Heat Flux and Thermal Response Measurements for Designing a Propane Fuel Fast Cook Off Test Apparatus

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Agenda

• Background
• Description of Propane Burner at W91 Laboratory
• Instrumentation Overview
• Test Layout
• Test Results
  – Temperature Measurements
  – Heat Flux Measurements
• Summary
Background

• Increased Environmental Regulation has limited the use of Liquid Fuel Fires due to soil, ground water contamination, air quality
• Several countries have already switched to propane as an cleaner burning alternative fuel
  – Canada
  – Sweden
  – Germany
• Current joint effort with China Lake focuses on measuring heat fluxes in liquid fuel fires and in propane fires using multiple instruments
• This presentation focuses on the results of recent testing at a propane fast cook off facility in Germany.
W91 Laboratory
Propane Burner

Chamber Overall Dimensions

Burner Arrangement in Chamber

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Igniter tubes 4 5/8 I.D.
Same elevation as burner tubes

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Test No. 2 Video
Instrumentation

Plate Thermometer - PT

- 0.7 mm Inconel plate
- Thermocouple welded on back side of plate
- Insulation

Directional Flame Thermometer - DFT

- Inconel plates
- Type K thermocouples welded to centers of inner surfaces
- Insulation
High Temperature Heat Flux Gage - VT

\[ q'' = \Delta V_1 + \Delta V_2 \]

Alumel ®
Chromel ®
Insulation

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Generic Test Item

HTHFG - VT

- 3/18-16 Hole
- Sensor Recess
- Thermocouple Grooves
- 1/4-20 Hole
- Type K thermocouples welded to surface
Test Layout – Instrumentation Basket

Beaded Thermocouples
Test Layout – Instrumentation Basket
Test Layout – Instrumentation Basket

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PT and DFT Positions

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Test 2 wind, 1.6 m/s from the West
Temperature Data

Beaded Thermocouples

All temperatures are in degrees Celsius

- 935 Front, N
- 1170, East
- 900 Back, S
- 1105 West

Average = 1125 °C
Temperature Data

STANAG 4240 Test (Flame) Requirements: An average flame temperature of at least 800°C, as measured by all valid thermocouples (sample rate > 0.2 Hz) at the test item.

The flame temperature shall reach 550°C in the order of 30 seconds after ignition as measured by any two of four flame thermocouples.
Max Temperatures
PTs Test #2

<table>
<thead>
<tr>
<th>PT</th>
<th>Front</th>
<th>PT 2</th>
<th>PT 3</th>
<th>PT 4</th>
<th>PT B</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT 1</td>
<td>969</td>
<td>1055</td>
<td>n.d.</td>
<td>1018</td>
<td></td>
</tr>
<tr>
<td>PT 2</td>
<td>1055</td>
<td>1061</td>
<td>1018</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PT 3</td>
<td>1018</td>
<td></td>
<td>1061</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PT 4</td>
<td>n.d.</td>
<td></td>
<td></td>
<td>1008</td>
<td></td>
</tr>
</tbody>
</table>

Ave = 1022
Std Dev = 38

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Max Temperatures
DFTs Test #2

Note: Temperatures were still rising when flame was shut off

f = front plate of DFT
b = back plate

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Generic Test Item
Surface Temp Data

Ave = 462
S.D. = 49
degrees C
Centerline and Average of Beaded Thermocouple Temperatures

- Temperature rise at center of generic test item
- Temperature rise of the average of beaded thermocouples

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## Heat Flux Data

### PTs Test #2

<table>
<thead>
<tr>
<th>Location</th>
<th>Heat Flux (Kw/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT 1</td>
<td>50.6</td>
</tr>
<tr>
<td>PT 2</td>
<td>72.0</td>
</tr>
<tr>
<td>PT 3</td>
<td>59.2</td>
</tr>
<tr>
<td>PT 4</td>
<td>72.8</td>
</tr>
<tr>
<td>Front</td>
<td>60.8</td>
</tr>
<tr>
<td>n.d.</td>
<td></td>
</tr>
</tbody>
</table>

**Average:** 63.1  
**SD:** 9.4

**Graph:**

*Graph showing heat flux data over time for PTs Test #2.*
Heat Flux Data
DFTs Test #2

f = front plate of DFT
b = back plate

82 f
76 b

161 f
81 b

115 f
82 b

160 f
72 b

131 f
105 b

Average front = 131 kW/m²,
s.d. = 30
Average back = 84 kW/m²,
s.d. =12

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Generic Test Item
Heat Flux Data, Test #2

Grand average
100 Kw/m²
s.d. = 15

HF 3 & 4

HF 1 & 2

HF 5 & 6

Ave = 96
s.d. = 16

Ave = 99
s.d. = 17

Ave = 109
s.d. = 11

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Summary

• Extensive data on the test item thermal environment in a propane fuel fast cook off fire have been collected

• The data from each sensor type are self consistent, but there are significant differences between the data sets from the various types of sensors

• There are gradients in the temperature and heat flux as one travels from below the basket to above the basket.
Acknowledgements

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Questions??