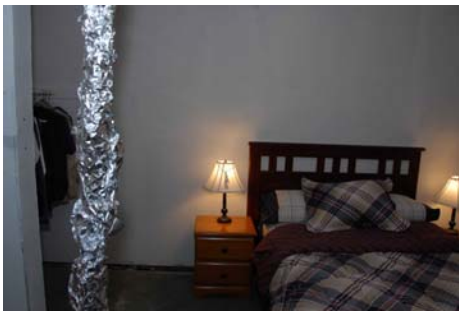
Fire Pattern Research in the US: Current Status and Impact

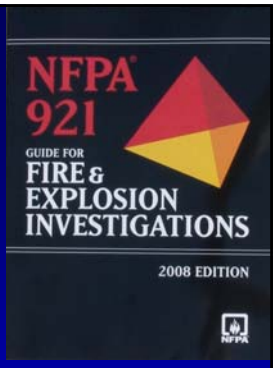


Ronald L. Hopkins, MS, CFEI, CFPS
TRACE Fire Protection and Safety
Richmond, Kentucky USA
August 2008

I. Introduction and Problem Statement

Fire Pattern Analysis as a Fire Investigation Tool?

NFPA-921, "Guide for Fire and Explosion Investigations: 2008



Chapter 17 Origin Determination

"17.1.2 Determination of the origin of the fire involves the coordination of information derived from one or more of the following:

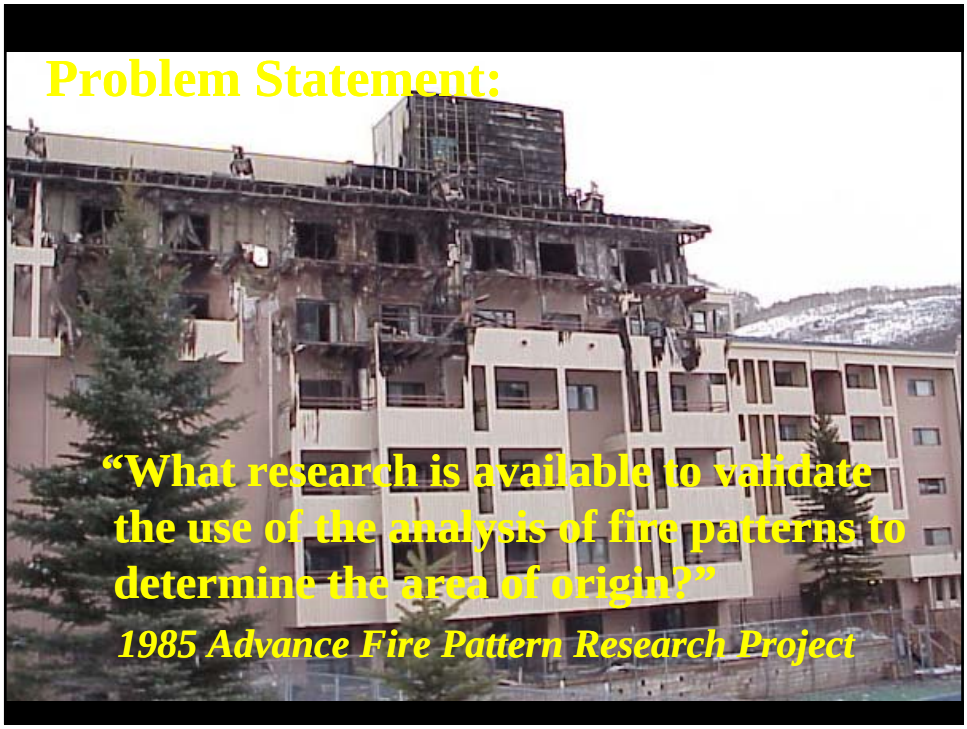
Chapter 17 Origin Determination

(1) Witness Information. The analysis of observations reported by persons who witnessed the fire or were aware of conditions present at the time of the fire

(2) Fire Patterns. The analysis of effects and patterns left by the fire (See Chapter 6.)

(3) Arc Mapping. The analysis of the locations where electrical arcing has caused damage and the documentation of the involved electrical circuits (See Section 8.10.)

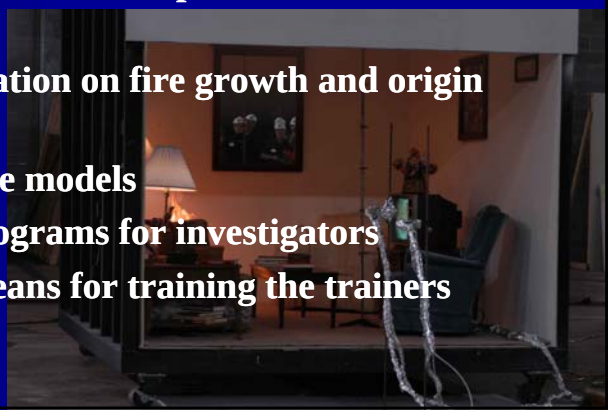
(4) Fire Dynamics. The analysis of the fire dynamics, that is, the physics and chemistry of fire initiation and growth (see Chapter 5), and the interaction between the fire and the building's systems (See Chapter 7.)"


