

Test Protocols for Motorcoach Fire Safety

Jason P. Huczek
Southwest Research Institute

R. Rhoads Stephenson
Friedman Research Corp

ABSTRACT

The Department of Transportation (DOT) National Highway Traffic Safety Administration (NHTSA) awarded a contract to Southwest Research Institute (SwRI) to conduct research and testing in the interest of motorcoach fire safety. The goal of this program was to develop and validate procedures and metrics to evaluate current and future detection, suppression, and exterior fire-hardening technologies that prevent or delay fire penetration into the passenger compartment of a motorcoach - in order to increase passenger evacuation time.

The program was initiated with a literature review and characterization of the thermal environment of motorcoach fires and survey of engine compartments, firewalls, and wheel wells of motorcoaches currently in North American service. These characterizations assisted in the development of test methods and identification of the metrics for analysis.

Test fixtures were designed and fabricated to simulate a representative engine compartment and wheel well. Fire scenarios were developed for each fixture, the current detection, suppression, and fire-hardening technologies were reviewed and a sample set selected to validate the test procedures developed during this program. Based on the results of testing and feedback from stakeholders, test methods and metrics were developed for evaluating wheel well warning systems, engine compartment detection and suppression systems, and fire-hardening systems. Detailed program conclusions and recommendations for areas of interest for further research and testing are also discussed.

CITATION: Huczek, J. and Stephenson, R., "Test Protocols for Motorcoach Fire Safety," *SAE Int. J. Passeng. Cars - Mech. Syst.* 8(2):2015, doi:10.4271/2015-01-1381.

INTRODUCTION

Regulatory Background

The Department of Transportation (DOT) Motorcoach Safety Action Plan of 2009 charges NHTSA to evaluate the feasibility of more-stringent flammability requirements for interior and exterior materials, and regulations requiring installation of fire detection and protection systems.

The Motorcoach Enhanced Safety Act of 2011 calls for standards to improve fire safety through evaluation of flammability criteria for exterior components of motorcoaches, smoke suppression to prevent inhalation of toxic gasses through improved fire resistance of interior components covered under FMVSS 302, prevention of and resistance

to wheel well fires to mitigate propagation into the passenger compartment, and evaluation of automatic detection and suppression systems.

Based on this legislation, NHTSA has funded research to develop test apparatuses and test procedures to evaluate candidate fire detection and suppression systems for motorcoach engine compartments, hot wheel warning systems to prevent tire fires in the wheel well, and assessments of motorcoach exterior wall and firewall materials.

This research was specific to motorcoaches or over-the-road buses characterized by an elevated passenger deck located over a baggage compartment.

Literature Review

Fires without injury are fairly common. However, in 2005 a motorcoach that was being used to transport assisted living facility residents in the Hurricane Rita evacuation effort caught fire killing 23 of the elderly occupants of the vehicle. This event was documented in a highway accident report by the National Transportation Safety Board (NTSB) [1]. There was also a motorcoach accident and subsequent fire in California in April 2014 that left ten dead. This accident is still under investigation by NTSB.

Estimates range from 160 reported motorcoach fires to 2200 total bus fires per year in the United States. The majority of those fires start outside the occupant compartment, in the wheel well or engine compartment. The components that have been identified to be the most common ignition points are the brakes, turbochargers, tires, electrical sources, and wheel/hub bearings [2].

There has been prior research focused on the development of test procedures to evaluate engine compartment detection and suppression systems [3, 4, 5, 6, 7]. Kidde has published research on development of a standard test for transit vehicle (motorcoach) extinguishing (suppression) systems [8] and for comparing various fire detection systems for engine compartment fires [9]. At the 2006 SAE Congress there was a session devoted to fire suppression research needs, which was summarized by Hamins [10].

Research Objectives

The objectives of the NHTSA-funded research project are the following:

1. Develop a test fixture and test procedures for evaluating fire detection and fire suppression systems for motorcoach engine compartments.
2. Develop a test fixture and test procedures for evaluating tire fire warning systems for motorcoach wheel well areas.
3. Develop small and intermediate scale fire hardening tests for motorcoach exterior wall and firewall materials.

