# Spark Ignition of Kerosene-Air Mixtures

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23rd International Colloquium on the Dynamics of
Explosions and Reactive Systems

University of California, Irvine
July 24-29, 2011

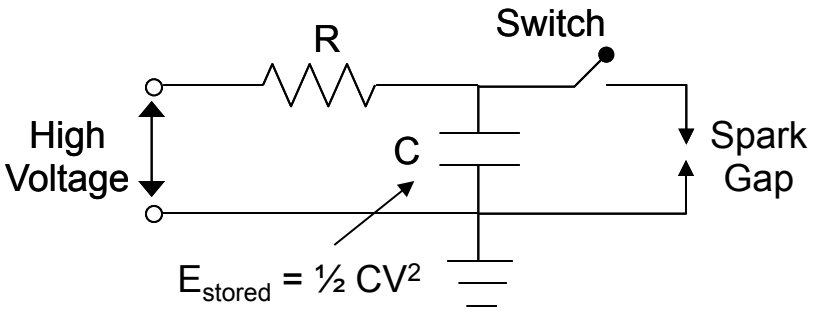
8/11/11

# Spark Ignition and Minimum Ignition Energy

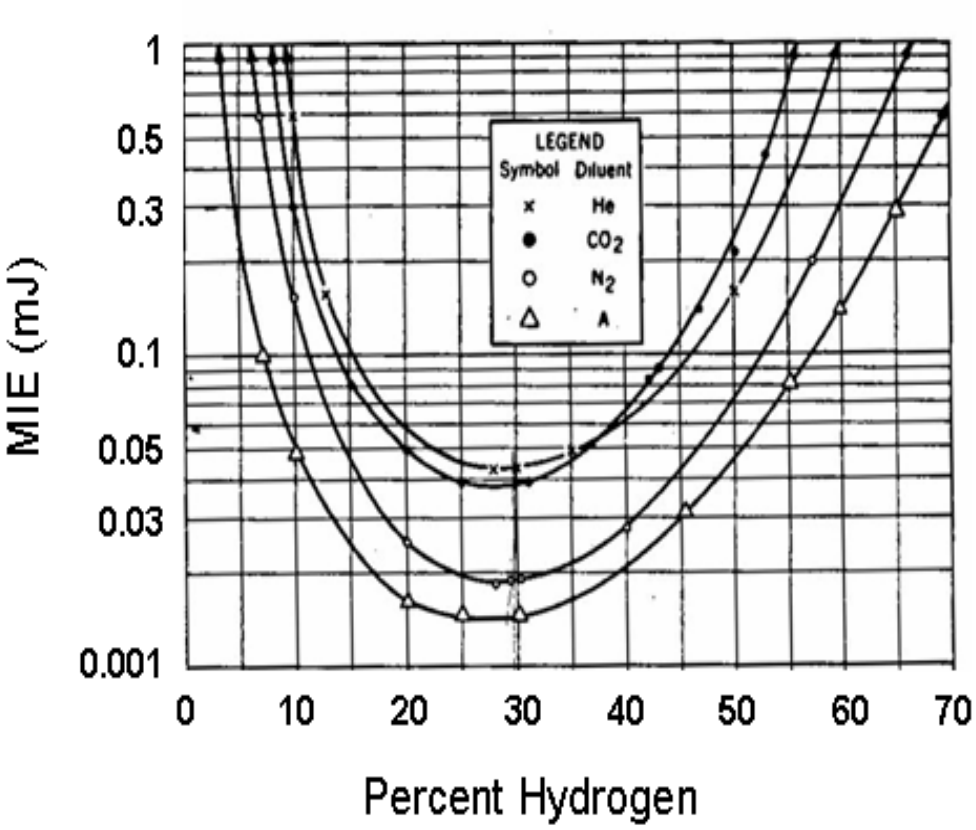
- ***Minimum Ignition Energy*** (MIE) – traditional basis for quantifying ignition hazards

- capacitive spark discharge as ignition source

- pioneering work – Blanc, Guest, Lewis, & von Elbe at Bureau of Mines (1940s)



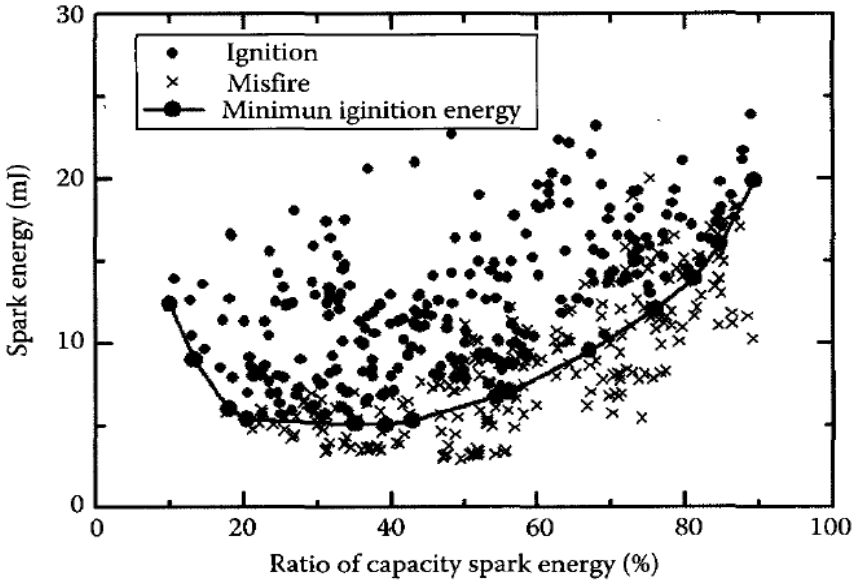

MIE curves for hydrogen mixtures, Lewis and von Elbe (1961)



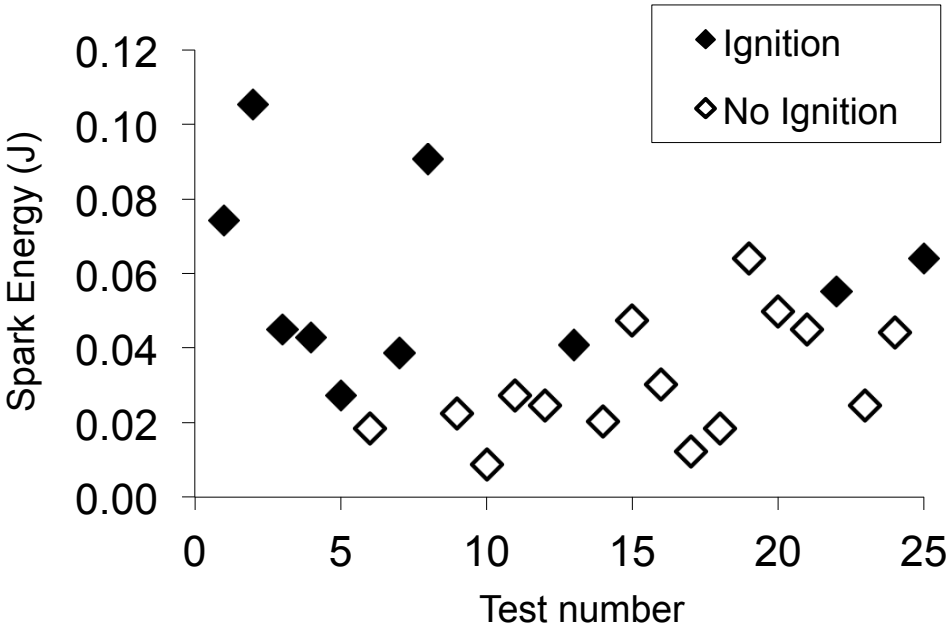
# Statistical Analysis of Ignition Test Data

