Characterization of Smoke Machines in Testing Aircraft Smoke Detectors

Presented to: Systems Working Group
By: Tina Emami
Date: November 1, 2017
Background

• This study is based on characterizing the smoke from theatrical smoke machines to understand what alerts different types of smoke detectors, and what would best be used for testing them.

New False Alarm Rejection Criteria

• Dust
• Insecticide
• Ambient Light (Dazzle)
• Combined Temperature, Pressure, and Humidity Cycling
Testing Equipment

Whittaker Smoke Detector

Kidde Smoke Detector
Testing Equipment

Rosco 1700 (water based fluid)
- Clear Fog Fluid
- Light Fog Fluid

Concept Aviator SDT Ultra Low (oil based fluid)
- Concept Smoke Oil
Characteristics to Measure

- Particle size of smoke
- Percent obscuration of smoke initially alarming the detectors
- Percent obscuration of smoke “leaving alarm”
PDPA

• Laser intersection point is measurement point. Light is refracted from here into the PDPA receiver.
• Test setup made to reduce noise and produce best data.
Optical Density Meters

- Meters are placed on the same plane as the PDPA lasers
- Measure percent obscuration of light per foot
Experimental Setup

PDPA

Test Chamber

Smoke detector

Optical Density Meter

Smoke Machine
Experimental Setup

Optical Density Meter

Kidde Smoke detector

Exit fan

PDPA Laser

PDPA Measurement Point
Detectors Leaving Alarm (%Obscuration Per Foot)

**Whittaker Detector**

<table>
<thead>
<tr>
<th>Aviator UL – Whittaker</th>
<th>Fan Exit Meter</th>
<th>Min % Obsc</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb7 001</td>
<td></td>
<td>4.4</td>
</tr>
<tr>
<td>Feb7 002</td>
<td></td>
<td>2.8</td>
</tr>
<tr>
<td>Feb7 003</td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>Feb7 004</td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td><strong>2.9</strong></td>
</tr>
</tbody>
</table>

![Graph showing %Obscuration over time](image)
## Detectors Leaving Alarm (%Obscuration Per Foot)

### Whittaker Detector

<table>
<thead>
<tr>
<th>Aviator UL – Whittaker</th>
<th>Fan Exit Meter</th>
<th>Min % Obsc</th>
<th>Rosco – Whittaker</th>
<th>Fan Exit Meter</th>
<th>Min % Obsc</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN</td>
<td></td>
<td></td>
<td>RUN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb7 001</td>
<td></td>
<td>4.4</td>
<td>Feb8 007</td>
<td></td>
<td>4.3</td>
</tr>
<tr>
<td>Feb7 002</td>
<td></td>
<td>2.8</td>
<td>Feb8 008</td>
<td></td>
<td>3.4</td>
</tr>
<tr>
<td>Feb7 003</td>
<td></td>
<td>2.0</td>
<td>Feb8 009</td>
<td></td>
<td>5.0</td>
</tr>
<tr>
<td>Feb7 004</td>
<td></td>
<td>2.5</td>
<td>Feb8 010</td>
<td></td>
<td>5.8</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td><strong>2.9</strong></td>
<td><strong>Average</strong></td>
<td></td>
<td><strong>4.6</strong></td>
</tr>
</tbody>
</table>
Detectors Leaving Alarm

Whittaker Detector

![Graph showing comparison between Aviator UL and Rosco in terms of %Obscuration/Foot. Aviator UL has a %Obscuration of 2.9, while Rosco has a %Obscuration of 4.6.](image-url)
Detectors Leaving Alarm

Detectors Leaving Alarm

%Obscuration / Foot

Aviator UL

2.9

5.2

Rosco

4.6

Whittaker Detector

Kidde Detector
Detectors Leaving Alarm

% Obscuration / Foot

- Whittaker Detector
- Kidde Detector

Aviator UL:
- 2.9
- 5.2

Rosco:
- 4.6
- 48.5
Detectors Going Into Alarm

Aviator UL - Whittaker - 2.5V Fan

- %Obscuration / Foot
- Time (sec)

