HWY-06-M-H026
Westport, New York

Vehicle Group Chairman's Factual Report

(26 Pages)

National Transportation Safety Board

Office of Highway Safety
Washington, DC 20594

Vehicle Group Chairman's Factual Report

A. THE ACCIDENT

Accident Type:	Motorcoach Run Off Roadway and Roll-Over
Date and Time:	August 28, 2006 at 6:40 p.m. (EDT)
Location:	Northbound Interstate Highway 87 near Mile Post Marker 114 (NY Ref. No. 87S1211.1341), near Westport, Essex County, New York
Vehicle:	2000 MCI 55-Passenger Motorcoach
Motor Carrier:	Greyhound Lines, Inc.
Fatal:	5
Injuries:	48
NTSB #:	**HWY-06-M-H026**

B. VEHICLE GROUP[1]

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[1] The vehicle Group is comprised of both official NTSB Parties to the Investigation and others who participated in limited ways, i.e., steering system examination, ABS Examination and tire examination. The only Parties in the NTSB Vehicle Group are Greyhound Lines, Motor Coach Industries, Goodyear Tire and Rubber Company, New York DOT, NHTSA and FMCSA.

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C. ACCIDENT SUMMARY

On August 28, 2006 about 6:40 p.m. a 2000 MCI 55-passenger motorcoach with 52 passengers on-board was proceeding northbound on Interstate Highway 87 (I-87) near the town of Westport, New York. The motorcoach, driven by a 52-year-old male, was descending a 5 per cent grade in the left lane at about 75 miles per hour, passing a tractor-semitrailer vehicle in the right lane. The left front tire on the motorcoach failed[3] and the vehicle veered sharply to the left. The motorcoach went off the pavement, through a 3-cable barrier, and down a dirt and grass depressed center median. The motorcoach struck several large rocks in the median and rolled over, coming to rest on its roof.

As a result there were 5 persons fatally injured, including the driver, and 48 passengers received various degrees of injuries.

The weather was cloudy and the roadway was dry.

D. HISTORY OF TRIP (brief summary)

On August 28, 2006, at about 10:30 a.m., the accident driver boarded a Greyhound bus, unit number 6528, trip number 2128, in Mt. Laurel, New Jersey, located about 25 miles east of Philadelphia. The driver was commuting as a passenger to the Port Authority Bus Terminal in New York City, where the bus was scheduled to arrive at about 12:10 p.m. The Vehicle Group Chairman interviewed the driver who drove unit number 6528 from Mt. Laurel to New York City on August 28th via telephone on September 4, 2006. He stated during the interview that "the bus was good, no shimmy, didn't pull, nothing unusual". After talking to the driver of unit #6528 while en route to New York City, the accident driver asked for the same bus for his trip to Montreal. According to the *Vehicle Inspection Report,* the driver of trip #2128 did a pre-trip inspection, and after arriving in New York City, a post trip inspection. The only notations were "old body damage" and "new M7 needed" (the M7 is the "Vehicle Inspection Report").[4]

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[3] **NOTE:** The term "tire failure, failed tire, etc." in this report is used in a generic sense, indicating that the tire lost air (complete or partial air loss), that a delamination occurred, or that the present condition (i.e., excessively low air pressure, large cuts, large chunk of the tread or side wall missing) of the tire was such that it would be in an unusable or unsafe condition, or otherwise create an imminent hazard. It does not imply, one way or the other, the presence of a manufacturer's defect.

[4] A copy of the *Vehicle Inspection Report,* completed by the driver of trip #2128, dated 8/28/06, is attached to this docket.

At about 1 p.m. on August 28th, the accident driver departed Port Authority Bus Terminal in New York City at about 1 p.m. on an international trip to Montreal, Quebec. Prior to departing, it cannot be stated definitively, one way or another, whether this driver did a pre-trip inspection in New York.[5] The pre and post-trip inspection require checking the tires. (Refer to the Human Performance Group Chairman's Report for additional information concerning this trip and the driver's activities.) The bus was scheduled to make stops in New York at Albany (30 minute stop), Saratoga Springs (10 minute stop), and Plattsburgh (5 minute stop) before arriving in Montreal at 9:10 p.m. The accident occurred at about 6:40 p.m., about 1-½ hours after departing Saratoga Springs.

E. THE VEHICLE

The accident vehicle was a 2000, model 102DL3, 3-axle, 55-passenger motorcoach, manufactured by MCI (Motor Coach Industries) of Pembina, North Dakota, and delivered to Greyhound on September 29,1999. It was equipped with a Detroit Diesel Series 60 engine with a Jacobs Engine Brake that activates on 4 of the 6 cylinders. The engine had a DDEC IV ECM (electronic control module) that had recorded a "Last Stop Record"[6] on August 28, 2006 at 6:35 p.m. According to the DDEC IV, the total coach mileage was 988,215.4.

The transmission was an Allison B-500, 6-speed automatic with a 0.64:1 gear ratio in high (6th) gear. The front steer axle was an ArvinMeritor, model FH941LX7, with a GAWR (gross axle weight rating) of 16,500 pounds[7]. The drive axle was an ArvinMeritor, model 61143WX-204, with a GAWR of 22,500 pounds and a carrier gear ratio of 4.30:1. The steerable weight-bearing axle, commonly referred to as a tag axle, was an ArvinMeritor, model FG952LX5, with a GAWR of 12,000 pounds. The motorcoach was equipped with airbrakes and a 4-channel Bendix EC-17 ABS (antilock braking system).

The motorcoach was assigned a factory VIN (vehicle identification number) of 1M8PDMRA6YP052551, Greyhound company unit # 6528, and it bore Texas registration plate number R7HW58. The motorcoach was 102 inches wide, 11.4 feet high, about 45.5 feet long, and had a wheelbase[8] of 26.5 feet. The front overhang[9] was 6.16 feet and the rear overhang[10] was about 8.8 feet. The GVWR (gross vehicle weight rating) was 48,000 pounds. Based on MCI estimates and Greyhound corporate experience, the GVW[11] (gross vehicle weight) to be about 48,000 pounds for a fully loaded MCI, model 102DL3, motorcoach.

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5 The driver was not required to fill out the *Vehicle Inspection Report* until the completion of his trip. (Refer to: FMCSR, Title 49, Part 396.11 and Part 396.13)

6 The "Last Stop Record" is a DDEC Report that is triggered any time the motorcoach goes from a moving state to a stopped state for 15 seconds or more. The "Last Stop Record" records vehicle speed, engine rpm, engine load, percent throttle and brake and clutch use (if equipped) for the previous 1 minute and 45 seconds from the time the event is triggered. The report also records 15 seconds of the same data after the time the event is triggered.

7 According to the VIN plate, this axle is rated at 16,000 lbs. Arvin Meritor records show it is rated at 16,500 lbs.

8 On an MCI 3-axle motorcoach, the wheelbase is the distance from the center of the steer axle to the center of the drive axle.

9 The "front overhang" is the distance from the center of the steer axle to the forward edge of the front bumper.

10 The "rear overhang" is the distance from the center of the "tag axle" to the very rear of the motorcoach.

11 In this case, the GVW (gross vehicle weight, or actual weight of the bus) was estimated to be about the same at the GVWR.

The NTSB Event Data Recorder Specialist interrogated the DDEC IV ECM on September 1, 2006 [12] According to the DDEC printout and information furnished by Greyhound Lines, the VSG (variable speed governor) was set at 70 mph, thus designed to cut-off fuel to the engine at 70 mph. According to the "Last Stop Record", the coach gradually achieved a maximum speed of 78 mph while traveling downgrade just prior to the brakes being applied.[13] During the next second, the motorcoach decelerated from 78 to 75 mph, and during the next 5 to 6 seconds, from 75 mph to 0 mph. The coach speed is based upon the revolutions of the transmission output shaft. According to a truckdriver, who was being passed by the bus at the time of the tire failure, his truck was traveling at about 65 mph and he estimated the bus to be traveling at about 70 mph.[14] Reports from the DDEC IV showed the cruise control to be "Off" at the time of the accident occurrence.

F. VEHICLE INSPECTION

The primary vehicle inspection took place on August 30-31 and September 6-7, 2006, at the New York DOT facility, located at 81 South Peru Street in Plattsburgh, New York. The motorcoach was on a flatbed trailer during the entire inspection. Participating in the inspection were personnel from the NTSB, Greyhound Lines, Motor Coach Industries, the Federal Motor Carrier Safety Administration and the New York DOT. Personnel from Goodyear Tire and Rubber Company and James Gardner, a private forensic tire expert retained by the NTSB for the purpose of assisting in determining the mode of tire failure, participated in the "at scene" examination of the left front bus tire and roadway evidence.

