LOG OF MEETING

DIRECTORATE FOR ENGINEERING SCIENCES

SUBJECT: The Smoke Alarm Research Project

DATE OF MEETING: April 18, 2001

DATE OF LOG ENTRY: April 26, 2001

SOURCE OF LOG ENTRY: Arthur Lee and Margaret Neily, ESME

LOCATION: National Institute of Standards and Technology (NIST), Building 205

CPSC ATTENDEES: See attached list of attendees.

NON-CPSC ATTENDEES: See attached list of attendees.

SUMMARY OF MEETING: Richard Bukowski, NIST, gave a presentation overview on the Smoke Alarm Research Project. titled *Home Smoke Alarm Tests* (see attachment). Jason Averill, NIST, gave a presentation on the *Experimental Overview* for the Smoke Alarm Research Project (see attachment). Tom Clearly, NIST, gave a presentation on *Detector Response Tests (Calibration)* for the Smoke Alarm Research Project (see attachment).

The following questions and responses were noted-

1. The alarms tested should be stored for archived for later characterization.
2. Is there a model to model variation?
3. Off-the-shelf smoke alarms should be placed in the tests, perhaps the bedroom if ceiling real estate is a problem.
4. Questions were raise if the tests will include doors open or closed? (testing includes doors opened)
5. The number of velocity meters to be used is three.
6. The number of TEOM to be used is one but sampled at two locations.
7. The number of cascade impactors to be used is one.
8. Will the characteristics of the furniture be characterized?
9. A sample of the fuel products to be used in the test should be archived for future analysis.
10. Concerns that a large number of fires include plastics.
11. There are no fire tests in the basement.
12. Will the home be fully furnished during the testing? (Dick – past testing has shown that fully furnished homes does not play a significant role in smoke alarm response)
13. How will smoldering fires be defined? (smoldering fires will be bounded between 30 to 60 minutes)
14. Comments to incorporate tests with closed doors will be beneficial.
15. The entrance characteristics of the smoke alarms will be tested in the NIST FE/DE facility.
16. A common method of zeroing the data needs to be established

17. When the data is produced for publication, approximately 10 minutes of background data will be included.
18. The thermocouple size is 30AWG to be used in the test.

ATTENDANCE

Smoke Alarm Research Project at NIST
April 18th Meeting

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Home Smoke Alarm Tests

April 18, 2001

Project Steering Committee

- **Help guide the project to meet objectives, interpretation of results, advance review of reports to aid understanding (comments are officially non-binding on NIST).**
  - Richard Bukowski, Chair (NIST)
  - Pauline Harvey (CDC)
  - Ellen Taylor (HUD Healthy Homes)
  - Bob McCarthy (US Fire Administration)
  - Margaret Neily (CPSC)
  - Paul Patty (Underwriters Laboratories)
  - John Hall (NFPA)
  - James Milke (U of Maryland)
  - J. Russell Thomas (National Research Council of Canada)

Project Logistics

- Funding
  - $200k from each participant; $100k now, $100k at the start of year 2.
  - CPSC, CDC, and USFA through CPSC, HUD and UL direct to NIST.
  - NFPA and NRCC (In-kind), U of MD (BFRL Grant)
  - Inter Agency Agreements (Statement of work)
- Reporting
  - Quarterly progress reports
  - Semi-annual briefings (NIST or test site)
  - Site visits
  - Final technical report, summary report, data access

Project Objectives (1)

- ***Evaluate the performance of current smoke alarm technology.*** **Smoke alarms of both the ionization and photoelectric type representative of current product sold will be evaluated with regard to the quantity of escape time provided when installed in actual one- and two-story residential arrangements. In addition, resistance to common nuisance alarm sources will be evaluated.**

Project Objectives (2)

- ***Test conditions are representative of current, fatal residential fires.*** **Fire scenarios utilized, including ignition sources and fuel items, will be selected based on current NFIRS data on fatal residential fires to demonstrate the potential for mitigation. (John Hall)**

Project Objectives (3)

- ***Tests evaluate the efficacy of current requirements for number and location of smoke alarms.*** **Smoke alarm locations will be consistent with current code requirements but will also examine whether more or different locations would result in cost effective improved performance.**

Project Objectives (4)

- ***Develop the basis for standard nuisance sources.*** **Currently there are no agreed set of nuisance alarm sources for smoke alarms in any standard. Such a set will be developed and characterized for incorporation into existing test programs.**

Project Objectives (5)

- ***Examine other fire detection technologies in combination with smoke alarms to provide data useful in establishing code requirements.*** **Residential heat detectors and sprinklers (without water to record activation times and conditions without affecting the test) will be included to develop useful data on their benefits when used with smoke alarms. Sprinklers discharging water may be used in the last test in any dwelling.**

Project Objectives (6)

- *Obtain data on the potential for improvements in performance by new technologies.* New technologies such as combined smoke and CO detectors and aspirated smoke detectors will be included to develop an understanding of their potential benefits for improved fire safety performance and reduced nuisance alarms. This project will provide the opportunity to evaluate the potential performance gains both for fire (smoke) and CO hazards detection and nuisance alarm reduction in actual dwelling configurations.

Project Objectives (7)

- *Fuel items incorporate materials and constructions representative of current residential products.* Combustible items used will to the extent possible employ materials and constructions representative of current residential products. While, as in the earlier tests, used items may be employed, these will be selected to represent current practice.

Project Objectives (8)

- ***Fully characterize test detectors and alarms in a consistent manner to facilitate comparisons.*** **All detectors evaluated will be initially characterized in NIST's FE/DE apparatus and will be re-examined between each group of field tests to ensure that they continue to perform normally following fire exposure. Use of the FE/DE will allow all detectors to be characterized in a consistent way regardless of operating principle.**

Project Objectives (9)

- ***Utilize fire models to extend the applicability of the test arrangements and maximize the test instrumentation.*** **Fire modeling techniques will be utilized with all test residences to plan effectively the fire scenarios and instrumentation. Modeling will also be used to extrapolate the limited number of test configurations to enhance data usefulness.**

Project Objectives (10)

- ***Make all of the data collected as widely accessible as possible.*** **All data collected in the tests will be published and made available electronically in a common fire data format on the World Wide Web. This will include experimental measurements, modeling results, and photographic documentation.**

Project Objectives (11)

- ***Use the project to enhance public education on the use of smoke alarms.*** **The project will provide opportunities to enhance public fire safety education, both from the dissemination of what is learned and by the development of video material during testing. Information to be developed includes the optimum use of smoke alarms alone and in conjunction with residential sprinklers, use of smoke alarms for the hearing impaired, and reinforcement of proper maintenance, testing, and replacement policies.**

Work Plan (1)

- **Experimental Devices**
  - Smoke alarms modified for analog output representative of all sensor designs
  - Mechanical heat detectors
  - Residential sprinklers (tell-tale)
  - CO, aspirated, other emerging technology as identified
- **Instrumentation**
  - Temperature
  - Smoke (density, aerosol characterization)
  - Gasses (CO, CO_2, O_2, FTIR by NRCC)
  - Purser Tenability Criteria (mostly)

Work Plan (2)

- **Tenability criteria and other assumptions to underpin conclusions but all data will be published so any other assumptions can be applied**
- **Major database for a range of uses in the future**
- **Test Sites**
  - Donated homes (Kinston NC)
  - Purchased manufactured home at NIST
  - Atlanta (?)

