Active Fire Protection for Motorcoach

Fire Safety: Development of Test Apparatuses and Procedures

Jason Huczek,  
Principal Engineer

Southwest Research Institute  
Fire Technology Department
OUTLINE

- Introduction
- Research Objectives
- Engine Compartment (EC) Summary
  - Characterization and Final Test Fixture
  - Ventilation
  - Fire Scenarios / Baseline Testing
  - Vendor Testing
  - Final Procedure and Test Criteria
- Wheel Well (WW) Summary
  - Characterization and Fire Scenarios
  - Final Test Fixture/Procedure
  - Baseline Testing
  - Vendor Testing
  - Final Procedure and Test Criteria
INTRODUCTION

- Regulatory Background
  - 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
  - DOT Motorcoach Enhanced Safety Act of 2011
    - Calls for standards to improve fire safety through prevention of and resistance to wheel well fires to mitigate propagation into the passenger compartment, and evaluation of automatic engine compartment detection and suppression systems.
RESEARCH OBJECTIVES

- **Major Objectives**
  - Develop a test fixture and test procedures for evaluating fire detection and fire suppression systems for motorcoach engine compartments.
  - Develop a test fixture and test procedures for evaluating tire fire warning systems for motorcoach wheel well areas.

- **Secondary Objective**
  - Further investigate the topic of fire hardening of a bus and propose a standard test method(s) that would be useful to compare potential fire hardening materials for this purpose.
EC CHARACTERIZATION (1)
EC CHARACTERIZATION (2)
EC FINAL FIXTURE DESIGN
EC VENTILATION (1)

- Can vary widely between coach manufacturer and coach design/model and can greatly impact potential fire scenario.
- Two extreme designs observed: floor more open, floor less open
EC FIRE SCENARIOS (1)

- 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:
- These fire scenarios cover most of the engine compartment geometrically and they also involve most of the typical types of combustible materials scattered throughout the space.
- It is recommended to conduct tests for each scenario with and without the fan running, with the exception of the hot surface re-ignition test and the battery compartment test. When the fan is running, the nominal airflow measured from the fan is 3 m³/s and the average air speed is 6 m/s.
- Each fire scenario (test) has a designated pre-burn time ranging from 30 to 105 seconds, which is based on observations and measurements during baseline and vendor testing.

Overview of Scenarios
- Hot Surface Re-Ignition (oil)
- Spray Fires (power steering fluid and diesel)
- Distributed Pool Fires Test (heptane)
- Plastics Fire (PP and ABS)
- Battery Compartment Fire (various solid combustibles)
EC FIRE SCENARIOS (2)

- Hot Surface Re-Ignition Scenario

![Graph showing temperature over time for different heaters.](image)

Southwest Research Institute – Fire Technology Department
EC FIRE SCENARIOS (3)

- Spray Fires
EC FIRE SCENARIOS (4)
EC FIRE SCENARIOS (5)

- Distributed Pool Fire Test – Forward View
EC FIRE SCENARIOS (6)

- Distributed Pool Fire Test – Rear View
EC FIRE SCENARIOS (7)

- Plastics Fire
EC FIRE SCENARIOS (8)

- Battery Compartment Fire

1. 3 EACH, PIPE INSULATION
   1-3/8" ID X 1/2" WALL X 28" PRE-SPRAYED WITH DIESEL FUEL

2. 18" X 16"
   EGG-CRATE FOAM
   PLASTIC INSULATION

3. OVER HEATED TO IGNITION CONTROL CABLE

4. 4 EACH PLASTIC TOOL BOXES
   SIMULATING BATTERIES

Southwest Research Institute – Fire Technology Department
EC VENDOR TESTING
System Description

- Vendor A (14 tests)
  - Dry Chemical / Cooling Agent Hybrid System with LTD and Optical Fire Detection
  - 25-30 lb dry chemical capacity / 13 L cooling agent capacity / 5 Nozzles

- Vendor B (15 tests)
  - Dry Chemical System with LTD and Optical detection
  - 10 kg dry chemical capacity / 2-4 nozzles
  - 15 tests in one session

- Vendor C (26 tests)
  - Compressed Air Foam (CAF) System with no detection system
  - 10 gallon capacity / 10-12 nozzles
EC VENDOR TESTING
Test Results

- **General Observations:**
  - Typically, if the detection system activated, it did so within the proposed pre-burn times. However, in some cases, the detection system did not activate and this usually occurred for tests with the fan running, which provides some convective cooling to the linear heat detector and may also affect the fire size and shape for the optical detectors.
  - The most challenging fire appears to be the distributed pool fire scenario with the fan running.
  - Dry chemical does not seem to be an ideal agent for the hot surface re-ignition scenario and the cooling agent performed much better.
  - Typically, if extinguishment is to be observed, it occurs within 3 s. This is the time period that the system has the most momentum to penetrate obstructed fires and if the fire cannot be extinguished quickly, it tends to not be extinguished at all.
  - The CAF/mist system was challenged by the fire scenarios and in particular the heavily obstructed fires.
EC TESTING
Example Videos
EC SUMMARY
Final Procedure and Criteria

