Advanced Fire Detection in Cargo Compartments

Thomas Cleary

Building and Fire Research Laboratory

National Institute of Standards and Technology

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Motivation

- Cargo compartment detection systems have historically experienced a “high” false alarm rate
- New detection/sensing technologies developed for other applications may be helpful

Sensing Technologies

- Particulate Smoke
- Combustion Gases
- Temperature Rise
- Combinations of the Above

- Others - Radiant Emission

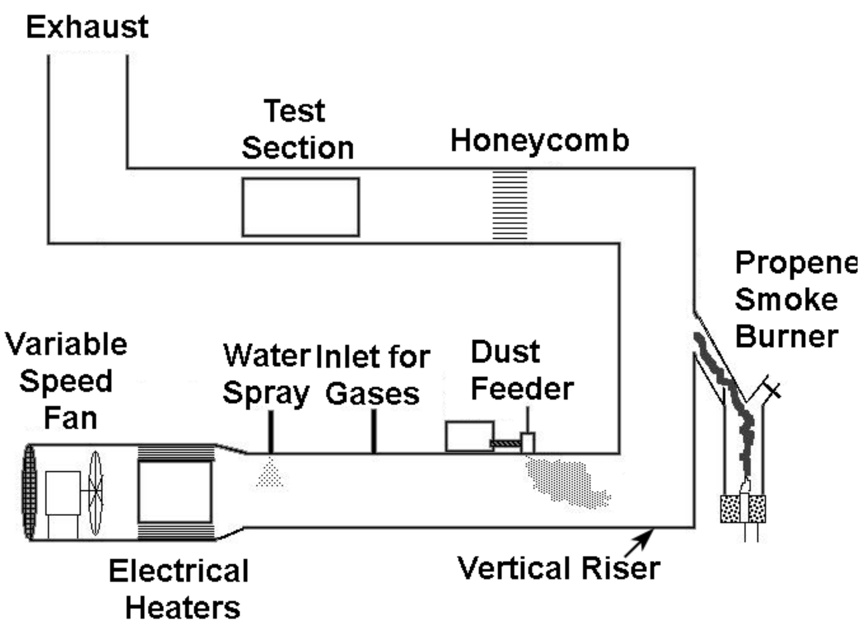
Objectives

- Improved immunity to false alarms
- Assured detection of real fire events
- Compartment monitoring

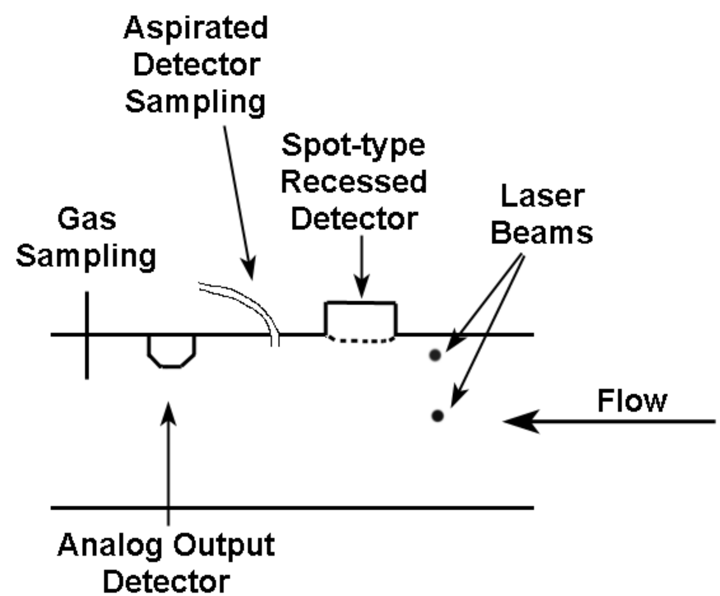
Approach

- Laboratory testing of fire and nuisance source scenarios
- Characterize detector environment during exposures
- Analyze data for improved detection

Schematic of FE/DE and Test Section Arrangement



Fire Emulator Detector Evaluator



Test Section Side View

Fire and Nuisance Conditions in Cargo Compartments

- Flaming Fire
  - simulate small hydrocarbon liquid spill
- Smoldering Fire
  - Match conditions of smoke concentration found in FAA test fires
- Low Smoke Fire
  - alcohol soaked fabric

- Pyrolyzing mixed plastics plaque
- Dust exposure
- Non-volatile liquid mist (Oil)
- *Condensed water vapor cloud*
- *Temperature gradient between detector and ambient*
- *Pyrolyzing wood smoke*

Fire and Nuisance Source Scenarios

The selection of scenarios was guided by a desire to cover the range of potential fire and nuisance alarm scenarios progressing to a point were current aircraft detectors would alarm. *There is no basis for these scenarios from analysis for aircraft fire data, nor service difficulty reports addressing false alarms.*

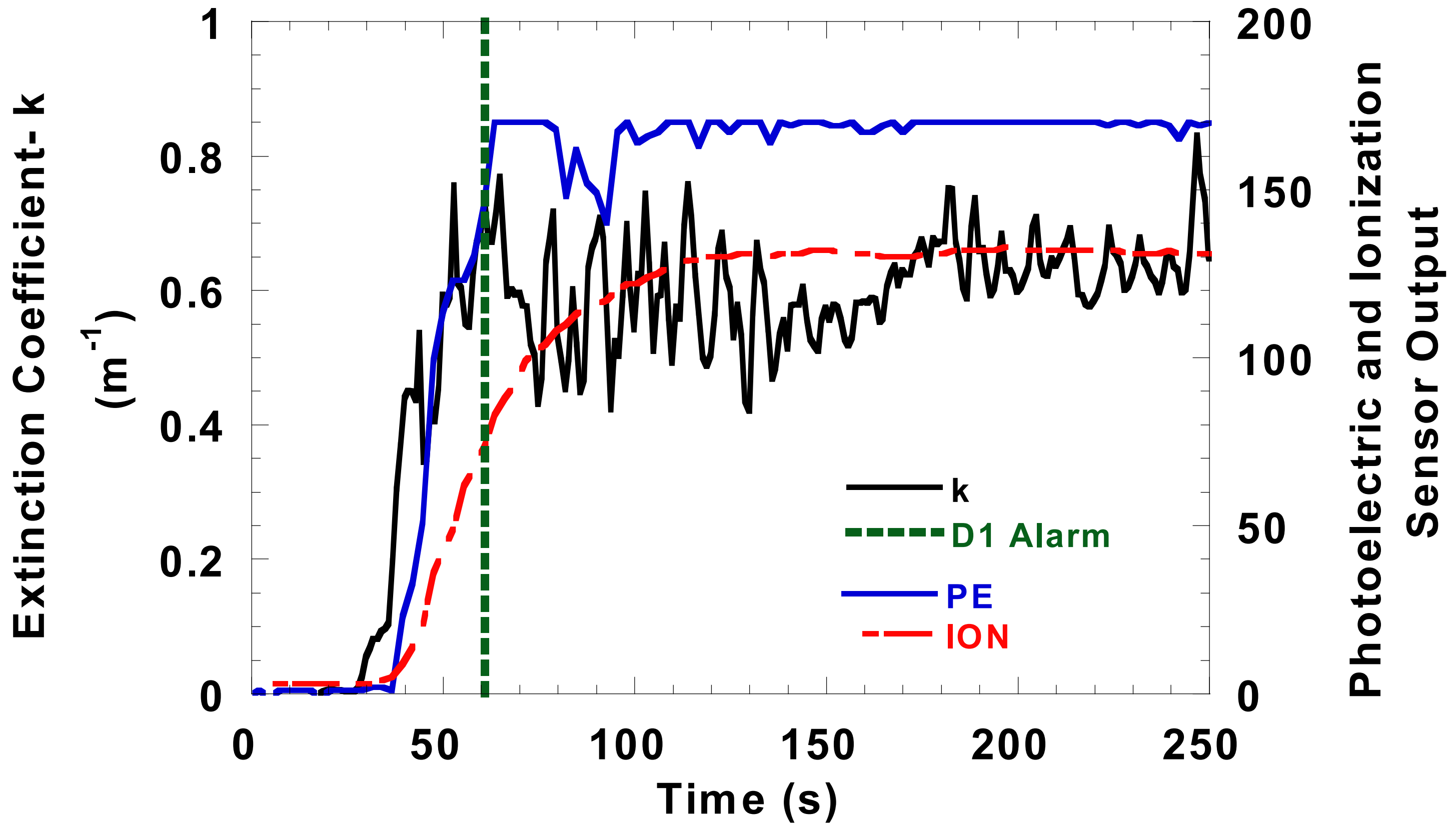
Sensor Signals Recorded During the Tests