General Schedule

Task		Schedule
1.	Acquire test detectors/alarms and conduct initial characterization.	Months 1-3
2.	Identify potential dwellings for test sites	Months 1-3
3.	Acquire long term site at NIST	Months 1-3
4.	Review NFIRS data and develop scenarios (NFPA)	Months 1-3
5.	Perform modeling studies of sites	Months 3-6
6.	Develop instrumentation and test plans for sites	Months 3-6
7.	Identify and acquire fuel items	Months 3-6
8.	Shake down tests in long term test site	Months 3-6
9.	Conduct initial fire testing	Months 6-12
10.	Conduct initial nuisance alarm testing	Months 6-12
11.	Analyze data, model tests and prepare initial test report	Months 12-15
12.	Conduct second round of testing	Months 15-21
13.	Analyze data, model and prepare final test report	Months 21-24
14.	Format data and publish on the Web	Months 23-24
15.	Develop public educational materials from test results	Months 23-24

Home Smoke Alarm Tests

Experimental Overview

Overview

- **Fire Scenario Development**
- **Instrumentation**
- **Hazard Analysis**

Fire Scenario Development

- Data origin:
  - John Hall from NFPA report commissioned by Linda Smith from CPSC
  - Data summarizes major residential structure fires according to the National Fire Incident Reporting System (NFIRS) database from 1992 - 1996

Fire Scenario Development

- Subsequent statistical analysis ranked scenarios by frequency of occurrence and contribution to death statistics.

Fire Scenario Development

	Rank By Most Frequent	
1	**K F Cooking Materials**	**82,905**
2	**BR F Mattress**	**15,914**
3	K F Wire/Cable	7,499
4	**BR S Mattress**	**6,437**
5	**K FF Cooking**	**5,234**
6	BR F Wire/Cable	4,551
7	K F Interior Wall Covering	4,271
8	**LR S Upholstered Furniture**	**4,060**
9	**LR F Upholstered Furniture**	**3,715**
10	LR F Wire/Cable	3,481

Fire Scenario Development

	Rank by Most Deaths	
1	**LR S Upholstered Furniture**	**372**
2	**BR S Mattress**	**251**
3	**BR F Mattress**	**249**
4	**LR F Upholstered Furniture**	**160**
5	**K F Cooking Materials**	**142**
6	K F Clothing	79
7	LR F Wire/Cable	61
8	LR F Interior Wall Coverings	52
9	BR F Clothing	51
10	K F Structural Mem/Framing	50

Test Matrix: Mobile Home

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8
Fuel Package	Upholstered Furniture	Upholstered Furniture	Upholstered Furniture	Upholstered Furniture	Upholstered Furniture	Upholstered Furniture	Upholstered Furniture	Upholstered Furniture
Fire Condition	Smoldering	Smoldering	Smoldering	Flaming	Flaming	Flaming	Flaming	Smoldering
Location	Living Room	Living Room	Living Room	Living Room	Living Room	Living Room	Living Room	Living Room
HVAC On?	No	No	No	No	No	No	Yes	Yes
Sprinklers	No	No	No	No	No	No	No	No

	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15	Test 16
Fuel Package	Mattress	Mattress	Mattress	Mattress	Mattress	Mattress	Mattress	Mattress
Fire Condition	Smoldering	Smoldering	Smoldering	Flaming	Flaming	Flaming	Smoldering	Flaming
Location	Bedroom	Bedroom	Bedroom	Bedroom	Bedroom	Bedroom	Bedroom	Bedroom
HVAC On?	No	No	No	No	No	No	Yes	Yes
Sprinklers	No	No	No	No	No	No	No	No

	Test 17	Test 18	Test 19	Test 20	Test 21
Fuel Package	Grease	Grease	Grease	Grease	Upholstered Furniture
Fire Condition	Flaming	Flaming	Flaming	Flaming	Flaming
Location	Kitchen	Kitchen	Kitchen	Kitchen	Living Room
HVAC On?	No	No	No	Yes	No
Sprinklers	No	No	No	No	Yes

Test Matrix: 2 Story Home

	Test 1	Test 2	Test 3	Test 4	Test 5
Fuel Package	Upholstered Furniture	Upholstered Furniture	Upholstered Furniture	Upholstered Furniture	Upholstered Furniture
Fire Condition	Flaming	Flaming	Flaming	Smoldering	Smoldering
Location	Living Room	Living Room	Living Room	Living Room	Living Room
HVAC On?	No	No	Yes	No	Yes
Sprinklers	No	No	No	No	No

	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12
Fuel Package	Mattress	Mattress	Mattress	Mattress	Grease	Upholstered Furniture	Extra
Fire Condition	Smoldering	Flaming	Smoldering	Flaming	Flaming	Flaming	Space
Location	Bedroom	Bedroom	Bedroom	Bedroom	Kitchen	Living Room	Built
HVAC On?	No	No	Yes	Yes	No	No	In
Sprinklers	No	No	No	No	No	Yes	Here

Fire Scenario Development

- Family Room
  - Flaming Upholstered Furniture
  - Smoldering Upholstered Furniture
- Bedroom
  - Flaming Mattress
  - Smoldering Mattress
- Kitchen
  - Grease Fire

