

# **PROOF OF CONCEPT TEST FOR A REAL-TIME FLARE COMBUSTION EFFICIENCY MONITOR**

**Presented at  
Air & Waste Management Association Louisiana Section  
2013 Fall Conference**

**By  
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# A BRIEF REVIEW OF THE CONCEPT PRESENTED AT 2012 FALL CONFERENCE

Ref.: Zeng and Morris, "A New Method to Measure Flare Combustion Efficiency in Real-Time", presented at AWMA Louisiana Section 2012 Fall Conference, Baton Rouge, Louisiana, October 30-31, 2012

## Flare Combustion Efficiency (CE):

$$CE(\%) = \frac{[C]_{CO_2}}{\sum_i n_i [C]_{HCl_i} + [C]_{CO_2} + [C]_{CO}} \quad \text{Eq. (1)}$$

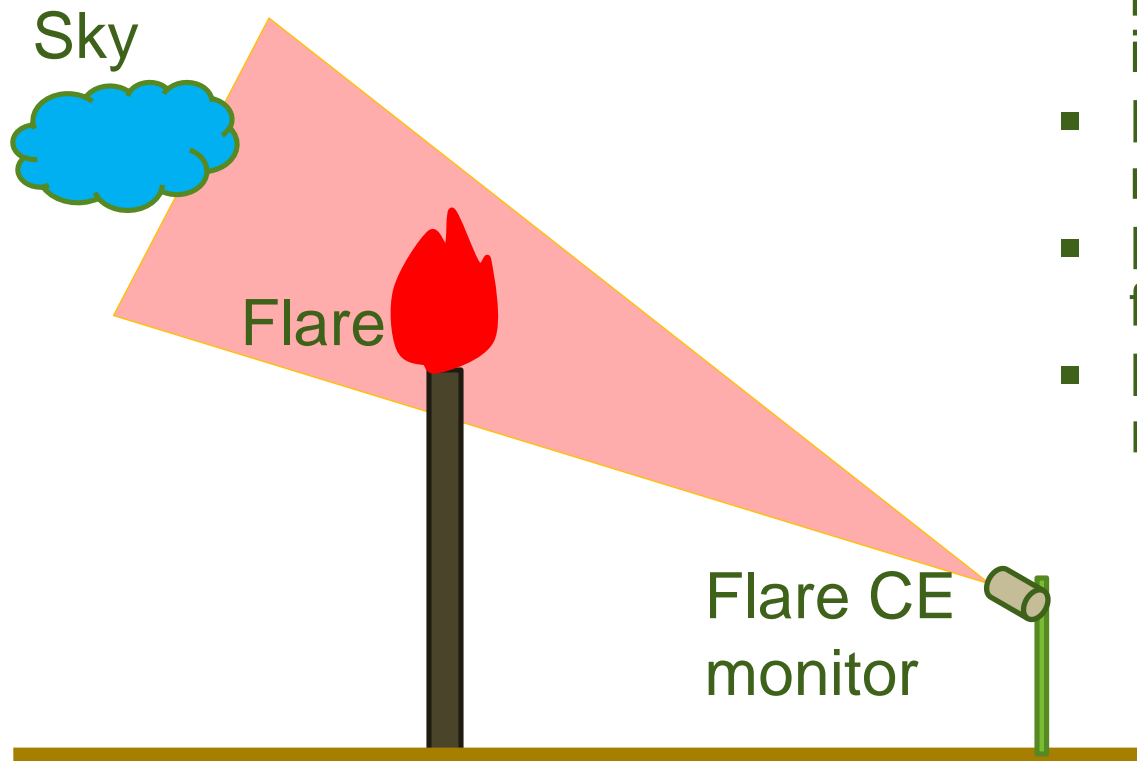
Flare CE – Very difficult to measure



Source: TCEQ/UT



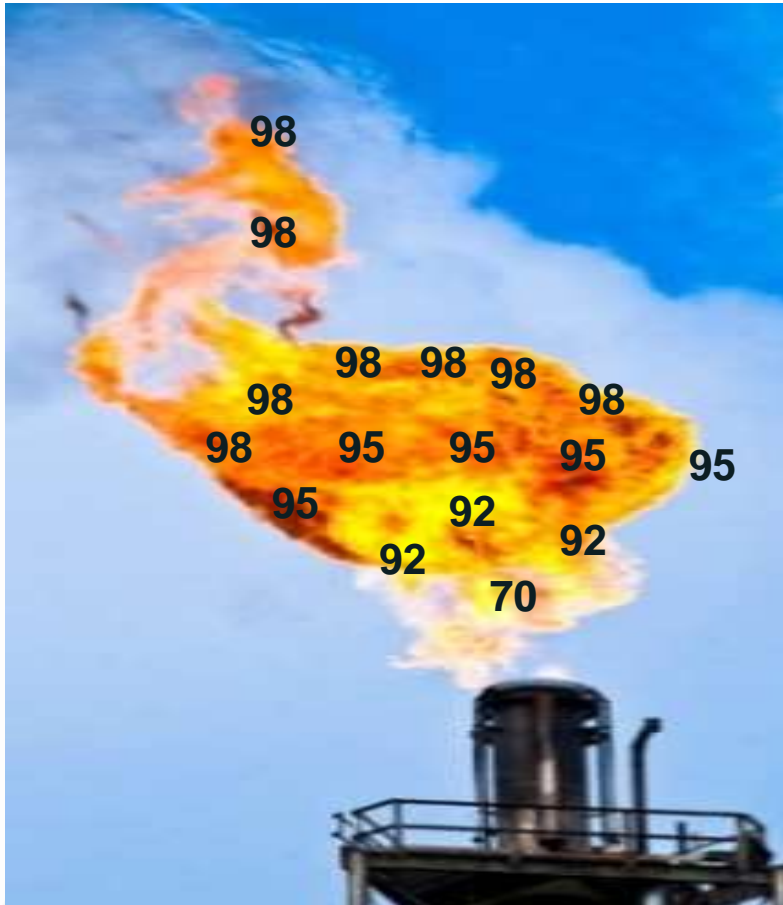
# THE CONCEPT



- Monitor and map flare CE in real time through a special multi-spectral IR imaging device
- Not a path measurement
- No scanning; high frame rate
- No operator required