Problem Statement:
"What research is available to validate the use of the analysis of fire patterns to determine the area of origin?"
1985 Advance Fire Pattern Research Project


International Conference
on
Fire Research
for
Fire Investigation (1997)
Bureau of Alcohol, Tobacco,
and Firearms (BATF) Sponsor
and Hughes and Associates
(Coordinators)

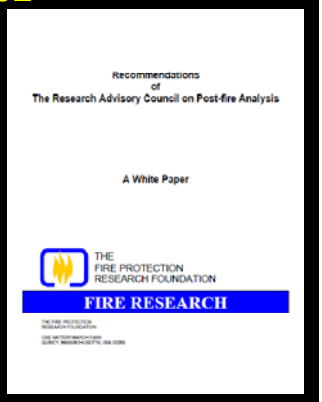
Conference Proceedings:

- Validation of pattern analysis – patterns on walls and ceilings and patterns resulting from liquids on floors
- Impact of flashover on fire patterns and other indicators
- Effects of ventilation on fire growth and origin determination
- Validation of fire models
- Certification programs for investigators
- Methods and means for training the trainers



BATF Fire Research Lab

"Recommendations of The Research Advisory Council on Post-Fire Analysis" NFPA February 2002



Research Need:

"Knowledge of ignition, early fire growth, flame spread and smoke generation as related to the genesis of fire patterns needs to be developed and integrated into the models being used to interpret fire patterns and test origin and cause theories. "

II. Historical overview of the use of Fire Patterns to determine the origin of structure Fires.

A. "Fire Investigations" written in 1945 by Rethoret, states:

"In which direction is the wood carbonized?

Study closely the depth of carbonization at various places. Bear in mind that superheated gases spread upwards. This again will assist you in getting back to the point of origin."

A. "Fire Investigations" written in 1945 by Rethoret, also states:

"During the course of a fire, substances undergo changes which show themselves in different manners. These changes are characteristic of these substances and, by themselves, furnish valuable leads to the fire investigator."

A. "Fire Investigations" written in 1945 by Rethoret, also states:

"The direction of the flames and gases is governed entirely by air currents. Partly burnt wallpaper, the heavy soot deposits previously mentioned, the position of embers, etc., clearly show to the investigator the direction of the air currents."

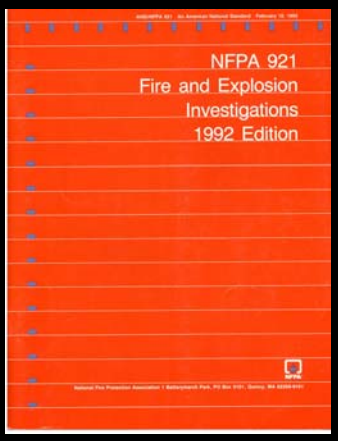
B. "Fire and Arson Investigation" 1962; John A. Kennedy, Cause and Origin chapter describes the Arrow or Pointer theory.

C. "Fire Investigation" written by Dr. Paul L. Kirk, published in 1969 states:

"Every fire forms a pattern that is determined chiefly by the configuration of the environment and the availability of combustible material."

D. NFPA-921-1992 "Guide for Fire and Explosion Investigation", includes the following:

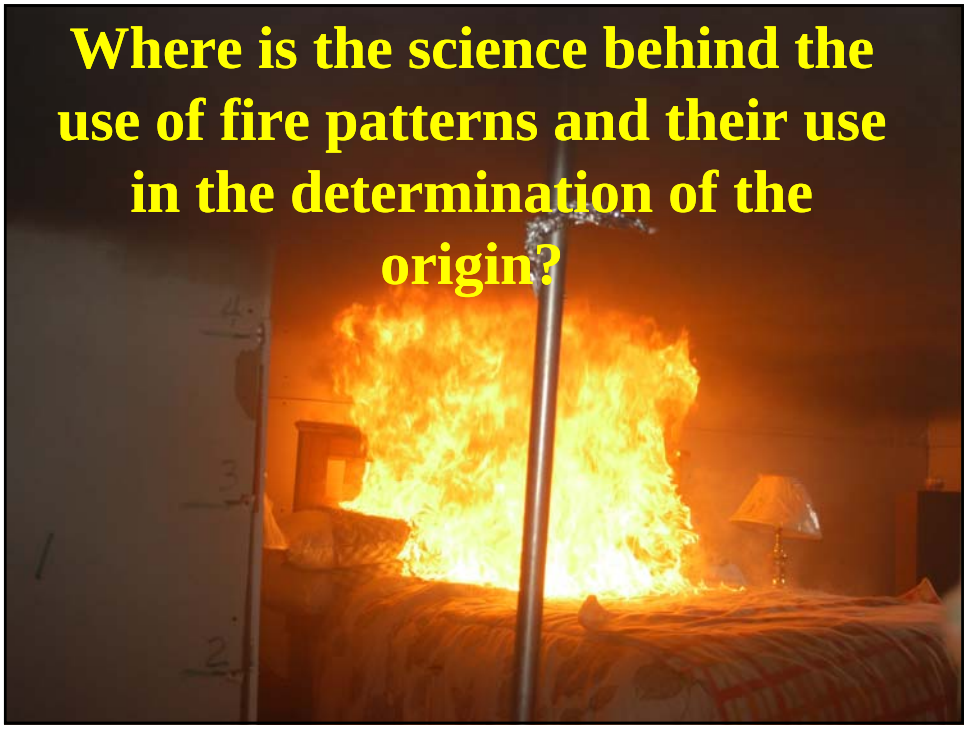
"4-1 Introduction. One of the major objectives of a fire scene examination is the recognition, identification, and analysis of fire patterns. The analysis of the fire patterns is performed in an attempt to trace fire spread, identify areas and points of origin, and identify the fuels involved."



