



U.S. Department  
of Transportation

**National Highway  
Traffic Safety  
Administration**

## ODI RESUME

**Investigation:** EA 16-001  
**Prompted by:** Field Incident, PE14-020  
**Date Opened:** 02/03/2016  
**Investigator:** Kyle Bowker  
**Approver:** Stephen Ridella  
**Subject:** CNG Fuel System Integrity

**Date Closed:** 09/10/2021  
**Reviewer:** Joshua Neff

### MANUFACTURER & PRODUCT INFORMATION

**Manufacturer:** Daimler Trucks North America, LLC  
**Products:** 2014 Freightliner Business Class M2  
**Population:** Confidential

**Problem Description:** During a braking maneuver, an unsecured forklift rolled forward, penetrated the front wall of the cargo compartment and struck a compressed natural gas (CNG) fuel container mounted behind the truck cab, causing it to burst with explosive force.

### FAILURE REPORT SUMMARY

|                              | ODI | Manufacturer | Total |
|------------------------------|-----|--------------|-------|
| <b>Complaints:</b>           | 0   | 1            | 1     |
| <b>Crashes/Fires:</b>        | 0   | 0            | 0     |
| <b>Injury Incidents:</b>     | 1   | 1            | 1**   |
| <b>Number of Injuries:</b>   | 1   | 1            | 1**   |
| <b>Fatality Incidents:</b>   | 1   | 1            | 1**   |
| <b>Number of Fatalities:</b> | 1   | 1            | 1**   |
| <b>Other*:</b>               | 1   | 1            | 1**   |

\*Description of Other: The subject incident was widely reported in the news media.

\*\* Total eliminates duplicates received by ODI and manufacturer.

### ACTION / SUMMARY INFORMATION

**Action:** This Engineering Analysis has been closed.

#### Summary:

The Office of Defects Investigation (ODI) is only aware of the one subject fuel container rupture incident on the subject vehicles that first prompted this investigation. The subject CNG fuel system and fuel container design, material, manufacture, assembly and performance appear to be consistent with certain other manufacturers of CNG vehicles and related items of motor vehicle equipment, and in accordance with standards in effect at the time of manufacture. Since the subject incident, new and revised industry standards have advanced CNG fuel system and fuel container integrity and safety. In 2019, NHTSA noted an "extremely low failure rate of CNG fuel containers," in a notice of proposed rulemaking (NPRM) to amend the visual inspection labeling requirement in FMVSS 304. NHTSA also entered a strategic partnership project (SPP) with the National Renewable Energy Laboratory (NREL) to assess fuel system and fuel container integrity requirements in an effort to update FMVSS Nos. 303 and 304. In NREL's report, they provided several considerations that reflect minimum safety standards, as well as industry best practices, to harmonize applicable light-, medium-, and heavy-duty natural gas and propane fuel vehicle codes and standards.

Given these activities and the low rate of CNG fuel container ruptures in general, and the lack of other incidents among the subject vehicle population, indicating a lack of a safety defect trend, NHTSA is closing this investigation. The closing of this investigation does not constitute a finding by NHTSA that no safety-related defect exists. The agency reserves the right to take further action if warranted by the circumstances.

Please see the Engineering Analysis closing report for more information.

## EA16-001 Closing Report

**Subject:** CNG Fuel System Integrity

**EA No:** EA16-001

**Date Opened:** 02-Mar-2016

**Date Closed:** 10-Sep-2021

**Subject Vehicles:** Certain model year (MY) 2014 Freightliner Business Class M2 vehicles originally equipped with a compressed natural gas (CNG) fuel system.



Figure 1. April 3, 2014, Subject Incident Vehicle

**Basis:** On July 7, 2014, the Office of Defects Investigation (ODI) opened PE14-020 to investigate a report of a fatal incident that occurred on April 3, 2014 in Howard, WI, involving a MY 2014 Freightliner Business Class M2 truck manufactured by Daimler Trucks North America LLC (DTNA) and Delta Waseca Inc. The subject vehicle experienced a catastrophic CNG fuel container<sup>1</sup> rupture when it was struck by an unsecured forklift truck being transported inside the truck's cargo compartment. Special Crash Investigations Team 2, working for Indiana University's Transportation Research Center under contract with the National Center for Statistics and Analysis (NCSA) on behalf of ODI, conducted a field examination of the incident vehicle and the incident scene (Case Number: IN14016). ODI subsequently

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<sup>1</sup> See 49 CFR 571.304, a CNG fuel container means a container designed to store CNG as motor fuel on-board a motor vehicle.

sent an information request (IR) letter to DTNA on November 12, 2014 and received two responses dated January 23, 2015 and June 24, 2015, respectively.