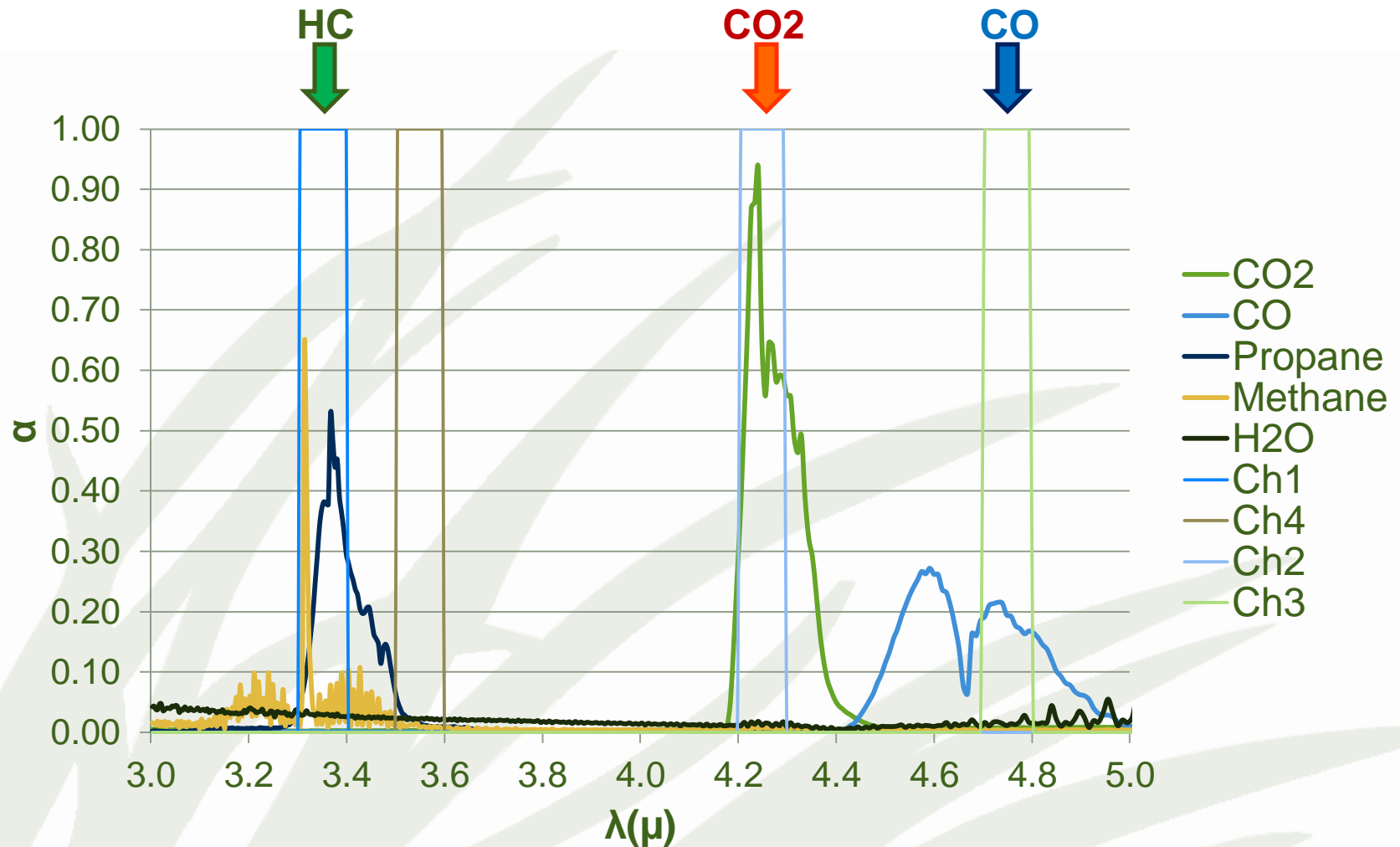
We call it “Flare Efficiency Monitoring System” or “FEMS”

# VISION



- Monitor flare CE in real-time
- Image the full flare flame; measure both overall CE and CE at a pixel level (CE mapping)
- Industrial grade device, suitable for integration with PLC or DCS
- One monitor covers multiple flares on site (step and stare)

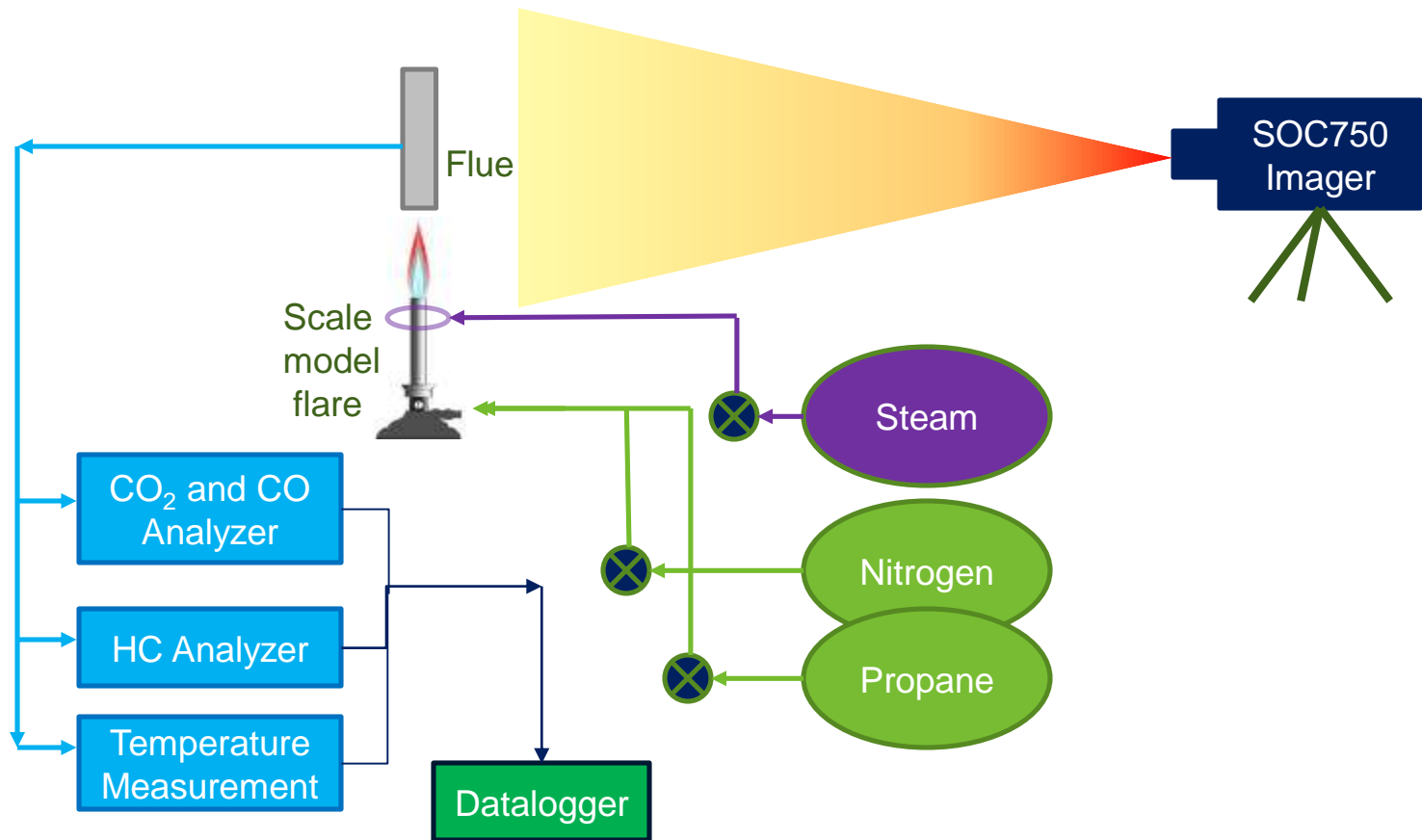
# WORKING PRINCIPLE



# PROOF OF CONCEPT TEST

The proof of concept test was partially funded by EPA SBIR Phase I grant.

