Hot Surface Ignition Apparatus for Aviation Fluids

N. Albert Moussa, Kulbhushan Joshi, Kevin Vier and Tensin Nanchung
BlazeTech Corp., 29B Montvale Ave., Woburn, MA
&
Gregory Czarnecki
USAF AFMC, 96 TG/OL-AC, WPAFB
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Outline

• Background
• Difficulty of measuring hot surface ignition
• BlazeTech Approach
• Experimental setup
• Test results
Background

Auto Ignition Temperature (AIT)  Hot Surface Ignition Temperature (HSIT)
Factors Affecting HSIT

• Hot surface
  – Material (catalytic), geometry, dimensions, orientation, shape, thermal mass, thermal properties, presence of obstacles

• Fluid
  – Composition, presence of contaminants, thermophysical properties, Leidenfrost effect, ignition kinetics
  – Rate and amount of fluid injection

• Environment
  – Air pressure, temperature and velocity (direction, flow regime, boundary layer dimensions relative to liquid drop)
Hot Surface Ignition Temp. from Various Sources
Challenges in HSIT Measurements – Temperature Variation with Time During Tests

![Graph showing temperature variation with time during tests.](image)

**5606 Spray Onto Duct**

- **5606 Spray On**: 5606 spray onto duct
- **THSI-n**: Duct thermocouple no. "n"
- **5605 Spray On**: 5605 spray on
- **Air Heated Duct**: Air heated duct
- **Ventilation**: Ventilation
- **Ignition**: Ignition

**Parameters**

- **Va = 2 FT/SEC**
- **Po = 14.2 PSIA**
- **Ta = 110 DEG F**

**Graph Details**

- **X-axis**: Time (seconds)
- **Y-axis**: Duct temperature (deg F)
- **Legend**: Various temperature readings from different locations (THSI-1 to THSI-8)

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**BlazeTech**

Bringing Science to Safety
BlazeTech Approach to Measuring HSIT

- Design an apparatus with:
  - Flat horizontal plate with simplest flow field (buoyancy)
  - Minimize quenching so that
  - $T_{\text{surface}}$ (before liquid injection) $\sim T_{\text{surface}}$ (at ignition)

- Requirements:
  - Low injected volume (20 to 300 µL – used micropump)
  - Plate must have high thermal mass and high thermal diffusivity ($\alpha_{\text{SiC}} \gg \alpha_{\text{Stainless steel}}$)
Hot Plate Design

Heater (Silicon Nitride, 8mm thick)

Insulation (Cordierite, 10 mm thick)

Hot Plate (Silicon Carbide, D=30 cm, 15 mm thick)

Insulation (CS85, 1 in thick)

Durock Cement Board (3 ft x 5 ft)
Plate with Step vs. Flush Plate

Velocity Contours

Temperature Contours
Surface Temperature Distribution of Plate

Surface Temperature Distribution with 600°C Setpoint

- Avg: 490.1°C
- StdDev: 3.57°C

Surface Temperature Distribution with 750°C Setpoint

- Avg: 747.9°C
- StdDev: 8.05°C
Surface vs. Internal (7mm) Temperature

Steady state 1-D heat transfer analysis (infinite slab of SiC)
Surface emissivity $\epsilon$ is grey
Heat transfer coefficient and $\epsilon = f(T)$

<table>
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<th>$T_{surf}$ [$^\circ$C]</th>
<th>$T_{TC}$ [$^\circ$C]</th>
<th>$\Delta T$ [$^\circ$C]</th>
<th>$\Delta T$ [%]</th>
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<td>800</td>
<td>808.3</td>
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Test Parameters

• n-Decane

• Initial tests:
  – Injected volume 20 to 300 μL, instantaneously (0.2 s), injection tip diameter: 0.8 mm, injection tip distance from plate: 20 cm
  – Transition from individual droplet to stream – 50 to 60 μl

• Variations of test parameters:
  – Flow rates of 3 to 30 ml/min, injection duration to 7.8 s, injection tip diameter: 0.6 mm, injection tip distance from plate: 50 cm
Probability of Ignition
5 Repeat Tests

Temperature criteria for Ignition: Probability > 50%
HSIT vs Injected Volume

Temperature criteria for Ignition: Probability > 50%
Effect of Injection Flowrate

![Graph showing the effect of injection flowrate on MHSIT temperature. The graph plots volume injected (μL) against MHSIT (°C). There are different flow rates represented by different markers: 50 μL/s (red squares), 167 μL/s (orange stars), and 500 μL/s (black circles). The graph demonstrates a decrease in MHSIT with an increase in injected volume.](image-url)
MHSIT vs Duration of Injection

![Graph showing the relationship between MHSIT and duration of injection. The graph includes data points for different volumes of injection: 300 µL (blue), 250 µL (green), 200 µL (yellow), 150 µL (orange), and 100 µL (gray).]
Effect of Distance from Injection Tip to Plate

Tip Size = 0.8 mm
Summary of Variations in Test Parameters

• Adding an enclosure decreases the HSIT significantly
• Increasing the tip-to-hot plate distance from 20cm to 50cm decreases the HSIT by 20 °C – effect decreases with increase in volume
• Placing a 3 ft (1 m) diameter screen around the hot plate mostly raised the HSIT by 5°C
• Changing the fuel injector tip diameter from 0.8 to 0.6 mm (at 50cm) produced the same HSIT within ±5°C.
Closure

• HSIT for n-Decane on a flat horizontal plate in a buoyancy-driven flow is given by:

\[ HSIT = 764 \cdot Volume^{0.036} \]

Where HSIT in °C
Volume in µL

• Results consistent with HSIT=650 °C by Kuchta, 1985

• Test parameters scoped out but need to be quantified
Thank you for listening

Questions?