On February 3, 2016, ODI upgraded the investigation to an Engineering Analysis (EA16-001) to further evaluate the CNG fuel system integrity on the subject vehicles and other medium- and heavy-duty CNG vehicles. During this time, ODI sent IR letters to 7 peer natural gas vehicle manufacturers and 1 fuel system integrator. The Principal Investigator also investigated 51 significant incidents (including 21 fuel container ruptures) involving a variety of natural gas vehicles; continually engaged with stakeholders across industry and government; and participated in committee meetings hosted by industry associations and standards development organizations that performed incident reviews, created new industry standards and revised existing industry standards related to natural gas vehicle safety.

**System Description:** The subject vehicles are heavy-duty single unit straight trucks manufactured by DTNA as chassis-cab incomplete vehicles<sup>2</sup> equipped with the entire CNG fuel system. The final-stage vehicle manufacturer then completes the vehicle by addition of cargo-carrying, work-performing, or load-bearing components necessary for the vehicle to perform its intended functions. The subject vehicles were originally equipped by DTNA with CNG fuel systems supplied by Agility Fuel Systems LLC (Agility). (Agility has since reincorporated as Agility Fuel Solutions LLC after a merger with Hexagon Composites ASA's CNG Automotive Products Division, and subsequently reorganized and rebranded as the Hexagon Agility business unit of the Hexagon Group, a conglomerate controlled by Hexagon Composites ASA). Five (5) Type 4 composite non-metallic full wrapped<sup>3</sup> CNG fuel containers, manufactured by Hexagon Lincoln Inc., are mounted transversely and stacked vertically in a 5x1 array behind the truck cab. The subject fuel containers are neck mounted inside an enclosure made of an aluminum metal framework and aluminum sheet metal covering.

DTNA specified the mounting interface for the fuel container assembly to be affixed to the truck chassis, and validated conformity with its specification to ensure that the installed fuel system met DTNA durability expectations. DTNA did not specify any other performance or safety requirements beyond those stipulated in the applicable standards: Federal Motor Vehicle Safety Standard (FMVSS) No. 304 "Compressed natural gas fuel container integrity," and voluntary industry standards ANSI NGV 1 "Compressed natural gas vehicle (NGV) fueling connection devices," ANSI NGV 2 "Compressed Natural Gas Vehicle Fuel Containers," ANSI NGV 3.1 "Fuel system components for compressed natural gas powered vehicles," ANSI PRD 1 "Pressure relief devices for natural gas vehicle (NGV) fuel containers," and NFPA 52 "Vehicular Gaseous Fuel Systems Code." The subject vehicles are exempt from FMVSS No. 303 "Fuel system integrity of compressed natural gas vehicles," because their Gross Vehicle Weight Rating (GVWR) is in excess of 10,000 pounds and they are not classified as school buses. DTNA relied on Agility's expertise to ensure the fuel system it manufactured and supplied met all the applicable standards.

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<sup>2</sup> See 49 CFR 567.3 "Certification; Definitions."

<sup>3</sup> See 49 CFR 579.304.S5.1 "Federal Motor Vehicle Safety Standard No. 304; Compressed natural gas fuel container integrity; Container designations."

The purpose of the fuel container enclosure is to provide some level of protection from environmental conditions like weather and UV exposure and protect from it from minor mechanical damage in accordance with applicable industry standards. For instance, NFPA 52-2013 (the version of the standard that was in effect at the time the subject vehicle was manufactured) states:

“6.3.2.1 Fuel supply containers shall be protected with a means to prevent damage that occurs due to road hazards, loading, unloading, direct sunlight, exhaust heat, and vehicle use, including accidental cargo leakage.”

Additionally, NFPA 52-2013 describes in Sections 6.3.4 and 6.3.5 how, “Each fuel supply container rack shall be secured to the vehicle” and “Each fuel supply container in the rack shall be secured to its cradle in a manner that is capable of withstanding a static force, applied in the six principal directions... of eight times the weight of the fully pressurized container with a maximum displacement of 0.50 in. (13 mm).” The purpose of this requirement is to ensure the fuel container mountings are robust enough to withstand ordinary use and mitigate the risk of a fuel container becoming detached from the vehicle. This requirement is not intended for crashworthiness. The fuel container mounting location above the chassis frame rails and/or the enclosure properties may contribute to fuel container integrity and crashworthiness, but there are no specific related regulatory requirements.