# TEST SETUP







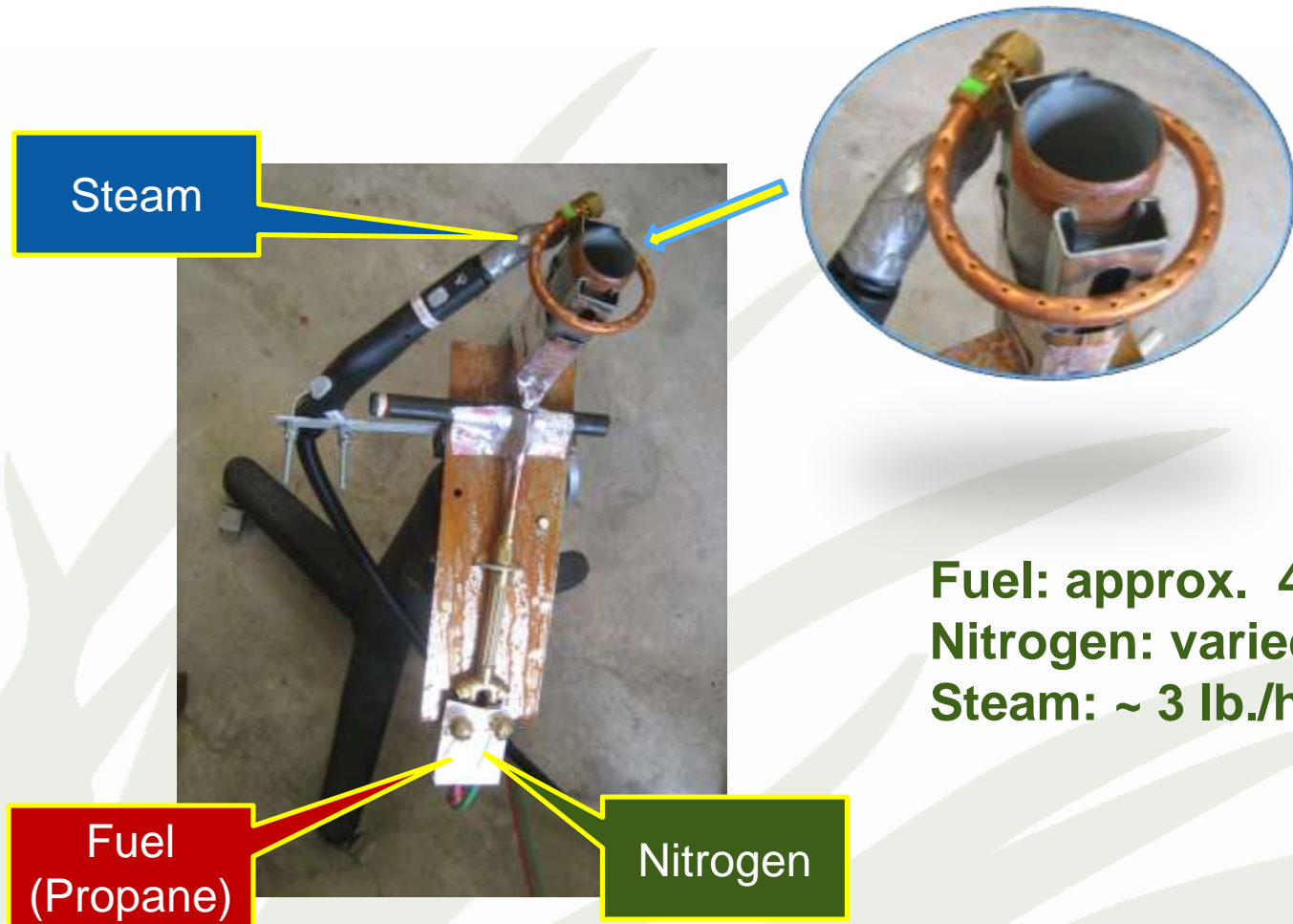
**Scale model flare,  
Flue w/ Sampling Probe, and  
Analyzers**