- ***New viewpoint*** – ignition as statistical phenomenon
- more consistent with test data
- little work done on statistics of ignition of other flammable mixtures
- can't assign a probability to historical MIE data

Stoichiometric Methane-Air
Kono and Tsue (2009)

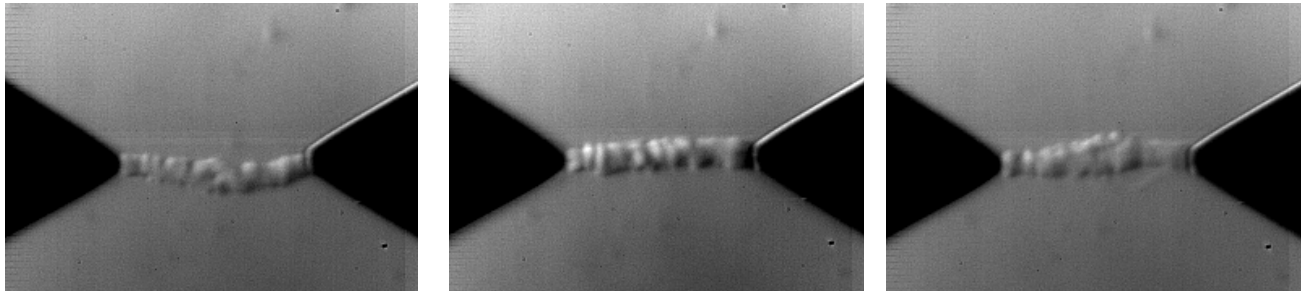



Jet A, Lee and Shepherd (1999)