**Subject Incident Vehicle:** The subject Freightliner Business Class M2 incident vehicle was equipped with a dry freight van body manufactured by Delta-Waseca Inc. At the time of the incident, the subject vehicle was not operated with a cargo securement system (e.g. vehicle structure, securing devices, and blocking and bracing equipment) suitable for transporting a forklift truck in accordance with Federal Motor Carrier Safety Administration (FMCSA) cargo securement requirements.<sup>4</sup> There was no suitable front-end structure to resist penetration by a forklift truck nor did the CNG fuel system have any shielding to protect against such impacts. The unsecured forklift truck rolling forward, penetrating the cargo compartment and fuel container enclosure, and then striking the fuel system directly led to the CNG fuel container rupture. The motor carrier received a citation for violation of 49 CFR 393.100(a) “No or improper load securement.”

**DTNA Assessment:** According to its January 23, 2015, IR response letter, DTNA’s assessment of the fatal April 3, 2014 incident states the causal and contributory factors include: loading the forklift truck into the truck’s cargo compartment with the forks facing forward towards the CNG fuel system; improper cargo securement; driving the truck at speed greater 17mph (driving at a slower speed may have reduced the opportunity for the unsecured cargo to shift); abrupt braking vehicle maneuver; and potential driver distraction. DTNA states that no unreasonable risk to motor vehicle safety is identified, provided industry required cargo securement and safe driving practices are followed.

**Agility’s Assessment:** According to its January 18, 2019, IR response letter, Agility’s assessment of the fatal April 3, 2014 incident is like that of DTNA and states the causal and contributory factors include: unsecure load, speed of the transporting truck, and whether the forklift truck parking brake was applied

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<sup>4</sup> See 49 CFR 392.9 “Inspection of cargo, cargo securement devices and systems” and 49 CFR 393 Subpart I “Protection Against Shifting and Falling Cargo.”

and the performance and condition of the parking brake if it was. Based on Agility's observations and investigation of this incident, Agility believes the primary cause of the fuel container rupture was the failure to secure the forklift. It emphasized that the fuel system and the container that was impacted by the forklift were manufactured to, and complied with, all codes and standards in effect at that time. Furthermore, Agility does not believe that the subject vehicle fuel system or the subject fuel containers pose an unreasonable risk to motor vehicle safety.

**Problem Experience:** This investigation sought to discover how often explosive CNG fuel container ruptures occur as a result of crashes or load shifts, which are foreseeable events that might require the fuel containers to be positioned a certain way or otherwise protected from such events, and how many vehicles exist that are potentially at risk. It also sought to understand whether the subject vehicles are at particular risk, and if other CNG vehicles may be similarly at risk, and to determine whether there may exist a defect that represents an unreasonable risk to motor vehicle safety.

CNG fuel container ruptures, although relatively rare events, have potentially severe safety consequences. During this investigation, ODI evaluated 21 CNG fuel container rupture incidents on a variety of natural gas vehicles (see Appendix 1). Each incident involved unique vehicles, with varied contributing factors and root causes including: expired CNG fuel containers that had exceeded the end of the manufacturer's recommended service life, fire, vehicle crash, or some other damage mechanism such as corrosion, road hazard impact or routine over-pressurization due to improper refueling. ODI observed no specific defect trends. However, each incident prompted discussion among industry stakeholders at various venues about how best to address the hazard potential. In certain cases, this led to education outreach efforts for vehicle owners and fire fighters, or the creation of new industry standards and best practices, such as CSA/ANSI NGV 6.1 "Compressed natural gas (CNG) fuel storage and delivery systems for road vehicles" and CSA SPE-2.1.1, "Best practices for defueling, decommissioning, and disposal of compressed natural gas vehicle fuel containers."

It is difficult to determine how many explosive CNG fuel container rupture incidents have occurred, as there is no nationwide mandatory reporting requirement. This is in contrast the US Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Agency (PHMSA) Hazardous Materials Regulations (HMR),<sup>5</sup> which regulate cylinders used to transport compressed gases for industrial use. Such cylinders are pressure vessels similar in construction to CNG fuel containers.<sup>6</sup> The HMR require immediate notification if a person is killed or injured requiring hospitalization, and require written notification within 30 days whenever there is a cylinder rupture. Similarly, the Railroad Commission of Texas requires immediate CNG incident/ accident reporting.<sup>7</sup> While NHTSA has certain Early Warning Reporting (EWR) requirements for certain vehicle and equipment manufacturers, NHTSA does not have an explicit incident reporting requirement for CNG fuel container ruptures that would allow them to be independently assessed. Vehicle and equipment manufacturers may not even be

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<sup>5</sup> See 49 CFR 171.15 "Immediate notice of certain hazardous materials incidents," and 49 CFR 171.16 "Detailed hazardous materials incident reports."