A follow-up inspection of the front tires occurred on September 15, 2006, at the Goodyear Tire and Rubber Company in Akron, Ohio. Personnel from the NTSB, Greyhound Lines, Goodyear Tire and Rubber Company, NHTSA (National Highway Safety Administration), and James Gardner participated in the examination of the tires. On January 16, 2007, an X-Ray of the left front tire occurred at Goodyear Tire and Rubber Company and personnel from the NTSB, NHTSA, and Goodyear participated. An additional follow-up examination of the front tires occurred on September 14, 2007, with only the NTSB Vehicle Group Chairman and Goodyear participating. The purpose of this latter examination was to take additional tire measurements and photographs.

The Bendix EC-17 ABS ECU (electronic control unit) was interrogated on September 14, 2006 at the Bendix Commercial Vehicle Systems facility in Elyria, Ohio. A follow-up inspection of the accident motorcoach ABS system occurred on May 20, 2007 at a Greyhound facility in Louisville, Kentucky. Personnel from NTSB, Bendix and Greyhound participated.

An examination and functional testing of the steering gearbox and steering pump occurred on December 4, 2006, at the TRW Commercial Steering Systems, World Headquarters, located in Lafayette, Indiana. Personnel from NTSB, TRW and Greyhound participated in the examination and testing.

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[12] The Event Data Recorder, Group Chairman’s Factual Report, is attached to this docket.

[13] A "brake-on" indication is recorded at a brake application of about 3-6 psi., the force it take to activate the stoplight switch.

[14] The truck driver's statement is contained in the Survival Factors Group Chairman Report.

1. Brake System:

The motorcoach was equipped with a conventional airbrake system with S-cam/drum foundation brakes. The drive axle was equipped with Bendix DD-3 parking/emergency brake chambers. Air was supplied to the system by a Bendix Tu-Flo 750 air compressor, which produces 16.5 CFM (cubic feet per minute of air) at 1,250 rpm. The ABS was equipped with a Bendix EC-17 ECU, which controlled a 4-channel ABS system designed with wheel sensors and modulator valves for the steer and drive axle. The system was designed so the tag axle, which was not equipped with a separate modulator valve, would follow the lead of the drive axle when an ABS event[15] occurred. Therefore, when the drive axle is cycled by the ABS system after wheelslip is detected, the brakes on the tag axle would brake and cycle in the same manner as those on the drive axle.

The air chambers, from the front axle to the rear axle, were size Type 24, Type 30/DD3, and Type 16, respectively. All wheel positions were equipped with Haldex automatic slack adjusters. In order to measure the pushrod stroke to determine brake adjustment during the post-accident inspection, air was supplied to a service air tank at about 85 psi from an auxiliary compressor. Pushrod measurements were taken by making applications to the foot brake pedal (treadle valve). The following chart shows the axle position, size of air chamber, slack arm length (lever length), pushrod stroke measurement at about 85 psi, brake adjustment limit and rated stroke:

Axle	**Size Air Chamber[16]**	**Slack Arm Length[17]**	**Pushrod Measurement**	**Adjustment Limit[18]**	**Rated Stroke[19]**
1L	Type 24	5 ½ in.	1 ¼ in.	1 ¾ in.	2 ¼ in.
1R	Type 24	5 ½ in.	1 ¼ in.	1 ¾ in.	2 ¼ in.
2L	Type 30 - DD3	7 in.	2 1/8 in.	2 ¼ in.	2 7/8 in.
2R	Type 30 - DD3	7 in.	**2 ¾ in.***	2 ¼ in.	2 7/8 in.
3L	Type 16	5 ½ in.	1 1/8 in.	1 ¾ in.	2 ¼ in.
3R	Type 16	5 ½ in.	Damaged	1 ¾ in.	2 ¼ in.

*** Indicates brake out of adjustment.**

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[15] An "ABS event" occurs when wheelslip is detected by the ABS ECU. This causes the ABS to cycle to prevent the affected wheel(s) from locking. An ABS event usually occurs during braking on a slippery surface or when the retarder (engine, driveline, or transmission) is applied at too high of force on a slippery surface, causing the drive wheels to loose traction.

[16] The air chamber size, i.e. Type 24, Type 30, refers the size of the rubber diaphragm in total square inches.

[17] "Slack Arm Length", also known as the "lever length", is the distance between the center of the splined camshaft to the center of the clevis pin, which secures the pushrod to the slack adjuster.

[18] The brake "adjustment limit" is the maximum pushrod stroke permitted prior to the slack adjuster needing adjustment. The values utilized for the "brake adjustment limit are those stated in the CVSA (Commercial Vehicle Safety Alliance) North American Out-of-Service Criteria (Revised Edition: April 1, 2007).

[19] The "Rated Stroke" is ½ inch beyond the "adjustment limit". When a pushrod measurement is the same as the "rated stroke", it is well out of adjustment and there are generally minimal or no braking forces available when the brakes are applied. In this instance, however, because the DD-3 has a 2 7/8 inch total stroke, some brake force was still available, even with the pushrod measurement at the "rated stroke".

Although the 2R brake measured ½ inch beyond the adjustment limit, the end of the "control arm", which is necessary for automatic adjustment, was found broken off.[20] After examining the point of separation, it could not be determined with any degree of certainty if this was accident damage or was broken prior to the accident, as "control arms" are known to occasionally fail after long term use (see photos #15 and #16). Even though the 2R brake was out-of-adjustment, because the DD3, Type 30, air chamber has a 2 7/8 inch stroke, it still should have had 2100 lbs. of pushrod force with a 90 psi brake application.[21] However, with only 1/8 inch of pushrod stroke remaining, these forces are known to diminish quickly as brake drum/shoe temperature rises during heaving braking.

The front brake drums were measured with a Central Tool digital brake drum gauge. The 1L drum measured 16.521 inches and the 1R drum measured 16.526 inches, both within the manufacturers maximum diameter wear limit of 16.830 inch**,** which is stamped on the drums. Both front drums had slight lips and were heat checked, but there was no oil or grease contamination. The remaining brake drums were not measured.[22] The front drums were size 16 ½ X 6 inches, the drive axle were 14 ½ X 10 inches and the tag axle 14 ½ X 5 inches. All of the brake linings were measured in the center of the lining and were at least ½ inch thick, which exceeds the ¼ inch thickness requirement specified in the Federal Motor Carrier Safety Regulations.

According to the date code, the Bendix EC-17 ECU was manufactured on August 2, 1999, was assigned serial number K195152 and was equipped with 1030R software. According to Bendix personnel, this EC-17 was part of a NHTSA recall that occurred in the year 2000 and should have been replaced.[23] According to Greyhound maintenance personnel, they received the NHTSA recall notice, as well as the replacement Bendix ECU's. They believed the recall was performed on all the affected buses in the fleet, but were unable to determine why a "trouble ticket" was not placed on unit number 6528, indicating to maintenance personnel that the ABS ECU needed to be replaced.

The ABS ECU was interrogated on September 14, 2006, at Bendix Commercial Vehicle Systems located in Elyria, Ohio. Fault codes that pre-dated the accident were present for the left drive axle. According to Bendix engineers, the presence of these codes indicated a condition that would have disabled the ABS on the left drive and tag axle. Due to this condition, Bendix personnel did a follow-up physical inspection of the accident motorcoach. On May 20, 2007, Bendix engineers met with an NTSB representative at the Greyhound maintenance facility in

[20] According to a brake engineer from the Haldex Corporation, the broken "control arm" would have prevented the brakes from adjusting, but would not have allowed the brakes to "back off", which would lengthen the pushrod stroke.

[21] Reference: National Transportation Safety Board "Heavy Vehicle Airbrake Performance", Safety Study, NTSB/SS-92/01, Appendix I (page 176) Pushrod Force Chart for Bendix DD3-Type 30. (A copy of this Pushrod Force Chart is attached to this docket.

[22] The remaining drums were not checked, as the rear drums would have little or no effect on the steering during brake applications, regardless of the condition of the rear brake drums.

[23] On July 17, 2000, Bendix Commercial Vehicle Systems wrote the NHTSA (National Highway Traffic Safety Administration) in accordance with 49 CFR part 573, "Defect and Noncompliance Reports", as the first step in a voluntary recall. In essence, there had been a number of instances where chafed ABS wheel speed sensor wires sent a false signal to the Bendix ABS, EC-17, ECU (electronic control unit), which resulted in a partial or total loss of braking at low speeds. At the time the report was made to the NHTSA, there had already been several non-injury accidents and a number of other non-accident low speed braking losses. The NHTSA recall number was 00V-232. According to both Bendix and MCI, there have been no reported instances of brake failure on MCI motorcoaches due to the Bendix ABS EC-17 ECU.