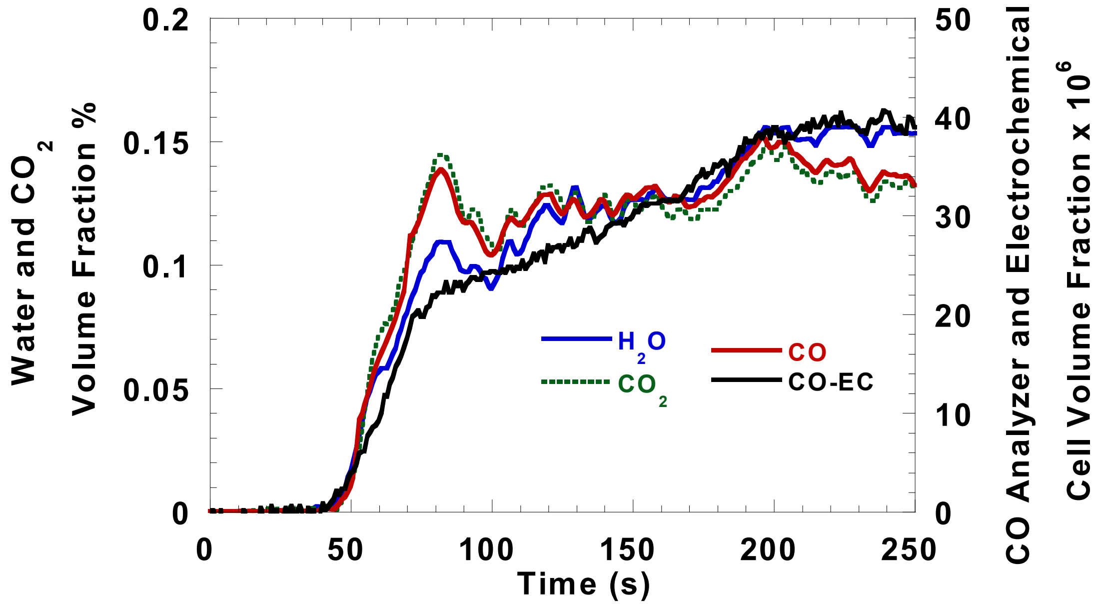
- Smoke particulates
  - photoelectric (light scattering), extinction measurement, ionization
- Combustion gases
  - carbon monoxide, carbon dioxide, water,
- Temperature
  - thermistor, thermocouple
- Aircraft Detector Alarm

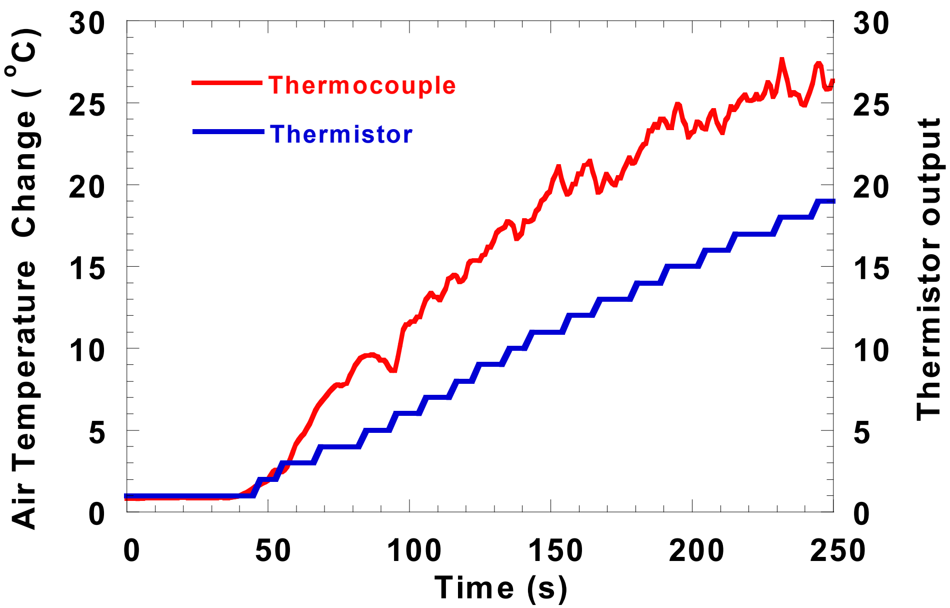
Flaming Fire Scenario

- Emulate a liquid pool fire source located in a cargo compartment.
- Fixed airflow with ramping temperature and smoke concentration
- Black smoke from the propene smoke generator.

Flaming Fire Scenario




Water and CO_2
Volume Fraction %
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
Time (s)
50
40
30
20
10
0
CO Analyzer and Electrochemical
Cell Volume Fraction x 10^6
H_2O
CO_2
CO
CO-EC

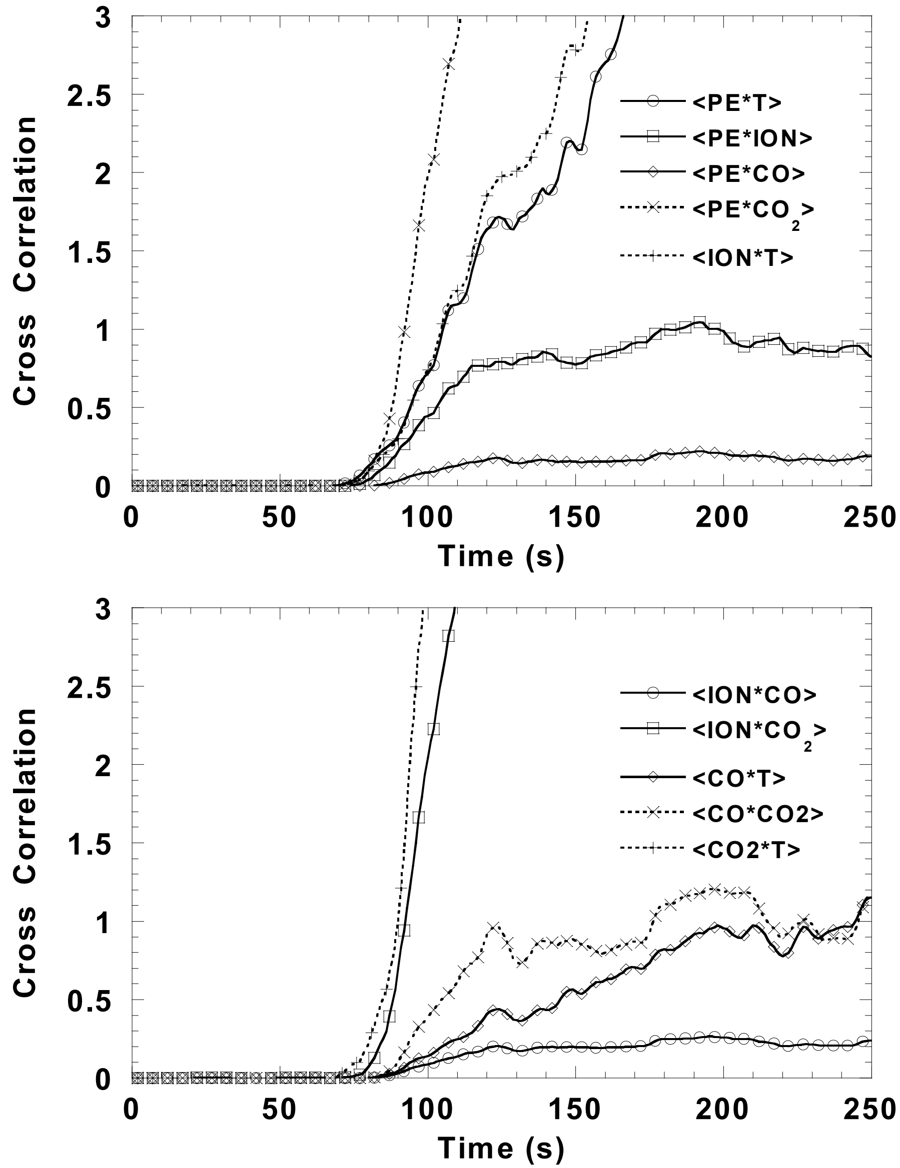

Air Temperature Change (°C)
30
25
20
15
10
5
0
0
50
100
150
200
250
Time (s)
Thermistor output
Thermocouple
Thermistor

Cross Correlation Equation

$$\langle A \bullet B \rangle \left(t_o, \tau_c, \tau_s\right) = \left(\tau_c \big/ \tau_s \right)^{-1} \sum_{n=0}^{(tc/ts-1)} A(t_n) \bullet B(t_n)$$

Where A and B are the sensor values of interest, τ_0 is the present time, τ_n is the time n scans in the past, τ_c is the averaging time and τ_s is the scan interval. Heskestad and Newman, *Fire Safety Journal*, **18**, 1992.