E. NFPA 921-2008, "Guide for Fire and Explosion Investigations"

"6.1.1 The major objective of any fire scene examination is to collect data as required by the scientific method (see 4.3.3). Such data include the patterns produced by the fire. A fire pattern is the visible or measurable physical changes or identifiable shapes formed by a fire effect or group of fire effects. Fire effects are the observable or measurable changes in or on a material as a result of exposure to the fire. The collection of fire scene data requires the recognition and identification of fire effects and fire patterns. The data can also be used for fire pattern analysis (i.e., the process of interpreting fire patterns to determine how the patterns were created). This data and analysis can be used to test hypotheses as to the origin of the fire as discussed in Chapter 17.

Where is the science behind the use of fire patterns and their use in the determination of the origin?



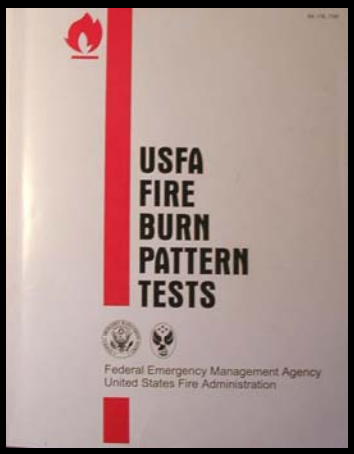
1. Advanced Fire Pattern Research Project (AFPRP)

Formed in 1985 by the National Association of Fire Investigators (NAFI) and Eastern Kentucky University (EKU) to study fire growth and spread in full and ¼ scale compartments.

2. USFA Fire Burn Pattern Tests, 1997

Included in the summary of results:

many of the concepts, investigative systems, dynamics of pattern production, and patterns analysis concepts put forward in NFPA-921-1995 were confirmed by the Programs tests.



2. USFA Fire Burn Pattern Tests, 1997

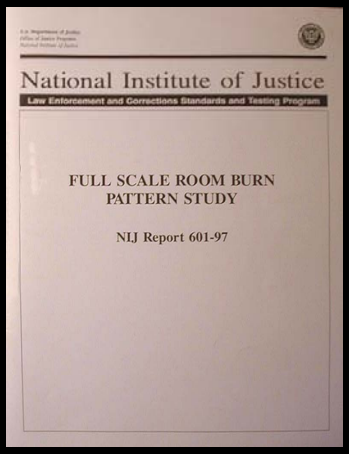
- **Formation dynamics of truncated cone patterns**
- **Intensity patterns**
- **Movement patterns**
- **Calcination (dehydration) of gypsum wallboard**
- **Pattern persistence through flashover**
- **Depth of char**
- **"V" patterns**
- **"U" Patterns**
- **Pointer/Arrow patterns**
- **Hourglass patterns**
- **Saddle bums**
- **Clean burn**
- **Heat shadowing**
- **Protected areas**
- **Beading of electrical conductors**
- **"Pulled" light bulbs**
- **Melting of materials**
- **Truncated cone patterns**

2. USFA Fire Burn Pattern Tests, 1997

Several of the "old wives' tales" and fire investigation misconceptions which are repudiated in NFPA 921 were also shown to be unsubstantiated by the program testing. Some of these theories include the following:

- **Wide "Vs" vs. narrow "Vs"**
- **Crazing of window glass**
- **Nature of charring**
- **Window sooting/staining**
- **Color of smoke and flame.**

3. "Full Scale Room Burn Pattern Study", December 1997



"Significant differences in the condition and appearance of the burn rooms and furnishings were present between experiments with the same method of ignition.

Ventilation an issue.

Review the photographs in the document, are they that different or are they within acceptable ranges?

3. "Full Scale Room Burn Pattern Study", December 1997

FIGURE 29. *Photograph of the chair as viewed through doorway. Experiment 1.*

Review the photographs in the document, are they that different or are they within acceptable ranges?

III. Overview of Recent Fire Pattern Research Completed

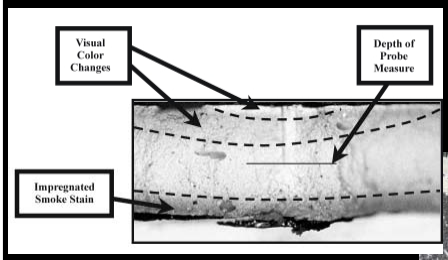
A. Depth of Calcination Measurement in Fire Origin Analysis