Louisville, Kentucky, to conduct an examination of the ABS system. By doing electrical continuity tests, Bendix engineers discovered that there was an open circuit between the left drive axle sensor and the left rear modulator valve. Further investigation revealed that there was a broken wire at a pin connector going into the left rear modulator valve, thus disabling the ABS for the left rear drive and tag axle. According to Bendix engineers, this condition would not have affected conventional (normal) braking of the left drive and tag axle and the motorcoach would have retained full braking capability under normal circumstances. Further, that except for the left rear axles, the ABS system was functioning properly on all other wheels.[24]

2. Steering:

The motorcoach was equipped with a TRW, model TAS 85-029, integral[25] power steering gearbox, rated at 2,175 pounds of pressure. The engine mounted power steering pump was a Luk Automotive, model LF73-21-16-100-LUUD-38-10, which furnished a maximum of 1550 pounds[26] pressure to the power steering gearbox. The gearbox and pump were removed from the motorcoach and shipped to TRW Commercial Steering Systems in Lafayette, Indiana, for functional testing. The steering wheel was broken off during the collision. The steering linkage (tie rod, drag link, and pitman arm) were found connected. An examination revealed that all of the linkage was tight and without noticeable free play.

The tag axle, an ArvinMeritor, model FG952LX5, was steerable. It was designed to lock the tag axle wheel in a forward (straight) position at any time the motor coach exceeded speeds of about 20 mph. The tag axle locking pin was found in the "down", or locked position, but the tie rod slid inside the latching plate, allowing the wheels to turn (see photo #1 and #2).

On December 4, 2006, testing of the TRW steering gearbox and Luk Automotive power steering pump was conducted at the TRW Commercial Steering facility in Lafayette, Indiana. Personnel from the NTSB, TRW and Greyhound participated in the examination and testing. The testing consisted of an external examination of the steering gearbox and pump and then putting the steering gearbox and pump on a test stand and plumbing it with gauges and hydraulic fluid. A steering wheel was installed on the test stand. As hydraulic fluid was pumped into the gearbox through the pump, the steering wheel turned normally and no abnormalities were noted. Further, there were no leaks in the pump or the gearbox and the system functioned normally. According to the TRW engineer, the test gauges and marking on the pump revealed that the pump produced a maximum of about 1500 psi pressure. [27]

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[24] Bendix Commercial Vehicle Systems furnished the NTSB with a written report of the ABS ECU interrogation and ABS system examination. The report is attached to this docket.

[25] "Integral" refers to the power steering control valve, gears and housing to be in one enclosed unit.

[26] On November 30, 2007, Greyhound did pressure testing on an MCI 102DL3 and an MCI G-4500 and certified that the steering pump pressure was about 1500 pounds for both buses. Inquiries of other manufacturers of 45-foot motorcoaches (Prevost, Setra and Van Hool) revealed that all of them have steering pump relief valve settings between approximately 1950 to 2400 psi.)

[27] A written report of the steering gear bench tests was furnished by TRW and is attached to this docket.

3. Vehicle Damage:

The motorcoach was heavily damaged in the accident and is considered by Greyhound to be a total loss. Specific mechanical damage includes the following:

- Tag axle supports bent
- Lower radius rods bent
- Tag axle truss bent, causing 3R wheel to be displaced forward and 3L displaced rearward
- Engine cradle (frame) bent
- Engine cross bar displaced upward
- Crack in engine block near oil pump
- Transmission case broken behind bell housing and mounts broke
- LF auxiliary air tank displaced
- Tire rims on left side of bus dented and damaged (1L, 2L-O and 3L)
- Right tag axle brake damaged
- Major damage to driver compartment and dash
- Other major body damage to front, left side and roof of vehicle
  Scuffmarks with faint black marks were found in the left front wheel well, consistent with the tread flapping during tire failure.

G. TIRES AND TIRE RELATED ISSUES

1. General Information:

All wheel positions on the involved motorcoach, as well as the spare tire, were equipped with Goodyear, size 315/80R22.5, model G-409 tires. This tire has an 18-ply rating, a "J" load index (8270 pounds @ 120 psi) and an "L" speed rating (75 mph). A new tire has a tread depth of approximately 20/32nds inch. All of these parameters conform to those listed in the 2006 Year Book published by The Tire and Rim Association, Incorporated.[28] The Goodyear G-409 was manufactured either specifically for Greyhound Lines, or at their request, although it is utilized by other bus companies. According to sources at Greyhound and Goodyear, the wear expectancy of the G-409 is currently at about 140,000 miles.

This accident investigation focused on the front tires, with an emphasis on the failure of the left front tire. All tires have a DOT number with a manufacturing date code. In this case, the left front tire had a date code of 3705 and the right front 3905, which indicates the tires were manufactured during the 37th and 39th week of 2005, respectively. In essence, both tires were manufactured in September 2005 and were almost a year old at the time of the accident.

[28] The TRA (" Tire and Rim Association") is an independent association comprised of members who manufacture tires, rims, and other related wheel products. The Year Book is a publication that contains all TRA Standards and related information approved by the Association for tires, rims and allied parts for ground vehicles. These Standards include tire designations; tire load ratings and dimensions; approved rim contour(s) and valve(s) for each tire size; rim contour dimensions; valve dimensions; and other data necessary for tire/rim/valve interchangeability. The Goodyear Tire and Rubber Company is a member if the TRA and a Goodyear employee chairs the "Truck-Bus Tire and Rim Standards" Committee. (Source: 2006 Year Book - The Tire and Rim Association, Inc.)

According to information furnished by Goodyear, the tire is manufactured at a Goodyear plant in Topeka, Kansas. Goodyear records show that there were 178 G-409 tires, manufactured during the 37th week of 2005, which were delivered to Greyhound. Although some weeks the number could be higher or lower, 178 tires was considered by Goodyear to be a typical number of tires produced each week.

Goodyear has not requested or authorized any type of recall of the G-409 tire with the 3705 date code from Greyhound or any other carrier that utilized these tires.[29] As of April 30, 2007, Goodyear records showed that there were approximately 51 tires in the Greyhound fleet with the 3705 date code.

2. Post-Accident Inspection of Tires:

NTSB and NYDOT investigators examined the exterior of all of the tires on the bus. The tread depth was measured and air pressure readings taken on each tire. The following is a chart showing wheel positions, measured air pressure, required air pressure, average tread depth, and remarks concerning the condition of each tire:

Wheel Position	**PSI Measured**	**PSI Required**[30]	**Tread Depth****	**Remarks**
1L	Deflated	120 psi.	6-12/32nds	Tire damaged/irregular wear/ bent rim
1R	108 psi.	120 psi.	9-14/32nds	Irregular wear
2L (dual-outside)	Deflated	105 psi.	15-18/32nds	Tire damaged/rim bent
2L (dual-inside)	96 psi	105 psi.	14-16/32nds	None
2R (dual-outside)	105 psi	105 psi.	14-16/32nds	None
2R (dual-inside)	100 psi	105 psi.	15-17/32nds	None
3L	Deflated	105 psi	5-10/32nds	Tire damaged/rim bent
3R	92 psi	105 psi	7-10/32nds	None

****** The tread depth was measured by utilizing a "tread depth gauge" across the tire ribs. Both the minimum and maximum tread depths are listed in 32nds inch.

As demonstrated by the tread depth measurements, both front tires were irregularly worn and the outside rib of the left front tire was worn into the undertread, which is the layer of rubber just above the cords. (A forensic examination of the front tires is discussed later in this section.)

The Vehicle Identification Placard, commonly referred to as the VIN plate, for bus #6528, VIN 1M8PDMRA6YP052551, showed front axle GVAR of 16,000 lbs. (see photo #17 of VIN plate), although the actual GVAR was 16,500 lbs. The recommended tire size listed on the VIN plate was 12.75/22.5. According to the 2006 Year Book of the Tire and Rim Association,

[29] A letter from the Goodyear Tire and Rubber Company, dated May 29, 2007, is included in this docket.

[30] The required tire air pressures listed in this chart are based upon information in the PB K-91, *Procedure Guideline for Wheel and Tire Maintenance* (Revised 6/15/99), which is agreed upon between Goodyear and Greyhound and provides guidance for persons inspecting or maintaining the tires. These required air pressures conflict with information furnished on the VIN plate for this bus. (The VIN plate contains errors and is discussed in this section, G.2.)

the 12.75/22.5 tire has an "H" load range and carries a maximum load of 7,830 pounds @ 110 psi. In this case, the maximum load permitted on the steer axle tires would be 15,660 pounds (2 X 7,830 = 15,660), or 840 lbs. less than what is required for a 16,500-pound axle.[31] The recommended inflation pressure listed on the VIN plate was 115 psi for the steering axle and 95 psi for the drive and tag axles. Even with the heavier 315/80R22.5 tire, with a "J" load range, utilized by Greyhound, it still requires 120 psi for both the 16,000 or 16,500 pound axle, as the maximum load limit is 8270 lbs per tire, or 16,540 lbs for both front axle tires. With the 315/80R22.5 tires being inflated to 115 psi, the motorcoach would only be allowed to carry 15,840 pounds, or 660 pounds less than what is required for a 16,500-pound rated steer axle. The recommended tire air pressure listed on VIN plate for the drive and tag axles (95 psi) were within the load range permitted for the 22,500-pound drive axle and 12,000- pound tag axle. This was determined by dividing the GAWR (gross axle weight rating) by the number of tires carrying the load on the drive and tag axle.[32] Nonetheless, even though the VIN plate listed the incorrect tire size and required air pressure (for the front steer axle tires), the tire size and air pressures utilized by Greyhound and Goodyear were acceptable and within the guidelines published in the 2006 *Tire and Rim Association* Year Book.