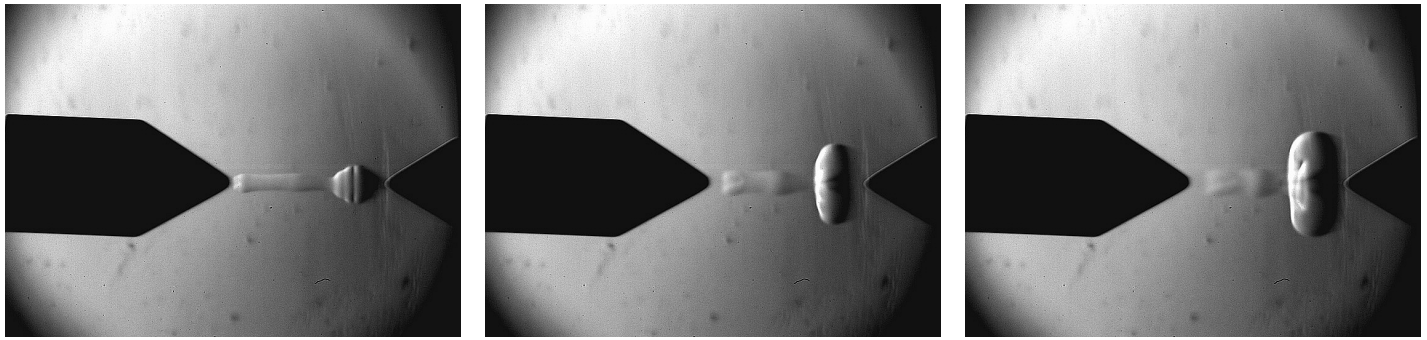


# Spark Breakdown and Spark Channel Formation

## Unpredictable Plasma Instabilities

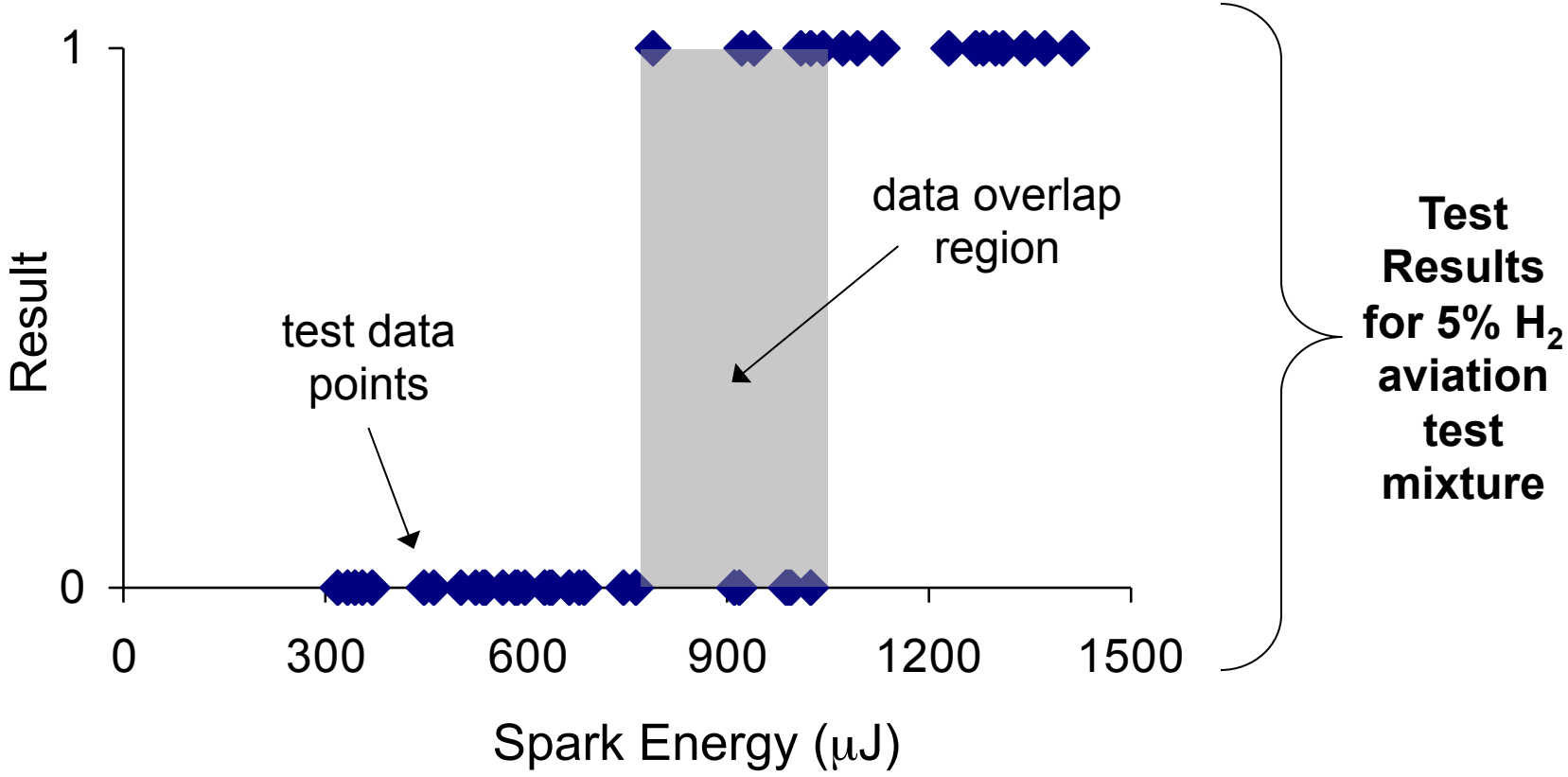


## Localized Ignition



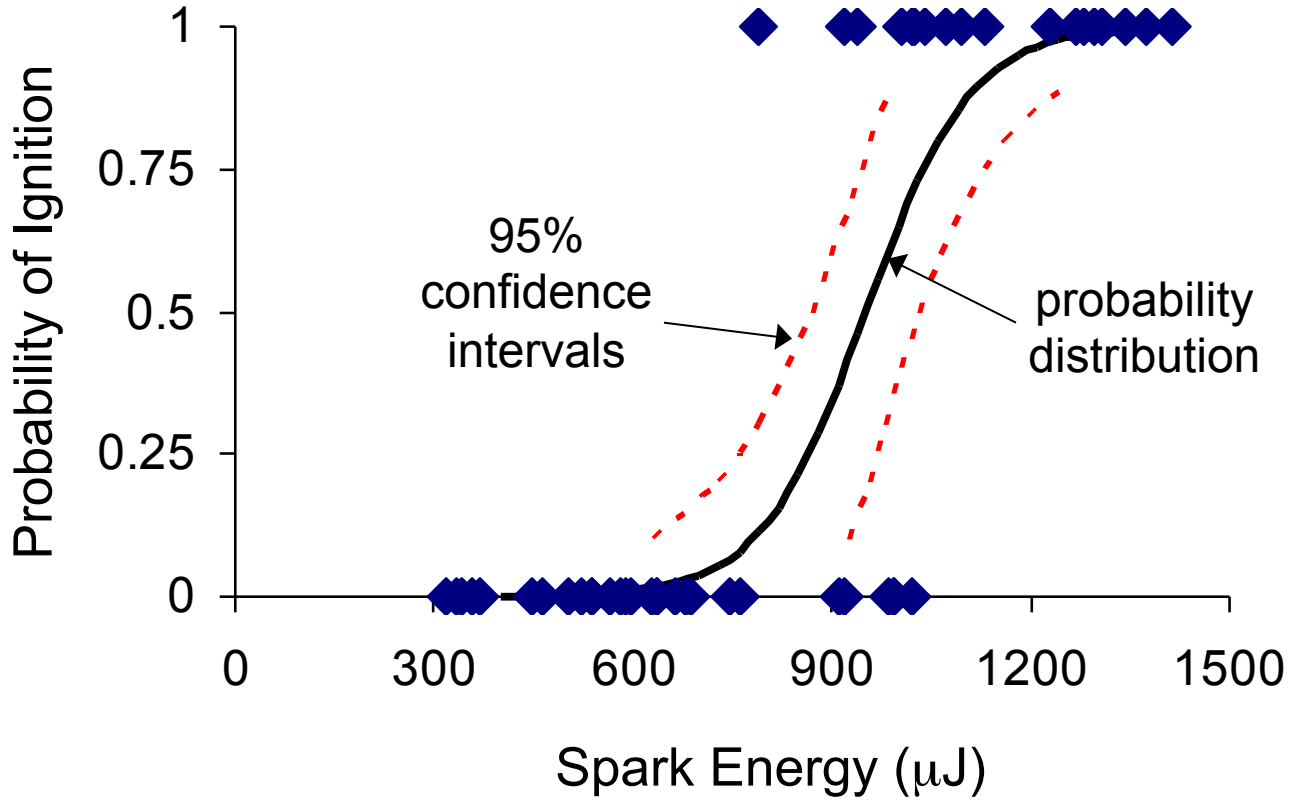
# Statistical Analysis of Spark Ignition Data

- 5% H2, 12% O2, 83% Ar (mixture used in aviation safety testing)
- fix gap (2 mm), vary C to vary spark energy
- no ignition = 0, ignition = 1