Fire and Materials, 2003

A. Depth of Calcination Measurement in Fire Origin Analysis

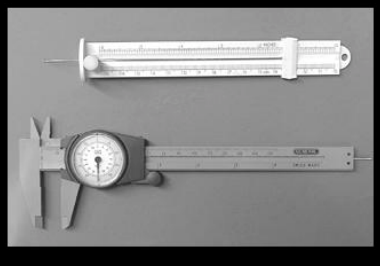
- **Research test results were good, providing accurate and reproducible fire movement analysis and supporting the calcination measurement techniques, systems, and tools advocated by NFPA 921.**
- **Collected data was comparable among participants with widely varied fire investigation experience and after only minimal instruction and practice in the calcination depth measurement techniques and tools.**

Depth of Calcination



Color Change

Probe Tools



B. Full Scale Room Burn Pattern Study

International Symposium on Fire Investigation Science and Technology (IFSI) 2006

March and November 2005 and March 2006 Test Burns

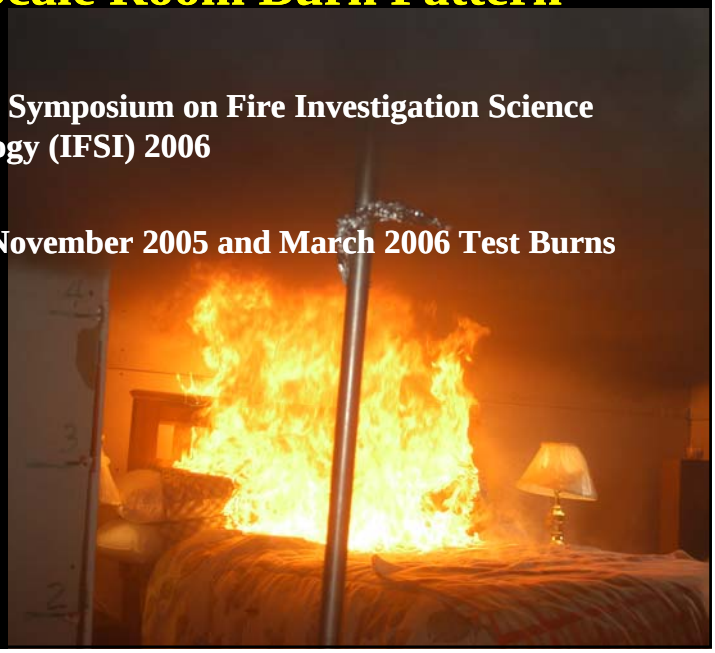


Figure 28-31 – Hallway (left to right) Exp. Set "A": Cell #1, Cell #2; Exp. Set "C": Cell #1, Cell #2

Figure 36-39 – East Wall (left to right) Exp. Set "A": Cell #1, Cell #2; Exp. Set "C": Cell #1, Cell #2

C. Advanced Fire Pattern Research Project: Single Fuel Package Fire Pattern Study.

International Symposium on Fire Investigation Science and Technology (IFSI) 2006

D. Fire Pattern Persistence and Predictability on Interior Finish and Construction Materials During Pre and Post Flashover Compartment Fires

Fire and Materials, 2007

Tests 2005 – 2006 total of 8 burns

E. Fire Pattern Persistence and Predictability in Pre and Post Flashover Compartment Fires

International Symposium on Fire Investigation Science and Technology (ISFI) 2008

Tests 2005 to 2007 total of 10 identical rooms and one actual fire and identical test room.

F. Full-Scale Single Fuel Package Fire Pattern Study

International Symposium on Fire Investigation Science and Technology (ISFI) 2008

IV. Advanced Fire Pattern Research Project (AFPRP)1985

IV. Advanced Fire Pattern Research Project (AFPRP)

Series of Full Scale Research Burns beginning March 2005 in duplicate rooms, ending in 2007. An additional test was completed to determine if fire patterns that were created in an actual scene could be duplicated.

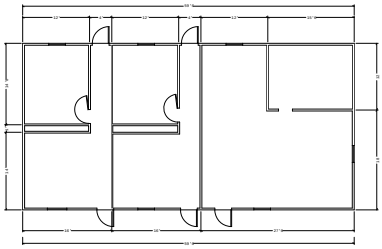
Problem Statements:

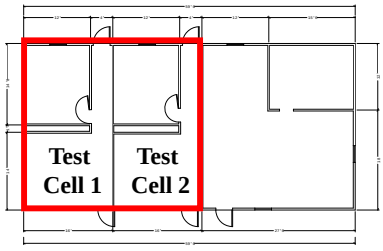
1. **Do fire patterns persist through flashover and full room involvement?**
2. **Can fire pattern geometry be reproducible in minimal variable testing methods?**
3. **Can standard fire patterns analysis methodologies, such as heat and flame vector analysis, depth of calcination measurement, depth of char, and truncated cone pattern formation and analysis be reaffirmed?**

As an added value these research burns were designed to test the validity of content of the National Fire Code© component document, *NFPA 921 – Guide for Fire and Explosion Investigations* chapters on Fire Patterns, and Origin Determination.