The full details and all the test results are available in the final report to NHTSA [11]. A discussion of the development of the test fixtures and test protocols is also publically available [12].

ENGINE COMPARTMENT

Characterization

In February of 2013, the SwRI team conducted a survey of three Model Year (MY) 2013 motorcoaches (one each from three different manufacturers) at their respective maintenance facilities. The purpose of this survey was to characterize the engine compartments of motorcoaches that are sold in the U.S. Figure 1 shows a photograph of each motorcoach engine compartment (view from rear of coach) surveyed.

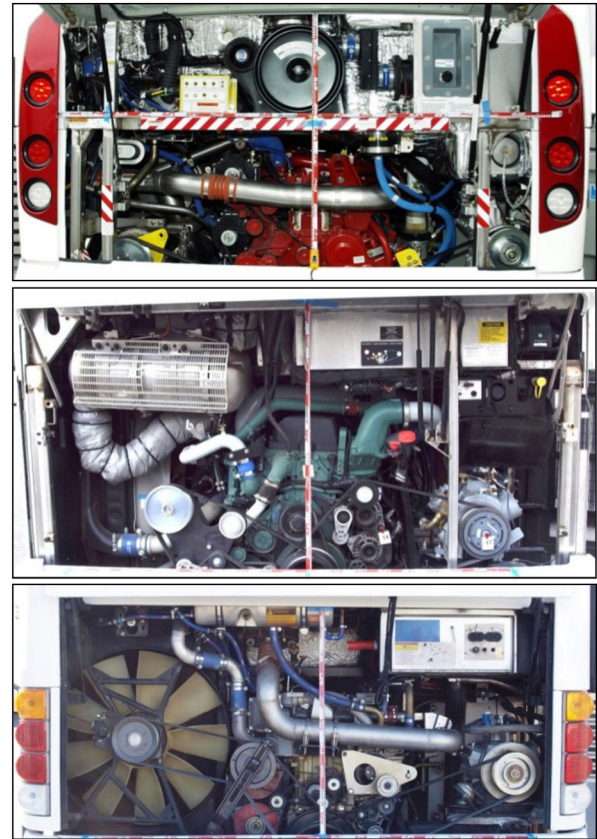


Figure 1. Photographs of Three Surveyed Motorcoach Engine Compartments.

Table 1. Summary of Location of Major Engine Compartment Components (as viewed from rear of coach).

Component Description	Motorcoach A	Motorcoach B	Motorcoach C
Engine assembly	Middle	Middle	Middle
Two coolers and fan	Left	Left	Left
Air filter (vertical/horizontal)	Top - middle	Top - right	Middle – Left
Lavatory equipment	Right	Right	Right
Emissions control* (vertical/horizontal)	Lower Left	Middle Left	Top Left
A/C Compressor	Lower right	Lower right	Lower right
Turbo	Left side of engine	Left side of engine	Left side of engine
Surge tank – engine coolant	Above engine cooler	Above engine cooler	Above engine cooler
Alternators	Left side	Left side	Right side

* Modern emission control equipment includes a catalyst and a Diesel Particulate Filter (DPF). The DPF requires a fuel line to deliver diesel fuel. In some cases the canisters for these two devices can get very hot and become a potential ignition source.

The interior gross volume of the engine compartments surveyed varied between approximately 6-9 m³. Table 1 provides a summary of where several of the major components in the engine compartment are located.

Engine Compartment Test Fixture

Based on the survey task, three-dimensional CAD models of each motorcoach were developed so that they could be overlaid and compared and contrasted. Based on these models, a single representative model was created. This final model was then fabricated. A photograph of the fixture is shown in Figure 2.