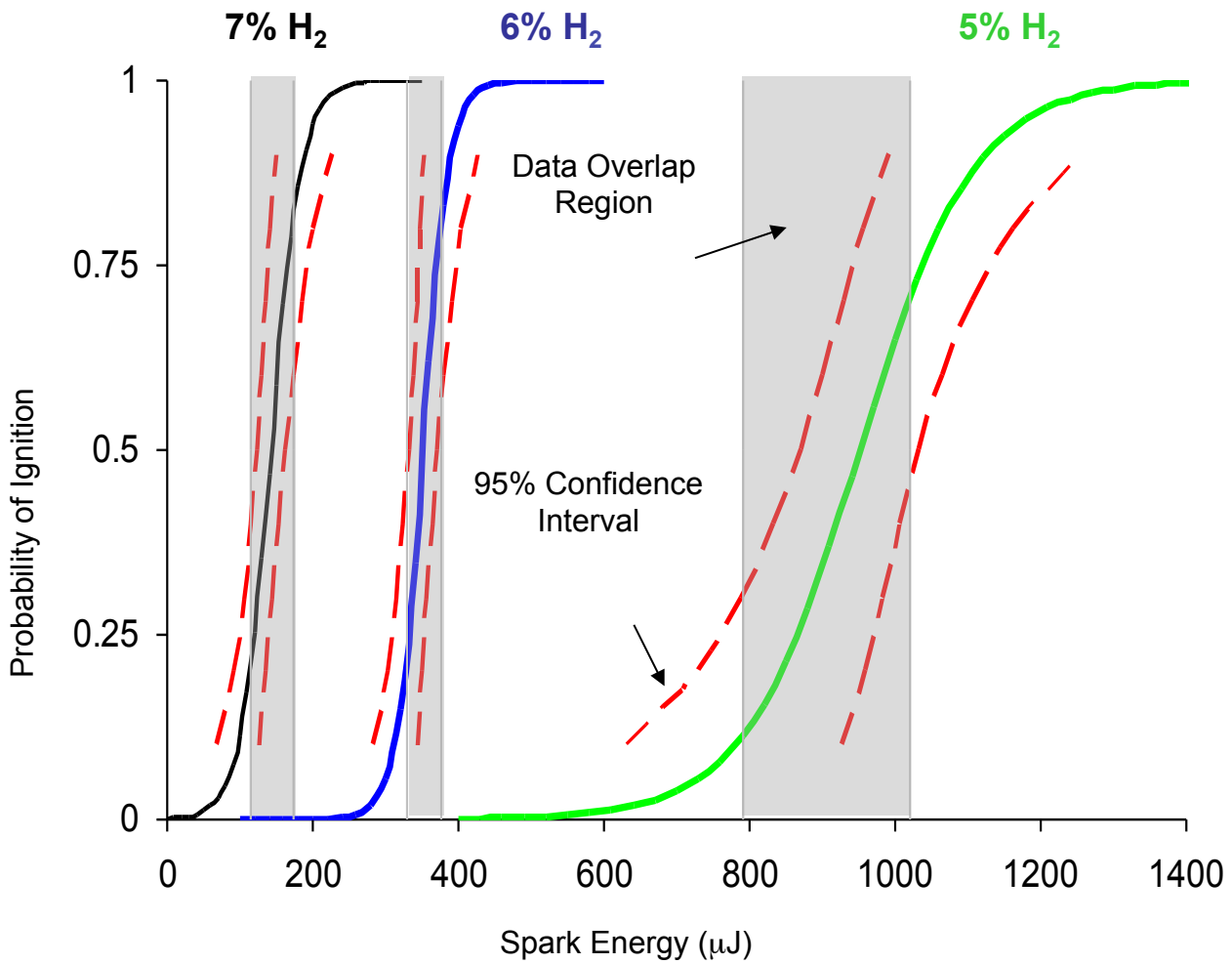


# Statistical Analysis of Spark Ignition Data

**5% H2, 12% O2, 83% Ar**

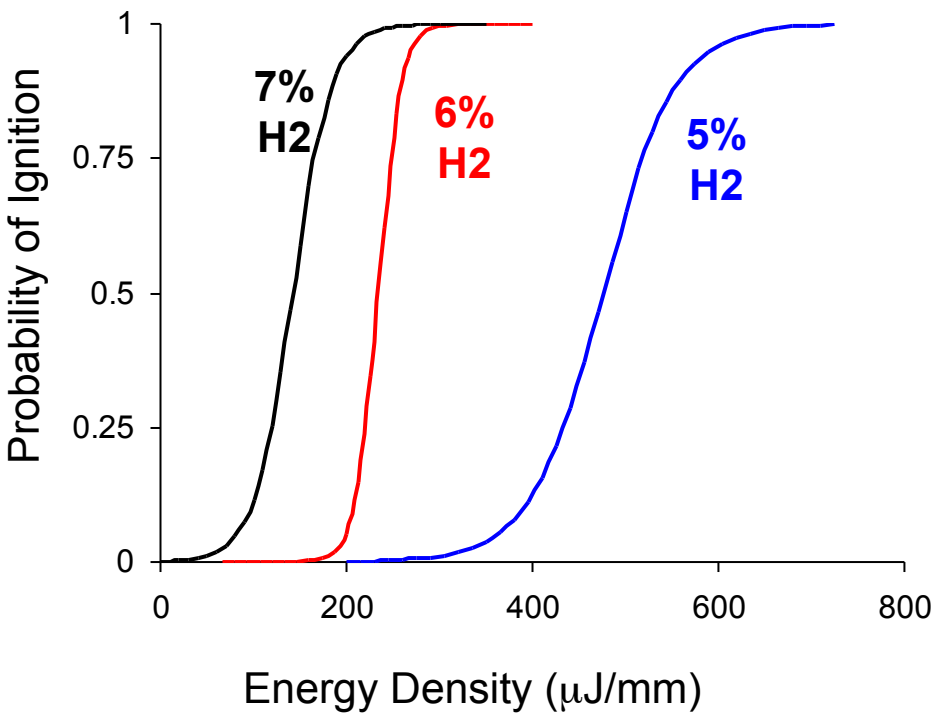


# Probability of Ignition vs. Spark Energy

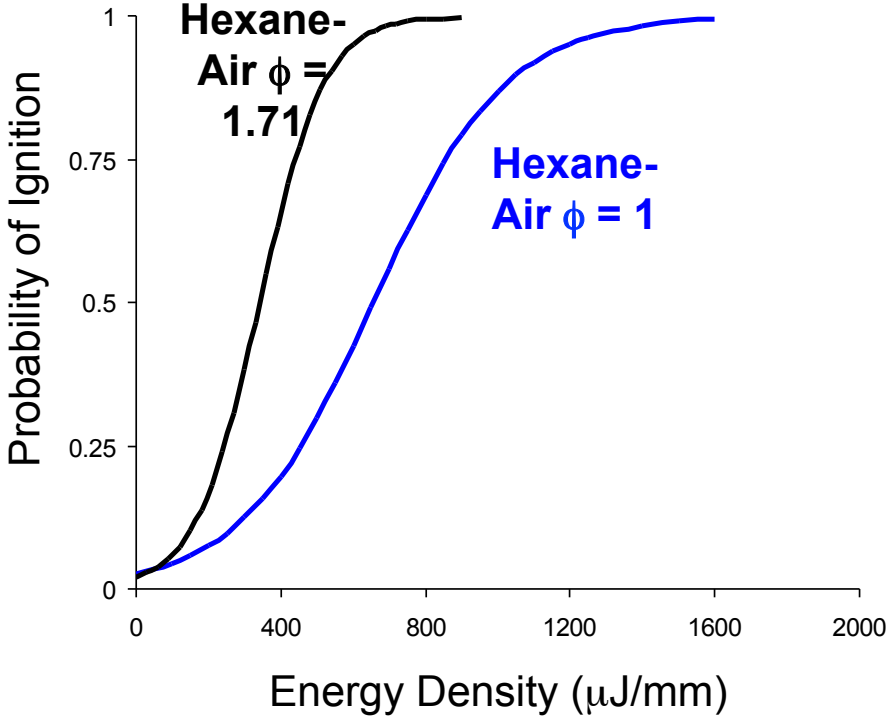


# Spark Energy Density

**Lean-Hydrogen Mixtures, Fixed Spark Length**



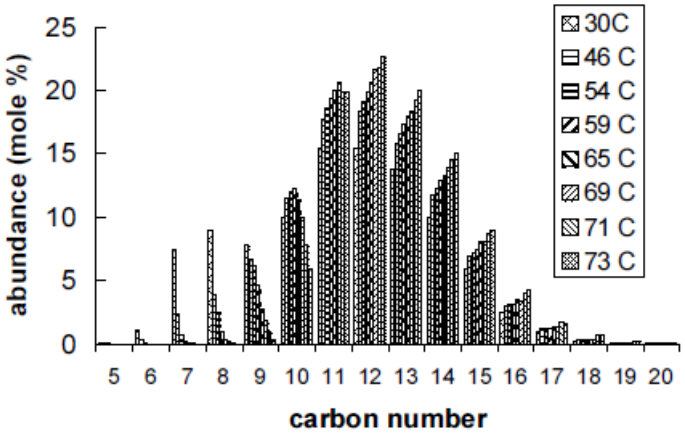

**Hexane-Air Mixtures, Variable Spark Lengths**



# Kerosene Tests: Experimental Considerations

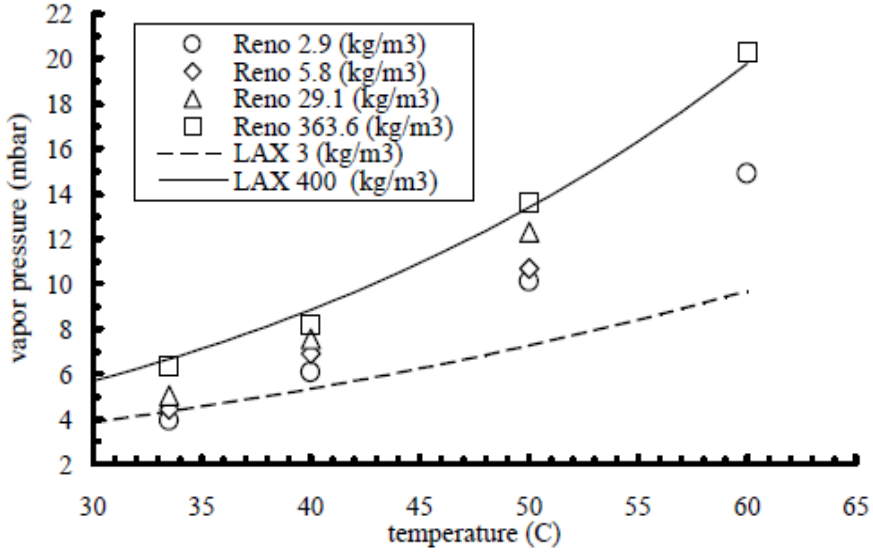
**Much more complex than gaseous explosions with pure fuels**