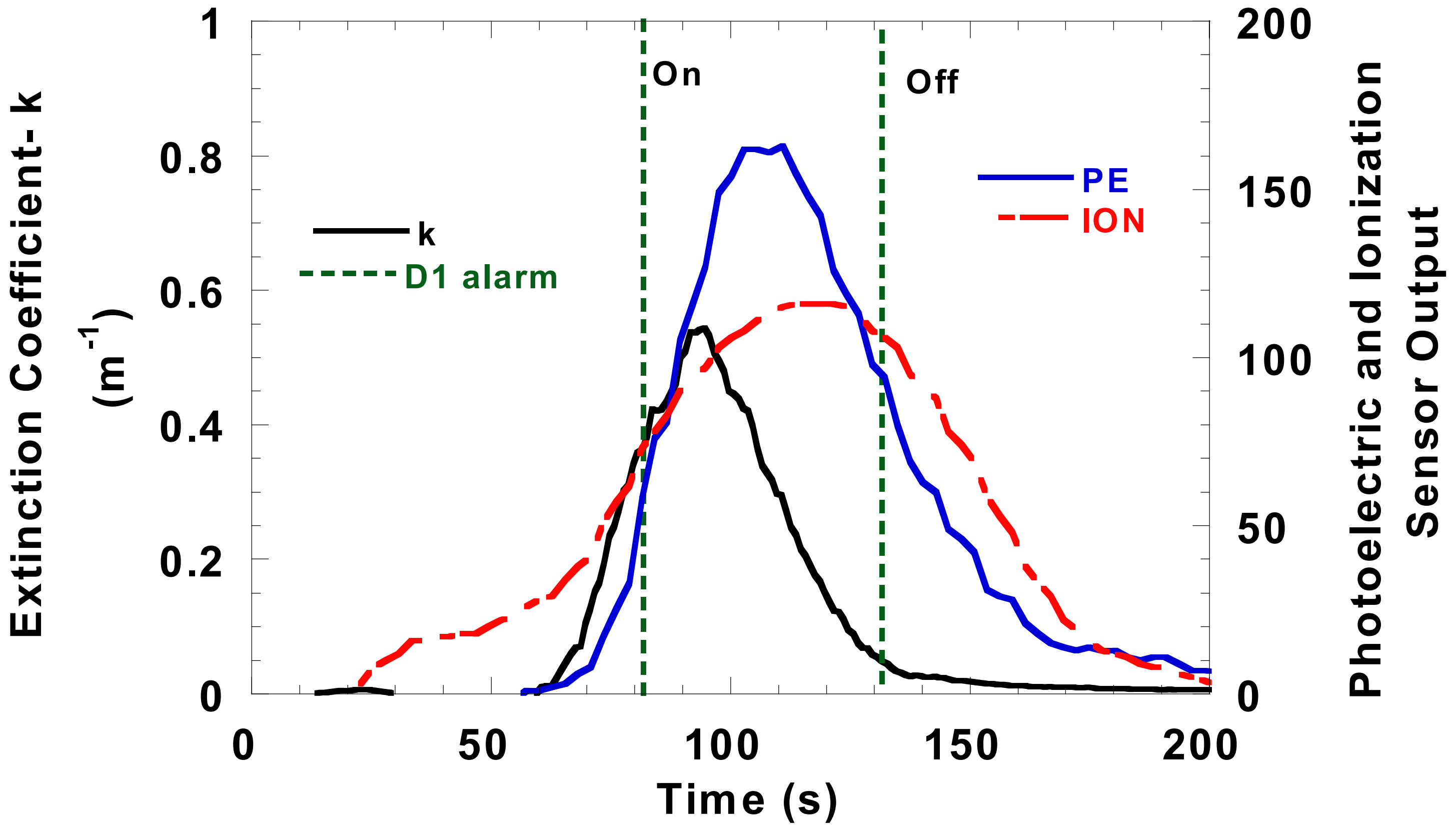
Signal Cross Correlation - Flaming Fire Scenario

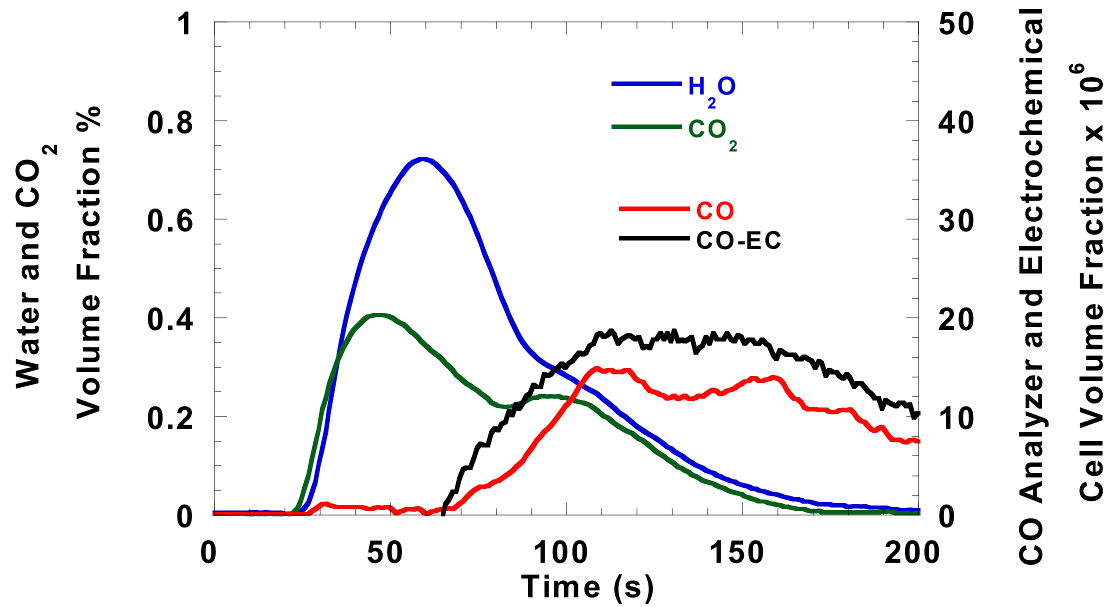


Low-Smoke Flaming Fire

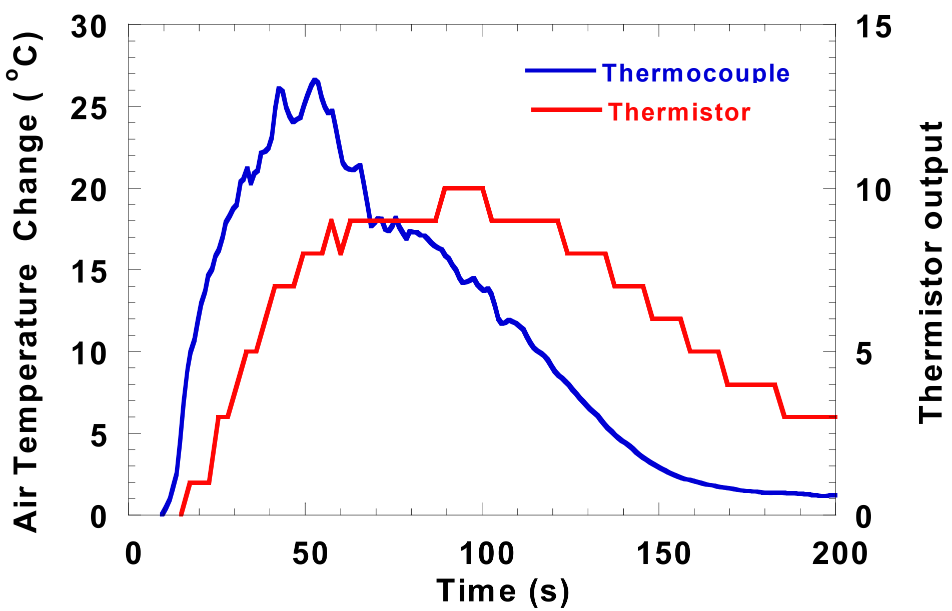
- Ethanol-soaked polyester/cotton fabric circles 7 cm in diameter saturated with 5 cm^3 of liquid
- Ethanol is ignited, burns, then ignites fabric
- early low-smoke transitioning to heavy smoke as fabric burns
- Example ignition of alcohol-soaked baggage