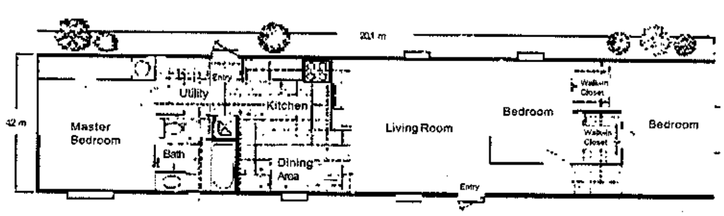
Instrumentation

- Manufactured Home
- Off-Site 2 Story Home
- Instruments
- Instrument Locations

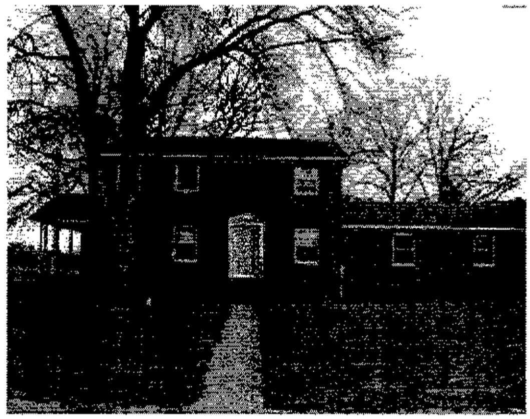
Manufactured Home

- 3 Bedroom
- 1 Bath
- Kitchen
- Dining Area
- Living Room
- 902 ft^2

Manufactured Home

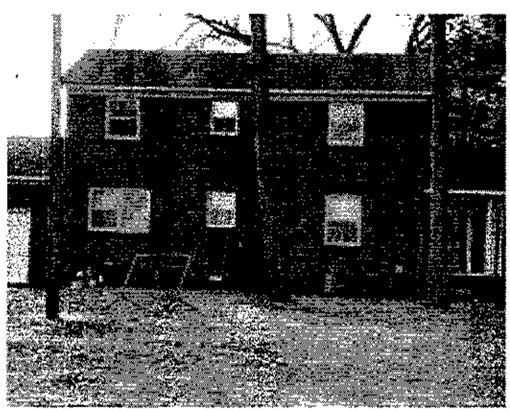


Off-Site 2 Story Home



Front of House

Off-Site 2 Story Home



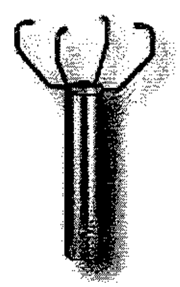
Back Of House

Instruments

- Detectors
  - Photoelectric
  - Ionization
  - Combination
  - Carbon Monoxide
  - Heat
    - Mechanical, eutectic, and rate of rise
  - Aspirated

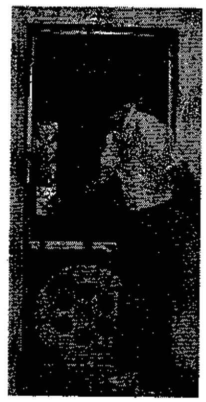
Instrumentation

- Temperature
  - Small diameter, bare bead, type-k thermocouples
- Velocity
  - 2-D Ultrasonic Anemometers Accurate to 0.01 m/s Anicipated Flow: 0 – 0.5 m/s



Instrumentation

- House Leakage
  - Infiltec Door Mounted Blower



Instrumentation

- Gas Analysis
  - Nondispersive Infrared (NDIR)

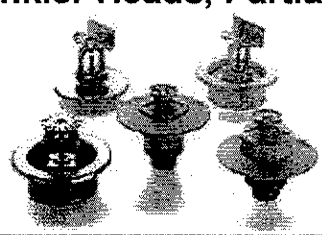
    Primary Gas Analysis will Measure CO, CO_2, and O_2

  - Fourier Transform Infrared (FTIR)

    Secondary Gas Analysis will Measure HCl, HCN, NO_x, HBr, and HF

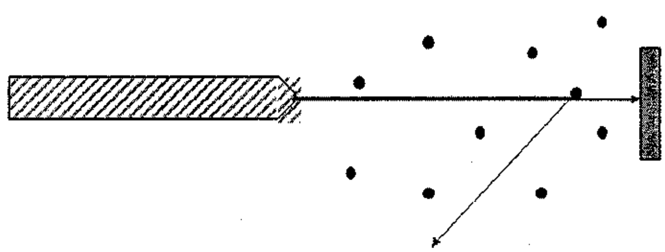
Instrumentation

- **Mass Loss Rate**
  - **Floor Mounted Load Cell Apparatus**
- **Sprinkler Response**
  - **Code Compliant 13-R Domestic Sprinkler Heads, Partially Charged**



Instrumentation

- **Smoke Obscuration**
  - **Laser-based light extinction measurements**

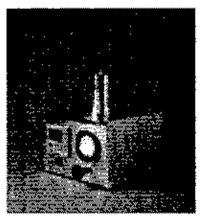


Instrumentation

- Tapered Element Oscillating Microbalance (TEOM)

Temporal Mass Flux

- Cascade Impactor



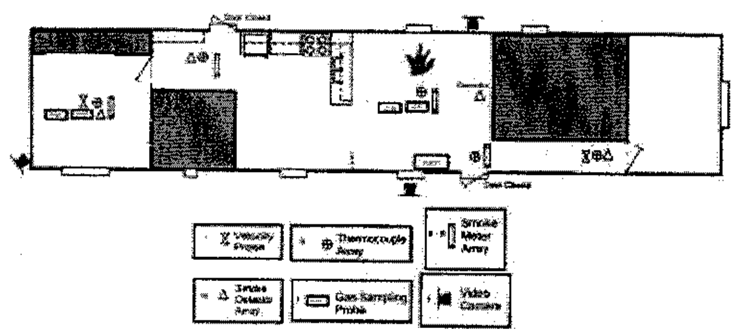
Geometric Distribution

Instrumentation

- Video Recording
    - Room of Origin
    - Target Room
    - Primary Exit

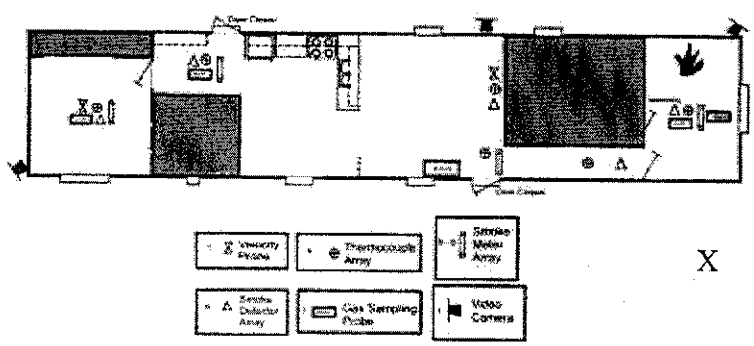
Instrumentation

Furniture Fire in the Family Room



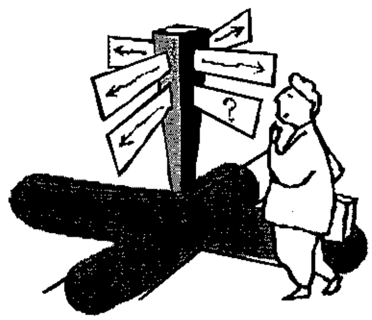
Instrumentation

Mattress Fire in the Bedroom



X

What do we do with All this data?