<sup>6</sup> Prior to FMVSS 304, natural gas vehicles typically used DOT cylinders as CNG fuel containers, and they were subject to the HMR and the incident reporting requirements.

<sup>7</sup> See Texas Administrative Code Title 16 RULE §13.36 "Report of CNG Incident/Accident."

aware of such incidents themselves, and if they do become aware, it might occur years after the incident pursuant to litigation.

Over the years, various stakeholders have documented and analyzed certain CNG fuel container rupture incidents, including, but not limited to, Powertech Labs Inc.,<sup>8</sup> Clean Vehicle Education Foundation,<sup>9</sup> NGVAmerica,<sup>10</sup> and the Hydrogen Safety Panel.<sup>11</sup> They typically received incident notification via private communication from someone with awareness of the incident, or via routine monitoring of news media, although some incidents go unreported in the news or are misreported. The National Center for Statistics and Analysis (NCSA) collects and analyzes certain data in support of NHTSA's mission. However, there are limitations in existing NCSA data sets, such as sampling methods that may not capture relatively rare but serious incidents on small population vehicles, non-fatal or non-injury incidents, non-traffic incidents and no uniform method for identifying natural gas vehicles in state registration databases or by encoding the information within the 17-digit Vehicle Identification Number (VIN). Accordingly, there is no data clearinghouse nor any publicly available, comprehensive database of CNG fuel container rupture incidents.

During this investigation, ODI sent IR letters to the subject vehicle manufacturer (DTNA), the subject vehicle fuel system integrator (Agility, also known as a motor vehicle equipment manufacturer), and to 7 peer natural gas vehicle manufacturers: 1) The Heil Company, doing business as (d/b/a) Environmental Solutions Group, an amalgamation of businesses owned by Dover Corporation; 2) New Flyer of America Inc. and Motor Coach Industries International Inc.; 3) Navistar Inc.; 4) Oshkosh Corporation and McNeilus Truck & Manufacturing Inc.; 5) PACCAR Inc., Peterbilt Motors Company and Kenworth Truck Company; 6) Volvo Trucks North America, Inc. and Mack Trucks Inc.; and 7) GILLIG LLC.

The manufacturer IR responses indicate varying business practices related to the design, manufacture and assembly of CNG fuel systems, vehicle/ system integration, performance testing and record keeping. Some manufacture motor vehicles with natural gas engines but without associated fuel systems to store and deliver CNG as a motor fuel. Such vehicles manufactured in two or more stages have fuel systems installed by an intermediate manufacturer, final-stage manufacturer, or a vehicle alterer, who may have detailed production records. Some manufacture motor vehicles with CNG fuel systems supplied by a fuel system integrator, and may or may not have detailed records documenting the fuel container serial numbers or the end of the manufacturer's recommended service life for each container. Some manufacture vehicles with a mix of CNG fuel systems integrated by themselves and

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<sup>8</sup> M. Hernandez, L. Ma, C. Huang, M. Rossetto, J. Martin, D. Poisson, "Powertech Cylinder Failure Study" in Safety Investigation of CNG Leaks in Enclosed Parking Structures - CFD Modelling and Analysis, Transport Canada, 2013.

<sup>9</sup> J. Lapetz, "Voluntary Natural Gas Vehicle Incident Reporting Program Assures Highest Levels of Vehicle Safety," Available: <https://web.archive.org/web/20101204032422/http://www.cleanvehicle.org/IncidentReportingNoticeforWeb.pdf>, [Accessed Mar 18, 2021].

<sup>10</sup> P. Speraw, "NGVAmerica Hosts Stakeholder Meeting to Discuss Key Safety and Technical Issues," Available: <https://ngvamerica.org/2017/01/30/ngvamerica-hosts-stakeholder-meeting-to-discuss-key-safety-and-technical-issues/>, [Accessed Mar 18, 2021].

<sup>11</sup> "Safety issues associated with the use of alternative fuel tanks: What can the hydrogen community learn from the CNG experience?", Hydrogen Safety Panel, June 2018, Available: [https://h2tools.org/sites/default/files/HSP-CNG\\_White\\_Paper-June\\_2018.pdf](https://h2tools.org/sites/default/files/HSP-CNG_White_Paper-June_2018.pdf), [Accessed Mar 18, 2021].

manufactured by other fuel system integrators, with different records kept for each vehicle or fuel system.