Ethanol-soaked Fabric Circles



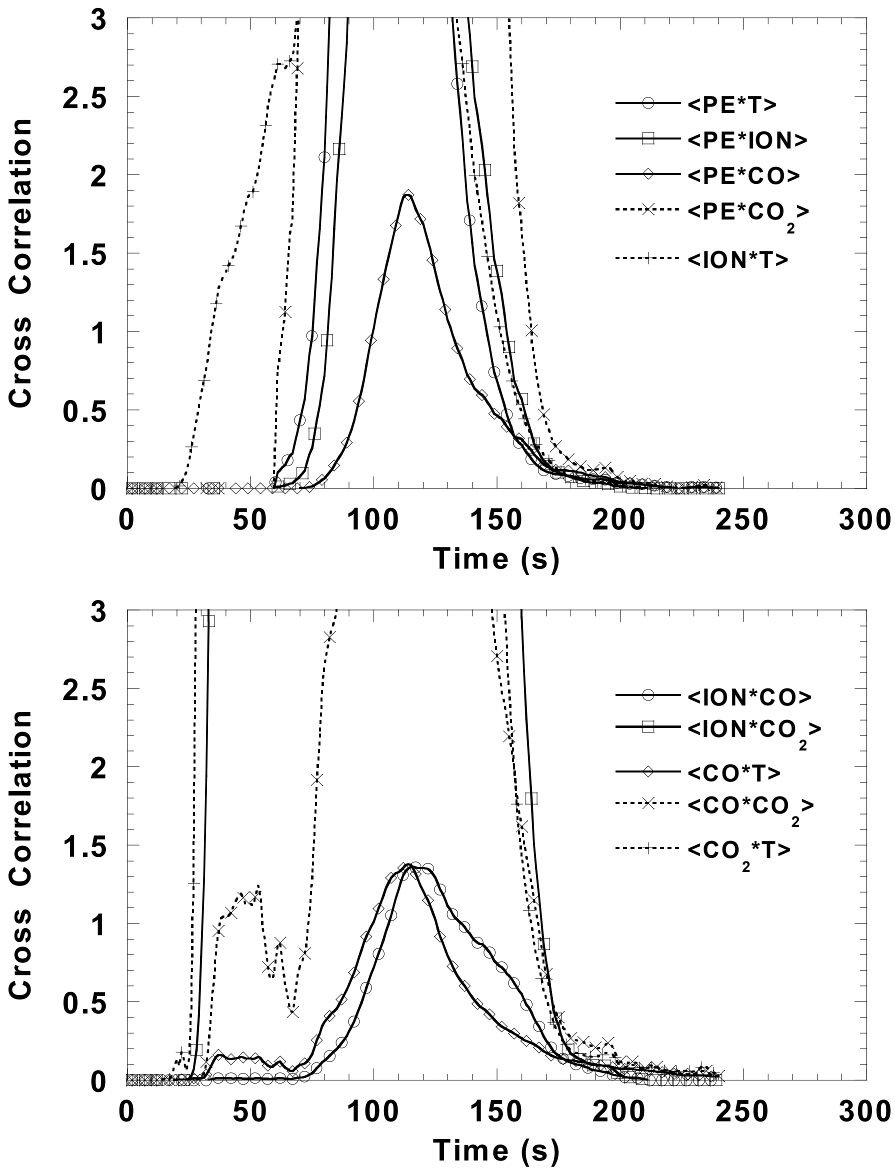


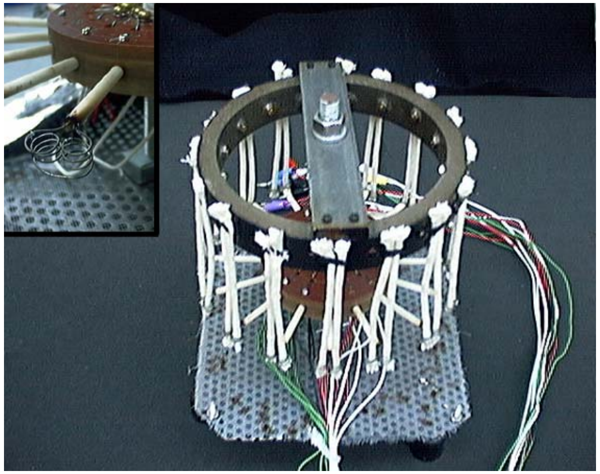
Water and CO_2 Volume Fraction %
CO Analyzer and Electrochemical Cell Volume Fraction x 10^6
Time (s)
H_2O
CO_2
CO
CO-EC