Hazard Analysis

- **Primary Objective**
  - Quantify the time available to residential occupants to escape a fire
- **Key Measurements**
  - Time to occupant notification (typically detector activation)
  - Time to untenable conditions along the egress path

Hazard Analysis

- **Detector Activation**
  - Analog signals allow posteriori analysis of multiple alarm criteria and algorithms
  - Capabilities and shortcomings of various detection technologies can be compared

Hazard Analysis

- **Tenability Criteria**
  - Elevated Temperature
    - 65°C and Layer Height = 1.5 m
  - Smoke Obscuration
    - OD = 0.5 m and layer height = 1.0 m
  - Convected Heat
    - Purser hyperthermia equation

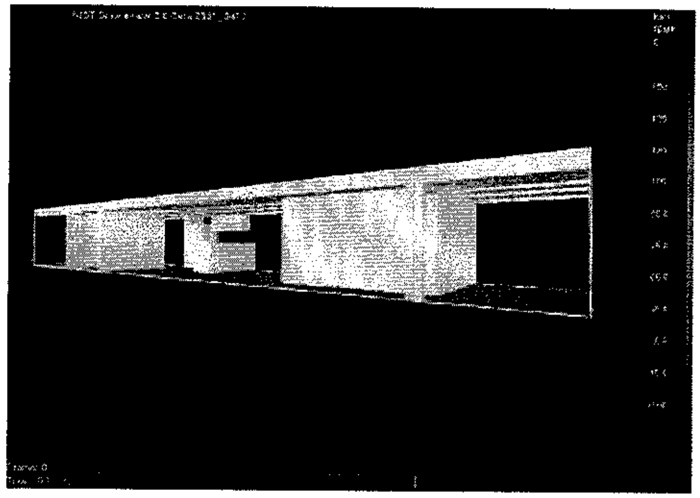
Hazard Analysis

- **Tenability Criteria (cont'd)**
  - **Toxic Gases**
    - **Fractional Incapacitating Dose from Purser for CO, HCN, O_2, and CO_2**

Hazard Analysis

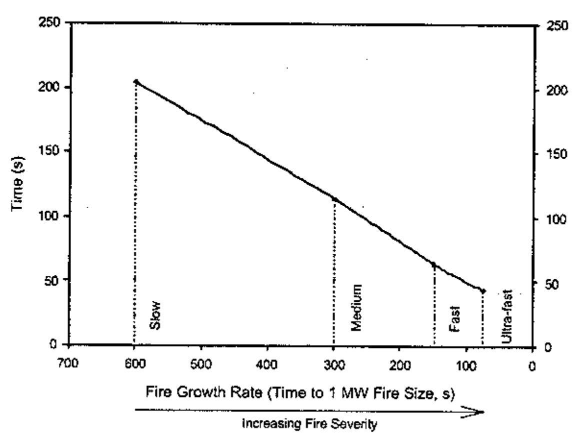
- **Fire Modeling**
  - **Fire Dynamics Simulator (FDS)**
    - **Computational Fluid Dynamics model which uses the Large Eddy Simulation (LES) method to simulate fire phenomena**
  - **Used to both plan mobile home and off-site experiments, as well as further analyze the experimental results.**

Fire Dynamics Simulator



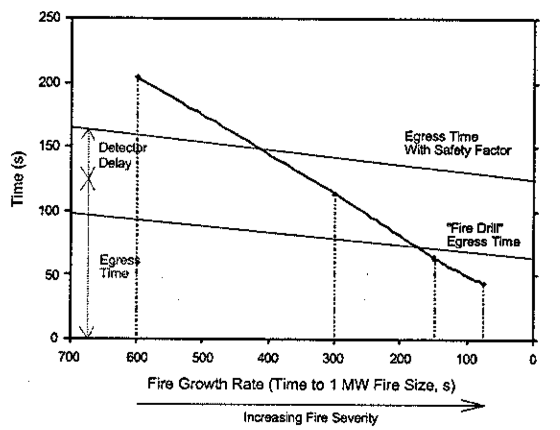
Hazard Analysis

- **Fire Performance Curves: Baseline**



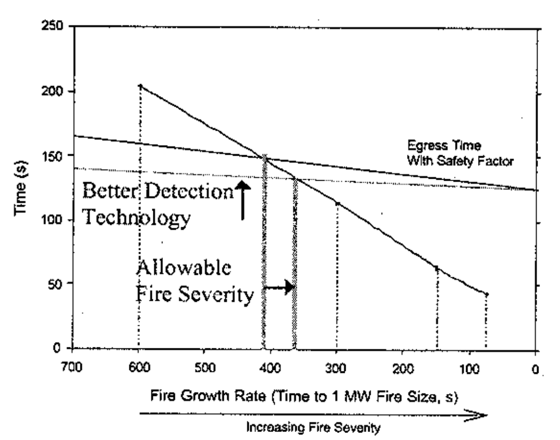
Hazard Analysis

- **Fire Performance Curves: Egress**

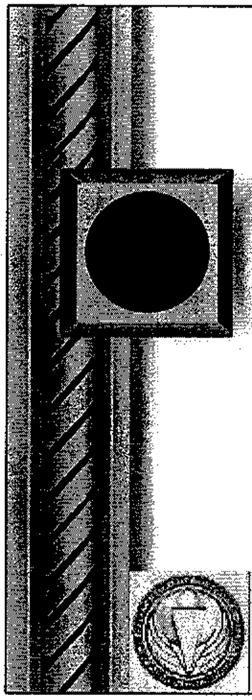


Hazard Analysis

- **Fire Performance Curves**



Questions?