**Distance from  
the scale model flare  
to the Imager: 23 ft.**



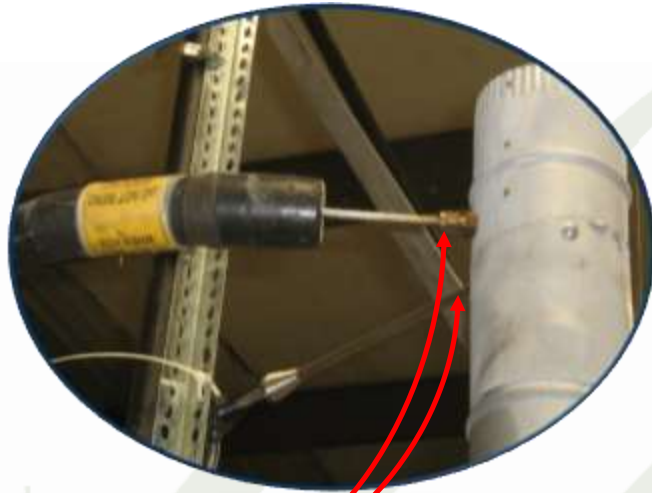
**SOC750  
Hyper-Spectral  
Imager**

# SCALE MODEL FLARE

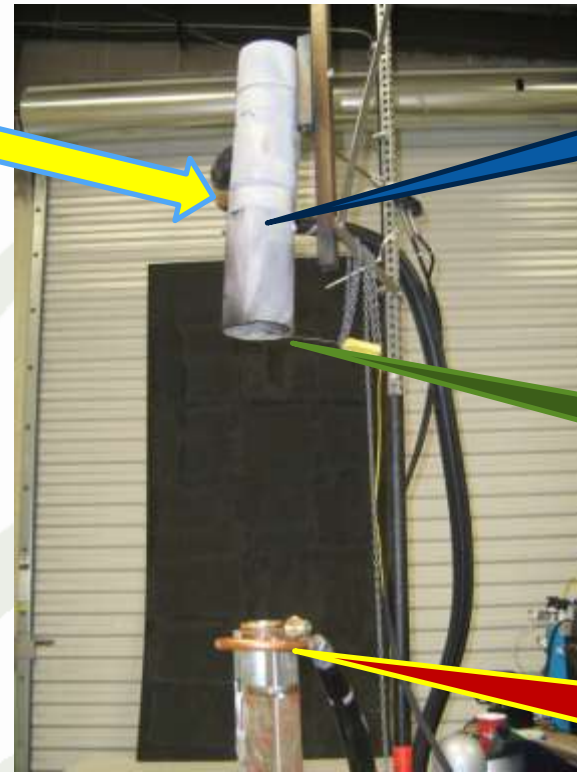


**Fuel: approx. 40k Btu/hr.**  
**Nitrogen: varied**  
**Steam: ~ 3 lb./hr.**

# FLUE AND SAMPLING PROBE



Sampling probe

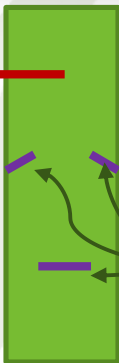


Flue

Thermal Couple

Scale Model Flare

Inside view of the flue



Baffle for mixing

# ANALYZERS AND IMAGER



**Testo 350 XL**  
(CO<sub>2</sub> using NDIR,  
CO, O<sub>2</sub>, NO<sub>x</sub>, H<sub>2</sub>,  
Temp, etc.)



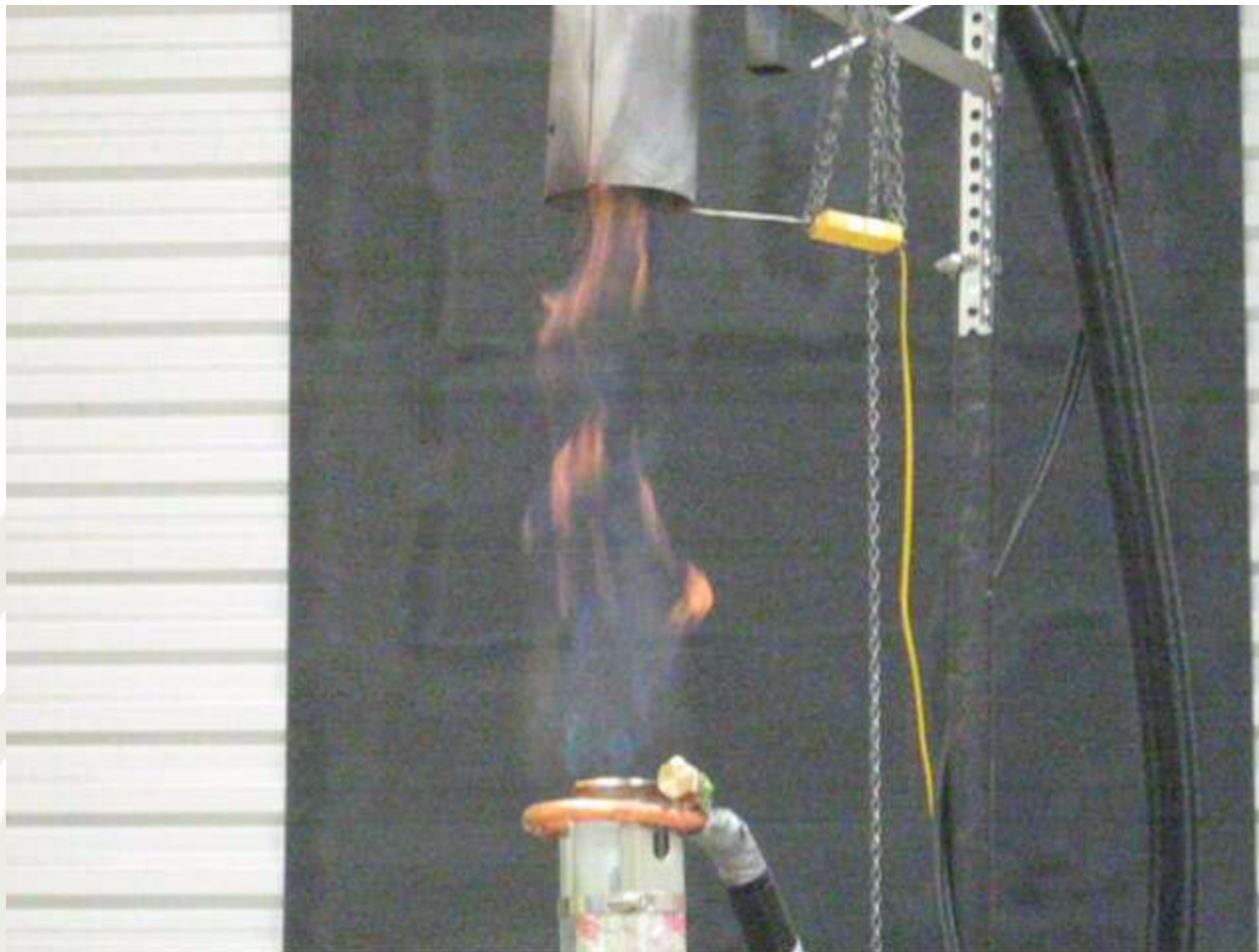
**3010 Mini  
FID**  
Calibrated  
to  
Propane



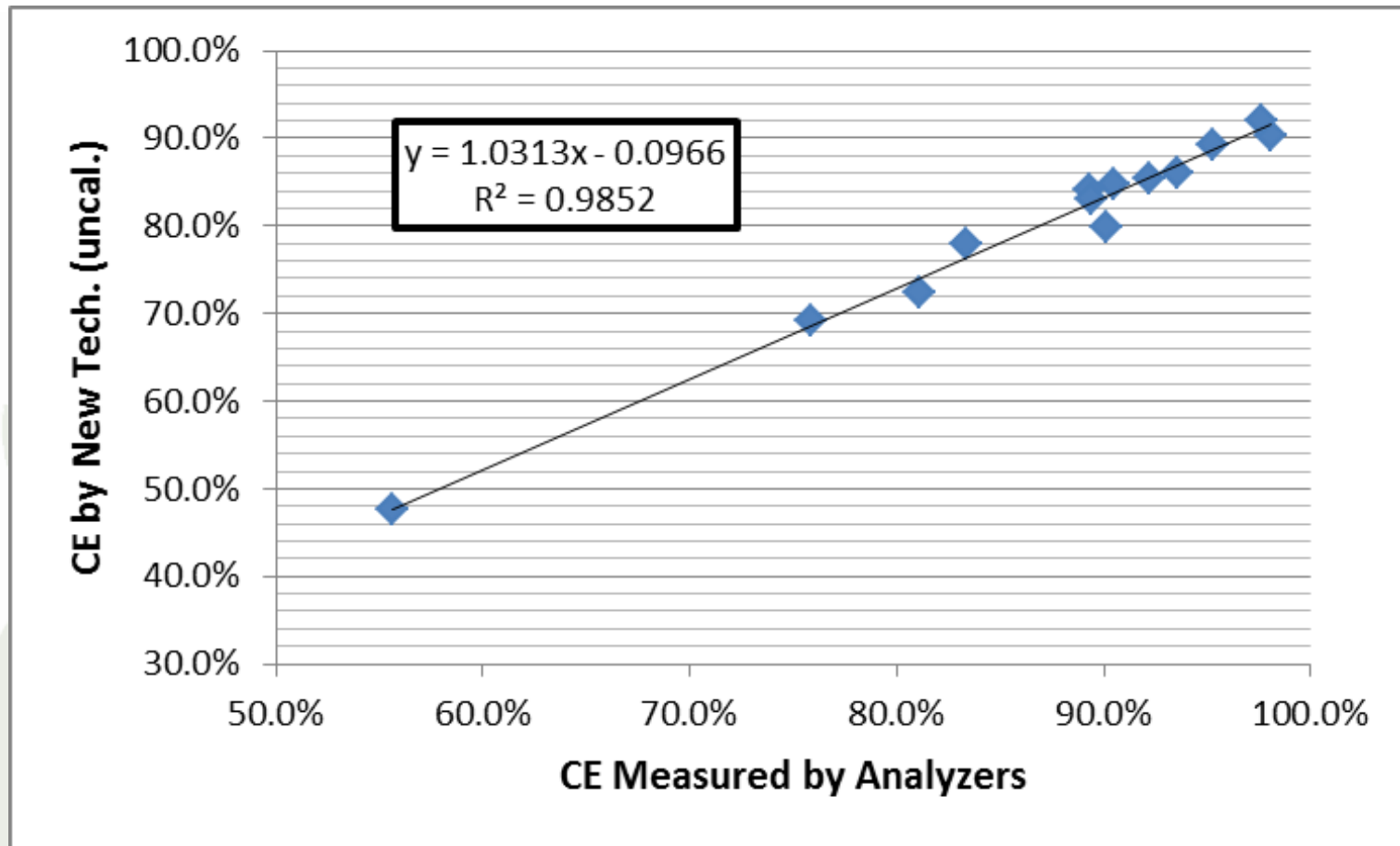
**SOC750 Hyper-  
spectral imager**  
42 spectral channels,  
operated at 22 cubes  
per sec.