3. Tire Maintenance Policies and Procedures:

Greyhound and Goodyear had a long term lease agreement whereby Greyhound pays for the tires on a per mile basis. Further, the contract includes Goodyear and Greyhound sharing in tire maintenance duties. There were about 12 locations where Goodyear[33] contract personnel had tire maintenance duties and 7 other locations where Greyhound[34] did all of the tire maintenance. Also, there was one location (Nashville), where a commercial Goodyear tire dealer did tire maintenance as requested by Greyhound. The agreement between Greyhound and Goodyear is extremely complex, thus there will be no attempt to describe the responsibilities of each entity.

According to the Greyhound "Procedure Guideline",[35] all new tires are to be balanced and placed on the drive axle, in order to start the tires on an even wear pattern. The drive axle tires, which have about 20/32nds inch tread depth when new, are transferred to the front steering axle when worn to between 10/32nds and 16/32nds inch. When the front tires wear to about 6/32nds inch, the tires are then rotated to the tag axle where they remain until they need to be replaced.

[31] According to the 1998 edition of the MCI "102D Series" Maintenance Manual, page 15C-5, MCI had been using a 14,400 lb. rated front axle on both 102DL3 (45-feet long) and 102D3 (40-feet long) motorcoaches.

[32] The tire load carrying limits and required air pressure, at various weights, for the 315/80R22.5 and 12.75/22.5 tires are listed on page 3-08 and 3-40 of the 2006 *Tire and Rim Association* Year Book. (Copies of these pages are attached to this docket.)

[33] The locations with Goodyear contract personnel were: Dallas, Atlantic City, Boston, St. Louis, Chicago, Richmond, Atlanta, Miami, Denver, Philadelphia, Seattle and Los Angeles.

[34] The locations were Greyhound personnel did all the tire maintenance were: Las Vegas, Salt Lake City, Kansas City, Louisville, Sacramento, San Francisco, and San Diego.

[35] Greyhound has a "Procedure Guideline" for wheel and tire maintenance, designated a PB K-91, that is to be adhered to by both Greyhound and Goodyear personnel.

4. Forensic Examination of Front Tires:

Both front tires were shipped from Plattsburgh, New York, to the Goodyear Tire and Rubber Company in Akron, Ohio, on September 9, 2006, via Federal Express. On September 15, 2006, forensic tire experts from Goodyear, NHTSA, and James Gardner, P.E., a private expert working on behalf of the NTSB, conducted a follow-up examination of the tires. Also participating in the examination were personnel from the NTSB and Greyhound. Prior to the tire examinations, the NTSB IIC (Investigator-In-Charge) briefed the attending personnel on the known circumstances of the accident and tire failure.

The examination began by opening the crate that contained the left front tire and attempting to place the tire pieces[36] in their proper position on the tire. During the examination, a small puncture was discovered. An air cup was placed on the inside of the tire liner at the suspected location of the puncture and air pressure was delivered at about 75 psi. At this time, no air could be heard or felt on the outside of the tire where the tread was missing. A liquid solution was then placed on the suspected puncture on the outside liner and small bubbles could be seen. This would be consistent with a slow leak (see photos #26, #27 and #28). All three of the experts agreed, to varying degrees, that it was probable or likely that this slow leak created a reduction in air pressure, causing the tire to overheat and eventually delaminate and blowout. There was no consensus on the rate of air loss or how long the puncture had existed.

Because of the delamination and blowout, the carcass wires were visible in approximately ¼ of the outside diameter (see photo #22 and #23). This condition put some limitations on examining the entire tire for other possible punctures or abnormalities that may have affected the integrity of the tire. Further, due to the damaged condition of the tire, a dynamic air loss test to determine the rate of leakage was not possible.

During the examination, additional tread depth measurements were taken. The outer rib was measured in four locations and the tread depth was between 5/32nds and 6/32nds inch. The remaining ribs, also taken at different 4 locations, were between 10.5/32nds and 12/32nds. Measurements on the right front tire, from the outside rib to the inside, taken an arbitrary 12 o'clock position, were 9/32nds, 13.5/32nds, 14/32nds, and 12.5/32nds inch, respectively.

When the outer ribs were measured individually, with the tread depth gauge in alignment with the groove, there was as much as 6/32nds difference between the first and second rib of the left front tire and 7/32nds difference for the right front tire (see photos #32 and #33). For both tires, the measurements, especially of the outside rib, were indications of the tire being run misaligned, and/or under inflated, or for other unknown reasons wore irregularly.

On July 11, 2006, about 6 weeks before the accident, the driver of unit #6528 filled out a daily "Vehicle Inspection Report" and noted in the pre-trip and post-trip inspection that the front tire had uneven tread wear on both the inside and outside of the tire.[37] The pre-trip inspection

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[36] Personnel from the NTSB and NY State Police collected these tire pieces on scene. The NTSB retained forensic tire expert also recovered tire pieces at the accident scene.

[37] A copy of the "Vehicle Inspection Report" for July 11, 2006, is attached to this docket.

took place in Knoxville, Tennessee and the post-trip occurred after he completed the trip to Cincinnati, Ohio. The driver did not specifically state which tire was wearing unevenly, but the tire measurements taken by the NTSB and forensic tire expert working for the NTSB showed that both front tires had significant uneven wear. According to the Greyhound "Fuel and Mileage Record" for bus #6528, dated July 9, 2006, the bus had been driven about 5,389 miles between July 11th and August 28, 2006, the date of the accident.[38]

It should be noted that the Greyhound document PB K-91, *Procedure Guideline for Wheel and Tire Maintenance*, states the following: "If front tires are wearing unevenly, they must be removed for rear use on bogie/tag or drive axle wheel positions. Coaches with suspected mechanical defects contributing to uneven wear will be checked". Neither front tire had been removed from service, either by Greyhound or Goodyear, after the July 11th "Vehicle Inspection Report" had been completed and submitted.

During the examination, diagonal bead undulation was also noted (see photo # 31). The participating forensic expert from Goodyear furnished the following working definition of bead undulation: "Diagonal undulations on the bead face of a RMT[39] (radial medium truck tire) are an indication of overdeflection. Overdeflection can result from underinflation, overloading or a combination of both. Overdeflection causes excess stress and heat in the lower sidewall/bead area, which results in weakening and loosening of components. Over time, the loose components cause irregular distortions on the outside surface of the tire. The diagonal orientation of the undulations normally follow the direction of the angle of the reinforcement material in the lower sidewall/bead. The amount of overdeflection, length of time the tire is overdeflected, speed and ambient temperature are all factors that contribute to the presence and magnitude of the diagonal undulations."

On January 16, 2007, the NTSB Vehicle Group Chairman, accompanied by a forensic tire expert from NHTSA, returned to Goodyear to have the tire X-rayed. A Goodyear technician X-rayed the tire. The construction of the tire appeared normal, with no defects discovered. The puncture area was seen on the X-ray and a foreign object was observed within the tire. The object was not removed, due to the possibility of follow-up tests or examinations.

On September 14, 2007, the NTSB Vehicle Group Chairman returned to Goodyear for the purpose of a follow-up exam, to include reviewing tire wear and measurements and taking additional photographs. Goodyear personnel assisted in this examination.

5. History of Front Tires:

As stated previously, the both tires were manufactured at the Goodyear Tire and Rubber Company, Topeka, Kansas plant in September of 2005. Every tire furnished to Greyhound has a

[38] A copy of the "Fuel and Mileage Record" for bus #6528, dated July 9, 2006, is attached to this docket.

[39] RMT (radial medium truck tire) is a generic tire industry term that generally applies to most commercial truck and bus tires used in highway and/or "off-road" service. RMT tires include those in the TRUCK-BUS section of the Tire and Rim Association Yearbook and have load ranges of F, G, H, J, L, and M. RMT tires typically have steel ply wire body ply and steel belts and can be tube type or tubeless. Examples of tires not considered RMT tires would be passenger car tires, motorcycle tires, light truck tires and special industrial tires.

branding number, vulcanized on the side of the tire. In this case, the branding number for the failed left front tire was G62945 and the undamaged right front tire was G58651.

According to "Mileage Sales and Administration - Tire History Report" records furnished by Goodyear[40], the left front tire was initially installed on the steer axle of Greyhound unit #1091 (a 40-foot 102D3 motorcoach, manufactured by Motor Coach Industries) at the Boston, Massachusetts, Greyhound facility on October 25, 2005. On November 7, 2005, it was rotated to the right front of the same unit, #1091, in Philadelphia. On December 21, 2005, it was rotated to the left tag axle (3L) of unit #6528, the accident bus. The following day it was rotated to the left front axle (1L) of unit #6528. Between December 22, 2005 and August 28, 2006, the date of the accident, the tire (branding # G62945) remained on the left front of unit #6528. Goodyear records[41] showed that this tire had about 91,000 miles on it the day of the accident.