Home Smoke Alarm Tests

Detector Response Tests (Calibration)

Overview

- **Analog Output Detectors**
- **Fire Emulator/Detector Evauator**
- **Calibration Protocols**

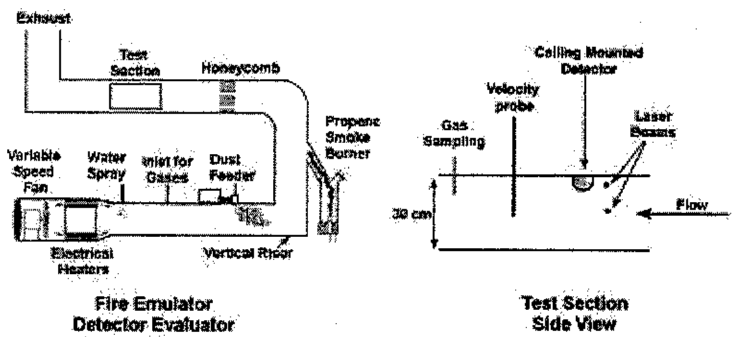
Modified Residential Detectors

- "Continuous" analog output of the sensor response to environment
  - Photoelectric, Ionization, Carbon Monoxide (electrochemical and Tin Oxide semiconductor sensors)
- Binary output heat detectors

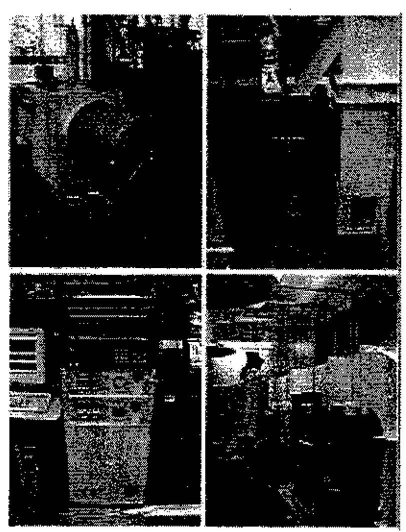
The Fire Emulator/Detector Evaluator

- The Fire Emulator/Detector Evaluator is a single-pass flow tunnel with a 0.3 m x 0.6 m cross section.
- Designed for evaluating fire detector response to fire and non-fire stimuli.
- Experimental or modeled phenomena programmed into FE/DE.

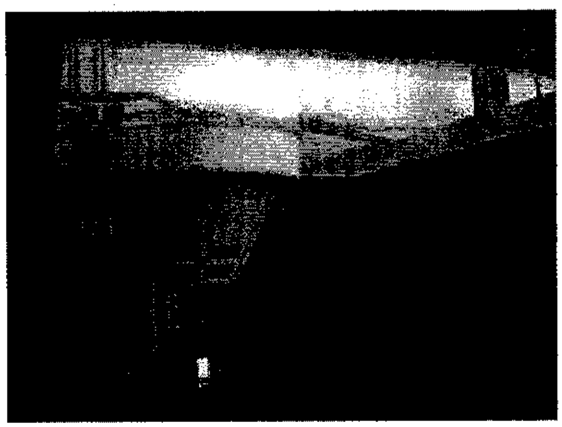
The Fire Emulator/Detector Evaluator



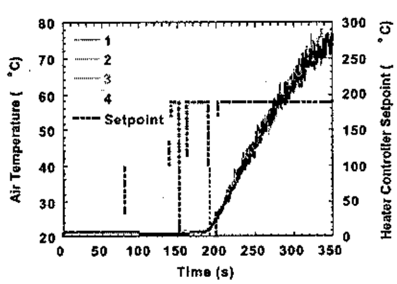
The FE/DE

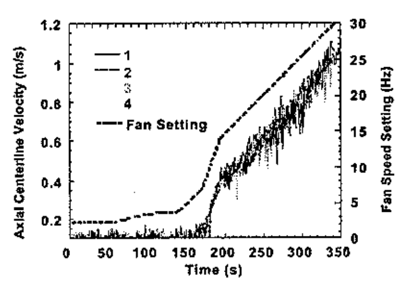


Detector at the Test Section



Temperature and velocity at a detector location reproduced from a a modeled fire

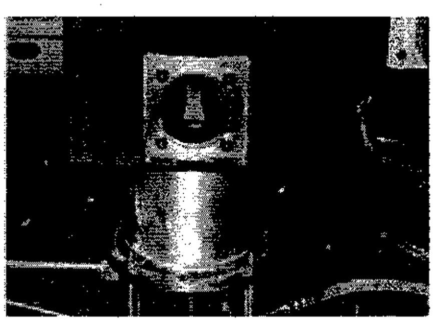


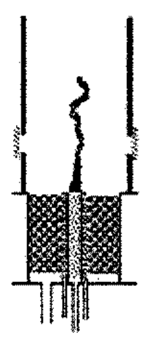


Calibration Smokes

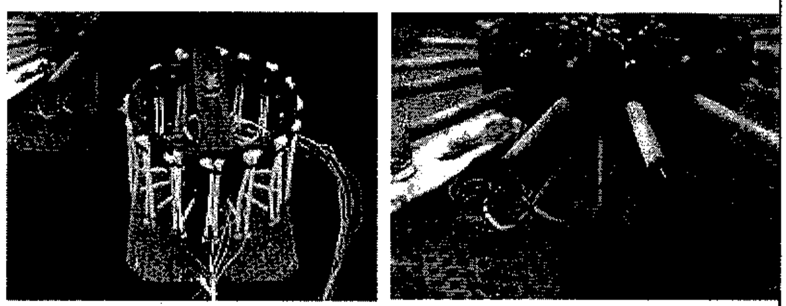
- **Black soot from propene flame**
- **Smolder smolder from cotton wicks**

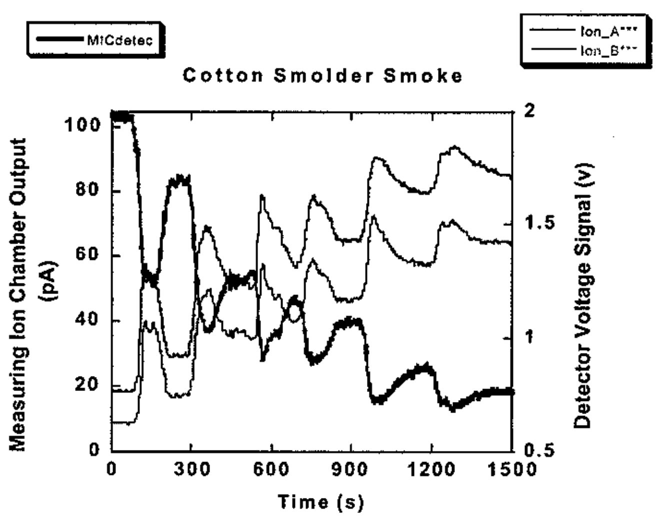
Propene Diffusion Flame Burner
Steady black smoke generator

