A Fire Test Protocol for Off-Road Vehicle Fire Extinguishing Systems

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Outline

• Background
• Overview of the test protocol
• Evaluation of the test protocol
• Status
Types of Off-Road Vehicles

- dragline/power shovel
- backhoe
- bucket wheel excavator
- bulldozer
- compactor
- crane
Types of Off-Road Vehicles

- excavator
- grader
- loader
- telescope handler
- tractor
Fire Incidents
Fire Hazards

- Internal or external fires
- Spray, pool or spill fires
- Exposures:
  - Engine compartment ventilation up to 7 m$^3$/s (15000 cfm).
  - Wind up to 6 m/s.
  - Hot surface temperature up to 600 °C.
SP Method 4912

- Evaluate extinguishing systems for engine compartments of transportation vehicles:
  - ✓ consider pool and spray fire hazards.
  - ✓ consider re-ignition propensity caused by hot surface.
  - ✓ ventilation up to 3 m³/s (6400 cfm).
  - ✓ does not consider external fires.
Proposed Approach for Off-Road Vehicles

A two-pronged approach:

- Engine compartment test facility – to evaluate pre-engineered systems for the typical engine compartment of large off-road vehicles.

- Single nozzle test facilities – to evaluate a single nozzle’s fire extinguishing capability => provide flexibility for configuring customized systems for internal or external fires, based on a vehicle’s specific conditions, such as configuration, size, fire hazard, and fire shielding.
Typical Engine Compartment Configuration
Engine Compartment Mock-up

Compartments: 2.50 x 1.50 x 1.00 m high
Engine block: 2.11 x 1.15 x 0.70 m high
Exhaust manifolds: 73 mm in diameter
Exhaust manifold shield: 0.10 m wide
Air filter drum: 0.15 m diameter
Pan: 1.52 x 1.52 x 0.10 m high

Hazard conditions:
- Diesel injection/release rate: 1 liter/min
- Ventilation rate: 7.5 m$^3$/s (16000 cfm)
- Exhaust manifold temperature: 600 °C
Engine Compartment Test Facility

Grainger Model 3C111 Blower

610-mm Dia. Duct

0.91-m Long Transition

1.22-m Long Flanged Duct

1.52-m Long Flanged Duct

610-mm Diameter

0.76-m Long Transition

0.31-m Long Straightener & Screen Section

0.20-m Long Round Duct Section

1.5000

8.0000

1.52 x 1.52 x 0.1-m Pan

Propane

Air Outlet

0.47-m
Single Nozzle Scenario 1 – A Spray Fire Partially Obstructed by a Hot Cylindrical Object

Pipe OD: 75 mm
Pipe-wall distance: 90 mm
Pipe temperature: 600 °C
Diesel spray rate: 1 lpm
Nominal maximum wind speed: 6 m/s
Single Nozzle Scenario 2 – A Spray Fire Obstructed by Banks of Cylindrical Objects

Pipe OD: 75 mm
Pipe separation in each bank: 30 mm
Each pipe bank dimension: 1200 x 1200 mm
Inner pipe bank to wall: 75 mm
Outer pipe bank to wall: 180 mm
Diesel spray rate: 1 lpm
Nominal maximum wind speed: 6 m/s
Single Nozzle Scenario 3 – A Vertical Spill Fire Partially Obstructed by a Hot Cylindrical Object

Pipe OD: 75 mm
Pipe-wall distance: 75 mm
Pipe temperature: 600 °C
Spill opening: 6.5 x 150 mm wide
Spill opening elevation: 610 mm above pipe centerline

Diesel spill rate: 1 lpm
Nominal maximum wind speed: 6 m/s
Single Nozzle Scenario 4 – A Spray Fire Impinging on a Vertical Wall

Diesel spray rate: 1 lpm
Diesel spray nozzle to wall: 510 mm
Nominal maximum wind speed: 6 m/s
Fuel: Diesel
Pan dimension: 610 x 915 mm long
Pan to horizontal raised floor: 150 mm
Pan offset from vertical wall: 75 mm
Nominal maximum wind speed: 6 m/s
Single Nozzle Scenario 6 – A Partially Obstructed Pool Fire in Open Space

Fuel: Diesel
Pan diameter: 915 mm
Obstruction: 355 mm dia. x 480 mm tall
Obstruction above pan: 75 mm
Nominal maximum wind speed: 6 m/s
Single Nozzle Scenario 7 – A Combined Spray and Pool Fire

Pan diameter: 915 mm
Diesel spray rate: 1 lpm
Diesel spray nozzle elevation above pan: 305 mm
Diesel spray nozzle from pan edge: 230 mm
Nominal maximum wind speed: 6 m/s
Protocol Evaluation with Three Extinguishing Agents

- Water mist – 40% potassium acetate (CH₃CO₂K)
- Foam – 3 % AFFF, 8:1 expansion ratio
- Monoammonium phosphate (NH₄H₂ PO₄)
### Results - Engine Compartment Fires

<table>
<thead>
<tr>
<th>Agent</th>
<th>Spray Fire</th>
<th>Spill Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:1 3% AFFF</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Water mist with 40% Potassium Acetate</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Monoammonium phosphate</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Note: Yes/No is determined if the fire was extinguished in the agent discharge period.
## Single Nozzle Test Results

<table>
<thead>
<tr>
<th>Fire Scenario</th>
<th>Extinguishing Agents</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8:1 3% AFFF</td>
<td>Water mist with 40% Potassium Acetate</td>
<td>Monoammonium Phosphate</td>
</tr>
<tr>
<td>Spray fire obstructed by hot cylinder</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Spray fire obstructed by pipe banks</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Spill fire obstructed by hot cylinder</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Spray fire impinging on vertical wall</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Obstructed corner pool fire</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Obstructed open pool fire</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Combined spray and pool fire</td>
<td>No Test</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Approval Standard for Off-Road Vehicle Protection

FM Approvals Class 5970: Off-Road Vehicle Protection Systems

- 8/31/13 – Completion of draft standard for 1st internal review
- 10/31/13 – Revised draft standard sent for external comments
- 12/31/13 – Revised draft standard sent for 2nd internal review
- 2/28/14 – Revised draft standard for final approval
- 3/31/14 – Publish the approval standard
Questions?