The same history records furnished by Goodyear show that the right front tire (branding #G58651, was initially installed on the right front (1R) of unit #6216 (a 45-foot MCI, model 102DL3) on November 14, 2005. On December 19, 2005, it was transferred to the right front (1R) of unit #6528, the accident bus. Records show that this tire stayed on the right front position of unit #6528 from December 19, 2005 until the date of the accident on August 28, 2006. Goodyear records showed that this tire had run a total of about 82,000 miles.

Goodyear employees utilize a "Coach Tire Record"[42], form B-329, in which air pressure and tread depth measurements are recorded. This form is kept on the coach and is usually replaced monthly with a new form. If air pressure is added, the tire serviceman should record the air pressure when the tire was checked and after air is added. Forms for unit #6528 were obtained only for December 2005 and for March, April, May and September 2006. In some months, there is an overlap where more than one month's entries are recorded on the same form.[43] One form was obtained for November 2005 for unit #1091, an MCI, model D-3, 40-foot motorcoach. This form, along with the Tire History Report from Goodyear, showed that the tire with branding number G62945 was taken out of tire stock in Boston and mounted "new" on the right front axle of unit #1091 on October 26, 2005 at the Greyhound facility in Boston, Massachusetts. After having been run about 8,000 miles, it was taken off unit #1091 on December 21, 2005.

On December 22, 2005, the tire with branding number G62945 was put on the left front of unit #6528, the accident bus, in Richmond, Virginia. On this day, it was recorded on the "Coach Tire Record" that air was added to all 8 tires, with 12 psi being added to the left front tire and 10 psi added to the right front tire to bring the air pressure to 120 psi. There are no records that show air was added to any of the tires on unit #6528 between December 22, 2005, and August 28, 2006, the date of the accident. The most recent entry was on August 18, 2006, about 10 days before the accident, and was listed on the September 2006 "Coach Tire Record". The August 18th entry showed that air pressure was checked on the left front tire at 115 psi and 114

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[40] A copy of the Goodyear "Mileage Sales and Administration Tire History Report" records are attached to this docket.

[41] Goodyear mileage records are based upon mileage information furnished by Greyhound Lines.

[42] The Goodyear "Coach Tire Record" forms for 6 different months are attached to this docket. These form comprise the entire use the tire with branding #62945, which was the left front tire on unit #6528 at the time of this accident.

[43] Only 5 "Coach Tire Record" forms were available for unit #6528 from December 05 to August 06. Some forms had entries for 2 months. With coach "down time" and multiple month entries, these records may constitute all entries by Goodyear contract personnel. Goodyear personnel related that these were the only "Coach Tire Record" forms that existed for this time period.

psi for the right front tire, with no indication that air was added. (According to Greyhound "Unit Detail History" for unit #6528, the bus was at the Greyhound facility in Richmond, Virginia, from July 17 to August 18, 2006, for a major overhaul, which included changing out the engine.) At this point, the left front tire would have already been underinflated by 5 psi and the right tire was underinflated by 6 psi. (According to the *Tire and Rim Association 2006 Yearbook*, a 315/80R22.5 tire inflated at 115 psi has a load limit of 7,920 pounds.)

With both front axle tires minimally underinflated, at 115 psi and 114 psi, the total front axle tire load limit would be about 15,840 pounds, or about 660 lbs. less than what is required for a fully loaded bus with a 16,500 pound GAWR. This servicing on August 18th occurred at the Greyhound maintenance facility in Richmond, Virginia, and the "Coach Tire Record" shows that the tires were checked when cold, but that no tread depth measurements were recorded. On August 22nd, Greyhound personnel performed a "Federal Annual Vehicle Safety Inspection" on unit #6528, which included checking the tires.[44] About 3 ½ months before the accident, on May 1, 2006, the tread depths were checked for all the tires on unit #6528 and the left front tire was 12/32nds and the right front 10/32nds.[45] According to the records obtained by the NTSB, this was the last time the tread depths were checked [and recorded] prior to the accident.

6. Other Tire Related Accidents and Incidents:

There are no federal or state requirements for motorcoach operators to report or record tire failures. Therefore, it was difficult to locate non-Greyhound accidents or incidents where handling problems were present as the result of a tire failure. Nonetheless, the NTSB is aware of two other accidents, one Greyhound (injury to the driver) and one El Expresso (fatal to the driver), where passengers and/or the driver reported difficulty in controlling the motorcoach due to a failed steer axle tire. Additionally, two different Greyhound drivers were interviewed and described their tire failure experiences, both of whom had two tire failures each in the summer/fall of 2007. The accidents and incidents are summarized below:

On October 25, 2005, at about 2:30 p.m., a 2005 MCI, model J-4500, 45-foot, 55-passenger motorcoach, carrying the driver and 24-passengers, was southbound on Interstate 35 within the city limits of San Antonio, Texas. The motorcoach was operated by El Expresso, a Coach America subsidiary, located in Houston, Texas. According to the police report, the left front tire[46] blew out. The police report stated that after the tire failure, the "bus swerved hard to its left, crashed through the guard rail, traveled into the northbound lanes and collided with an eighteen wheeler".[47] According to a witness on the bus, the driver tried to control the bus, but did not succeed.[48] The impact resulted in fatal injuries to the driver. Three other passengers were transported to the hospital with non life-threatening injuries. One witness in another vehicle saw

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[44] The "Periodic Inspection" must be done annually according to FMCSR, Title 49, Part 396.17. The items checked are listed in Appendix G. Although the tread depth for steer axle tires must be at least 4/32nds inch, in the 14 items listed concerning front tires, and while a prudent thing to do, it is never clearly stated that the air pressure must be checked. Appendix G, section 10 (Tires), item 11 states: "Weight carried exceeds tire load limit. This includes overloaded tire resulting from low air pressure". A copy of MN-80, the "Federal Annual Vehicle Safety Inspection" for unit #6528 is attached to this report.

[45] This was a single measurement at an unknown location, and would not give any indication of irregular wear.

[46] The involved tire was a Firestone FS-400.

[47] Portions of the San Antonio Police Report, which describe the details of the collision, are attached to this report.

[48] This statement was originally given in Spanish, but translated by a San Antonio Police Officer.

a piece of tread come off the left front tire, a piece that was later matched to the left front tire of the bus (see photo #38 and #39). The large piece of tread found on the roadway [where the bus was traveling before leaving the roadway and crossing over the median] is consistent with a delamination. This motorcoach had a front axle weight similar to the one in the Westport, New York accident. The bus was only about 8 months old at the time of the accident and is believed to have had the original tires. The motorcoach sustained heavy damage and was most likely a total loss (see photo 37). The chartered bus had just left a restaurant where the group had eaten about 10 minutes before the accident occurrence.

On June 29, 2006, at about 7:20 p.m., a 2001 MCI, model 102DL3, 45-foot, 55-passenger motorcoach, unit #6563, operated by Greyhound Lines, was traveling north on Interstate 85 near Opelika, Alabama, with 23-passengers on board. According to the police report and Greyhound report[49], the right front tire blew-out and the motorcoach went off the right side of the roadway and struck several trees, causing heavy damage to the right front of the bus. Twenty-four occupants, including the driver, were transported to local hospital, but the extent of injuries is not known. In a statement to company officials, the driver related that as soon as she heard the tire blow, the bus started pulling to the right and she "tried and tried to keep it on the roadway". One passenger related that she heard the tire blow on the right side and "the driver held steady as long as possible". Another passenger stated the tire blew and the bus was uncontrollable. Although the NTSB did not investigate this accident, the motorcoach and right front tire[50] were retained by Greyhound and observed and photographed by NTSB personnel (see photos #40, #41, and #42).

On November 29, 2007, NTSB personnel interviewed two Greyhound drivers at the Greyhound Bus Station in Denver, Colorado. One is a driver trainer[51] with 34 years at Greyhound and the other driver has 21 years driving experience at Greyhound. Both of them had had two front tire failures each within the previous 5 months (summer and fall of 2007) of the interview, while driving 45-foot motorcoaches. Prior to these occurrences, the drivers related that neither of them had ever experienced a front tire failure. The following is a brief summary of the circumstances surrounding these tire failures:

The driver trainer related that on July 21, 2007, at about 1:15 p.m.[52], he was westbound on Interstate 80, near Wamsutter, Wyoming, on a trip between Denver and Salt Lake City. He was driving an MCI; model G-4500, unit #7256, with about 32 passengers on board. He related that he was traveling at about 70 mph when the left front tire suddenly blew out. He related that, although taken by complete surprise, he was able to control the vehicle without problems. He related that this was his first flat tire on a bus in 34 years of driving.