EKU FSE Burn Building

EKU FSE Burn Building





Fire Tests

Experiment Set "A" March 2005 Bedroom

Experiment Set "B" November 2005 Living Room

Experiment Set "C" March 2006 Bedroom

Experiment Set "D" October 2006 Living Room

Experiment Set "E" March 2007 Bedroom

Each Set: 2 tests in identically furnished rooms

Documentation

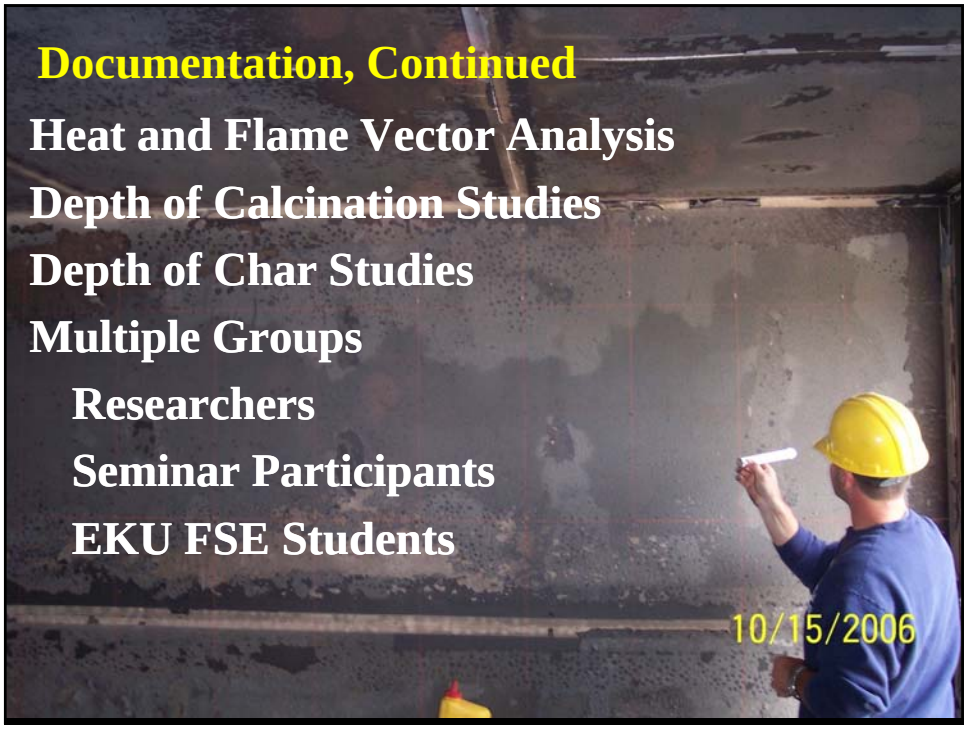
Thermocouple Data

Radiometer Data

Extensive Photography
Prior, During, and After

Documentation, Continued

- Heat and Flame Vector Analysis
- Depth of Calcination Studies
- Depth of Char Studies
- Multiple Groups
  - Researchers
  - Seminar Participants
  - EKU FSE Students



Experiment Set A: Experiment 1 March 2005

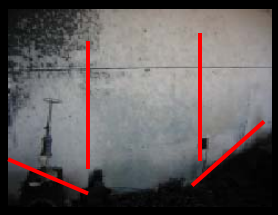

Experiment Set A: Experiment 1
March 2005


Experiment Set A: Experiment 1
March 2005

Experiment Set A: Experiment 2 **March 2005**

Experiment Set A: Experiment 2 **March 2005**



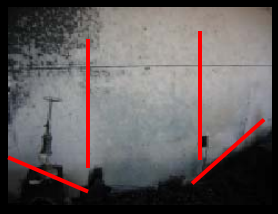


Experiment Set A: Experiment 2 **March 2005**



Experiment Set A: Experiment 1 **March 2005**





Experiment Set A: Experiment 2 **March 2005**

Experiment Set C: Experiment 5 March 2006

Experiment Set C: Experiment 5 March 2006

Room did not progress to full room involvement

Experiment Set C: Experiment 5 **March 2006**

Room did not progress to full room involvement

Experiment Set C: Experiment 6 **March 2006**

Experiment Set C: Experiment 6 March 2006

Experiment Set C: Experiment 6 March 2006



Experiment Set C: Experiment 5 March 2006



Experiment Set C: Experiment 6 March 2006

Experiment Set A: Experiment 1
March 2005

Experiment Set A: Experiment 2
March 2005

Experiment Set C: Experiment 5
March 2006
Room did not progress to full room involvement

Experiment Set C: Experiment 6
March 2006

Experiment Set B: Experiment 3 November 2005

Experiment Set B: Experiment 3 November 2005



Experiment Set B: Experiment 3 **November 2005**

Experiment Set B: Experiment 4 **November 2005**

Experiment Set B: Experiment 4 November 2005

Experiment Set B: Experiment 4 November 2005



Experiment Set B: Experiment 3 November 2005



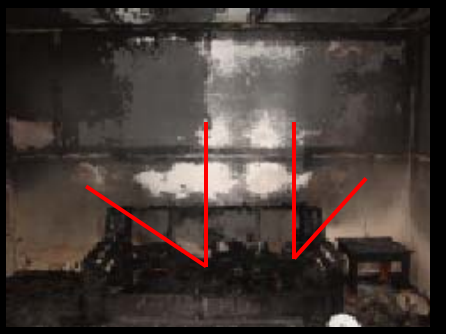
Experiment Set B: Experiment 4 November 2005