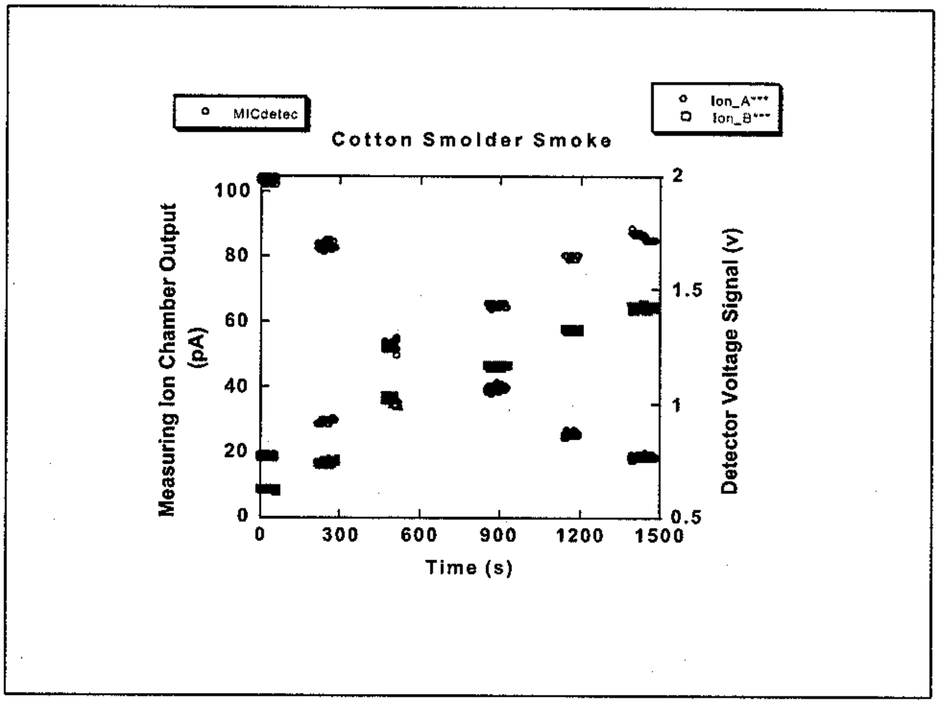


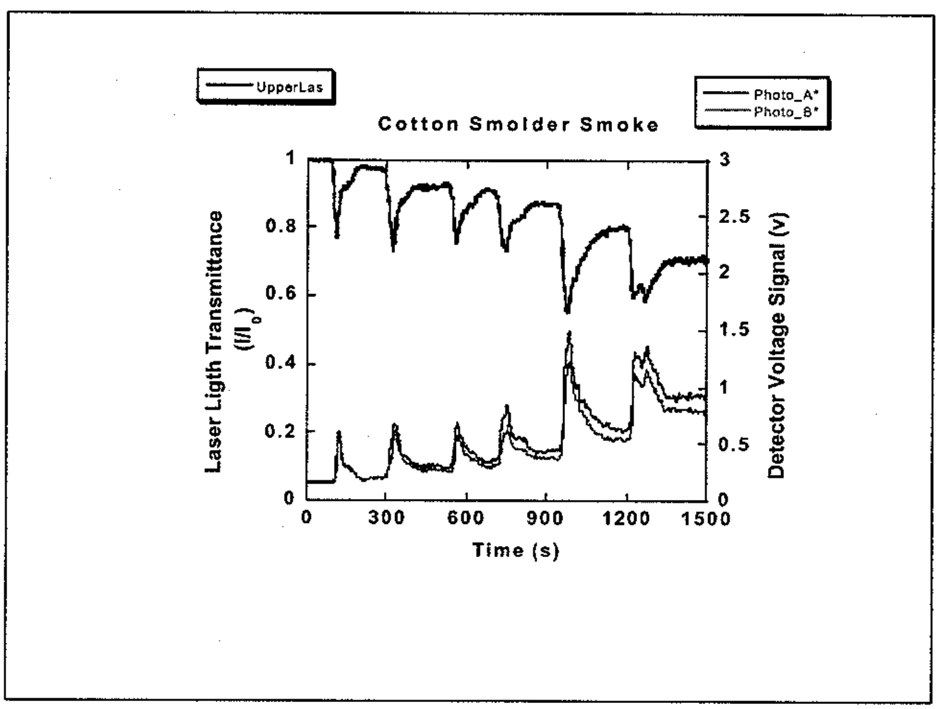


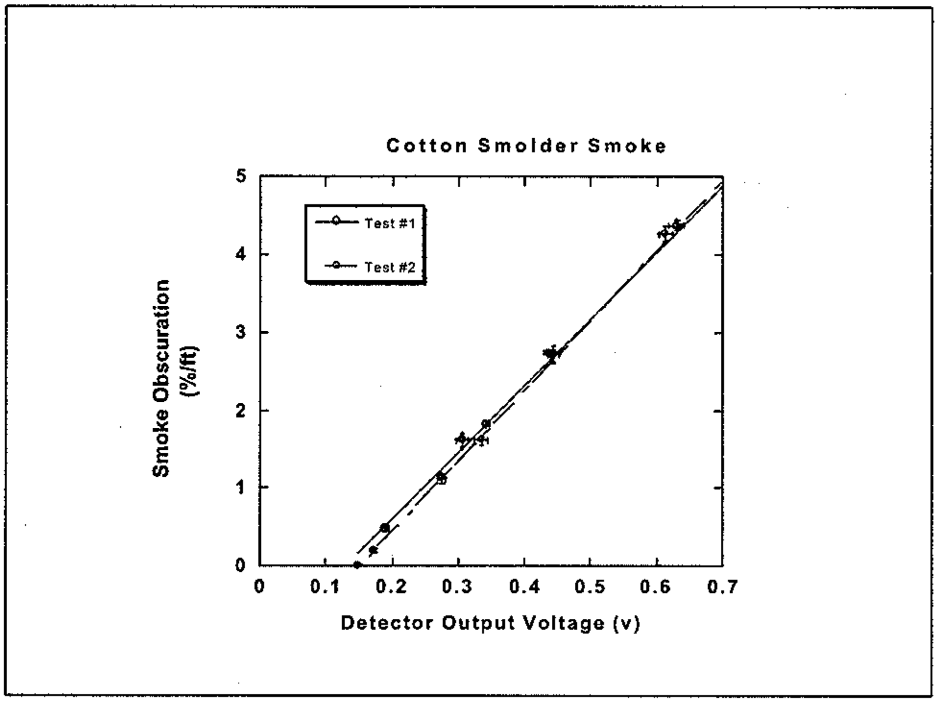
Staged Wick Ignition Device

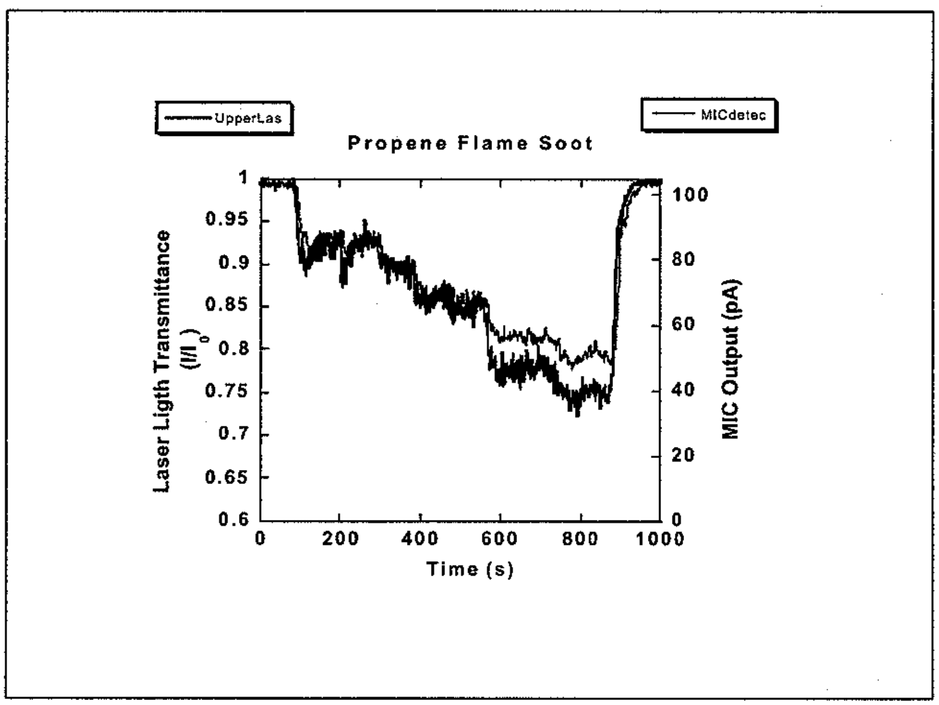


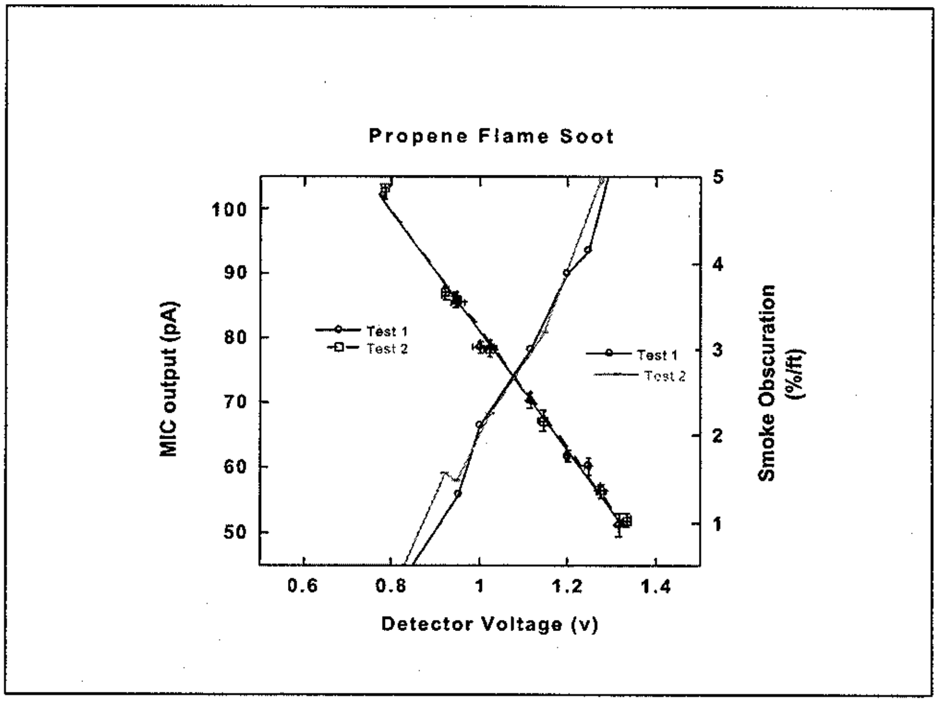



MICdetec
Ion_A***
Ion_B***
Cotton Smolder Smoke
Measuring Ion Chamber Output (pA)