- low vapor pressure – must heat significantly or decrease pressure
- vapor pressure depends also on fuel mass loading



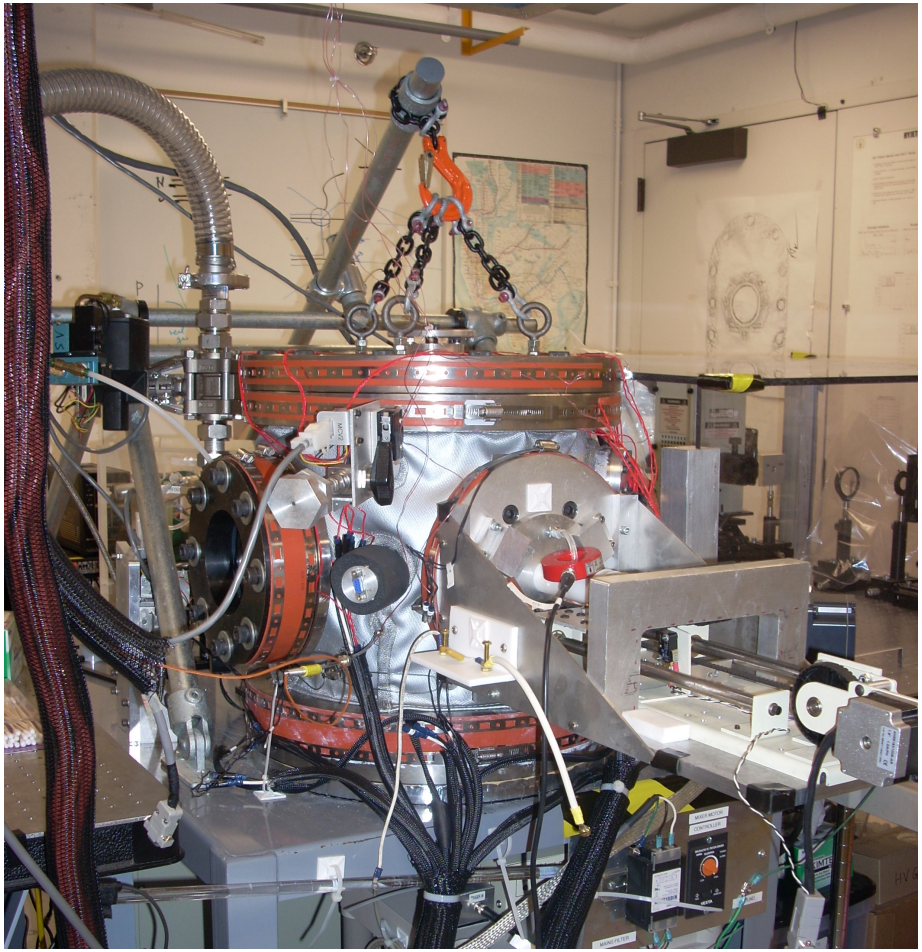

**Gas chromatograph (Woodrow, 2000)**

**Fuel vapor pressure vs. temperature and fuel mass loading (Lee and Shepherd, 1999)**




- exact fuel composition difficult to determine
- composition changes from batch to batch, can be affected by history, transport
- composition of liquid not the same as fuel vapor

# Experimental Setup

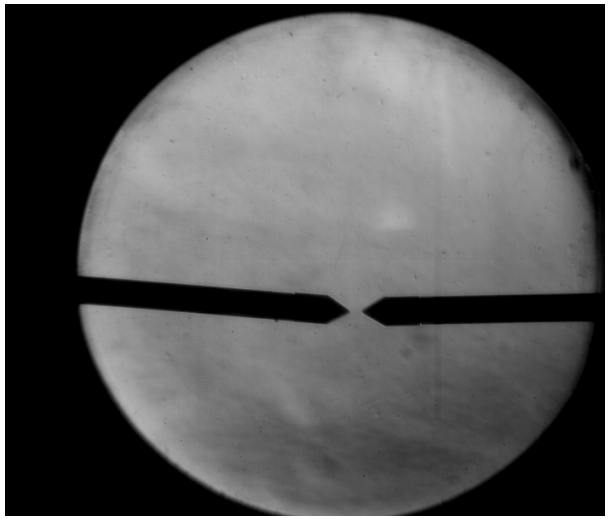


**22 L, stainless steel, cylindrical combustion vessel**

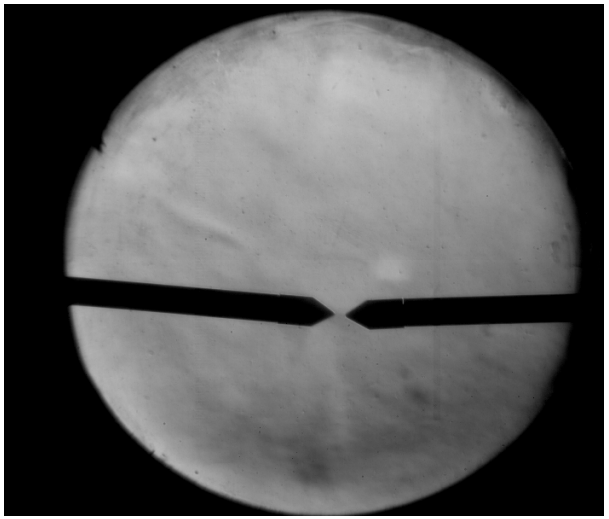
- **Ignition Detection**
  - flame visualization
  - pressure transducer
  - thermocouple
- **Schlieren visualization**
  - high-speed camera (10,000 + frames per second)
- **Vessel Heating System**
  - silicone heaters, 4 zones
  - high-current heater control unit
  - up to ~ 150°C

# Results: Kerosene Ignition

- 1-K kerosene at 45-62°C, 100 kPa
- fixed 3.3 mm spark gap
- 50 kg/m$^3$ fuel mass loading
- C ~ 11 – 68 pF, V ~ 6.4 – 11.4 kV → $E_{spark}$ ~ 0.3 – 2.3 mJ

