# The Arson Research Project

## Fire Pattern Analysis and Case Study Review in Post-Flashover Fires

The Arson Research Project is a criminal justice research project hosted by the Constitutional Law Center of Monterey College of Law.
Our mission is to examine the reliability of evidence used in the investigation and prosecution of arson,
and to identify convictions obtained secondary to unreliable evidence.

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## Abstract

Until the 1992 publication and eventual acceptance of *NFPA 921: Guide for Fire and Explosion Investigations* by the National Fire Protection Association, fire pattern analysis was a widely accepted method of determining the presence of an ignitable liquid. There were specific burn patterns that fire investigators believed could only be created in the presence of an ignitable liquid; therefore, if any of these suspected fire patterns were found at a fire scene, there must have been an ignitable liquid present to have caused them. Furthermore, if a fire was perceived to have burned hotter than normal, the abnormal heat was often attributed to the presence of an ignitable liquid. Because the presence of an ignitable liquid in an unexpected location is such a strong indicator of an intentionally set fire, the presence of these fire patterns and the perception of abnormal heat were considered prima facia evidence of the crime of arson.

This report will examine three case studies where criminal defendants were convicted secondary to this type of evidence and review the evidence that led to each conviction. That evidence will be compared to the current standard of care expressed in *NFPA 921* and the results of recent independent research where the suspected fire patterns were created in the presence, as well as in the absence, of an ignitable liquid, and where the maximum temperatures throughout each cell were closely monitored to develop a better understanding of the maximum temperatures created in the presence and the absence of a liquid accelerant.


## Methodology

Case studies were analyzed by review of the fire reports and trial testimony of the fire investigators involved in the origin and cause investigations. Photographs for each case were examined and, when available, are included in this report where appropriate.

In October 2011, The Arson Research Project conducted live-fire research in Palo Alto, California, in order to compare the fire patterns and maximum room temperatures created by fires allowed to burn beyond flashover in the absence of an ignitable liquid with fire patterns and maximum room temperature created in the presence of an ignitable liquid. The research consisted of burning four 12’ by 12’ furnished burn cells beyond flashover. Three of the burn cells were ignited without liquid accelerant; the fourth burn cell was ignited in the presence of liquid accelerant (approximately 90 oz. of paint thinner poured in the center of the room). Temperature measurement instrumentation was installed throughout each burn cell in order to monitor temperature changes at various locations in each cell.

Fire development and burn damage was recorded with video and still photography. Burn patterns created in each of the burn cells were compared to illustrate differences and similarities between those created in the presence and the absence of liquid accelerant.

In November 2011, twelve burn patterns removed from the various burn cells were examined by thirty-three fire investigators. Four of the burn patterns were created in the presence of the ignitable liquid, and eight were created in the absence of an ignitable liquid. The volunteer participants were asked to determine, through visual examination of the burn patterns, which burn patterns were the result of an ignitable liquid.

## Case Studies

The three case studies reviewed in this report each involve serious fires that resulted in the deaths of eight people, seven of them children. In each, the defendant was convicted of arson and murder. Of the three men convicted, two continue to serve lengthy prison sentences, one in Texas and the other in California; the third was executed in Texas in 2004.

The purpose of this report is not to review all of the evidence of each case, nor is it to prove innocence or to confirm guilt. This report, and the live fire research that led to it, is concerned only with examining the reliability of the evidence used to determine if these fires resulted from intentional acts.

In Hewett, Texas, Ed Graf was convicted in 1986 of intentionally setting a fire in a backyard shed that killed his two sons. A Texas Arson Investigator testified that the burn patterns on the floor and walls of the shed could only have been created in the presence of a liquid accelerant, such as gasoline, even though chemical tests of debris in the suspected area of origin proved negative.

Five years later, and sixty-five miles away in Corsicana, Texas, Todd Willingham was convicted of starting a fire that killed his three young children. His conviction was also based on the testimony of fire investigators that fire patterns examined at the scene and an abnormally hot fire could only have been created by a liquid accelerant.

In 1997 George Souliotes was convicted in Modesto, California of setting his rental property on fire, killing three of the residents. Fire investigators testified that abnormally hot fire conditions and burn damage to the floor of the garage, kitchen and living room could only have been caused by a liquid accelerant.

