach **(Figure 1)**. The motorcoach was occupied by the 58-year-old male driver and 38 adult passengers. The motorcoach was traveling southbound on an interstate roadway when a fire initiated in the back of the vehicle. The driver was alerted to the fire by a passing truck driver. The motorcoach driver brought the vehicle to a controlled stop on the west shoulder of the interstate. He immediately ordered the evacuation of all passengers from the motorcoach. After safely evacuating all passengers without injury, the driver retrieved the onboard fire extinguisher and contained the fire. A cellular call was placed to the emergency response system to request fire and police support. The responding fire department arrived on-scene and suppressed the fire that was confined to the left rear engine compartment area.

Figure 1. Right side view of the 2001 MCI E4500 motorcoach.

The Crash Investigations Division (CID) of the National Highway Traffic Safety Administration (NHTSA) provided notification of this incident to the Calspan Special Crash Investigations (SCI) team on March 22, 2010. The SCI team initiated telephone contact with the Fleet Manager of the motorcoach company and established cooperation to conduct the on-site investigation. The motorcoach had been towed from the incident site to the company facility where it was inspected. The on-site investigation occurred on March 29-30, 2010, and involved a detailed inspection of the motorcoach, with disassembly of the exhaust system from the turbocharger, a review of the vehicle's service history, interviews with the driver, the chief mechanic and the service manager, and an inspection of the incident site. A fire expert conducted a review of the images and the documentation for this investigation. His opinion relating to fire origin and cause is included as *Attachment A* of this report.

SUMMARY

Incident Site

This fire incident occurred on a divided interstate roadway during nighttime hours. At the time of the incident, the conditions were dark and the asphalt road surface was wet. The driver reported mixed precipitation consisting of wet snow and rain. Local weather data reported the temperature 1.6 degrees C (35 degrees F) with 92 percent humidity. The winds were out of the north-northwest at 17 km/h (10.6 mph). In the vicinity of the incident site, the interstate consisted of four travel lanes in each direction that were

separated by a concrete median barrier. The southbound travel lanes were straight with a slight positive grade of less that 2 percent. A wide concrete surfaced shoulder supported the outboard travel lane. A construction work zone was present at the incident site and consisted of orange construction barrels that channeled traffic flow from the left lane to the inboard lane. The work zone was not active at the time of the incident. The work zone reduced the posted speed limit from 105 km/h (65 mph) to 89 km/h (55 mph). **Figure 2** is an overall view of the incident site. A schematic of the incident is included as **Figure 16**.

Figure 2. Overall view of the incident site.

Vehicle Data

The motorcoach involved in this incident was a 2001 MCI Model E4500, with a 55-passenger capacity. The motorcoach was manufactured in November 2000 and was identified by Vehicle Identification Number (VIN): 1M8TRMPA51P (production number deleted). The odometer reading at the time of SCI inspection was 829,956.9 km (515,711.3 miles). The motorcoach was a monocoque body/frame design. The front, side, and rear body panels were stainless steel and fiberglass composite; with trim and fascia consisting of plastic, aluminum, and rubber components. The motorcoach was configured with a rear-mounted Detroit Diesel Series 60 inline 12.7-liter, 6-cylinder turbocharged engine linked to an Allison B-500 6-speed automatic transmission. The engine cooling system consisted of a copper core radiator with a shaft driven cooling fan located at the left rear area of the motorcoach. The onboard air conditioning system was mounted forward of the left side forward of the drive axle. The exhaust system consisted of a single muffler with a tailpipe located on the left rear undercarriage.

The motorcoach was configured with three axles consisting of a front steer axle, a dual-wheel drive axle, and a non-steerable rear tag axle. The suspension was an air ride system with automatic leveling. As a feature to ease passenger access/egress, the steer axle position was equipped with a kneeling suspension that allows the front suspension height of the motorcoach to be lowered. The total Gross Vehicle Weight Rating (GVWR) of this motorcoach was 24,494 kg (54,000 pounds). The Gross Axle Weight Ratings (GAWR) and the placarded manufacturer recommended cold tire pressure at each axle are provided in the following table:

Axle	GAWR	Manufacturer Recommended Cold Tire Pressure
Steer (First)	7,485 kg (16,500 lbs)	827 kPa (120 PSI)
Drive (Second)	10,432 kg (23,000 lbs)	620 kPa (90 PSI)
Tag (Third)	7,485 kg (16,500 lbs)	827 kPa (120 PSI)