# TEST RUNS

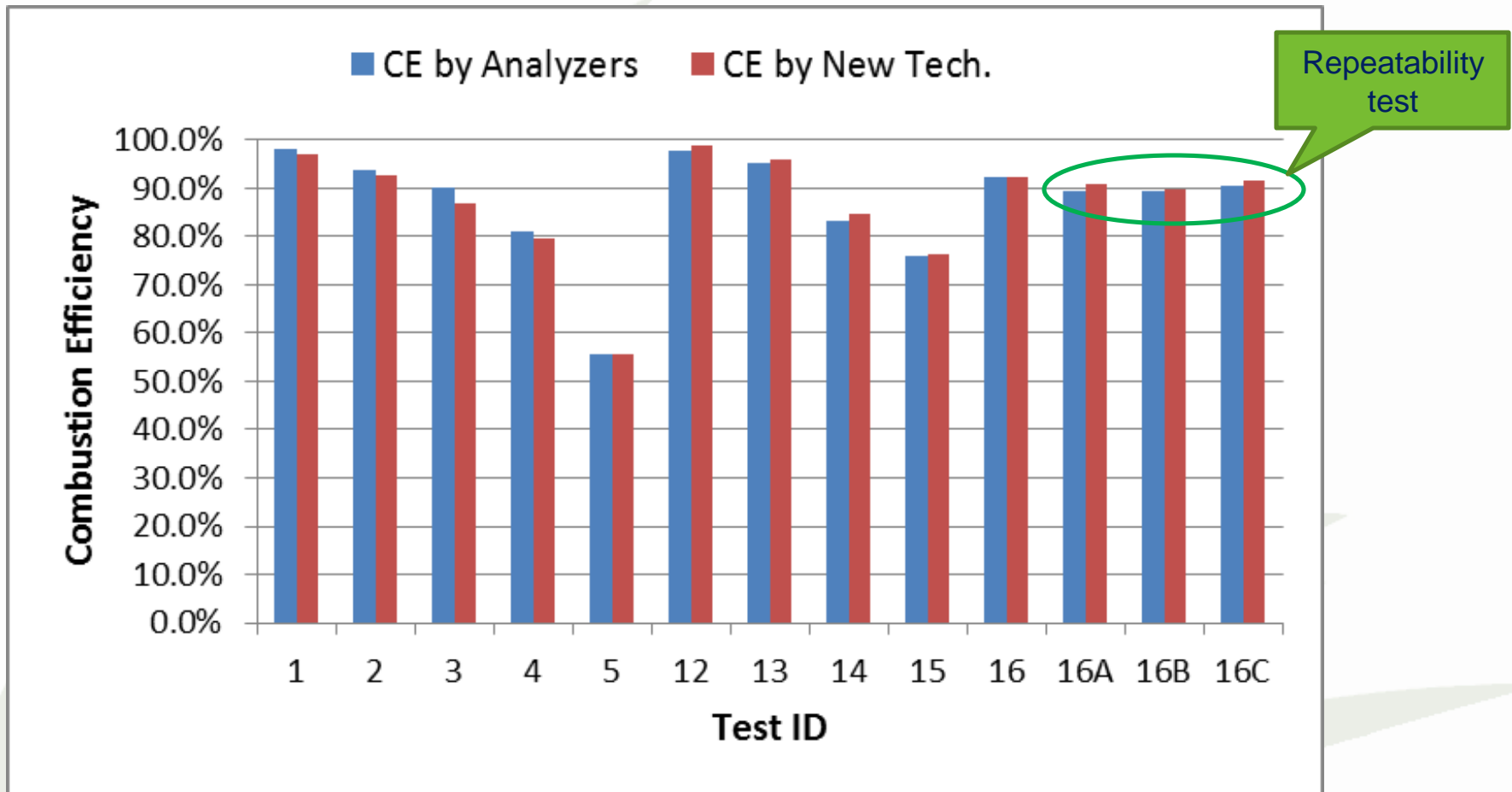


# PRELIMINARY RESULTS - WITHOUT CALIBRATION



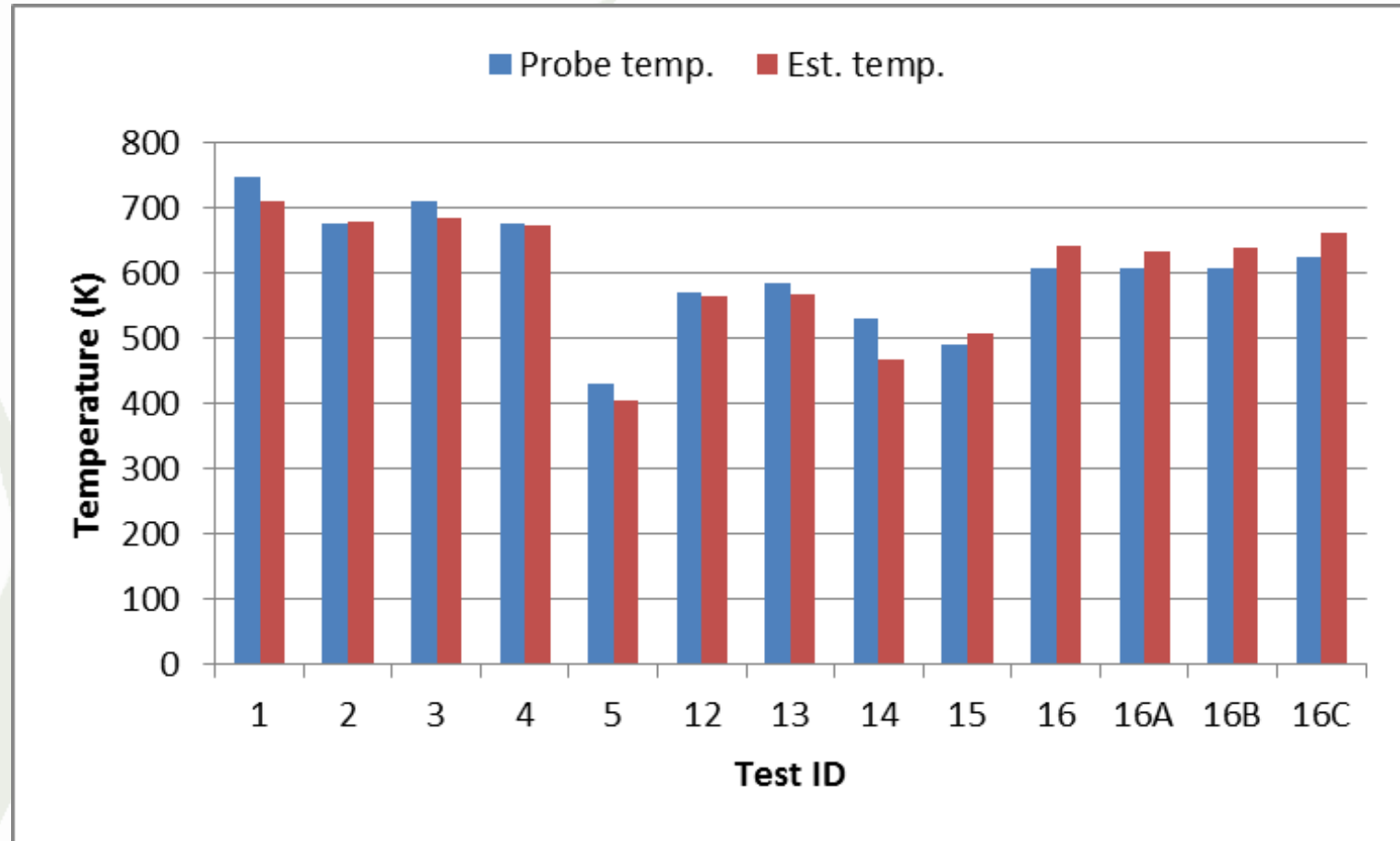
# PRELIMINARY RESULTS

## - WITH AN INITIAL CALIBRATION



# PRELIMINARY RESULTS

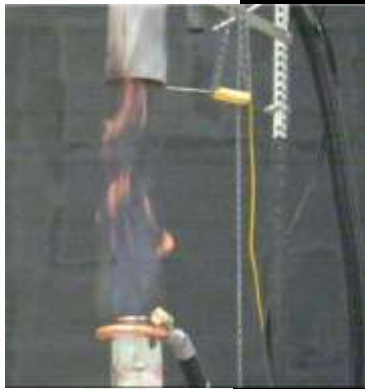