In each case, fire investigators identified the presence of a liquid accelerant only on the basis of visual examination of burn patterns, without the benefit of corroborating laboratory analysis. It is the reliability of this evidence that this report seeks to examine.

These three cases also track the historical emergence of a nationally recognized standard of care in the field of fire investigation. In 1986, at the time of the Graff conviction, the National Fire Protection Association (NFPA) Standards Council was just beginning its work in creating a comprehensive guide to fire investigation. Todd Willingham was sentenced to death in 1992, the same year the NFPA released its first edition of *NFPA 921: Guide for Fire and Explosion Investigation*. As will be discussed below, *NFPA 921* contains information regarding burn pattern analysis that is in direct conflict with the testimony of fire investigators in both the Graf and Willingham cases. By the time of the Souliotes trial in 1997 the NFPA guide had achieved national recognition, yet many of its core tenants were still not being followed.

**<u>Historical Background and the Emergence of a Standard of Care</u>**

Until the early 1990's, standard fire investigation training expressly endorsed the interpretation of specific fire patterns as clear indicators of the presence of an ignitable liquid. Some of the specific fire patterns previously associated with the presence of a liquid accelerant include alligator charring; crazed glass; depth of char; lines of demarcation; sagged furniture springs; concrete spalling; low burning; holes burned in the floor; V-pattern angle; and melted aluminum window and door framing.

Standard fire investigator training curriculums, including the National Fire Academy, included teaching modules confirming this type of fire pattern analysis.

> *"A lot has changed since I took my first fire investigation class in 1982. Our instructors were exposing us in good faith to fire scene indicators that they believed to be accurate. I have been a teacher since 1992. My biggest concern is that many of the pre-NPFA 921 students who were taught how to evaluate burn patterns and fire scene indicators need to be alerted to the changes that have occurred within the profession"*
>
> Brendan O'Leary, SFFD Fire Investigator (ret.)

Until 1992, the fire investigation community lacked a cohesive standard of care. Procedures for conducting a comprehensive origin and cause investigation were taken from a variety of separate books and publication including, but not limited to, *Kirks Fire Investigation*[i], *Arson and Arson Investigation: Survey and Assessmen*t (LEAA)[ii], *Fire Investigation Handbook* (NBS)[iii], and *Fire Cause Determination* (IFSTA)[iv]. Although some of the publications used cautionary language while discussing burn pattern analysis, many of the most popular publications reinforced the belief that the presence of a liquid accelerant could be determined through the visual examination of burn patterns and that if a fire was believed to burn abnormally hot, a liquid accelerant was likely involved.

In 1992 the National Fire Protection Association (NFPA) released its first edition of *NFPA 921*, *Guide for Fire and Explosion Investigations*, used to assist fire investigators throughout the United States in the investigation and analysis of fire incidents, as well as in drawing conclusions and rendering opinions as to a fire's origin and cause.[v] *NFPA 921* established guidelines and recommendations for the systematic investigation and analysis of fire incidents and contained specific procedures to assist in the investigation of origin and cause.

Since its first publication, *NFPA 921* has emphasized an understanding of fire dynamics, fire pattern analysis and the scientific method as the underpinnings of a comprehensive and objective cause and origin investigation. In the years following its first publication, *NFPA 921's* influence within the fire investigation community has steadily grown. By the second edition in 1995, *NFPA 921* had national recognition and was becoming the standard of care in fire investigations.

The 2000 publication of *U.S. Department of Justice, Fire and Arson Scene Evidence: A Guide for Public Safety Personnel* described *NFPA 921* as *"…a benchmark for the training and expertise of everyone who purports to be an expert in the origin and cause determination of fires."*[vi]

Several court decisions, both civil and criminal, have bolstered *NFPA 921*'s standing as a nationally recognized standard of care.