This motorcoach was equipped with OEM-style 23x57 cm (9.00x22.50 in) aluminum wheels at all three axle positions with the recommended tire size of 315/80R22.5 for all eight tires. The specific tire data documented at the time of the SCI inspection was as follows:

Position	Tire Make/Model	Measured Tread Depth	Measured Tire Pressure	Damage
Left Steer	Michelin Pilot EX ZAI	10 mm (12/32”)	758 kPa (110 psi)	None
Right Steer	Michelin Pilot EX ZAI	10 mm (13/32”)	758 kPa (110 psi)	None
Left Outer Drive	Michelin Pilot EX ZAI	10 mm (13/32”)	648 kPa (94 psi)	None
Left Inner Drive	Michelin Pilot EX ZAI	10 mm (12/32”)	Unknown	None
Right Outer Drive	Michelin Pilot EX ZAI	10 mm (13/32”)	620 kPa (90 psi)	None
Right Inner Drive	Michelin Pilot EX ZAI	10 mm (13/32”)	Unknown	None
Left Tag	Michelin Pilot EX ZAI	10 mm (13/32”)	717 kPa (104 psi)	None
Right Tag	Firestone FS400	10 mm (13/32”)	744 kPa (108 psi)	None

Two emergency exits were incorporated into the forward and aft sections of the roof, on the centerline. All seven of the side windows on each side of the motorcoach were push-out emergency exits.

The side body panels incorporated three compartments for the stowage of luggage within the wheelbase below the passenger compartment. There were also several equipment and mechanical maintenance access doors on both sides of the motorcoach. A large top-hinged access door to the engine compartment spanned the rear. The battery compartment was located on the right side, forward of the rear axles and aft of the luggage compartments. Two 12-volt batteries with a negative ground were located in this compartment along with the master cut-off switch and the battery equalizer.

Fuel System

The motorcoach was equipped with a single fuel tank that was mounted transversely to the undercarriage of the vehicle. The motorcoach was equipped with two filler tubes, one on each side near the midpoint of the wheelbase. At the time of SCI inspection, the filler caps were intact and in place. The fuel tank capacity was 727 liters (192 US gallons) with a Federal regulation not to exceed 689 liters (182 US gallons) of Low-Sulfur Diesel fuel. The fuel level at the time of this fire incident is unknown.

Cooling System

The cooling system was mounted to a hinged frame at the left rear corner of the motorcoach. The tubular frame served as a mounting platform for the copper-cored radiator, the shaft-driven cooling fan, and the louvered exterior compartment door. The total capacity of the cooling system was 91 liters (96 quarts). The cooling fan consisted of a 9-blade fan that was constructed of a plastic/fiberglass composite. The fan was powered through a shaft driven gearbox that transferred power from the engine PTO to the fan assembly. A fiberglass composite fan shroud was mounted to the radiator. The fan was thermostatically clutched and engaged at an operating temperature of 96 degrees C (205 degrees F). The radiator tubing was connected to the goosenecks with high-temperature silicone hose connectors.

Interior

The interior of the motorcoach was configured for the driver and 55 passengers. The driver's seat and the forward controls were conventionally mounted to the left side of the motorcoach and left of the center aisle, directly opposite of the loading door and curved staircase. The driver's fully adjustable seat was equipped with a 3-point lap and shoulder belt system.

Passenger seating consisted of 15 rows of seats on the left side of the motorcoach and 13 rows on the right side. The forward 13 rows consisted of four seats, laterally offset in groups of two on either side of the center aisle. All seats were constructed of tubular steel framing with foam padding, and covered with a synthetic blend fabric. Each seat was also equipped with a reclining seatback, adjustable head restraint, and a metal foot rest. All seats were equipped with an outboard-mounted vinyl-surfaced armrest. A restroom was incorporated into the right rear corner of the motorcoach, and was constructed of polymer walls. **Figures 3 and 4** are interior views of the motorcoach.

Aircraft-style overhead storage compartments extended the length of the passenger compartment on both sides of the motorcoach **(Figure 4)**. The compartments had top-hinged rigid fiberglass doors. On the underside of these compartments and directly above the passenger seats were courtesy reading spotlights, accompanied by six staggered video screens for passenger entertainment. The ceiling of the coach was covered with a synthetic carpet material, similar to the fabric on the seats.