About one month later, on August 17th, at about 2 p.m., the same driver trainer was driving eastbound on Interstate 80, about 30 miles east of Rawlings, Wyoming, on a trip between Salt Lake City and Denver, driving an MCI, model 102DL3, unit #6605, with about 35 passengers. Again, he believed he was traveling at about 70 mph when the right front tire blew.

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49 A partial copy of the police report and Greyhound report are attached to this docket.

50 The tire was a Goodyear G-409 with branding number G23656. The damaged tire was still mounted on the bus and the date code could not be located.

51 This driver is a senior route driver with additional duties as driver trainer.

52 The dates, times, bus numbers and passenger counts for the Greyhound drivers interviewed on November 29, 2007, were verified by Greyhound records kept in Denver, Colorado.

He did not recall any rumbling, but could not be sure. He stated "I did everything I could to keep it on the road". He further related that it was very difficult to control, much more difficult than the first one, but he managed to keep the bus on the road. He did not know if it was simply a blowout or a delamination and the tire was not available for examination by NTSB personnel.

On September 18, 2007, at about 9:30 a.m., a driver with 21-years Greyhound bus driving experience was traveling westbound on Interstate 70, about 10 miles west of Limon, Colorado, and was on the Denver-Salina, Kansas, portion of an express schedule between St. Louis and Denver. He was driving an MCI, model G-4500, unit #7247. The 55-passenger bus was loaded with 52 passengers, luggage, and an unknown amount of freight. He heard some rumbling and stated that he could feel it in the steering wheel when about 10 seconds later the right front tire blew out. He said that it was difficult to steer and it took a lot to control the bus, but he kept both hands on the steering wheel and kept it on the roadway. After the tire was changed by a local vendor, it was loaded in the baggage bay of the bus and taken to the Greyhound garage in Denver. NTSB personnel observed this tire about 6 weeks later. It was a Goodyear, G-409, size 315/80R22.5, the standard tire utilized in the Greyhound fleet. Tread measurements were not taken, but the tire appeared to have ample tread with very little, if any, irregular wear. The outer tread was separated from the tire carcass on most of the circumference of the tire, consistent with a delamination. Bead undulation was observed, which looked similar in appearance to the left front tire of #6528 in the Westport accident. While at the Greyhound garage, NTSB personnel observed about 8 other tires that had been removed due to normal wear and none of them were observed to have bead undulation.

About 2 weeks later, the same driver with 21-years experience, was driving another MCI, model G-4500, unit #7280, on the Denver-Salina portion of the Denver-St. Louis express run. The 55-passenger bus was loaded with 31 passengers, luggage and an unknown amount of freight. At about 10:45 a.m., when about 10 miles west of the Colorado/Kansas state line, he again felt a rumbling in the front of the bus. He estimated that about 10 seconds later the right front tire blew-out. He related that this time he knew what to expect and held tightly to the steering wheel, but it was still difficult to control. After calling the MRD (Greyhound Maintenance Response Desk), a vendor came and changed the tire. He related that the vendor took the tire with him, thus it is not available for NTSB examination.

This latter driver's description of the rumbling prior to the tire failures appeared similar to what was experienced by the test driver during the NTSB delamination tests in April 2007 at the Continental Tire test track in Texas. (This testing is briefly discussed in section G.9. of this report, and is described in more detail in the "Human Performance and Vehicle Group Chairmen's Report of Operational Testing, which is included in this docket.)

7. Greyhound Fleet History of Tire Issues:

At the request of the NTSB, Greyhound did both hand and computerized searches of tire failure data that go from January1997 to September 2007. While the incidence of all tire failures is included in the data, only front tire failures will be discussed in this report, as they are of primary concern due to potential handling problems. These statistics are based on records of road failures that require, with very few exceptions, a tire replacement prior to the bus continuing its scheduled trip. Greyhound Lines has an MRD (maintenance response desk) at their headquarters in Dallas. All road failures, including those involving tires, are reported to the MRD and notations are recorded (to include bus number, trip identification, date and time, number of passengers, wheel position of the failed tire and general comments). Although the overwhelming majority of these tire issues involve flat tires, there was no systematic characterization of the failure type on the MRD reports, such as blowouts, delamination, air leak, etc. There were also a small number of MRD front tire reports (less than 5%) that indicate miscellaneous problems, i.e., a chunk of tire was missing, the tire was low on air, tread coming off, a tire thumping and causing shimmy, or simply a bad tire, etc.

In 1997, Greyhound operated 2,077 buses, all 40-feet in length. Ten years later (between October 2006 to September 2007), the average fleet size was 1,233 buses; 317 of them were 40-feet long and 916 were 45-feet long. With the exception of a few buses in a tire test fleet, all of them used the same 315/80R22.5, Goodyear G-409 tire. For the entire year of 1997, Greyhound buses drove about 22.5 million miles per month and experienced 182 front tire failures, which resulted in a front tire failure rate of about .68 per million miles driven. Ten years later, from October 2006 to September 2007 (12 months), Greyhound experienced 238 front tire failures in 13.5 million miles driven per month, which resulted in a front tire failure rate of 1.47 per million miles driven. In other words, there were 56 more front tire failures in the latter 12-month period than in all of 1997 in a fleet that traveled 9 million less miles. This resulted in a front tire failure rate 2.16 times greater than the 12-month period for 1997.

In April of 1998 Greyhound took delivery of 16 MCI, model 102DL3 motorcoaches, their first purchase of 45-foot buses. By July of 1998 they had a total of eighty 45-foot buses. In July of 1997, there were 26 front tire failures and in August there were 27, with an overall tire failure rate of 1.0 per million miles driven for both months. In July of 1998, after the introduction of the 45-foot buses, there were 50 front tire failures and in August of 1998, 52 failures, with a total failure rate per million miles driven for both months of 1.7 and 1.8, respectively. In the summer of 1999, the B315/80R22.5 Goodyear Intercity Cruiser Tire was replaced with a new series 315/80R22.5 tire known as the G-291. That tire became the G-391 and was later replaced by the G-409.[53] The failures decreased in the summer of 1999 when they had 35 front tire failures in July of 1999 and 26 in August, although the fleet of 45-foot buses had grown to about 360. It should be noted that over the approximate 10 years worth of records furnished by Greyhound, tire failures in the summer months were generally at least twice as high as in the winter months, and in 2007 were about 3 times higher than in the winter of 2006 - 2007.

It was also noted in the tire failure information furnished by Greyhound that the MCI, model G-4500 (also a 45-foot motorcoach) had a higher failure rate than the MCI, model 102DL3. Between January 2005 and September 2007, Greyhound operated about 710 MCI 102DL3 coaches and about 280 MCI G-4500 coaches, a number that remained nearly constant during this reporting period. During this 33-month reporting period, the 780 MCI 102DL3 buses had a total of 323 front tire failures and the MCI G-4500 had 224 failures. When adjusted for the number of each coach type, the G-4500 had front tire failures on 80% of the buses operated during this time period and the 102DL3 had failures on 41% of the buses. While the exact operating mileage for these two coach models is not known, Greyhound does not differentiate

[53] The G-409 is interchangeable on all Greyhound fleet buses and on all wheel positions.

which model of 45-foot bus should be used on a certain scheduled route. It should be noted that when empty, the approximate front gross axle weight (GAW) of a 102DL3 is 10,680 pounds and the G-4500 is about 11,280 pounds, or is about 6% heavier.[54] The wheelbase on a G-4500 is about 13 inches longer than a 102DL3 and the rear overhang is about 21 inches shorter, thus putting more weight on the front axle of a G-4500. The 40-foot MC-12 has an empty front axle weight of about 9,900 pounds.[55]

8. Low Air Pressure Observation Tests of Exemplar Motorcoach:

The NTSB Human Performance Group Chairman, in cooperation with Greyhound, conducted a low air test of an empty MCI, model 102DL3, motorcoach at a Greyhound facility in Washington, D.C. The purpose of the test was to determine how low the air pressure would have to be [in an empty motorcoach] before the driver could reasonably be expected to determine, through visual observation, that the air pressure was low and the tire needed air. The tests revealed that the air pressure would have to be about 50 psi pounds before the tire deformed to the point it would become obvious to the observer that the tire was low on air.[56]

9. Summary of Bus Tire Delamination and Blow-out Testing:

NTSB investigators attempted to do research of any literature involving delamination tests of commercial vehicle tires and found only a couple of references. Further, no information could be found that involved dynamic testing where truck or bus tires were delaminated under controlled conditions. In April of 2007, the NTSB, in cooperation with Greyhound and Continental Tire, and with the participation of Goodyear, MCI, FMCSA, SmarTire, TRW Commercial Steering Systems and Stewart and Stevenson, did delamination and blowout testing on a 1999 MCI, model 102DL3, 45-foot motorcoach, owned by Greyhound Lines, at the Continental Test Track in Uvalde, Texas. (Note: This is only a summary of the test results, as a detailed report of the testing will be included in the Human Performance and Vehicle Group Chairmen's Report of Operational Testing). Additionally, a single tire test, resulting in a delamination of a tag axle tire, was done at the Firestone test track in Ft. Stockton, Texas, in August of 2006. This test was also conducted utilizing a 45-foot MCI motorcoach provided by Greyhound Lines and a 315/80R22.5 Firestone tire.