Experiment Set D: Experiment 7 October 2006

Experiment Set D: Experiment 7 **October 2006**

Experiment Set D: Experiment 7 **October 2006**

Experiment Set D: Experiment 8 October 2006



Experiment Set D: Experiment 8 October 2006

Experiment Set D: Experiment 8 October 2006

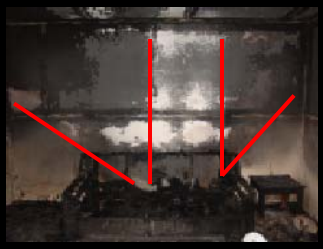
Experiment Set D: Experiment 7 October 2006

Experiment Set D: Experiment 8 October 2006

Experiment Set B: Experiment 3
November 2005

Experiment Set B: Experiment 4
November 2005

Experiment Set D: Experiment 7
October 2006



Experiment Set D: Experiment 8
October 2006

Experiment Set E: Experiment 9 March 2007

Experiment Set E: Experiment 9 March 2007

Experiment Set E: Experiment 10 March 2007

Experiment Set E: Experiment 10 March 2007

Experiment Set E: Experiment 9
March 2007

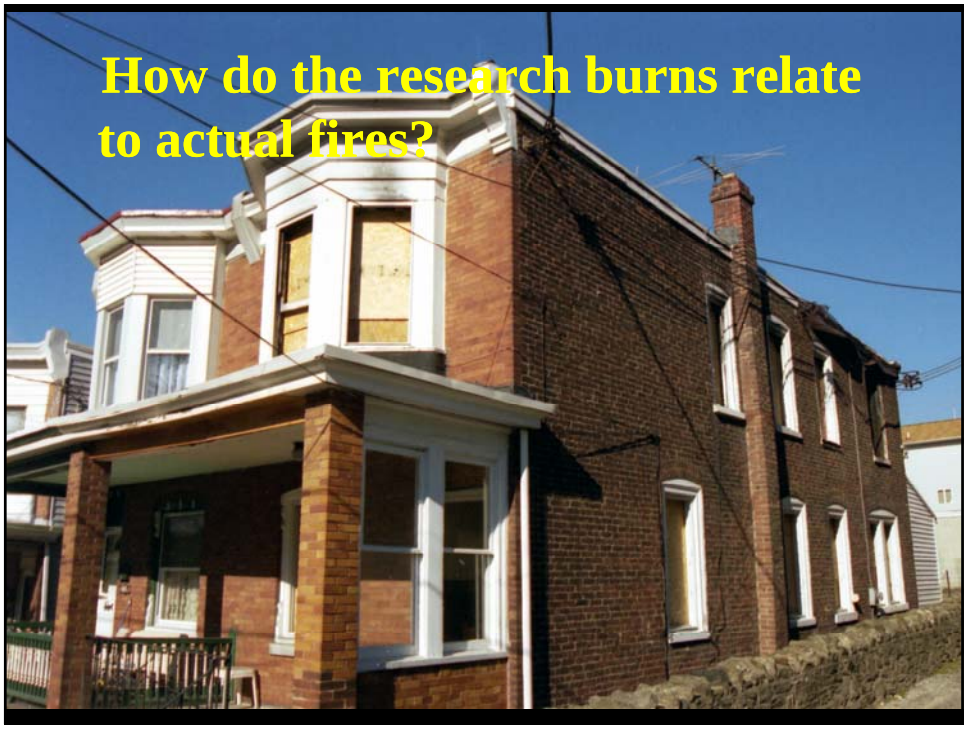
Experiment Set E: Experiment 10
March 2007

Does a low hrr fuel spreading into a high hrr fuel obscure patterns for accurate determination of an origin at the small fuel?

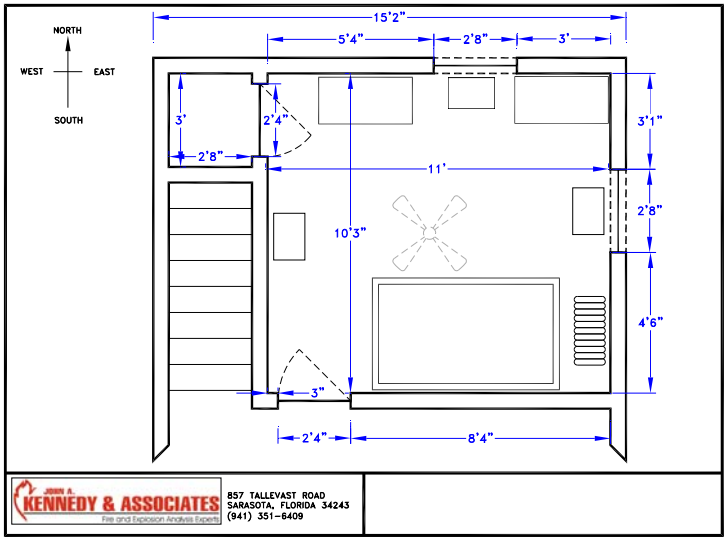
Experiment Set C: Experiment 6
March 2006

Experiment Set E: Experiment 9
March 2007

How do the research burns relate to actual fires?