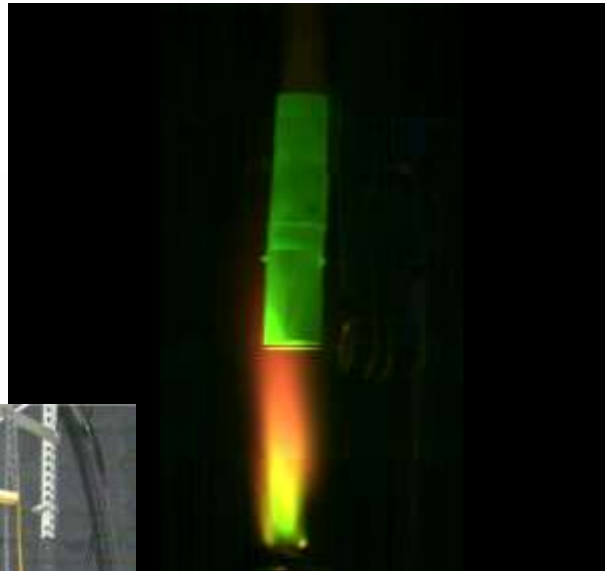
## - INITIAL METHOD TO MEASURE TEMPERATURE



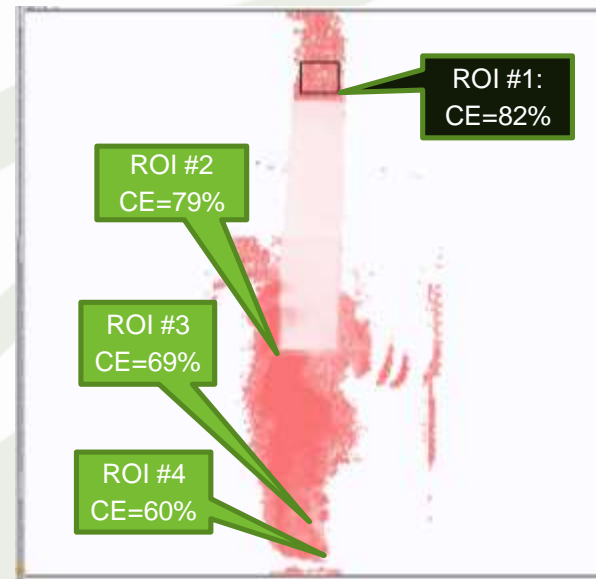
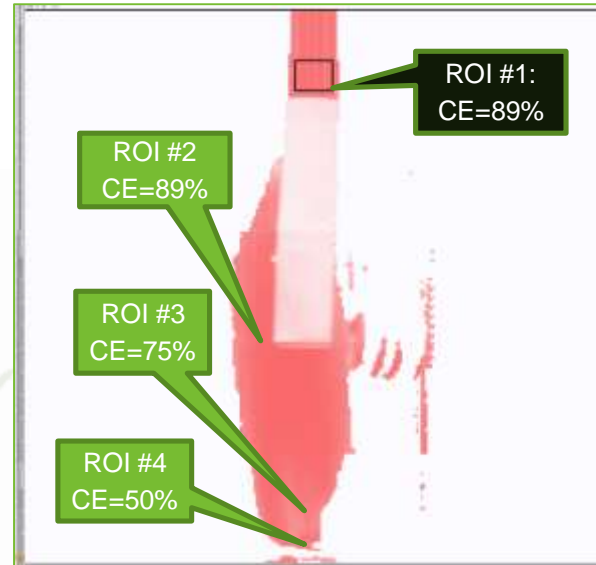
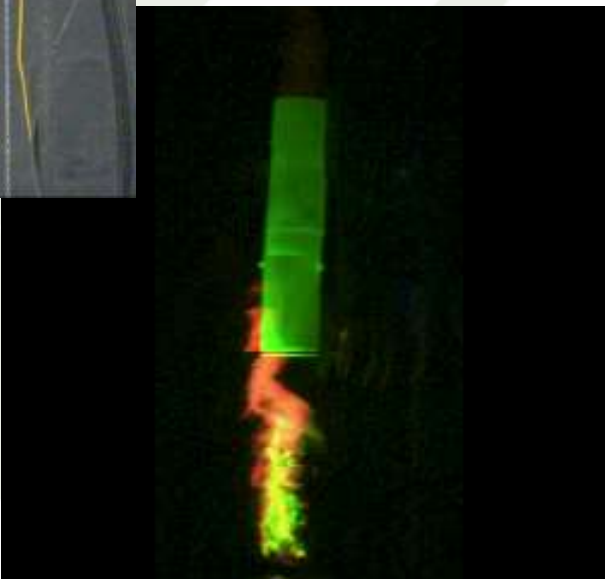