Figure 4. Forward view of the interior of the motorcoach.

Figure 3. Rearward view of the motorcoach interior.

Motorcoach Service History

The involved motorcoach was purchased new by the motorcoach company along with a "sister motorcoach" that is identical to this vehicle. This involved MCI motorcoach was involved in a previous fire incident on March 31, 2009. The fire involved and was contained within the battery equalizer. There was no other fire related damage to the motorcoach. The motorcoach was repaired and placed back into service.

The service history reported by the motorcoach company to the SCI investigator during the on-site investigation is detailed in the following table:

Service Date	Repair Issue(s)	Odometer Reading
August 2008	Replace drive axle brakes	241,000 km (150,000 miles)*
November 2009	Replaced steer axle brakes	Unknown
November 2009	Replaced tag axle brakes	Unknown
November 2009	Changed engine coolant	Unknown
March 2010	Engine oil test sample Replaced a wheel stabilizer valve stem Replaced the alternator belt Repaired luggage bay door Replaced an engine pulley	382,237 km (237,518 miles)*
Additional service work performed (Dates unknown)	Muffler replaced twice Turbocharger replaced twice Engine oil changed every 29K km (18K miles) Engine oil tested every 14K km (9K miles)	Unknown

**The total mileage on the motorcoach was 829,957 km. The source of these odometer readings is unknown.*

Motorcoach Driver

The driver of the motorcoach was a 58-year-old male with a height of 185 cm (73 in) and a weight of 113 kg (250 lb). He was retired from his full-time career and was working part-time as a motorcoach driver. The driver had been employed by this motorcoach company for three years and had previous experience as a driver for another motorcoach company. He was rated as an excellent driver with a clean driving record.

Incident

Pre-Incident

The driver was assigned an intercity trip for a tour group of 38 adult passengers. The trip originated in the afternoon hours and did not require an overnight stay. The driver travelled approximately 145 km (90 miles) in a southerly direction, picked up the tour group and then traveled back toward his point of origin, to his passenger's destination. He arrived at the scheduled destination in the early evening hours and unloaded the passengers from the motorcoach. The driver parked the motorcoach and waited approximately six hours for the planned return trip.

The passengers boarded the motorcoach at the predetermined time and the driver traveled south to their final destination. While en route, the weather changed from rain to mixed precipitation of rain and wet snow. The motorcoach traveled approximately 80 km (50 miles) on the interstate road toward its final destination when it approached the construction work zone. The work zone required a speed limit reduction from 105 km/h (65 mph) to 89 km/h (55 mph). As the driver of the motorcoach entered the work zone in the outboard travel lane, a tractor trailer was following the motorcoach in the adjacent inboard lane.

Incident

The driver of the tractor trailer noticed flames emanating from the rear left corner of the motorcoach. He further observed that the driver of the motorcoach was continuing his travel without any indication of knowing there was a problem. The driver of the tractor trailer accelerated in an attempt to gain the attention of the motorcoach driver. As the tractor trailer pulled alongside of the motorcoach, the tractor trailer driver motioned to the motorcoach driver to pull over. The tractor trailer driver then passed the motorcoach and changed lanes, pulling in front of the motorcoach. He activated the tractor trailer's hazard lights, slowed, and brought the vehicle to a controlled stop on the right shoulder of the roadway. The driver of the motorcoach came to a controlled stop behind the tractor trailer. The tractor trailer driver exited his vehicle and proceeded to the motorcoach where he tapped on the left side of the driver's compartment and informed the driver that the motorcoach was on fire. Until this point, the motorcoach driver and all of the passengers were unaware of the fire.

The driver of the motorcoach opened the right side door and ordered the immediate evacuation of the motorcoach. He manually shut-off all power to the vehicle with the instrument panel-mounted cut-off switch. The passengers exited the motorcoach onto the grass roadside. The driver retrieved the onboard ABC fire extinguisher and proceeded to

the back of the motorcoach in an attempt to suppress the fire. A cellular telephone call was placed to the emergency response system requesting police and fire assistance.

The driver stated to the SCI investigator that he did not experience a loss of engine power. He further stated that since he was slowing for the work zone, he may not have detected a loss of power at that time.