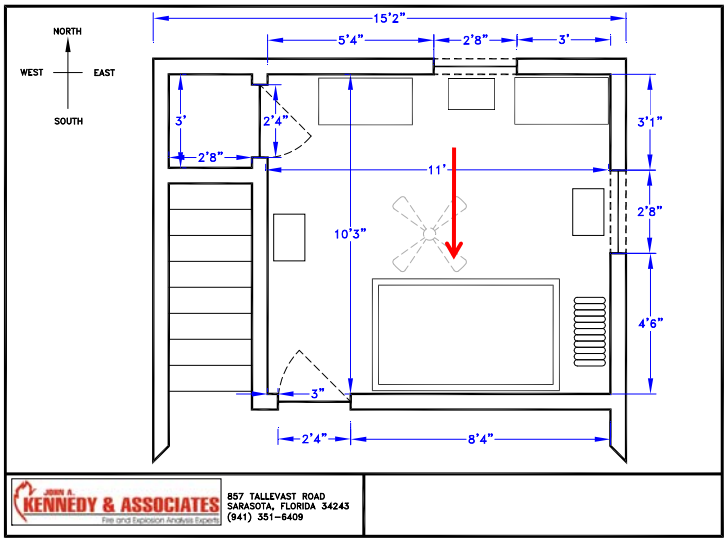
Bedroom Fire and Test Fire



Construction

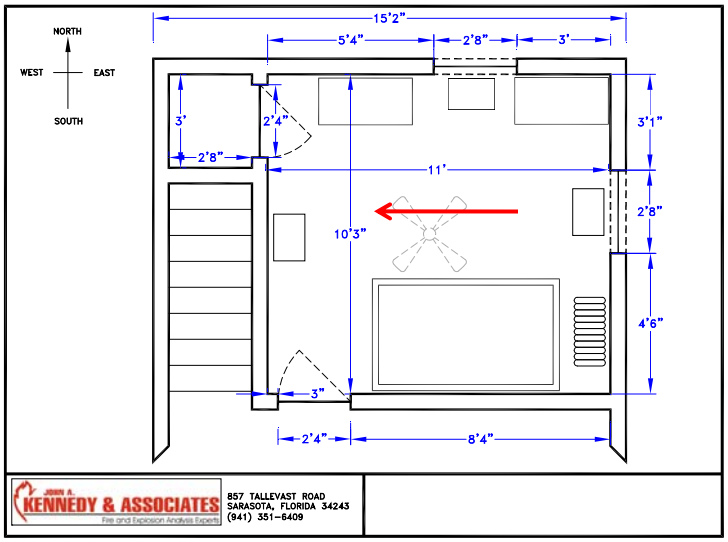
Documentation

Bedroom Fire and Test Fire



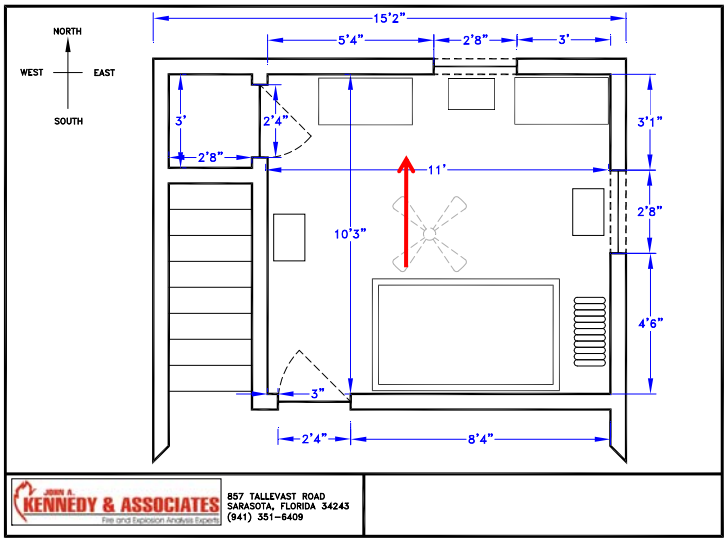
Bedroom Fire and Test Fire

Bedroom Fire and Test Fire



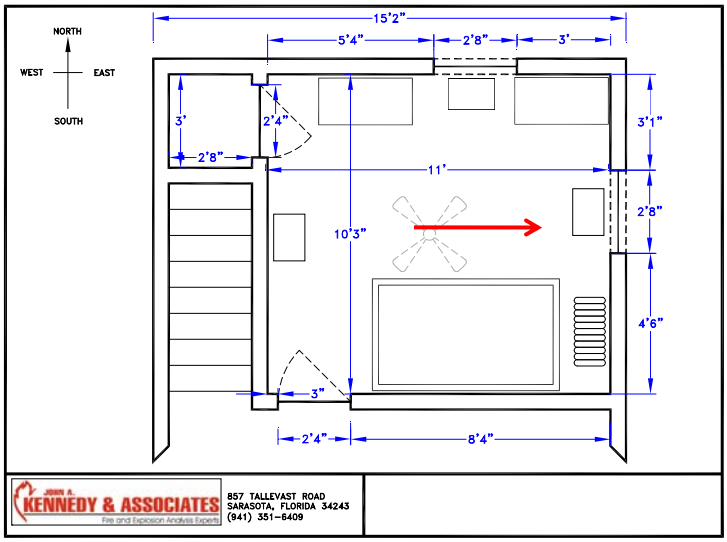
Bedroom Fire and Test Fire

Bedroom Fire and Test Fire



Bedroom Fire and Test Fire

Bedroom Fire and Test Fire

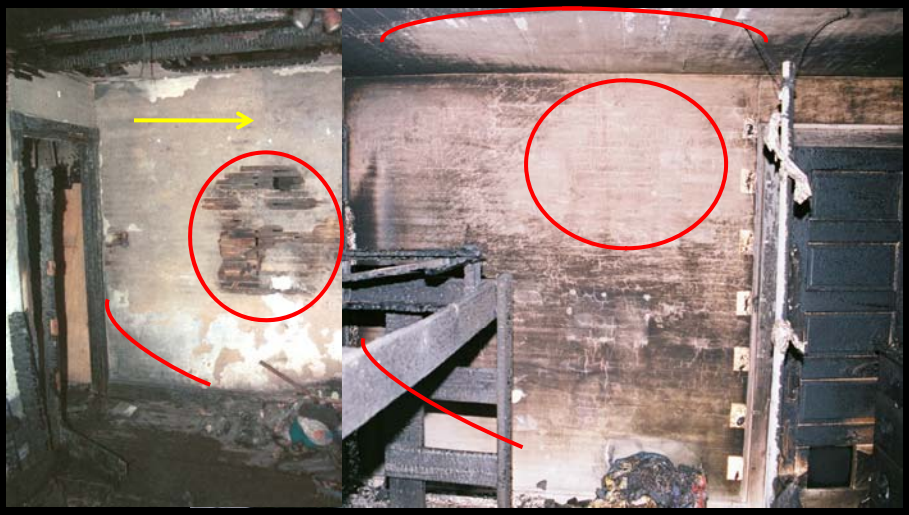


Bedroom Fire and Test Fire

South Wall

South Wall

West Wall



West Wall

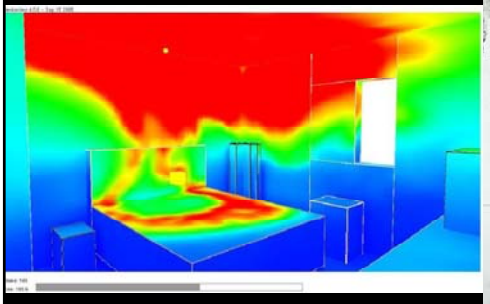
North Wall

North Wall

East Wall

East Wall

Computer Model Comparison



Problem Statements:

1. Do fire patterns persist through flashover and full room involvement? Yes

2. Can fire pattern geometry be reproducible in minimal variable testing methods? Yes

3. Can standard fire patterns analysis methodologies, such as heat and flame vector analysis, depth of calcination measurement, depth of char, and truncated cone pattern formation and analysis be reaffirmed? Yes

The tests reported here show reproducibility well within the parameters that can reasonably be expected and are a valid means for hypothesis testing.

Ventilation Issues:

1. Forced ventilation (positive and negative) or natural ventilation as a result of firefighting operations, may very well cause a fire pattern to be changed or altered. Additionally, ventilation may cause the fire to develop or spread in a direction that is not consistent with what the investigator would consider normal.

Ventilation Issues:

2. Recycling of air within the compartment and limited fresh air intake into the compartment may result in vitiation or a slower development. Conversely, an unlimited supply of fresh air, especially in the early stages of development may also affect the rate of fire growth as a result of cooling the space.