Air Temperature Change (°C)
Thermistor output
Time (s)
Thermocouple
Thermistor

Signal Cross Correlation - Low Smoke Scenario

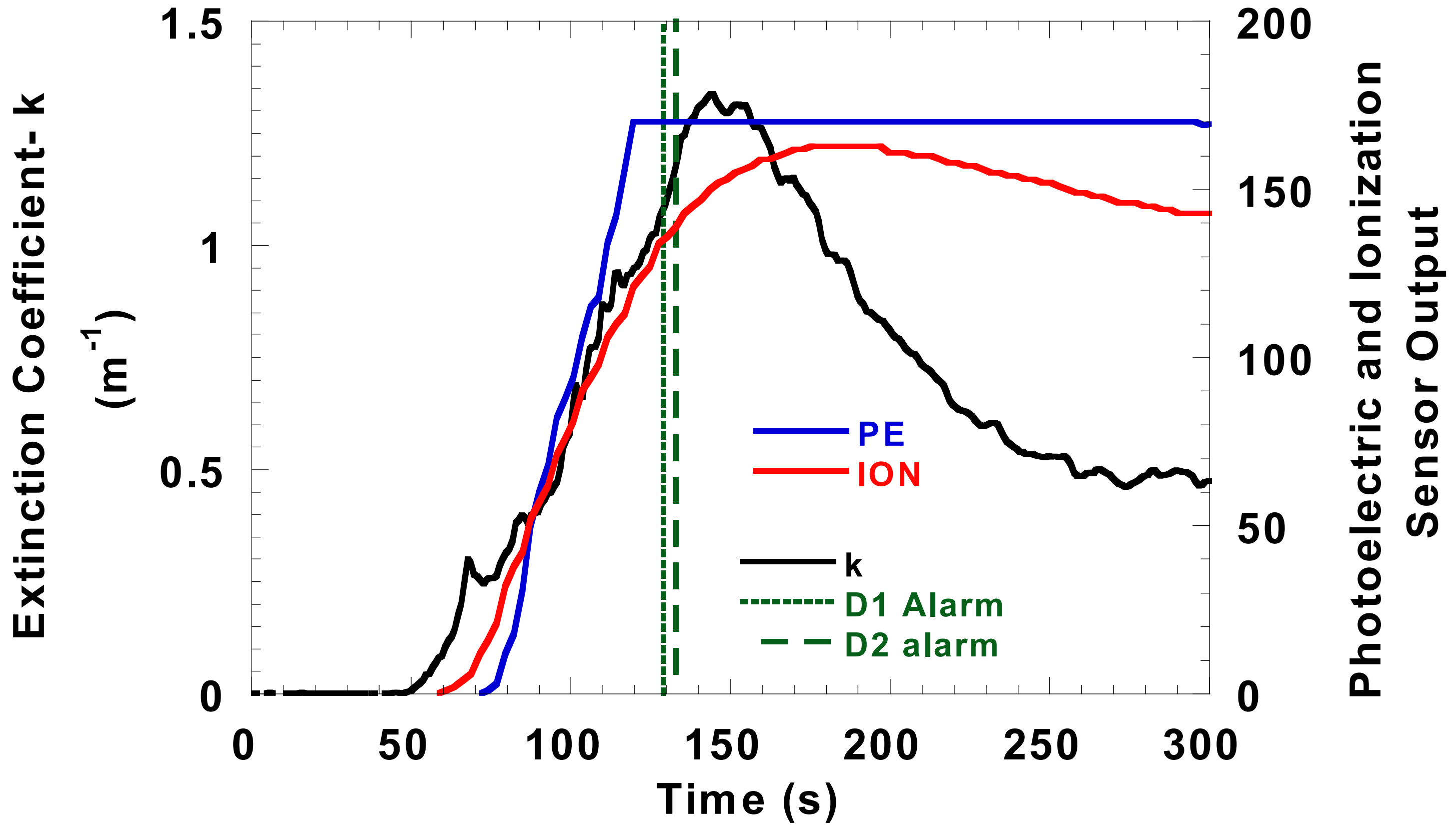




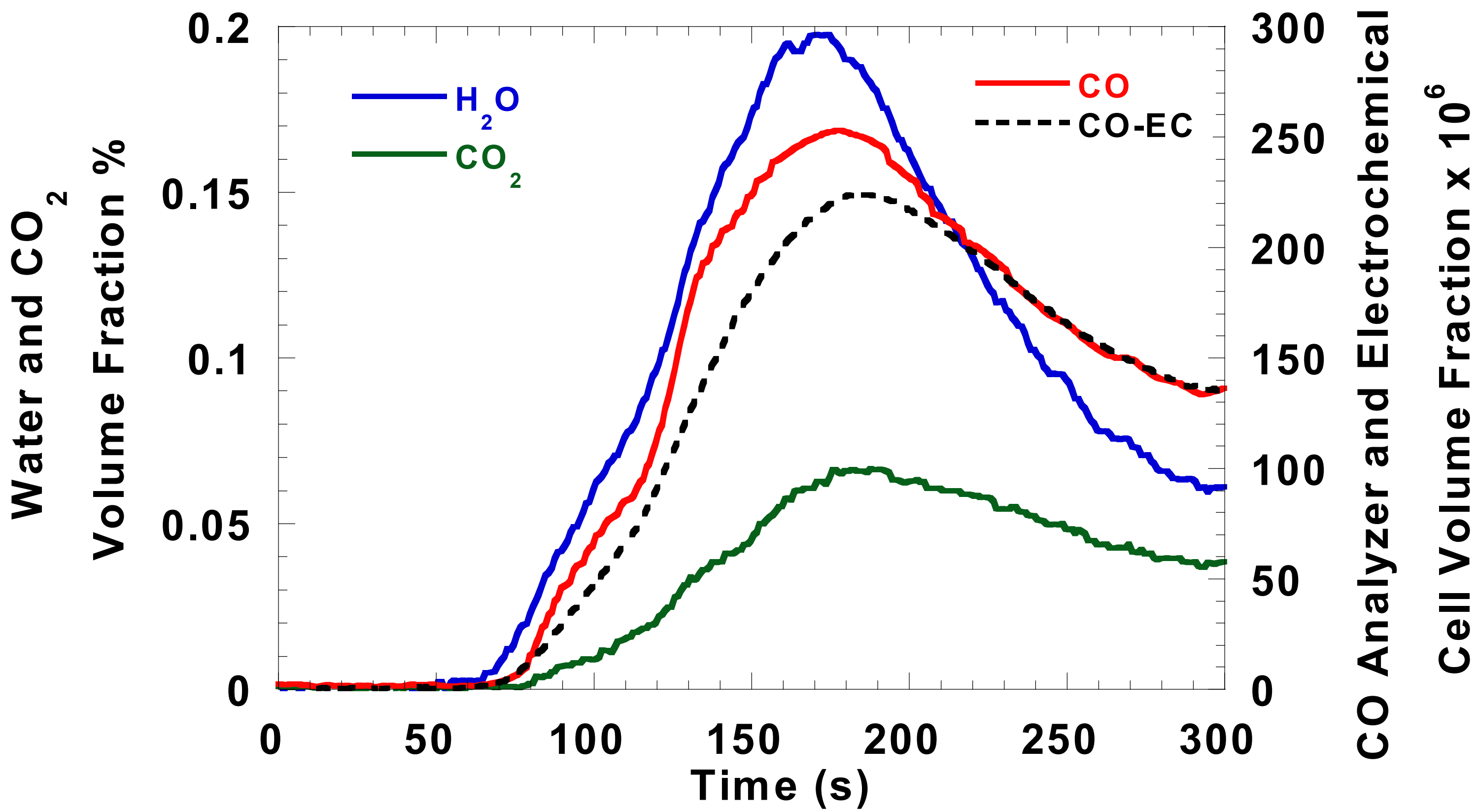
Smoldering Cotton Wicks

- Use Staged wick ignition device to provide rapidly increasing smoke concentration at test section
- 8 sets of 4 ignited in 12 s sequence