Accordingly, few manufacturers are fully aware of how many incidents have occurred that involve vehicles they manufactured in whole or in part, and not all have comprehensive production records that detail all the CNG fuel systems and CNG fuel containers that are equipped on those vehicles. If a CNG fuel container experiences damage that renders it unfit for continued service and cannot be repaired, the vehicle owner may contact the fuel system integrator or the fuel container manufacturer for a replacement, instead of the vehicle manufacturer, and sometimes service replacement containers are sourced from another manufacturer entirely. In the event of a CNG fuel container rupture, all, some, or none of the stakeholders in the supply chain may be aware. Some manufacturers may have awareness about an incident, but choose to only report to NHTSA certain incidents where they receive a formal claim or notice. And while CNG fuel systems require periodic detailed visual inspection, the inspector typically does not share those records beyond the vehicle owner. These conditions contribute to disparate record keeping and present challenges in understanding fuel container and fuel system integrity, and investigating critical incidents.

**Reason for Closing:** ODI is only aware of the one subject fuel container rupture incident on the subject vehicles. The design, material, manufacture, assembly and performance appear to be consistent with certain other manufacturers of CNG vehicles and in accordance with standards in effect at the time of manufacture. Since the subject incident, new and revised industry standards have advanced CNG fuel system and fuel container integrity and safety. In 2019, NHTSA noted an “extremely low failure rate of CNG fuel containers,” in a notice of proposed rulemaking (NPRM)<sup>12</sup> to amend the visual inspection labeling requirement in FMVSS 304. NHTSA also entered a strategic partnership project (SPP) with the National Renewable Energy Laboratory (NREL) to assess fuel system and fuel container integrity requirements<sup>13</sup> in an effort to update FMVSS Nos. 303 and 304. In NREL’s report, they provided several considerations that reflect minimum safety standards, as well as industry best practices, to harmonize applicable light-, medium-, and heavy-duty natural gas and propane fuel vehicle codes and standards.

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<sup>12</sup> Federal Motor Vehicle Safety Standards; Compressed Natural Gas Fuel Container Integrity, 84 FR 29145 (June 21, 2019).

<sup>13</sup> L. Lynch, L. Browning, A. Snelling, “Evaluation of Safety Standards for Fuel System and Fuel Container Integrity of Alternative Fuel Vehicles,” NREL/TP-5400-77455, February 2021.



## **Appendix 1**

CNG fuel container rupture incidents evaluated during PE14-020 and EA16-001:

| <b>Incident Number</b> | <b>Incident Date (yyyy-mm-dd)</b> | <b>Location</b>          | <b>Fuel Container Type</b> | <b>Failure Mechanism</b>            |
|------------------------|-----------------------------------|--------------------------|----------------------------|-------------------------------------|
| 1                      | 2014-04-03                        | Green Bay WI             | 4                          | Impact                              |
| 2                      | 2014-08-19                        | Arcadia CA               | 3                          | Fire                                |
| 3                      | 2015-01-27                        | Indianapolis IN          | 4                          | Fire                                |
| 4                      | 2015-03-23                        | Little River AR          | 4                          | Impact                              |
| 5                      | 2015-06-23                        | Buffalo NY               | 4                          | Impact                              |
| 6                      | 2016-01-26                        | Hamilton NJ              | 3                          | Fire                                |
| 7                      | 2016-03-11                        | Duderstadt, Germany      | 1                          | Corrosion                           |
| 8                      | 2016-05-04                        | Litomysl, Czech Republic | 1                          | Corrosion                           |
| 9                      | 2016-05-31                        | Nashville TN             | 4                          | Impact                              |
| 10                     | 2016-11-03                        | Waco TX                  | 4                          | Impact                              |
| 11                     | 2017-07-18                        | Milwaukee WI             | 2                          | Over-pressurized, Expired Container |
| 12                     | 2017-10-20                        | Columbus NE              | Undetermined               | Over-pressurized                    |
| 13                     | 2018-12-21                        | Buttonwillow CA          | 4                          | Undetermined                        |
| 14                     | 2019-03-10                        | Stockholm, Sweden        | 4                          | Impact                              |
| 15                     | 2019-06-04                        | Orlando FL               | Undetermined               | Fire                                |
| 16                     | 2019-07-17                        | Jefferson Township PA    | 2                          | Undetermined                        |
| 17                     | 2020-06-07                        | Riverside CA             | Undetermined               | Impact, Expired Container           |
| 18                     | 2020-07-15                        | LeRoy NY                 | 4                          | Impact                              |
| 19                     | 2020-10-18                        | Pompano Beach FL         | 4                          | Fire                                |
| 20                     | 2020-11-05                        | Janesville WI            | 2                          | Expired Container                   |
| 21                     | 2021-02-14                        | Pensacola FL             | 4                          | Fire                                |