Detector Voltage Signal (v)
Time (s)
0
20
40
60
80
100
0.5
1
1.5
2
0
300
600
900
1200
1500

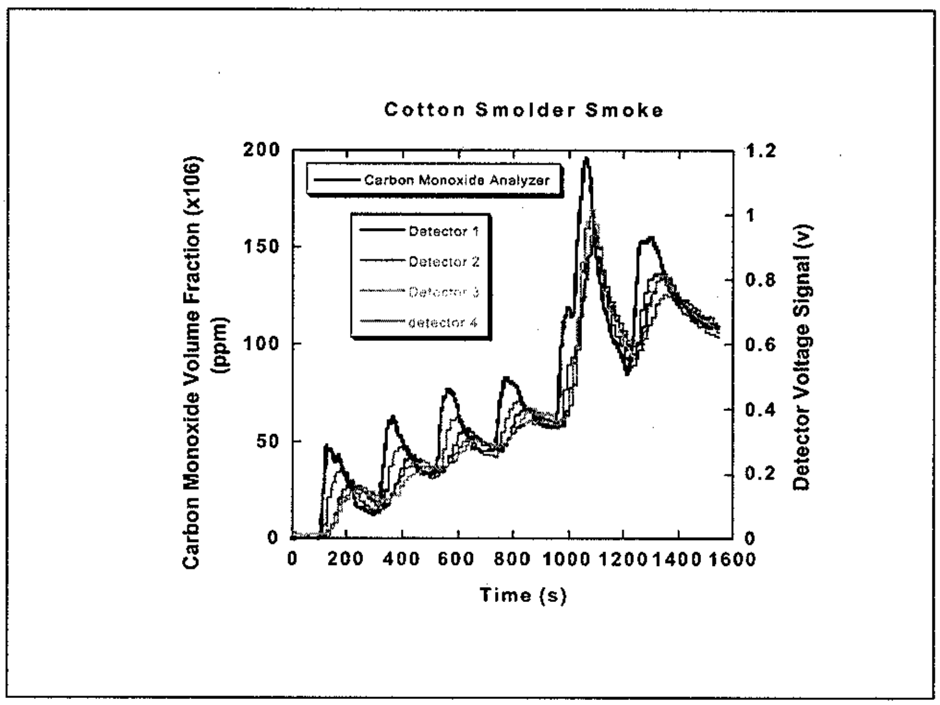

UpperLas
Photo_A*
Photo_B*
Cotton Smolder Smoke
Laser Ligth Transmittance (I/I$_0$)
Detector Voltage Signal (v)
Time (s)
0
0.2
0.4
0.6
0.8
1
0
0.5
1
1.5
2
2.5
3
0
300
600
900
1200
1500