Ventilation Issues:

3. In compartments that have transitioned through flashover or to full room involvement, conditions throughout the compartment are fairly consistent except at ventilation openings where the combustion process is more efficient and results in higher temperatures. The more efficient combustion will also cause the formation of “clean burn” fire patterns while in the remaining portions of the compartment “clean burn” fire patterns are a result of a fuel package.

For the Future!

1. Additional Research
   - Small Fuel Package Ignition
   - Move the Origins, Change Conditions
   - Use of FDS and other Models
   - Addition of Ignitable Liquids
2. Photography Protocols
   - Photo Log for duplication of Photographs
3. Wall Elevations to provide fire pattern diagrams
4. Develop Story Board for tests

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Experiment Sets "A", "B", "C", & "D"
John A. Kennedy & Associates
857 Tallevast Road
Sarasota, FL 34243

TRACE Fire Protection and Safety Consultants, Ltd
123 Redwood Drive
Richmond, KY 40475

Fire and Safety Engineering Technology
Eastern Kentucky University
Richmond, KY 40475

Experiment Set "A"
Mr. Daniel Churchward
Kodiak Enterprises, Inc.
6409 Constitution Drive
Fort Wayne, IN 46804

Mr. Douglas Carpenter
Combustion Science & Engineering, Inc.
8940 Old Annapolis Road, Suite L.
Columbia, MD 21045

Mr. William B. Johnson
Core Engineering Group
1000 J. Dodds Blvd. Suite 103-357
Mt. Pleasant, SC 29464

Experiment Set "D"
Mr. Lyle Donan
Donan Engineering
11321 Plantside Drive
Louisville, KY 40299

Travelers Insurance
Hartford, CT

Fire Pattern Persistence and Predictability in Pre and Post Flashover Compartment Fires

Ronald L. Hopkins, MS, CFEI, CFPS
TRACE Fire Protection and Safety Consultants, Ltd.
Richmond, Kentucky
www.TRACEfireandsafety.com
rhopkins1@earthlink.net