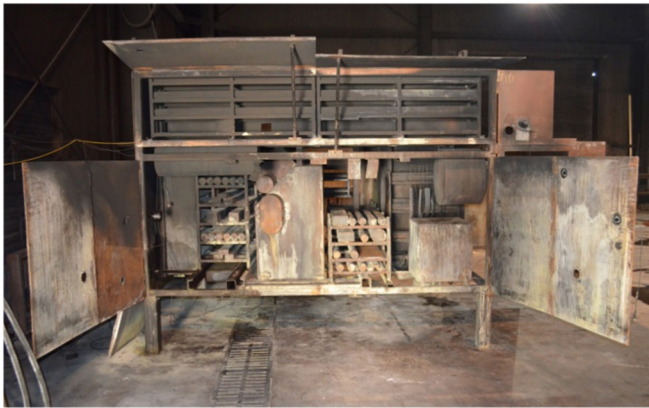


Figure 2. Photograph of Motorcoach Engine Compartment Fixture.

The fixture includes test modules that are used to represent clutter in the engine compartment and also to incorporate ignition sources and secondary combustibles that are utilized in a given fire scenario. These modules contain a combination of combustible and noncombustible materials.

Fire Scenarios

The project developed test procedures to evaluate both detection and suppression systems in the engine compartment. These may be tested as an integrated system, or separately.

In order to identify the most common fire scenarios for the engine compartment, detailed discussions with the NHTSA Office of Defects and Investigation (ODI) were held in addition to discussions with manufacturers, suppliers and operators. The following six fire scenarios are included in the testing protocol for evaluating engine compartment detection and suppression systems: Four of these scenarios are performed with the cooling fan on and fan off, and one has two locations; in total, there are twelve tests. Based on discussions with OEMs, a typical volumetric air flow of 3-4 m³/s was selected for the tests with ventilation. This results in an airflow velocity of approximately 6-8 m/s on the hot side of the fixture clutter. For more detailed information, reference the SwRI final report [11].

1. Hot Surface Re-Ignition Test (One Test - fan off)
2. Diesel Spray Fires (Four tests - two locations, fan on and fan off)

3. Power Steering Fluid (PSF) Fires (Two tests - fan on and fan off)
4. Distributed Pool Fires (Two tests - fan on and fan off)
5. Plastics Fire (Two Tests - fan on and fan off)
6. Battery Compartment Fire (One Test - fan off)

These six scenarios cover most of the engine compartment geometrically and they also involve most of the common types of combustible materials found in this space.

Test Results

Several test runs were performed to validate and improve various test fires, and to check-out and calibrate the instrumentation. The instrumentation includes videos of the exterior as well as videos looking through holes into the interior. There were also extensive thermocouple measurements throughout the engine compartment fixture.

Table 2. Summary of Engine Compartment Vendor A Test Results.

Test No.	Fire Scenario	Detection Time (s)	Extinguishment Time (s)
1	PSF Spray without Fan	N/A	1
2	PSF Spray without Fan	14	1
3	Hot Surface Re-Ignition	Activated during heating period at 600 °C, prior to start of test, at 750 °C	2, No Re-ignition
4	Diesel Spray with fan (lower position)	No activation	2
5	Battery Compartment Fire with fan	20	1
6	Plastics Fire with Fan	No activation	1
7	Pool Fires with Fan	N/A	No full extinguishment
8	Hot Surface Re-Ignition	N/A	1, Re-ignition in 32 s
9	Hot Surface Re-Ignition	N/A	1, No Re-ignition
10	Diesel Spray with Fan (upper position)	No activation	1
11	PSF Spray with Fan	No activation	2
12	Pool Fires with Fan	No activation	No full extinguishment
13	Pool Fires with Fan	10 (adjusted settings on optical detector)	3 (adjusted nozzle placement slightly)
14	Plastics and Battery Compartment Fire (combined due to time constraints)*	N/A	2

N/A: not applicable since a detection system was not installed on this test.

*: pre-burn times were aligned such that system could be discharged at appropriate time

Three vendors tested at SwRI and two of the vendors also provided integrated detection systems.  **Documents**
Document Sharing Hub