# PRELIMINARY RESULTS – CE MAP

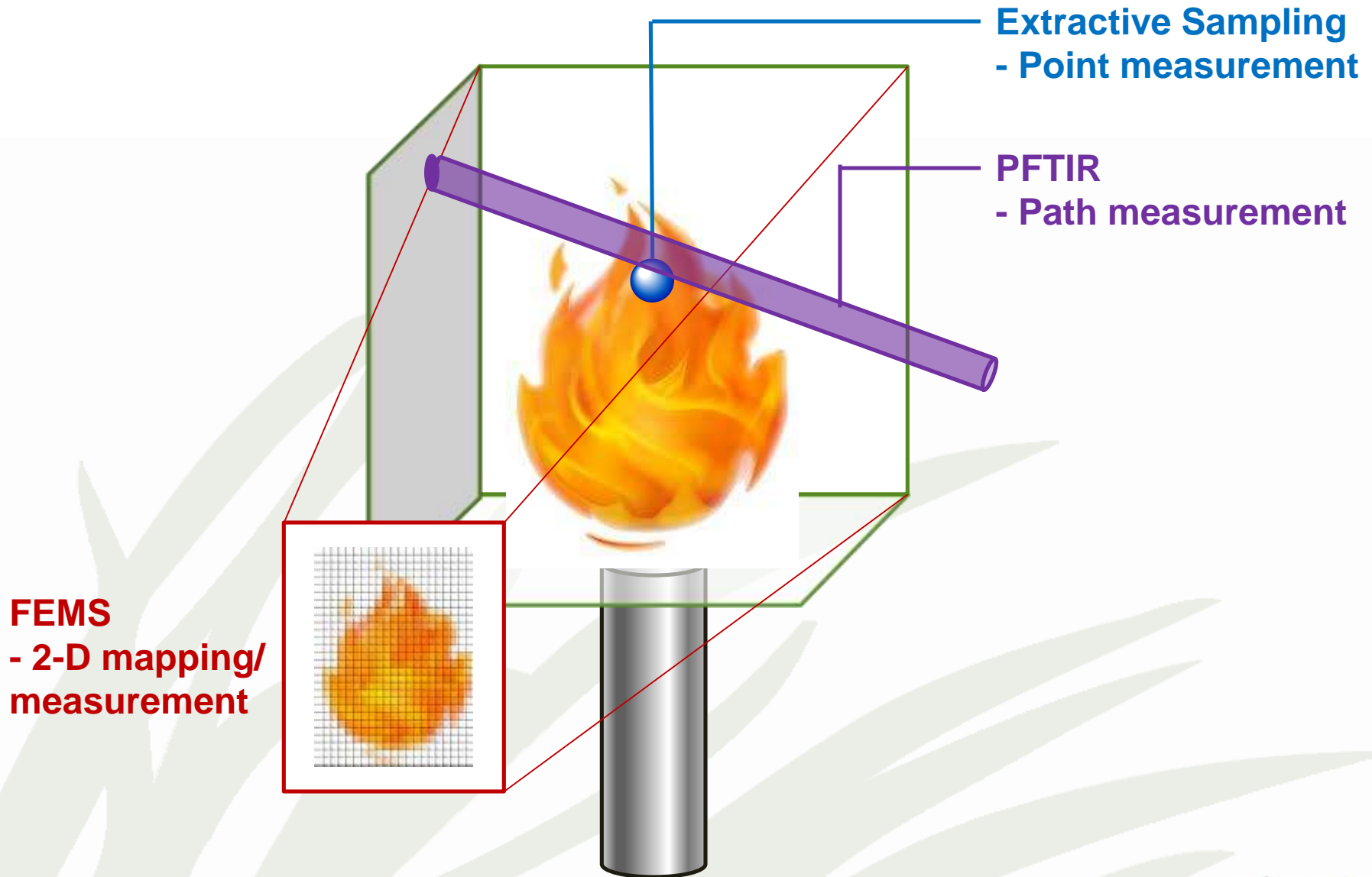
30 sec.  
average  
(670  
frames)



1 frame  
(~0.045  
sec.)



# Three Types of Measurement



# COMPARISON WITH PFTIR

## PFTIR

- “Scanning” -  $>1$  sec/scan  
– assuming that flare is static during that time
- Path measurement – aiming required
- Human operation