At the request of the NTSB, a Goodyear forensic tire expert[57] provided the following working definition of a tire delamination: "A tire is a complex, composite product, which is assembled by layering or laminating multiple components in a 'green' rubber state, and then curing or vulcanizing the whole unit to form the 'cured' tire, or the new tire. Delamination is a general term applied to the tearing apart and detachment of tire components. Delamination in the

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[54] At the request of the NTSB, in November 2007, Greyhound weighed the front axles of an empty 1023L3 and a G-4500 at certified public scales in Louisville, Kentucky. The front axle weight for the 102DL3 was 11,000 pounds and for the G-4500, 11,420 pounds, which were similar to the weights provided by MCI. It should be noted that the amount of diesel fuel in the fuel in the 195 gallon fuel tank could make a difference in the front axle weights.

[55] The MCI, MC-12, manufactured primarily for Greyhound, was introduced into the Greyhound fleet in the summer of 1992.

[56] The details of this test, with photos, are included in the "Human Performance and Vehicle Group Chairmen's Report of Operational Testing".

[57] This working definition of delamination was written by Mr. James Stroble, Manager, Product Analysis, of the Goodyear Tire and Rubber Company in Akron, Ohio.

crown of the tire can occur between the tread and the belts, between the belts or between the belts and the body ply. Delamination can involve one or more components tearing from the tire in one piece or multiple pieces. The delamination can involve the entire tread, or carcass and remaining belt package, while the tire retains full inflation pressure and is capable of supporting the load on the tire for a limited time. When a delamination involves tread and all the belts in any region of the crown, the unsupported casing/liner in that area will usually rupture, resulting in the loss of all inflation pressure, in essence causing a "blow-out". Overdeflection, due to underinflation, overload or a combination of both, is the primary cause of delamination. Overdeflection results in excess stress and heat, which weakens the components and the bonds between components, leading to looseness and separation. Separations between components grow due to the forces acting upon the tire. If the separation becomes large enough the component(s) will begin to detach and delaminate from the tire. Inflation pressure, tire load, vehicle speed, driving conditions/severity, and ambient and road surface temperature all are factors in delamination."

There were 8 delamination tests conducted at the Continental Test Track in April 2007. All tests were conducted on the left front steering tire. The lowest recorded temperature for the delamination to occur was 266 degrees Fahrenheit and the highest temperature was 320 degrees, with an average of about 303 degrees. The lowest tire air pressure for an occurrence was 24.3 psi and the highest was 54.6, with an average air pressure of about 37 psi. Both the temperatures and air pressure were monitored utilizing a SmarTire TPMS (tire pressure monitoring system), with the information captured on a data logger. The lowest speed driven when the delamination occurred was 71.5 mph and the highest was 80.5 mph with an average speed of 77 mph.

In every case, usually a few seconds prior to the delamination, a rumbling could be heard, usually accompanied by a slight vibration of the steering wheel. However, when driving at highway speeds, the driver never felt the steering wheel pulling and there were no other obvious indications that the motorcoach was being run on a tire with extremely low air pressure. The tests showed that a delamination on a fully loaded motorcoach can be relatively easy to control or may be extremely difficult. This was not only the subjective opinion of the test driver, but also was substantiated by a force chart prepared by a test engineer from TRW Commercial Steering Systems, who monitored the forces of the instrumented steering wheel.

The testing at the Firestone test track at Ft. Stockton, Texas, occurred in August of 2006. A 2003 MCI, model G-4500 motorcoach was used. These tests were conducted at about 68 mph. The delamination of the left rear tag axle tire occurred at about 235 degrees with the temperature being measured externally by utilizing a pyrometer. In this test, the majority of the tread came off in a large piece and the tire retained air pressure. During testing, both at the Firestone and Continental tracks, air pressure was incrementally lowered and the temperatures increased as the tire air pressure was decreased.

10. Other Issues Associated to this Investigation:

On August 3, 2006, almost a month before this accident, Greyhound Safety Officials came to the NTSB Headquarters in Washington, D.C. to brief the NTSB personnel regarding numerous safety concerns. The Vehicle Group Chairman of this accident investigation was present at the meeting. Included in the Greyhound presentation and group discussions was what appeared to be an increase in tire failures, especially an appreciably higher number of tire failures in their 45-foot buses over the 40-foot buses. On August 26-27, in conjunction with other wheel bearing tests, the NTSB did dynamic low tire air pressure testing of tag axle tire of a 45-foot Greyhound bus at the Firestone test track in Ft. Stockton, Texas. It was learned from the test of a new Firestone 315/80R22.5 tire, that the tire would delaminate at low pressures but would retain air and did not blowout. (Through other Greyhound road failures and the follow-up testing at the Continental Test Track, it was learned that this was not always the case and that many delaminations were quickly followed by a precipitate and total loss of air, or a blowout.) Further, the tag axle tire did not catch fire, which was of concern during the test.

During return travel from the testing at the Firestone track on August 28, 2006, the NTSB was notified by Greyhound personnel that a multiple fatality accident had just occurred with a Greyhound bus near Westport, New York, and police had already suggested a tire failure was involved in the occurrence.

After the occurrence of this accident, Greyhound officials informed the NTSB that they had another injury related accident about a month earlier due to a tire failure and the driver was unable to control the motorcoach (see section G.6 for the June 29, 2006 Greyhound accident at Opelika, Alabama). Due to these occurrences, Greyhound volunteered to furnish a motorcoach, mechanics and instrumentation, to do testing in an attempt to learn more about the controllability of steer axle tire failures in both delaminations and blowouts. The NTSB Human Performance Group Chairman attempted to do research in an attempt to find literature regarding delamination testing of heavy trucks or buses and none that involved dynamic testing.

Because this involved testing of a motorcoach at relatively high speeds, it was determined that the Goodyear Test Track was inadequate, but Continental Tire agreed to allow the NTSB to use their test track in Uvalde, Texas. Although details of the testing are included in the "Human Performance and Vehicle Group Chairmen's Report of Operational Testing", the testing showed that in most cases, blowouts and delaminations were controllable. However, in one delamination test vehicle control was difficult, and in another it was extremely difficult, even with the driver being aware and prepared for the impending left front tires failure.[58] Other information learned during the testing was that the test driver could not feel a pull on the steering wheel, driving at highway speeds, even when the tire air pressure was lowered to below 50 psi. It was also discovered during the testing that when the air pressure was lowered by about 50 psi, to about 70 psi, an observer could not easily tell, if at all, by an external inspection, that the tire was low on air pressure. Additionally, it was learned that heavy braking, after a blowout, actually made the motorcoach easier, rather than more difficult to control, which is contrary to what is found in current literature, as well as the model and state CDL (Commercial Driver License) manuals.[59]

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58 Steering force measurements, which are included in the NTSB "Human Performance and Vehicle Group Chairmen's Report of Operational Testing", substantiates these subjective comments, which is included in this docket.

59 Although this testing is supported by both the test driver's empirical experience and the force reading furnished to the data logger from the instrumented load cell steering wheel, it is recognized that more testing needs to be done prior to any suggestion that the CDL and other training manuals be revised.

The NTSB had meetings and discussions with Greyhound, Goodyear, the NHTSA representative in the Vehicle Group and James Gardner, the private forensic tire expert retained by the NTSB. Mr. Gardener related that due to the front axle weight of the bus, the 315/80R22.5 tire, which is the most common tire[60] for 45-foot motorcoaches in the United States, has very little safety margin when the 16,500 lb. rated front axle is fully loaded. Greyhound then checked their load factors and learned that during the last 3 years, they have gone from an average load factor of 45% (25 passengers) to 64% (35 passengers), thus resulting in heavier loading of the front axle. This load factor includes both 40 and 45-foot coaches, although the 40-foot coaches currently represent about 20% of the Greyhound fleet.

Through discussions with the involved entities (listed in the preceding paragraph), to include a tire design engineer from Goodyear, it was learned that manufacturing a tire with an "L" speed rating (75 mph) presents certain obstacles. Although tires with higher load ratings are made, they generally do not have a 75 mph speed rating, which is what is needed for intercity schedule and charter service in the bus industry at large. The 315/80R22.5 tire has an 8,270-pound load rating, or a total front axle load rating of 16,540 pounds at 120 psi. Since this motorcoach has a 16,500 lb. rated front axle, and presuming it is fully loaded, there remains only an additional 40-pound safety margin on the front axle. This is providing the tire has the required air pressure at all times and the motorcoach is not overloaded. The private expert utilized by the NTSB expressed concern that the front tire on the 45-foot coaches was operating a on a heavy duty cycle, with very little safety margin in the tire load rating, thus making it essential that the tire operate at the required air pressure of 120 psi.