- The detection and suppression system is installed per manufacturer direction and/or specifications.
- The installation remains unchanged for any of the twelve fire tests.
- For all tests, with the exception of the hot surface re-ignition test, the design fire must be extinguished.
- For all tests, with the exception of the hot surface re-ignition test, the detection system must have activated prior to the end of the pre-burn time of the design fire.
- For the hot surface re-ignition test, the installed system must prevent re-ignition for a minimum of 150 seconds. This time limit is derived from a recent Volpe Center report, which discusses egress times from a full motorcoach after an accident.
- It is recommended that detection and suppression systems that meet this test criterion also meet quality and reliability testing requirements for their individual system components.
WW CHARACTERIZATION
The project team has determined that the major heat sources for tire fires are:

- Dragging brakes;
- Failed bearings
- Underinflated tires (especially the inner tire of a set of dual drive axle tires).

A single tag axle that is supported at one end with a bearing structure and driven by an electric motor connected to the wheel lug nut assembly.

The wheel is heated by partially engaging the brakes on the tag axle, causing heat to be transferred through the wheel assembly and into the tire.

Find a quantity can be measured and used to predict an abnormal wheel heating condition.

Warn the driver well before a tire fire would develop.
WW FIXTURE DESIGN
WW FIXTURE INSTRUMENTATION
WW BASELINE TESTING (1)
Typical Summary Data Plots
WW BASELINE TESTING (2)
Videos
WW BASELINE TESTING (3)
Selected Photographs
WW VENDOR TESTING
System Description

- Vendor A (2 tests)
  - TPMS sensor mounted on backside of valve stem
  - 80 °C warning threshold

- Vendor B (3 tests)
  - Tire sensor (measuring temperature and pressure) mounted adhesively on inside surface of tire tread
  - 115 °C warning threshold

- Vendor C (3 tests)
  - TPMS sensor mounted on strap around wheel (2 sensors per test, one shorter and one taller)
  - 85 °C warning threshold
WW VENDOR TESTING
Example Vendor Test Results

Test No. 1 – Wheel Well Vendor C
Aluminum Wheel, Abbreviated Burnishing

Torque (N-m)
Power (kW)
Tire Speed (mph)
Energy (MJ)

Time (min)

Maximum Stationary Temperature
Maximum Rotating Temperature
Sensor 1 Temperature
Sensor 2 Temperature
Nominal Tire Ignition Temperature
Sensor Alarm Threshold
Sensor 1 Activation Point
Sensor 2 Activation Point

Sensor 1 activated at 18:17 (94 °C) and Sensor 2 activated at 11:12 (85 °C)
# WW VENDOR TESTING
## Summary Test Results

<table>
<thead>
<tr>
<th></th>
<th>Vendor A</th>
<th>Vendor B</th>
<th>Vendor C (Sensor 1)</th>
<th>Vendor C (Sensor 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hot Wheel Alarm Activated?</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Sensor Set Point (°C)</strong></td>
<td>80</td>
<td>115</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td><strong>Maximum Rotating Temperature at Alarm (°C)</strong></td>
<td>160</td>
<td>245</td>
<td>180</td>
<td>150</td>
</tr>
<tr>
<td><strong>Maximum Stationary Temperature at Alarm (°C)</strong></td>
<td>280</td>
<td>330</td>
<td>250</td>
<td>240</td>
</tr>
<tr>
<td><strong>Vendor Sensor Temperature at Alarm (°C)</strong></td>
<td>80</td>
<td>30</td>
<td>94</td>
<td>85</td>
</tr>
<tr>
<td><strong>Nominal Time at Alarm (min)</strong></td>
<td>7</td>
<td>No Alarm</td>
<td>18</td>
<td>11</td>
</tr>
<tr>
<td><strong>Nominal Time at Alarm + 10 °C (min)</strong></td>
<td>8</td>
<td>No Alarm</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td><strong>Nominal Time at Alarm + 20 °C (min)</strong></td>
<td>8</td>
<td>No Alarm</td>
<td>No Alarm</td>
<td>13</td>
</tr>
</tbody>
</table>
The early warning system is installed per manufacturer specifications.

The test utilizes an aluminum wheel (Size: 22.5 × 8.25) and either a new or used tire (Size: 315/8OR22.5). The tire is pressurized with air to 30 psig (for safety reasons).

The test is conducted at a tire rotation speed equivalent to 60 mph.

The brake pads are burnished.

The brakes are applied in order to input heat into the system until the brake pad temperature reaches 750 °C. Subsequent cycles from 650 – 750 °C are administered until sensor activation or until the maximum stationary temperature reaches 400 °C.
WW SUMMARY
Final Procedure and Criteria (2 of 2)

- If the sensor does not activate prior the maximum stationary temperature reaching 400 °C, the test is aborted and the sensor considered to have failed this evaluation.

- If the sensor activates, one additional heating cycle is performed, the wheel stopped, and the final observations made of additional heating and final sensor temperature.

- During the final cool down period, the fixture is monitored and during this time, if the maximum stationary temperature exceeds 400 °C, the sensor will be considered to have failed this evaluation. If the stationary temperature remains below 400 °C during the cool down period, the sensor is considered to have passed this evaluation.
QUESTIONS?

http://www.fire.swri.org

jhuczek@swri.org