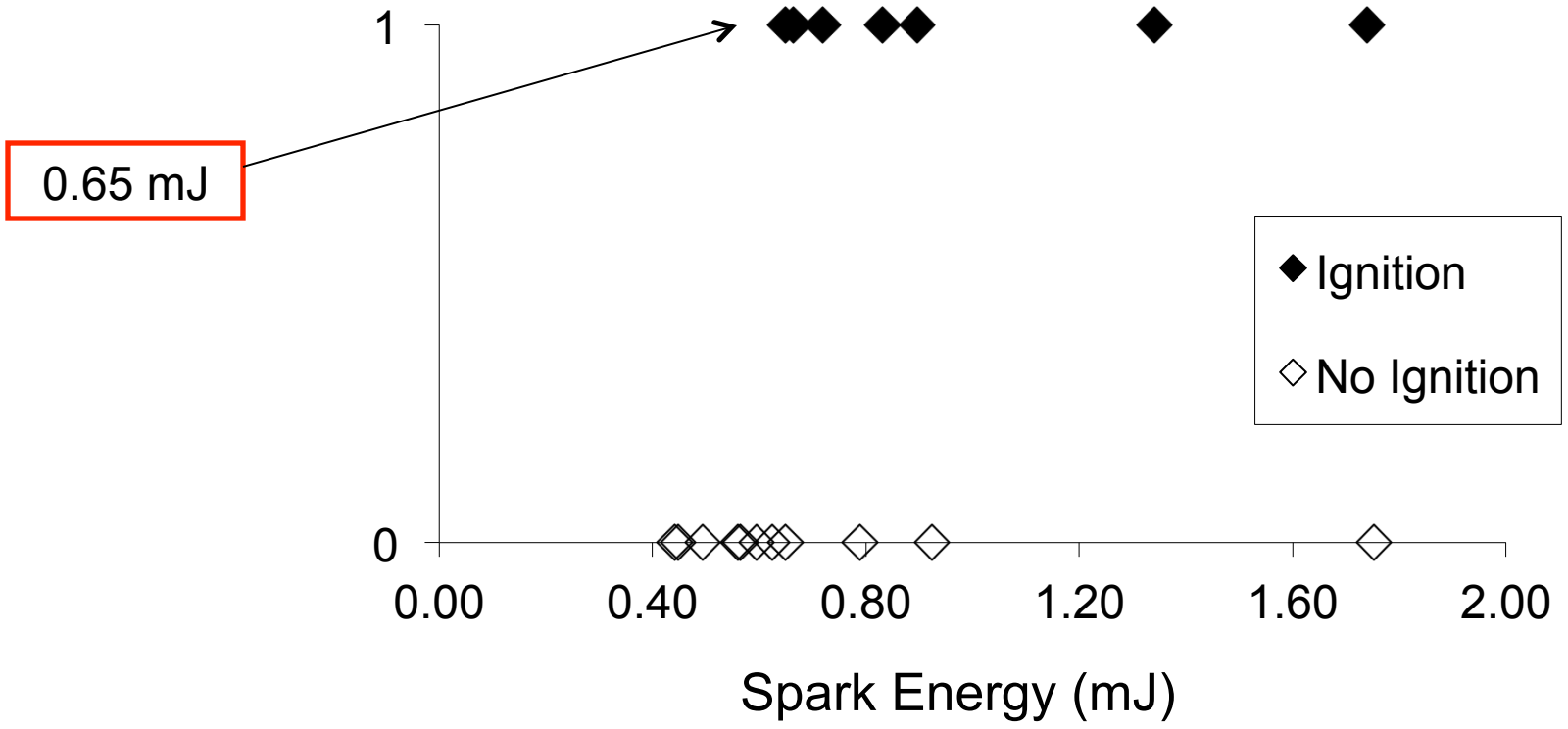


**kerosene-air, 45°C**



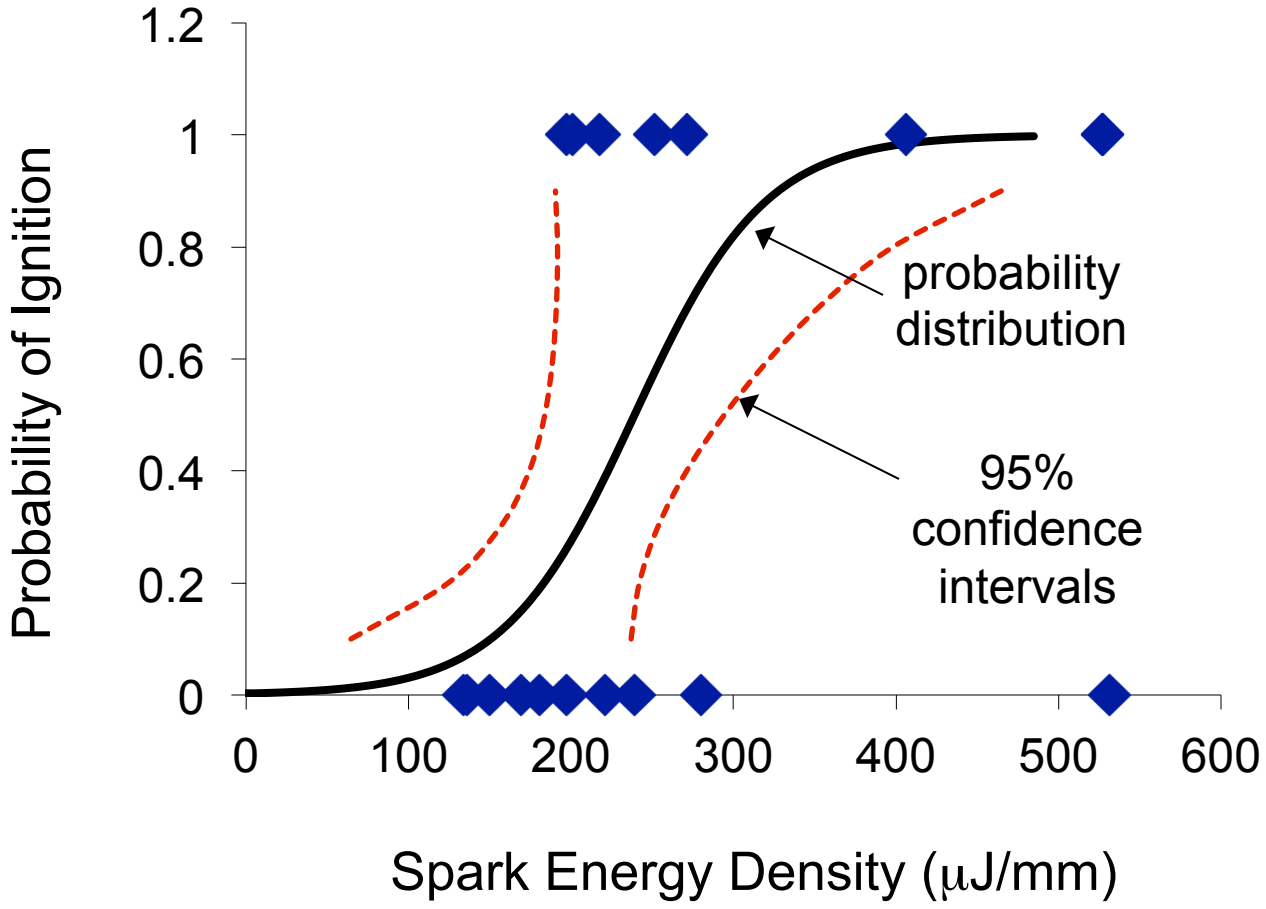
**kerosene-air, 55°C**

# Results: Kerosene-Air at 60°C

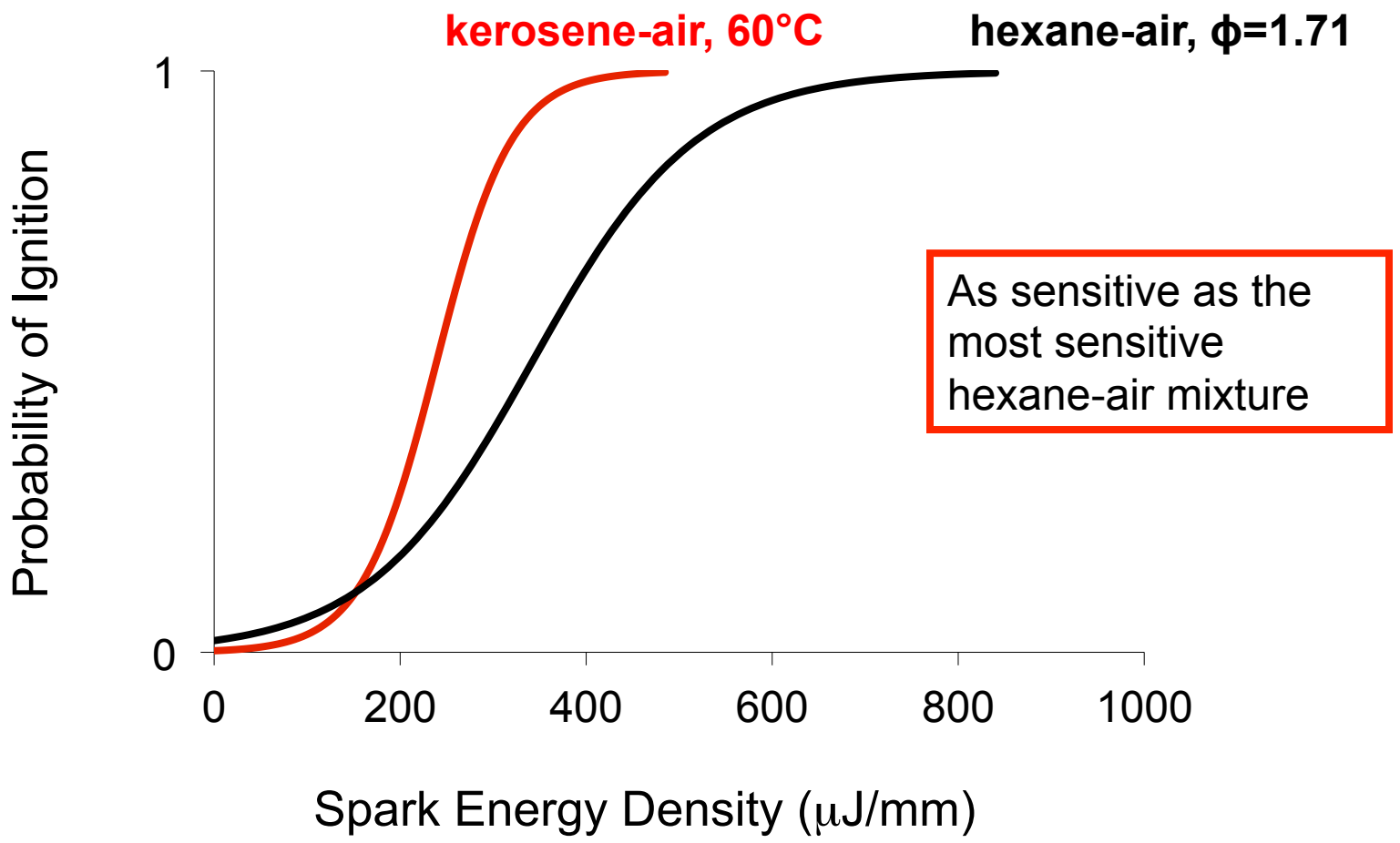



**Previous Work (Lee and Shepherd):** **Lowest ignition energy** = 40 mJ (52°C, 100 kPa); 2 mJ (56.1°C, 58.5 kPa)

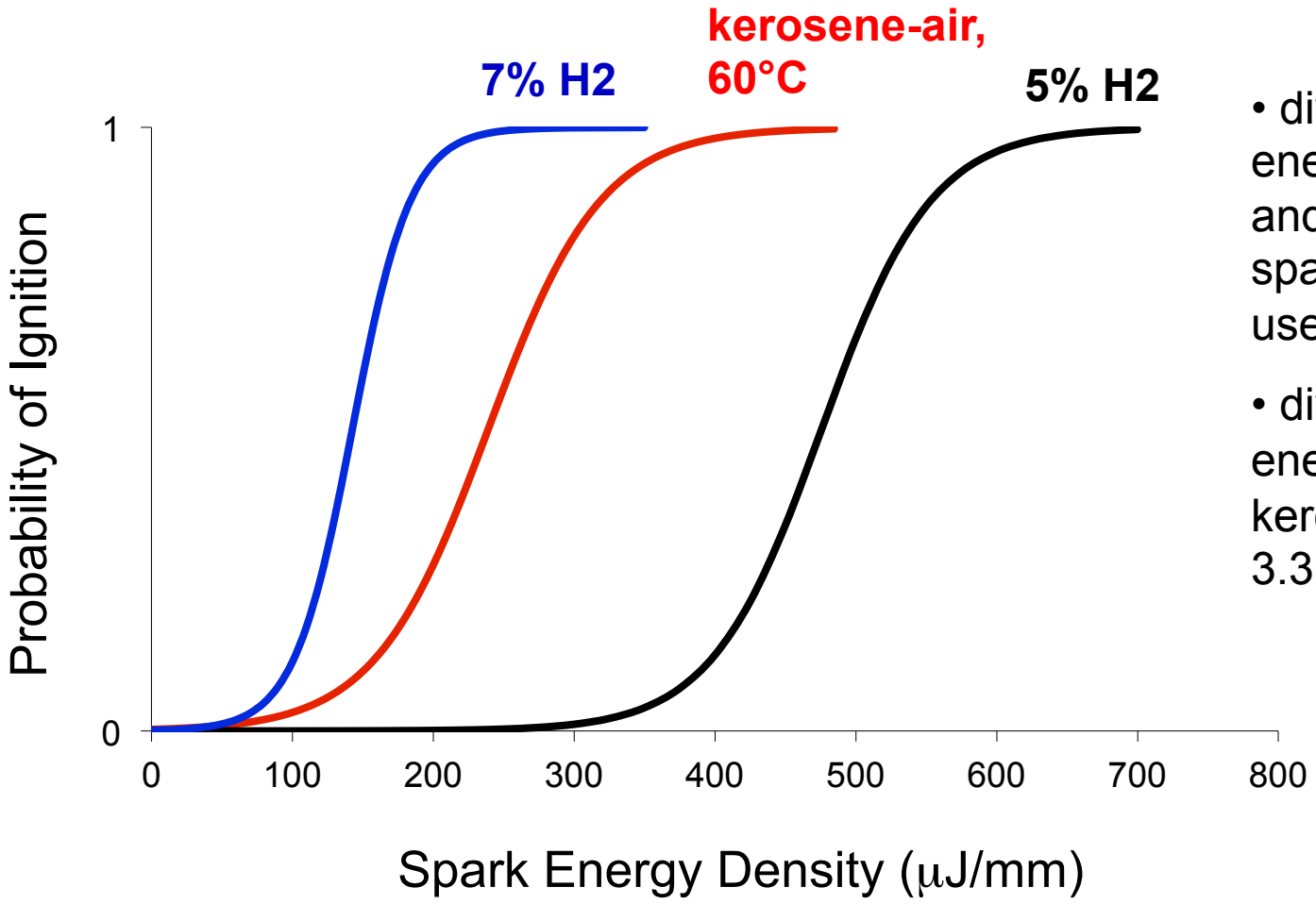
# Results: Kerosene-Air at 60°C



# Results: Comparison with Hexane

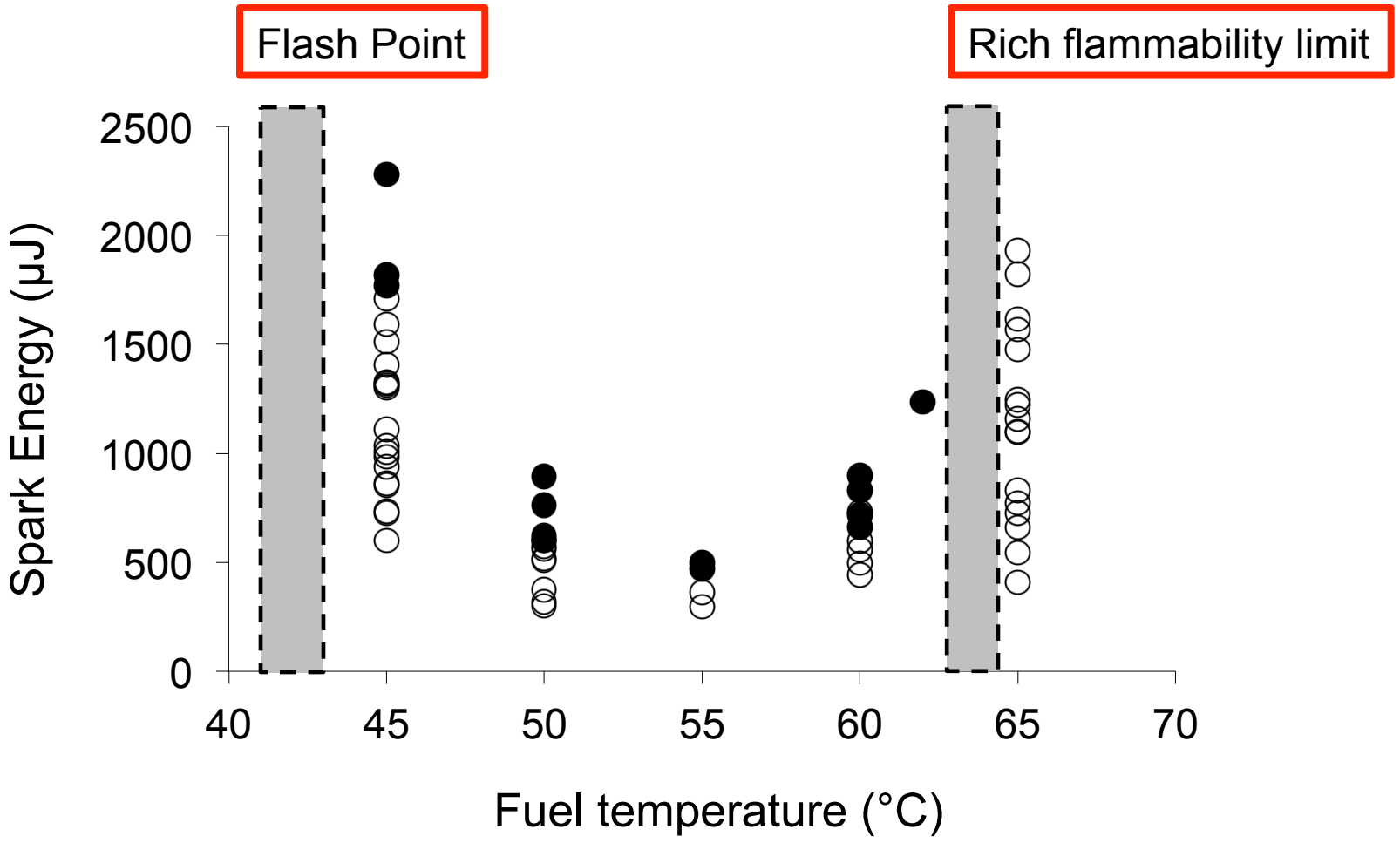