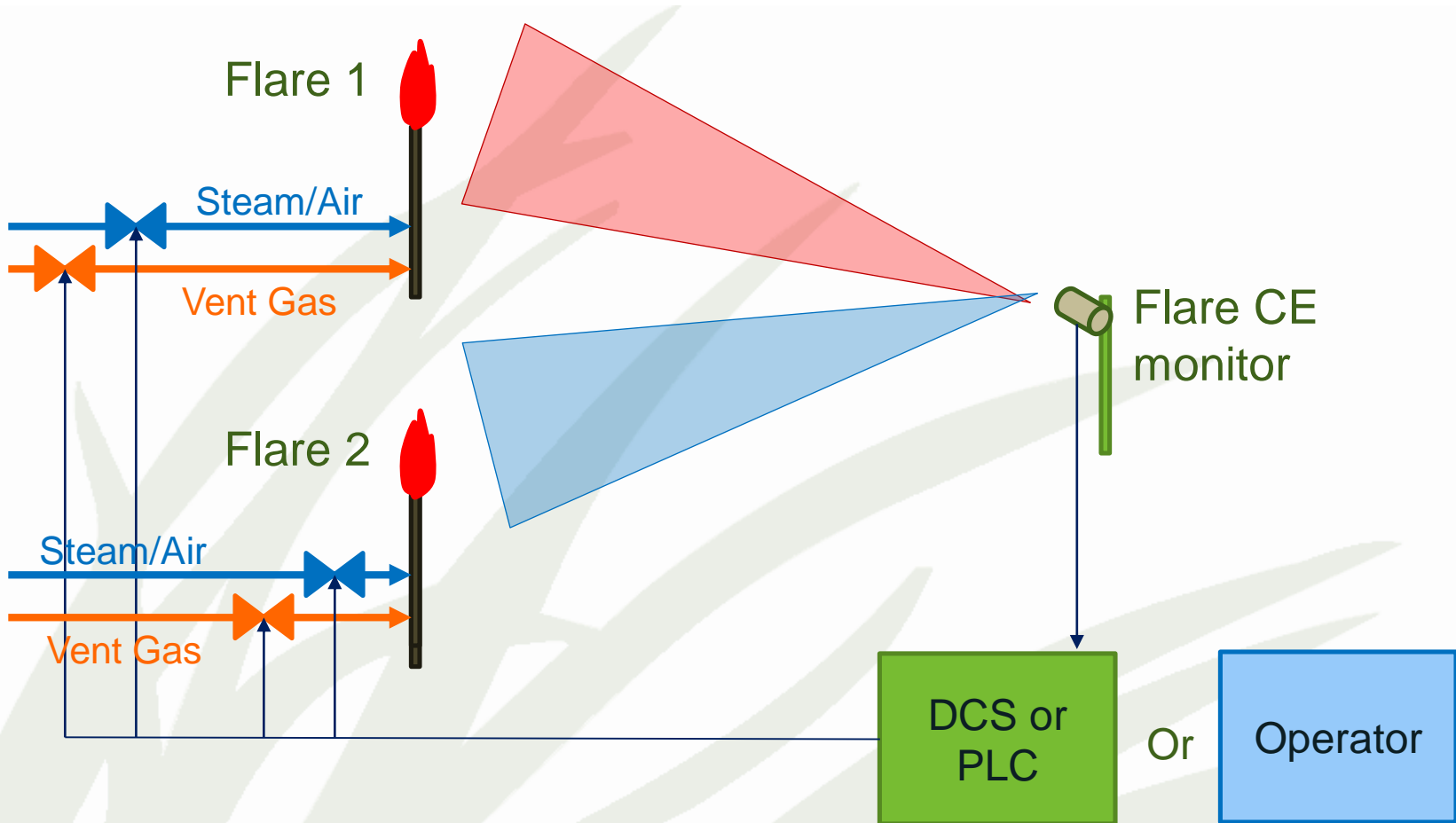
## FEMS

- Staring – 20-30 data cubes/sec – match the flare dynamics
- 2-D mapping of CE – no aiming required
- Automatic

# CONCLUSION

- The CE determined by the new technology correlate well with the CE measured by conventional analyzers
- With a further developed calibration method, real-time CE monitoring and feedback for flare optimization is feasible
- The new technology can determine CE at a pixel level, generating a CE map for the entire flare flame. No aiming issue.
- As a side benefit, it can also provide temperature mapping of the flare flame

# LOOKING FORWARD...



# OPTICAL GAS IMAGING WORKSHOP

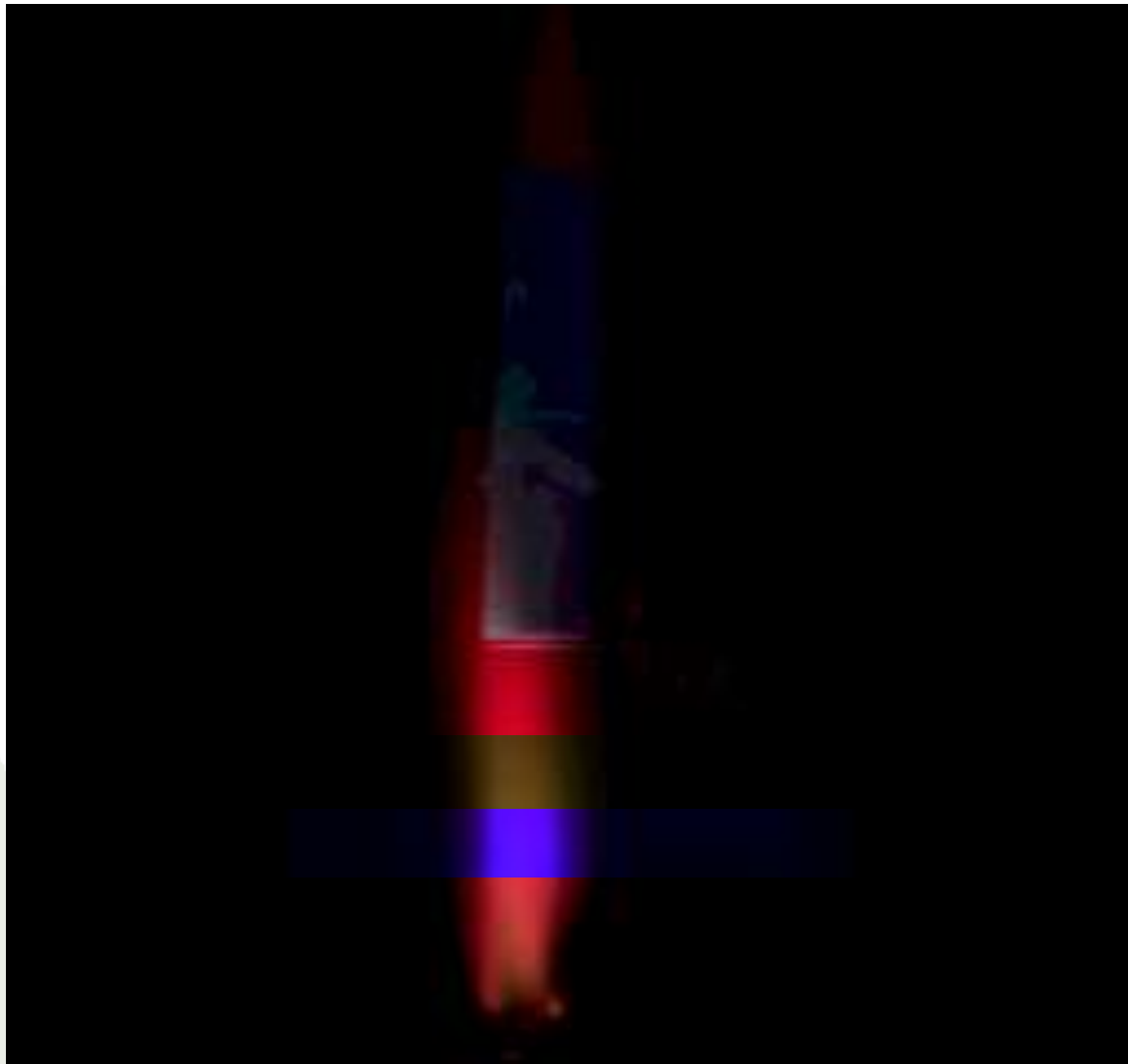
Wednesday, December 11, 2013

7:30 am - 4:30 pm

*Early registration ends November 15, 2013!*



***Recent Advancements in Optical Imaging of Gas Leaks and Flare Efficiency Measurement***



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