Federal Aviation Administration
Detectors Going Into Alarm
Rosco – 8V Fan

![Graph 1: %Obscuration vs. Time for Rosco - Whittaker - 8V Fan]

![Graph 2: %Obscuration vs. Time for Rosco - Whittaker - Fan 8V]

Federal Aviation Administration
Detectors Going Into Alarm

Detectors Leaving Alarm with Aviator UL

%Obscuration / Foot

Aviator UL 2.5V Fan

Whittaker Detector

Kidde Detector
### Particle Size

- Particle Sizes were measured while each detector alarmed to account for difference in alarm time
- Aviator UL recorded smaller particle sizes
- PDPA recorded significantly less amount of particles with the Aviator UL than with the Rosco

| Rosco – Whittaker | | | |
|-------------------|---|----------------|
| RUN               | D10 (um) | # Particles Averaged |
| March20 005       | 3.5       | 2079.0          |
| March20 006       | 3.5       | 502.0           |
| March20 007       | 3.5       | 2192.0          |
| March21 001       | 3.3       | 9457.0          |
| Average           | 3.5       |                 |

| Aviator UL – Whittaker | | | |
|-------------------------|---|----------------|
| RUN                     | D10 (um) | # Particles Averaged |
| March20 014             | 1.7       | 123.0          |
| March20 015             | 1.6       | 189.0           |
| Average                 | 1.7       |                 |
PDPA Limitations

• The lowest diameter size that it can measure is 0.4 microns and for the configuration that we have, 0.5 microns.

• The minimum and maximum particle size bounds depend on the transmitter fringe spacing, the PDPA receiver focal length, the off axis angle of the receiver to the transmitter and the refractive index of the particle we are measuring.

<table>
<thead>
<tr>
<th></th>
<th>Aviator UL</th>
<th>Rosco</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle Sizing Off</td>
<td>662 particles</td>
<td>2592 particles</td>
</tr>
<tr>
<td>Particle Sizing On</td>
<td>287 particles</td>
<td>2530 particles</td>
</tr>
</tbody>
</table>
Particle Size

- Particle Size between detector alarms only differed by 0.1-0.2 microns
- Aviator UL showed to have smaller particle sizes than the Rosco

<table>
<thead>
<tr>
<th></th>
<th>Whittaker Detector (microns)</th>
<th>Kidde Detector (microns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosco</td>
<td>3.5</td>
<td>3.6</td>
</tr>
<tr>
<td>Aviator UL</td>
<td>1.7</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Rosco Light Fog Fluid

- Rosco Light smoke is visually similar to Aviator UL smoke
- Rosco Clear fluid was able to alarm the Kidde detector at 48% Obscuration per foot.
- Average D10 Particle Size 4.0 microns
- Rosco Light fluid was unable to alarm Kidde detector, the %Obscuration per foot could not reach a high enough percent obscuration
- The Rosco Light has large particle size and doesn’t create smoke dense enough to alarm the false alarm resistant detector
Summary

• The Kidde detector is hypothesized to depend on particle size detection first and percent smoke obscuration second.

• The oil based particles brought the Kidde detector into and out of alarm sooner than with the Whittaker.

• With water based particles, smoke needed to be very dense to alarm the Kidde detector but not the Whittaker.

<table>
<thead>
<tr>
<th>Aviator UL</th>
<th>Into Alarm</th>
<th>Leaving Alarm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whittaker</td>
<td>5.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Kidde</td>
<td>3.3</td>
<td>5.2</td>
</tr>
</tbody>
</table>
Questions or Comments?

Tina Emami
FAA William J. Hughes Technical Center
ANG-E212 Materials Fire Test
Building 275
Atlantic City Int’l Airport, NJ 08405
tina.emami@faa.gov