Post-Incident

The local fire department responded to the scene and suppressed the engine compartment fire with approximately 1500 liters (400 gallons) of water to ensure the fire was completely out. None of the passengers were injured. A replacement motorcoach was dispatched to the scene and transported the passengers to their destination.

The splined drive shafts were removed from the motorcoach to allow it to be towed to the bus company's facility located approximately 160 km (100 miles) from the incident site. The motorcoach was undergoing an evaluation for repair by the service facility and the insurance company at the time of SCI inspection.

Fire Damage

The fire damage to the motorcoach was confined to the left rear side area of the cooling system, the back left corner of the bumper fascia, and the left side of the engine compartment, inclusive of the exhaust system. The fire originated in the insulation panel that was mounted over the top of the horizontally-mounted muffler and spread upward to involve the left side of the engine compartment. There was no fire or smoke related damage to the interior of the motorcoach. The following is discussion of the specific damage by vehicle area.

Exterior

The exterior damage involved charring and melting of the bumper fascia cutout over the tailpipe. The top right corner area of the cutout was melted with charring and smoke staining radiating outward and upward from this area **(Figure 5)**. The remainder of the bumper fascia was intact and undamaged.

Figure 5. Fire damage to the bumper fascia.

Subtle smoke staining was present on the top of the louvered cooling compartment door at the left rear corner of the motorcoach. The fiberglass louvers were intact and the painted surface was not damaged. There was no other exterior damage to the motorcoach. The tires were not involved.

Engine Compartment

The damage to the engine compartment area was limited the left side exhaust system, the cooling system, and the electrical and plumbing connections at the left rear corner area of the motorcoach.

The fire presumably originated in the muffler and caused extreme heat. The heat melted the fiberglass heat shield that was positioned over the horizontally mounted muffler, causing the heat shield to sag and come into contact with the muffler. The shield ignited and the fire burned through the shield into the left side engine compartment at the location of the cooling system.

The rear outboard aspect of the fiberglass reinforced heat shield was fragmented and holed. The forward area around the exhaust pipe from the turbocharger was burned through and the inboard side was burned to near full-thickness **(Figure 6)**.

The cooling system was positioned in close proximity to this heat shield. The lower aspect of the fan shroud was burned at the 4-8 o'clock positions. The burn pattern extended vertically upward and consumed the tips of the fan blades and the top of the fan shroud **(Figure 7)**. The lateral aspects of the fan shroud were charred.

The fire burned upward and consumed the wire loom and wire insulation. Evidence of high heat was present on the forward wall of the left side engine compartment and to the sheet metal shield located at the top of the opening. These shields contained the fire within this left side compartment.

There was no fire-related damage to the engine, transmission, differential, or tires. It should be noted that the engine oil was approximately 3.7 liters (4 quarts) low at the time of the SCI inspection.

Figure 6. Fire/heat related damage to the exhaust system heat shield.

Figure 7. Fire damage to the cooling system.

Turbocharger

The turbocharger was manufactured by Garrett and was mounted to the left side of the engine. The unit consisted of an alloy cold air intake housing and a cast iron exhaust housing. A vacuum operated waste gate was configured into the exhaust housing of the turbocharger. Internally, the turbocharger consisted of a steel shaft with intake and exhaust impellers mounted to the outboard ends of the shaft. Bronze-type oil bearings were mounted inboard of the impellers with oil journals for lubrication. The turbocharger's identifying information cast into alloy body was as follows: M24 B 05 7 L A/R 60 7844-58.

Intake air to the turbocharger was provided from the fresh air intake and through a radiator-mounted heated air exchanger utilizing separate ducting. The intake impeller side of the turbocharger was fitted with an aluminum deflector designed to channel the airflow into the intake impeller. The impeller blades engaged and damaged this deflector, separating it from the pressed fit within the intake opening. Fragments of this deflector were found in the intake port of the turbocharger **(Figure 8)**. **Figure 9** is a view of an exemplar turbocharger with damaged impeller blades and the deflector in place.

Figure 8. Damaged intake impeller and separated air deflector.

Figure 9. Exemplar intake with air deflector in place.

The post-fire inspection of the turbocharger determined that the impeller shaft was slightly deformed. The impeller shaft could easily be rotated by hand with a noticeable wobble to the intake impeller. The waste gate linkage remained operational.