# Results: Comparison with $H_2$



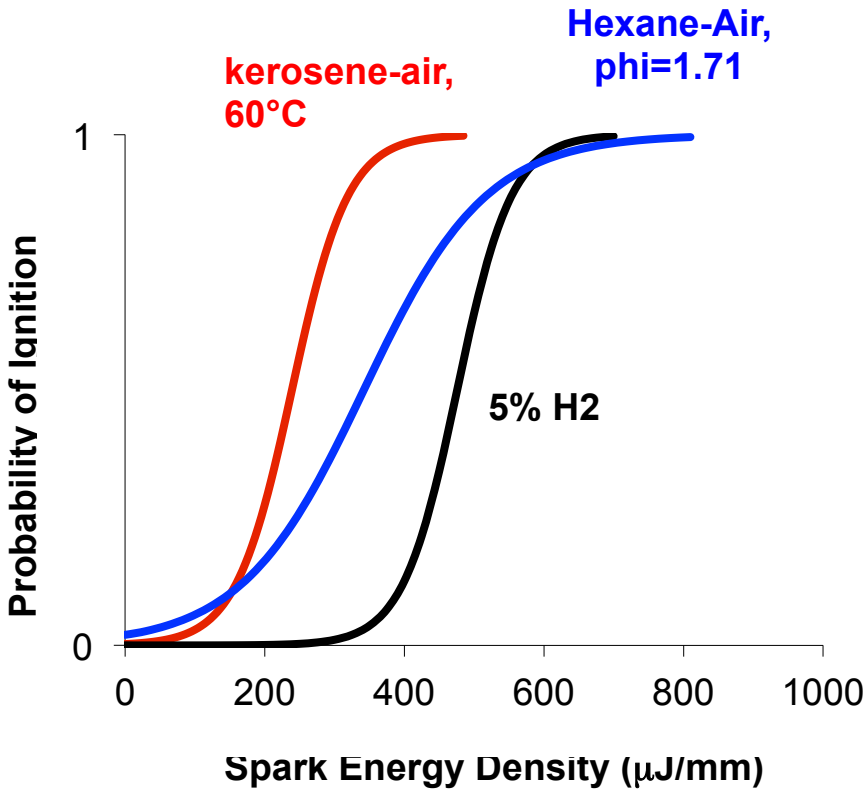

- divide spark energies from 5% and 7% $H_2$ tests by spark gap widths used (2 and 1 mm)
- divide spark energies from kerosene tests by 3.3 mm

# Results: Varying Kerosene Fuel Temperature



# Conclusions

- ❖Spark ignition tests in kerosene at various temperatures
- ❖ Statistical analysis probability of ignition vs. spark energy density
- ❖Comparison with hydrogen, hexane
- ❖ Kerosene-air, 60°C as sensitive as the rich hexane-air mixture
- ❖More sensitive kerosene-air mixture at a lower temperature




❖ The experimental work was carried out in the Explosion Dynamics Laboratory of the California Institute of Technology and was supported by the Boeing Company through a Strategic Research and Development Relationship Agreement CT-BA-GTA-1

# Questions