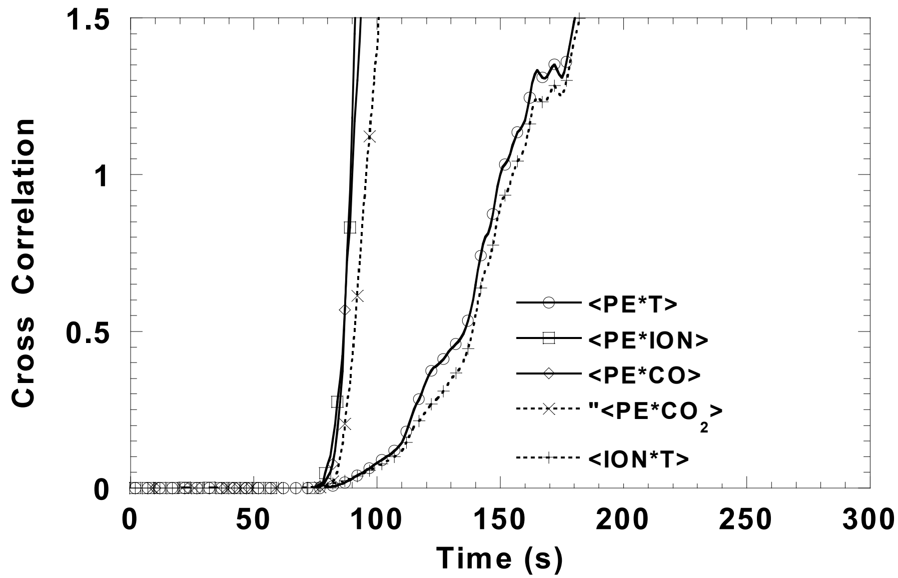
Smoldering Cotton Wicks

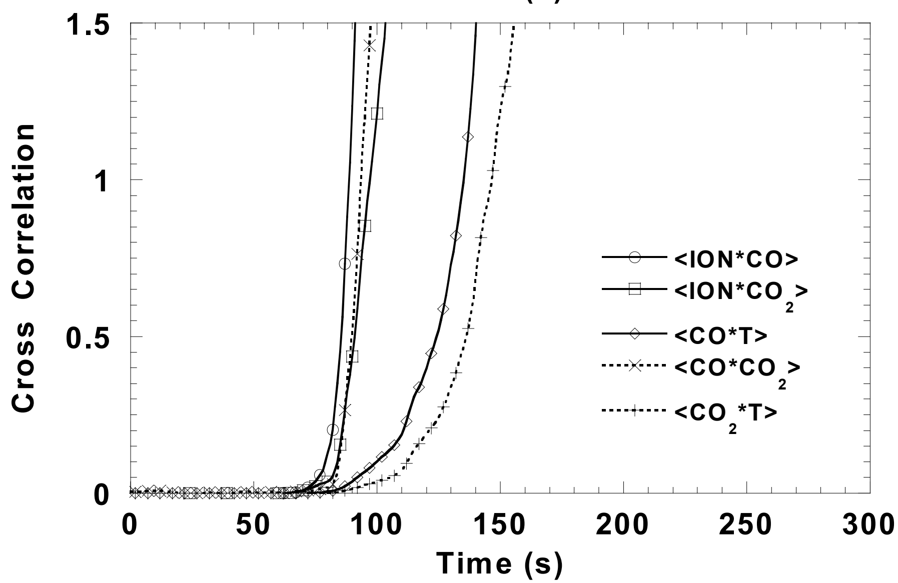


Smoldering Cotton Wicks



Signal Cross Correlation - Smoldering Scenario

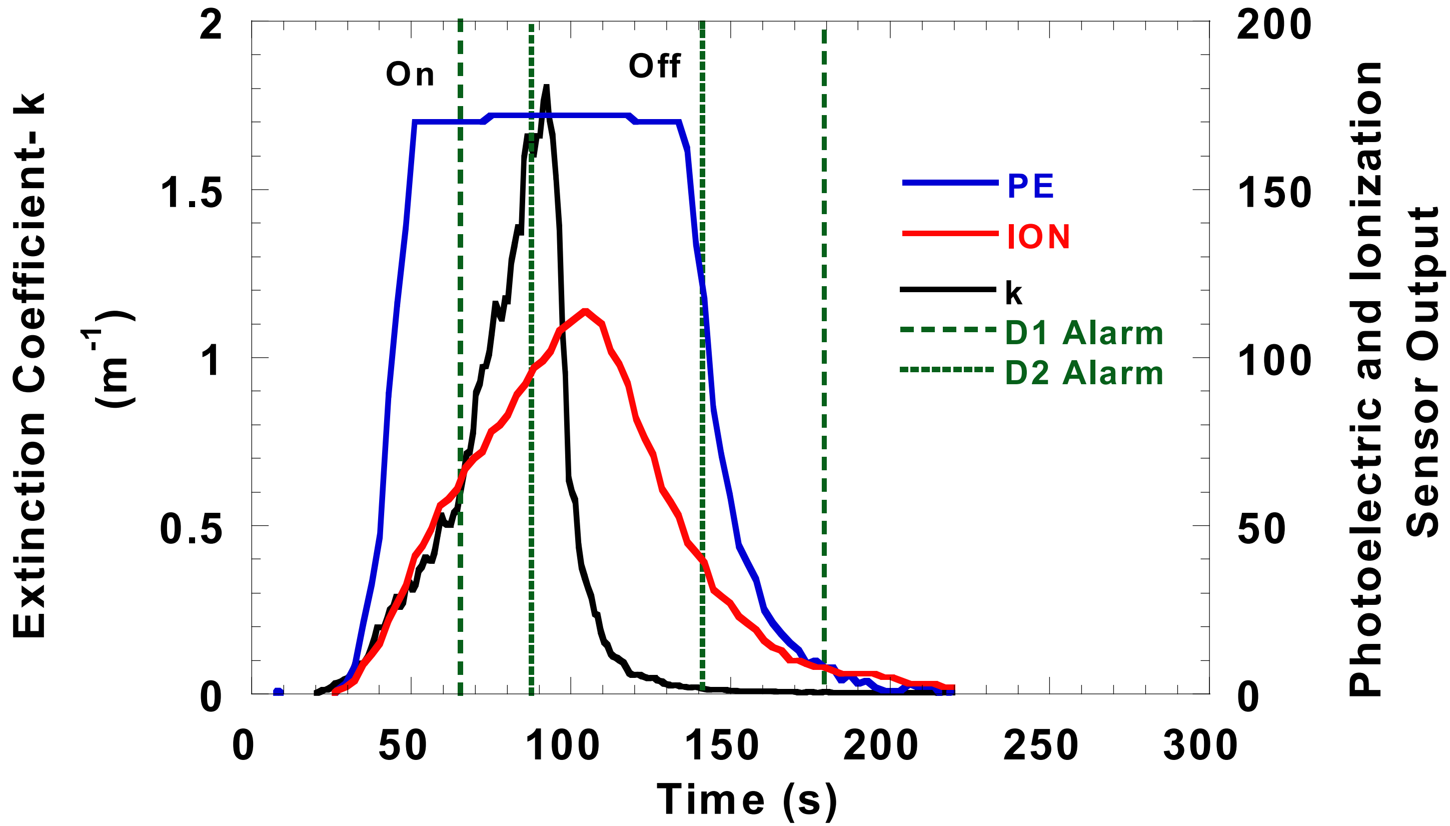




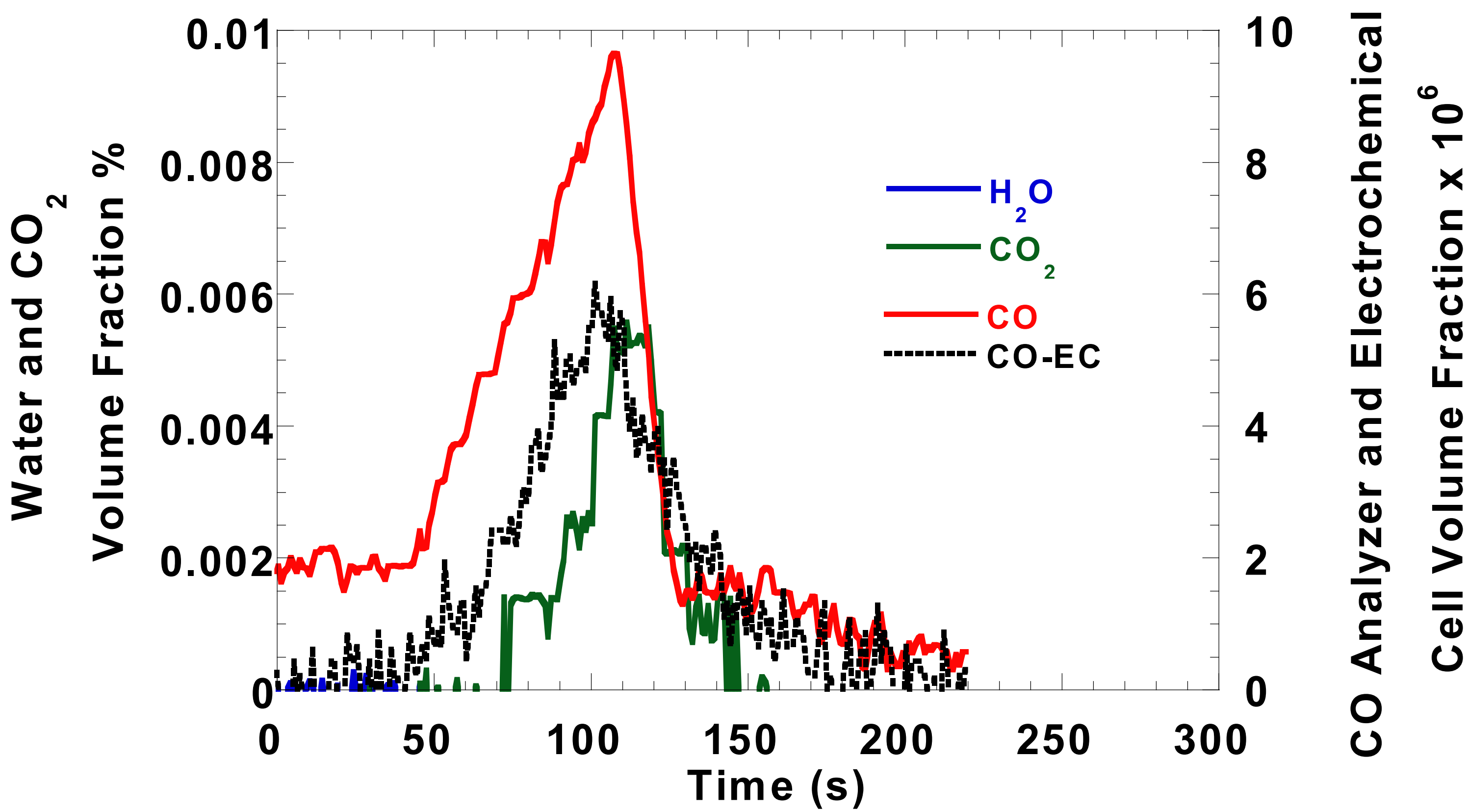
Pyrolyzing Mixed Plastics Plaque

- Mixed plastic pellets compressed into a plaque with an imbedded nichrome wire
- Current passed through wire to initial pyrolysis

Pyrolyzing Mixed Plastics Plaque



Pyrolyzing Mixed Plastics Plaque



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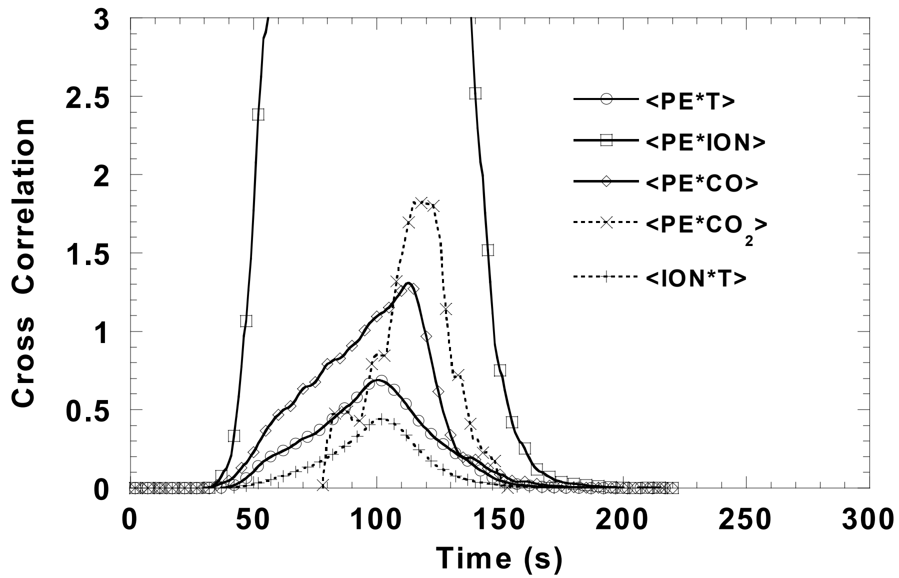
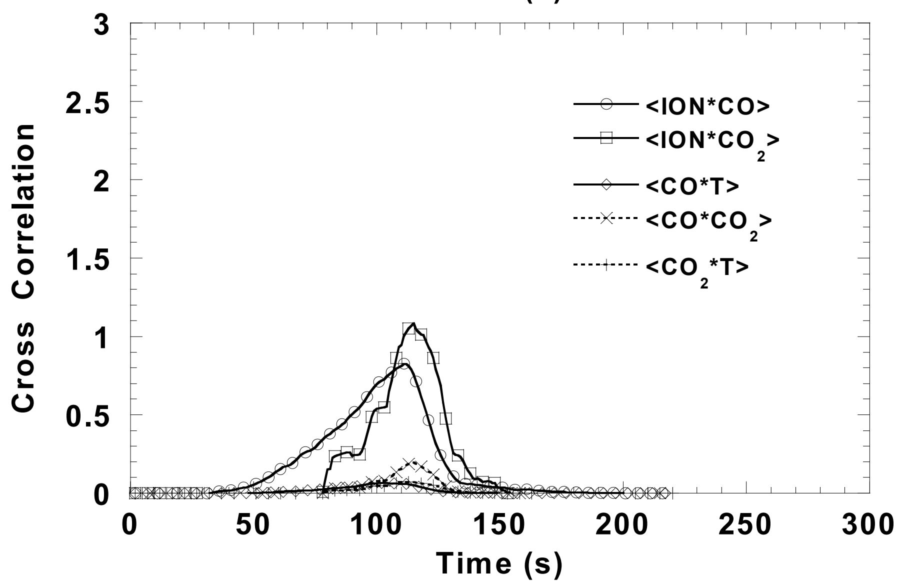
Signal Cross Correlation - Pyrolyzing Plastics