As there are no federal or state reporting requirements regarding failed tires, it was (and is) difficult for the NTSB to get a handle on the scope of this problem in the bus industry at large. However, it was learned from Coach America, that one of their subsidiaries, El Expresso, had a fatal-to-driver accident in October 2005 involving a 45-foot a 2005 MCI motorcoach that was only 8months old (details in section G.6. of this report). In all 3 of these accidents (Westport, NY; Opelika, AL; San Antonio, TX) there was witness testimony that the driver struggled or attempted to control the motorcoach, but was not successful. The ability to control the motorcoach was also a concern of the two Greyhound drivers who had front tire failures in the summer and fall of 2007 (discussed in section G.6 of this report).

11. Tire pressure Maintenance and Monitoring:

There are two basic categories of systems to enhance tire safety by ensuring correct air pressure; tire pressure monitoring and tire pressure maintenance. Although TPMS (tire pressure monitoring systems) are currently required equipment on all newly manufactured light vehicles, they are not required for buses or other commercial vehicles. Tire pressure maintenance systems, utilizing conventional airbrake system technology, have been in use in on some military vehicles since the 1940's.[61] Tire pressure maintenance systems can be divided into two categories; the CTIS (Central Tire Inflation System), which monitors and maintains the correct

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[60] The maintenance and/or driver's manuals for MCI, Prevost, Van Hool, and Setra, all show the 315/80R22.5 tire to be the specified size for all 45-foot motorcoaches.

[61] Source: Innovative Transport Equipment, a manufacturer and distributor of "Bigfoot" Central Tire Inflation Systems in New Zealand.

air pressure according to preset thresholds and the Dual Tire Pressure Equalizer, which maintains a balanced tire pressure between a set of dual wheels. While not de-emphasizing the significance of the Dual Pressure Tire Equalizers, but because they are primarily utilized for economic reasons, including longer tire life and increased fuel economy, it is the TPMS and the CTIS, which will be of concern in this report, as both systems monitor low tire pressure and the CTIS actually adds air to a leaking tire. Further, the emphasis of this discussion will be the TPMS and CTIS on intercity motorcoaches, rather than all commercial vehicles.

In January 2007, the FMCSA (Federal Motor Carrier Safety Administration) published the "Tire Pressure Monitoring and Maintenance Systems Performance Report". This report included research and vehicle testing of several TPMS, CTIS, and Dual Tire Pressure Equalizer Systems. According to the Abstract of this report, "Improper tire inflation leads to accelerated tire wear (which subsequently leads to compromised braking, poor handling, and reduced stability), increased fuel consumption, increased propensity for catastrophic tire failures (blowouts), increased dangerous roadside debris, and increased road calls to repair deflated tires. In addition, FMCSA's research has shown that despite these well-understood consequences, many fleets do not practice or enforce adequate tire maintenance practices - mostly because checking and maintaining proper inflation is a time-consuming, inconvenient chore. As a result, fleet operators are often unaware of tire pressure issues with their vehicles."[62] (In succeeding references to the "Tire Pressure Monitoring and Maintenance System Performance Report" in this report, it will simply be referred to as the FMCSA Report".)

As stated previously, to the best that can be determined through commercial research, the CTIS was developed in the 1940's for military vehicles. It was also used on a variety of off-road vehicles, including logging trucks and farm equipment. For commercial vehicles, the primary advantage of CTIS over TPMS is that it actually adds air to the tire while the vehicle is in motion. Further, some systems have the advantage of actually lowering the air pressure, whether it is needed due to increased temperature adjustments or lowering it for increased traction, as in slower speed off-road operations in mud and snow. The CTIS have been in use on motorcoaches, at minimum, in Brazil, Mexico, and other Central and South American countries for several decades. A web search of a motorcoach dealer in Mexico[63] revealed that all late model motorcoaches were equipped with CTIS. A commercial advertisement from Brazil, dated 1958, shows a GM (General Motors Corporation), model 4104, intercity motorcoach, with the CTIS (see photo #34) The CTIS can be easily recognized by the external air lines running to the rotary union in the outside center of the wheel hub (see photos #35 and #36).

A basic explanation of how CTIS works for a motorcoach is as follows: Air is supplied by the vehicle's air compressor, usually an engine mounted gear driven compressor, to the appropriate air tank. Air can be supplied to the tires through the secondary tank (used for the front brakes, which provide less braking than the rear brakes) or can be from a special auxiliary tank. Air lines run from the designated tank to a rotary union mounted on the center of the wheel hub, and from the rotary union by a short jumper line to a special inlet valve where the air goes

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[62] Source: Abstract, "Technical Report Documentation Page" of the "Tire Pressure Monitoring and Maintenance Systems Performance Report", Report Number: FMCSA-PSV-07-0001, January 2007. The "Technical Report Documentation Page" of this report is attached to this docket. (The entire report can be found on the FMCSA website.)

[63] Source: Cyber Buses, a Mexican website in Spanish. (http://www.cyberbuses.galeon.com)

into the tire. When a specific tire loses air pressure, the driver is alerted to the condition via a dash-mounted display monitor, while air is simultaneously and automatically delivered to the tire with low pressure. The systems tested, described in the FMCSA Report, are designed to shut down in the case of a large loss of air pressure in order to protect the vehicle air system. The primary advantage to this system is that in most cases, except for large punctures, the tire is inflated with the vehicle in motion; yet the driver is notified of the condition and can later notify maintenance personnel of a leak. The system is basically designed to re-supply the tire with air when slow leaks occur. There are several systems on the market, with some having the air delivered to the line going to the rotary union (exterior system, as described above) and some have the air running in lines through a hollow axle (interior system), although the latter is more common on trucks.

Unlike the CTIS, Tire Pressure Monitoring Systems only provide a warning system to the driver, who then has to ensure that the appropriate action is taken, whether adding air to the tire or having a tire leak fixed. As of September 1, 2007, TPMS are mandatory equipment on all newly manufactured automobiles, but not heavy trucks and buses. The TPMS was used as early as 1986 on a Porsche, model 959. Today, according to web research, there are over a dozen TPMS manufacturers worldwide. The FMCSA Report lists five different systems[64] that were tested, either on a tractor-trailer, or a 45-foot MCI motorcoach. Additionally, in April 2007 at the Continental Test track in Uvalde, Texas, the NTSB tested a TPMS manufactured by Continental Tire. This system will broadcast both air pressure and temperature, which is displayed on a dash-mounted console. The majority of the systems tested by FMCSA have dash-mounted monitors that record both the air pressure and temperature.

The following is a basic explanation on how most TPMS work: Each tire is equipped with a sensor, which broadcasts to an antenna and the signal is then relayed until it ultimately reaches the dash-mounted monitor. There are 3 basic mounting positions for the sensors; wheel mounted, valve stem mounted and tire mounted. The sensor broadcasts air pressure, and in most systems, temperature. An antenna picks up the broadcast signal where it is relayed, either by hard wire or electronic transmitter to a receiver/monitor that is usually dash-mounted. Some systems have a pre-set tire air pressure threshold and others can be set by the operator or maintenance personnel based upon the required tire pressure for each tire. When the air pressure is reduced to the pre-set level or the temperature rises to a pre-set level, the driver is alerted either audibly alarm or by a visual flashing signal, or both. At this point it is up to the driver to take the appropriate action to correct the situation based upon the information provided by the TPMS. Unlike the CTIS, the TPMS does not automatically add air to the tire.

For a motorcoach, two antennas are usually required, although one system is known to operate with a single antenna. Further, it would be necessary to utilize a system with programmable, rather than preset thresholds, as the required air pressure from the steer to the drive or tag axle could vary as much as about 25 psi or more.

In recent years the NTSB has become aware of a serious issue involving motorcoach fires. In the TPMS, the temperature sensing system, set within proper parameters, could be used

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[64] The 5 systems tested were: SmarTire, PressurePro, Tire-SafeGuard (HCI Corporation), eTire (Michelin North America), and Integrated Vehicle Tire Pressure Monitoring (Meritor WABCO).

to alert the driver to high temperatures from overheated bearing, brakes or tires themselves, all of which are known to be causal or contributing factors in bus fires. In the research of current CTIS, no instances were found of temperature sensing equipment being utilized.

H. SUPPLEMENTAL HIGHWAY INFORMATION:

Measurements taken by the Vehicle Group Chairman show that an outside mark from the 1L (left front tire) first appeared at 8 inches from the yellow edgeline. After 25 feet, the mark decreased to 6 inches and after 36 feet had decreased to 3 inches. After 47 feet, it was in contact with the yellow edgeline. At 80 feet, the 1L tire had completely crossed the yellow edgeline. At 157, both front tires were completely off the pavement. (The paved shoulder was 64 inches wide.) These measurements were taken with a small-wheeled rolling tape measure.

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