The turbocharger was not removed from the engine or disassembled. It was suspected that the bronze oil bearing was worn resulting in the wobble to the impeller shaft. The presumed bearing damage resulted in oil leaking into the exhaust side of the turbocharger and into the exhaust system. Wet oil was present in the warm air intake port of the turbocharger **(Figure 10).**

The exhaust side impeller of the turbocharger was intact and undamaged. The blades were covered with a layer of carbon. The exhaust housing port yielded heavy, oil soaked, carbon deposits **(Figure 11)**.

Figure 10. Oil present in the warm air intake port of the turbocharger.

Figure 11. Carbon and oil deposits on the exhaust impeller and port of the turbocharger

Exhaust System

The exhaust system was intact and in place at the time of the SCI inspection. The bottom of the muffler and tailpipe were abraded from the towing process. The muffler was loose within it mounting hangers, possibly due to towing.

The exhaust pipe on the outboard side of the turbocharger was not physically damaged. The pipe was removed for inspection. This was accomplished by loosening the clamps and removing the pipe. The inside surface of the flange above the flexible coupling contained black, oil soaked deposits of carbon **(Figure 12)**. The downstream end of the exhaust pipe contained heavy black carbon deposits without a noticeable presence of oil.

The intake gooseneck on the muffler contained a layer of carbon on the upper aspect and the lower area appeared to be clean, with only trace amounts of carbon present. Surface rust had formed on the inside surface as water from the fire firefighting efforts seeped, or was sprayed into exhaust system. The inside of the muffler could not be inspected.

The tailpipe was free of carbon deposits **(Figure 13)**. This was the result of either the fire within the muffler which burned the deposits clean, or the result of the firefighters spraying water in the exhaust system to cool the system, thus flushing away the deposits.

Figure 12. Oil and carbon deposits on the turbocharger exhaust pipe.

Figure 13. Inside view of the condition of the tailpipe.

SCI Fire Source

The SCI investigation determined that the origin of this fire was in the left rear engine compartment area around the exhaust system. Oil leaked from the turbocharger into the muffler, igniting within the exhaust system. The oil leak resulted from a worn or damaged internal bronze oil bearing within the turbocharger. This resulted in a wobble to the impeller shaft which damaged the oil seals. Oil leaked under pressure into the exhaust side of the turbocharger and into the exhaust system. The combination of high heat generated by the turbocharger and the heat of the exhaust ignited the oil. The fire was contained within the muffler; however, the heat generated by the fire melted the fiberglass heat shield located over the top of the muffler. This shield sagged and came into contact with the hot surface of the muffler **(Figure 14)**. The shield ignited and the fire burned upward within the left side of the engine compartment. The fire subsequently spread to the cooling system fan and the electrical and plumbing components located above within this compartment **(Figure 15)**. The fire was detected early in the event and was contained to the left side engine compartment.

Figure 14. Muffler heat shield damage.

Figure 15. Fire damage to the forward left side engine compartment.

