## Hot Surface Ignition Apparatus for Aviation Fluids

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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, Leindenfrost 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*





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# BlazeTech Approach to Measuring HSIT

- Design an apparatus with:
  - -Flat horizontal plate with simplest flow field (buoyancy)
  - Minimize quenching so that
  - $T_{surface}$  (before liquid injection) ~  $T_{surface}$  (at ignition)
- Requirements:
  - Low injected volume (20 to 300  $\mu$ L used micropump)
  - Plate must have high thermal mass and high thermal diffusivity ( $\alpha_{SiC} >> \alpha_{Stainless steel}$ )





# Plate with Step vs. Flush Plate



#### **Velocity Contours**

#### **Temperature Contours**







#### Surface Temperature Distribution of Plate







# 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  $\epsilon = f(T)$ 



# Photos of Test Setup







### **Test Parameters**

- n-Decane
- Initial tests:
  - Injected volume 20 to  $300 \ \mu$ L, 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  $\mu l$
- 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





### MHSIT vs Duration of Injection





# Effect of Distance from Injection Tip to Plate





# 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 buoyancydriven flow is given by:

Where HSIT in °C

Volume in  $\mu L$ 

- Results consistent with HSIT=650 °C by Kuchta, 1985
- Test parameters scoped out but need to be quantified



# Thank you for listening

Questions?