Cotton Smolder Smoke
Test #1
Test #2
Smoke Obscuration (%/ft)
0
1
2
3
4
5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Detector Output Voltage (v)

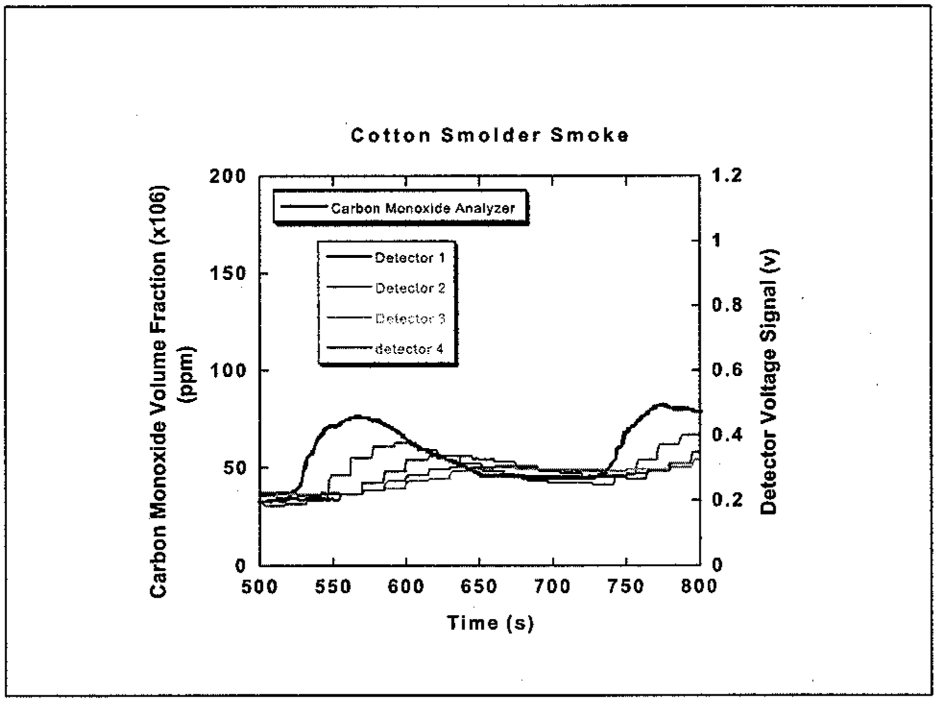

UpperLas
MICdetec
Propene Flame Soot
Laser Ligth Transmittance (I/I0)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
MIC Output (pA)
100
80
60
40
20
0
0
200
400
600
800
1000
Time (s)

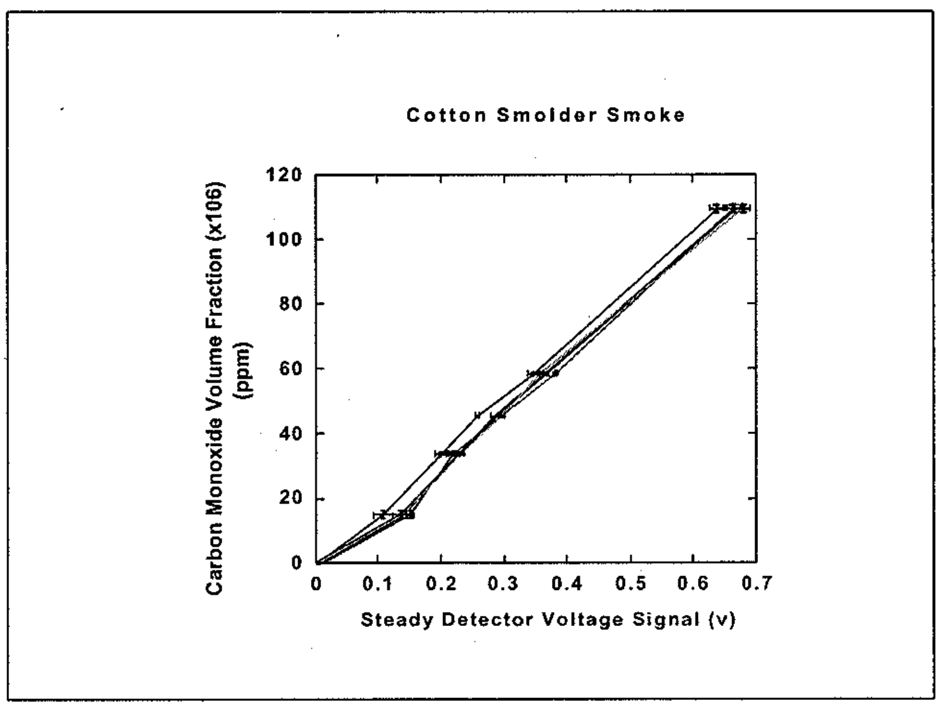


Propene Flame Soot
MIC output (pA)
Smoke Obscuration (%/ft)
Detector Voltage (v)
Test 1
Test 2
Test 1
Test 2
100
90
80
70
60
50
5
4
3
2
1
0.6
0.8
1
1.2
1.4



Cotton Smolder Smoke
Carbon Monoxide Analyzer
Detector 1
Detector 2
Detector 3
detector 4
Carbon Monoxide Volume Fraction (x106) (ppm)
Detector Voltage Signal (v)
Time (s)
200
150
100
50
0
1.2
1
0.8
0.6
0.4
0.2
0
0
200
400
600
800
1000
1200
1400
1600


Cotton Smolder Smoke
Carbon Monoxide Analyzer
Detector 1
Detector 2
Detector 3
detector 4
Carbon Monoxide Volume Fraction (x106) (ppm)
Detector Voltage Signal (v)
Time (s)
0
50
100
150
200
0
0.2
0.4
0.6
0.8
1
1.2
500
550
600
650
700
750
800


Cotton Smolder Smoke
Carbon Monoxide Volume Fraction (x106) (ppm)
Steady Detector Voltage Signal (v)
0
20
40
60
80
100
120
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

Questions?