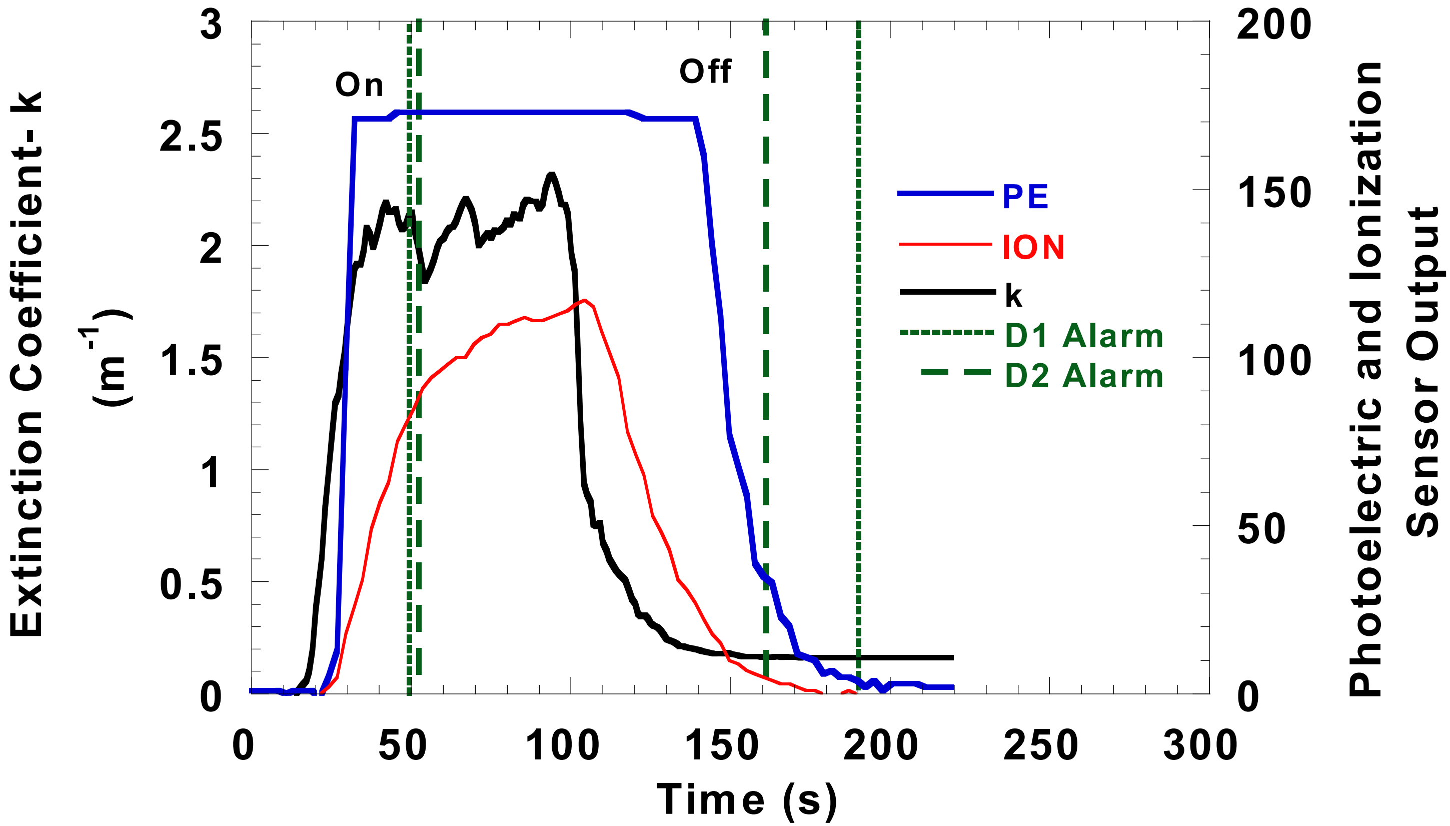




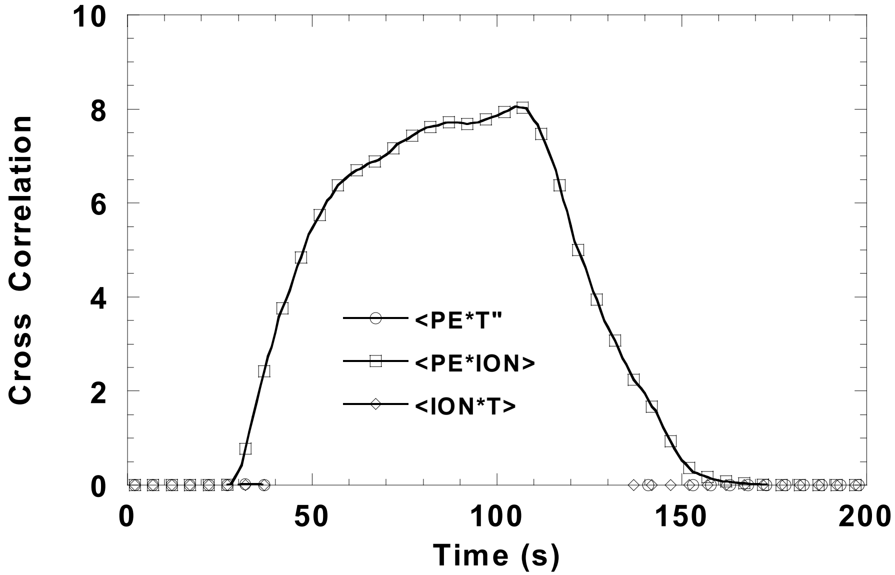
Arizona Test Dust Exposure

- Feed dust in at a constant rate

Arizona Test Dust Exposure



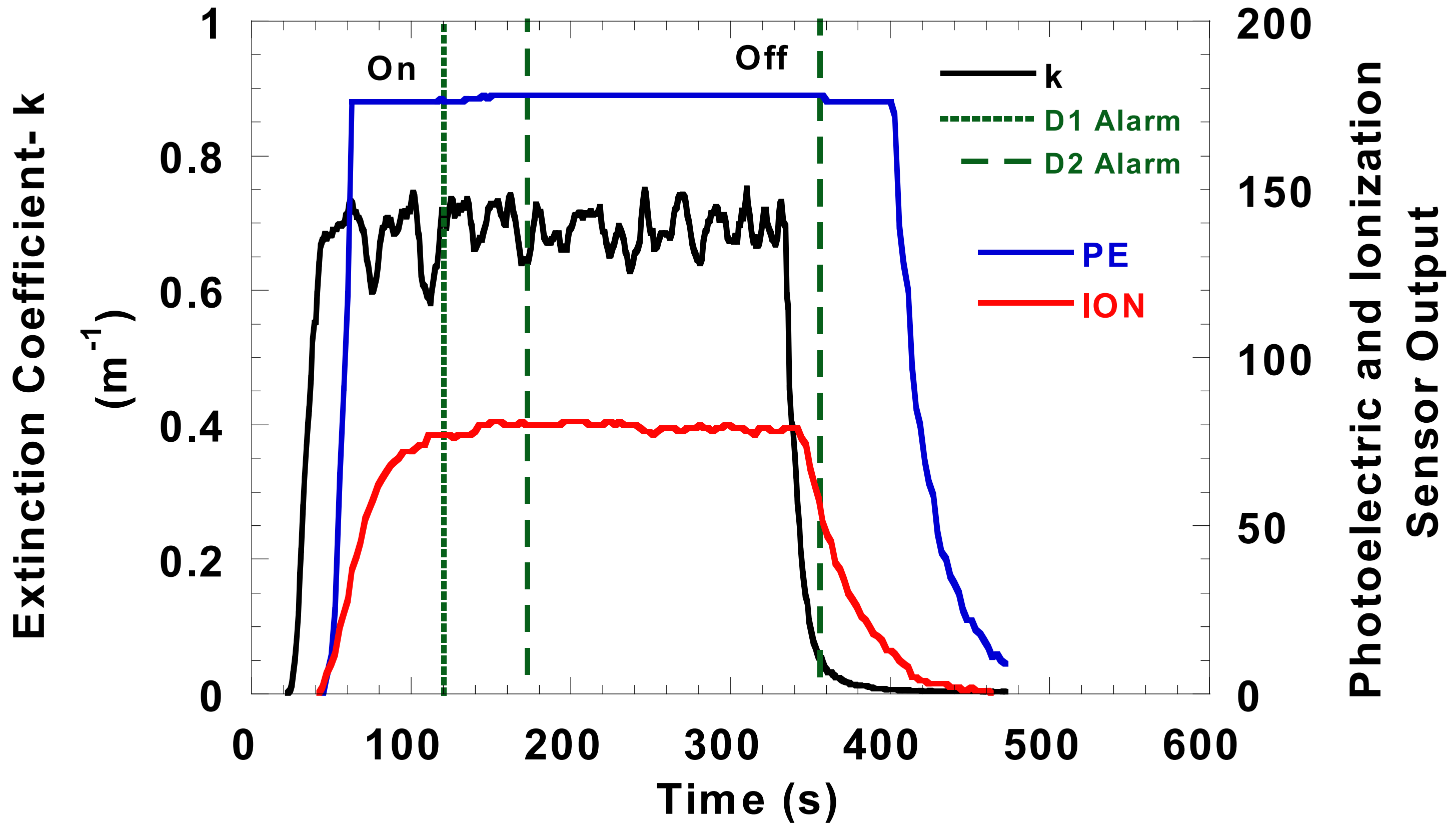
Signal Cross Correlation - Arizona Test Dust



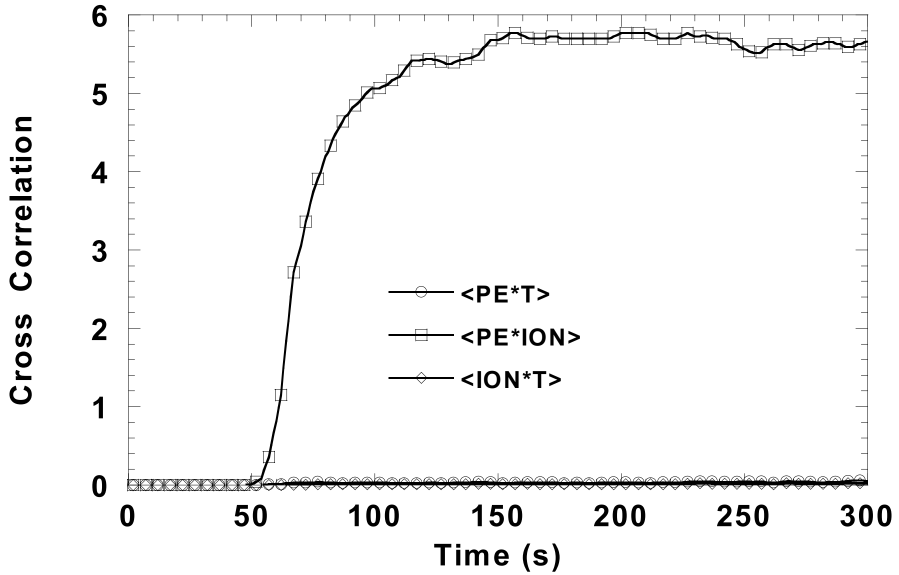
Nebulized Oil Mist

- Bank of medical nebulizers

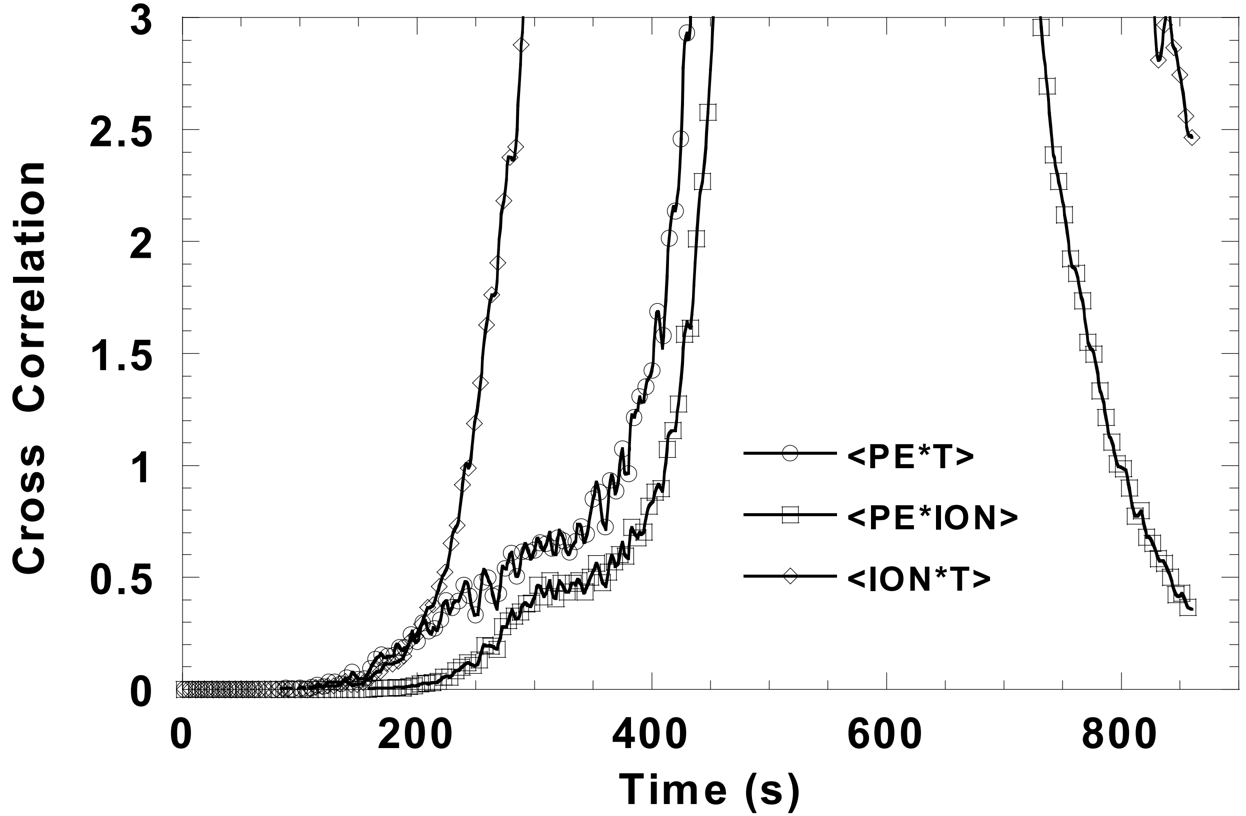
Nebulized Oil Mist



Signal Cross Correlation - Oil Mist



Signal Cross Correlation - High Humidity/Temp



Time to Cross Correlation = 1

Test	D1 Alarm (s)	D2 Alarm (s)	PE*T (s)	PE*ION (s)	PE*CO (s)	PE*CO_2 (s)	ION*T (s)	ION*CO (s)	ION*CO_2 (s)	CO*T (s)	CO*CO_2 (s)	CO_2*T (s)
Flaming Fire	54	-	51	42	69	44	59	86	46	114	60	50
Low Smoke Fire	86	-	71	78	94	61	29	96	30	87	35	27
Wood Blocks	768	1160	773	774	812	833	-	-	-	-	-	-
Pyrolyze Plastics	66	88	87	44	63	95	-	90	99	-	-	-
Cotton Wick	130	135	136	87	87	91	139	86	92	125	90	137
Flaming Plastics	-	-	48	35	58	59	57	61	59	66	61	61
High Humidity	446	396	256	349	-	-	222	-	-	-	-	-
Oil Mist	121	173	-	58	-	-	-	-	-	-	-	-
Arizona Test Dust	50	53	-	32	-	-	-	-	-	-	-	-

Summary

- Plausible cargo compartment fire and nuisance sources were emulated in the FE/DE.
- Photoelectric and ionization smoke analog output signals gathered along with CO_2, CO and H_20 gas concentrations and air temperature change

Summary Cont.

- Data suggests combinations of particulate and gas sensing
- Ambient concentrations of gases present in cargo compartments needs to be considered