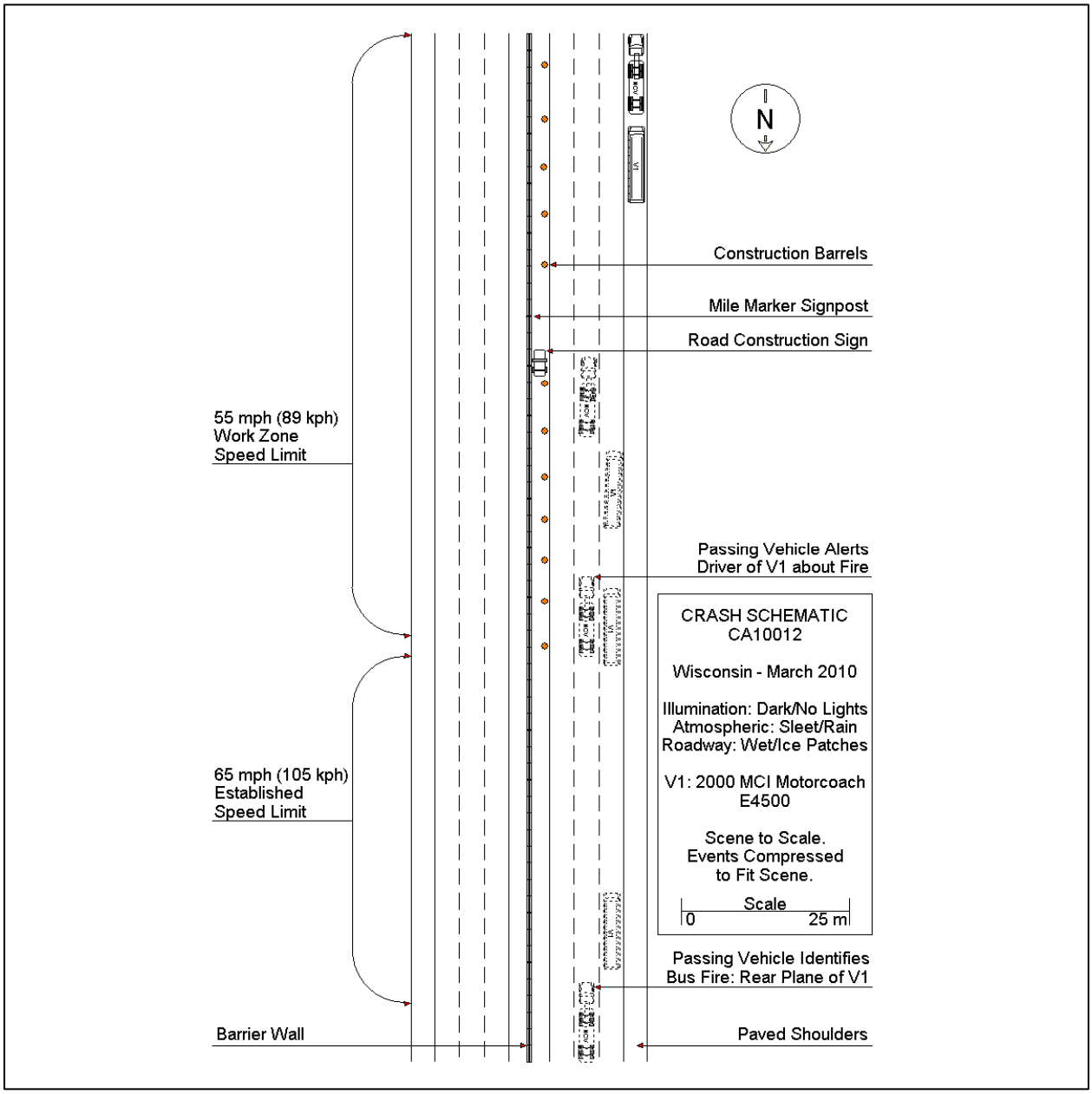

Figure 16. Incident Schematic.

ATTACHMENT A:

FIRE EXPERT'S REVIEW AND OPINION REPORT

Independent review and subsequent opinion by a fire origin and cause investigator:
It should be noted that this investigator was not directly involved with the vehicle fire or scene inspections, but rather depended on the photographs and documentations collected by the Calspan SCI team. Whereas this is not the optimal process when conducting an origin and cause investigation, the option of reviewing previous documentation is acceptable methodology according to NFPA 921, "Guide for Fire and Explosion Investigations" (2008 edition), and is adequate for the subject investigations given the scope and purpose of these evaluations.

For each case, photographs and documents were reviewed initially to determine an area or point of origin for the fire. Then this area was analyzed to determine a most probable cause. The area of origin was determined by an interpretation of the fire patterns left by the fire and supporting witness information. Interpreting fire patterns involves assessing the different amounts of damage to the various components involved taking into consideration the progression of the fire which is determined by the various fuel loads involved, the physical properties of the various materials, environmental effects, and the dynamics of the fire itself.

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Determination of Origin: The first witness was a tractor trailer driver following the motorcoach who reported flames coming from the left rear corner of the motorcoach. Inspection of the motorcoach show the fire and consequent damage was contained to the left side of the engine compartment in the area of the exhaust system. The only exterior damage observed was directly around the tail pipe. Within the engine compartment, the damage was centered around the exhaust system and then extending to the surrounding cooling system, and primarily affecting the materials around the muffler. The fire did not spread beyond the engine compartment. The area of origin was determined to be in the area of the muffler.

Determination of Cause: In evaluating the exhaust system, the turbocharger impeller blades were found to be damaged and the main shaft had play in the bearings. The engine was found to be approximately 4 quarts low on oil. This fire is therefore consistent with a turbocharger failure resulting in an engine oil fire within the exhaust system causing overheating of the materials surrounding the muffler as the most probable cause.