In Chester Valley Coachworks v Fisher Price, Inc. (2001)[vii], the court described *NFPA 921* as *"…the authoritative guide for fire investigations."*

In McCoy v Whirlpool (2003)[viii], the court goes so far as to say: *"The 'gold standard' for fire investigations is codified in NFPA 921, and its testing methodologies are well known in the fire investigation community and familiar to the Court".*

Furthermore, after the publication of *NFPA 921*, fire investigation course curriculums began to be updated to reflect a better understanding of flashover, ventilation and burn pattern analysis. With each new edition of *NFPA 921* the curriculum of the National Fire Academy's basic fire investigation course, *Fire/Arson Origin and Cause Investigation,* was incrementally adjusted to reflect the changing procedures in fire investigation methodology. In 2007 the course curriculum experienced a significant revision with the assistance of the U.S. Department of Justice – Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF). This curriculum included a module entitled "*Myths and Legends"* specifically designed to debunk some of the misconceptions associated with the interpretation of burn patterns linked to the use of ignitable liquids.[ix]

*NFPA 921* has been formally endorsed and accepted as its standard of practice by both the country's largest fire investigator professional associations, the American Association of Arson Investigators (AAIA) and the National Fire Investigators Association (NFIA).

**<u>Fire Pattern Analysis and Flashover</u>**

Prior to the publication of *NFPA 921*, fire pattern analysis had been widely interpreted to indicate the presence of a liquid accelerant. However, many of the conclusions regarding the presence of a liquid accelerant through examination of specific fire patterns or burn indicators have been disproven as they have been found to be present under fire conditions that did not include the presence of liquid accelerant, specifically by a fire condition known as *flashover*[x].

Flashover conditions and the dynamic ventilation paths often present during *full room involvement*[xi] create a complicating factor in the examination and analysis of fire patterns and the fire dynamics that lead to those patterns. During flashover, the temperature in a room fire rises so high throughout the room that combustible items begin to burn, even at floor level and in areas of the room away from the fire's origin. This is the point in the progression of an enclosed room fire where low burning and burning objects throughout the room can create conflicting burn indicators and fire patterns that can easily distort or mask the fire's true area of origin and create burn patterns in various parts of the compartment that can be easily misinterpreted as *pour patterns* or other fire patterns previously associated with the presence of an ignitable liquid.

From its first edition, *NFPA 921* clearly acknowledged the effects of flashover conditions and full room involvement on resulting fire damage and burn patterns. *NFPA 921* states that flashover conditions *"…may create, modify, or obliterate (fire) pattern."*(2001, 6.3.3.2) As the hot gas layer forms along the ceiling in a room fire approaching flashover, the area of the room below the hot gas layer is exposed to a large amount of radiant heat (heat flux). (2011, 6.3.2.3)

Once the fire reaches flashover, or "full room involvement", fire patterns are generated that can be easily confused with or attributed to the presence of an ignitable liquid. *NFPA 921* recognizes the formation of these patterns in a post-flashover fire:

> "*Damage can include charring of the undersides of furniture, burning of carpet and floor coverings under furniture and in corners, burning of baseboards, and burning on the undersides of doors. Full room involvement can result in holes burned through carpet and floor coverings."* (2011, 6.3.2.4)

**<u>Burn Pattern Analysis in the Case Studies</u>**

In each of the following case studies fire investigators relied heavily both on visual fire pattern analysis and a belief that the fires burned abnormally hot in their determination that an ignitable liquid was present.

| | **Graff** | **Willingham** | **Souliotes** |
|---|---|---|---|
| Low Burning | | ✓ | ✓ |
| Pour Patterns | ✓ | ✓ | ✓ |
| Holes Burned Through Floor | ✓ | | ✓ |
| Particularly Hot Fire | ✓ | ✓ | ✓ |
| Deep Charring | ✓ | ✓ | ✓ |

As will be discussed below, each of the burn patterns sited by fire investigators in the case studies has been found to be created in any fire that burns to or beyond flashover, regardless of the presence of an ignitable liquid, and live fire research has clearly documented that the maximum temperature achieved in a room fire is not the result of the presence or absence of an ignitable liquid.

**Ed Graff**
The fire occurred on Tuesday, August 26, 1986. Texas Fire Investigator Joe Porter arrived on the scene eight days later. By that time the fire structure, a backyard storage shed, had been torn down and disposed of at the local dump. Porter analyzed the fire damage and burn patterns by examining photographs taken by police and fire department personnel after the fire was extinguished.

> *"Examination of fire scene photographs taken by police and fire personnel indicate several characteristics that are commonly observed in incendiary fires. These characteristics include char and burn patterns that are commonly associated with the presence of liquid accelerants…Other items of interest observed in the photographs indicate that the level of intensity of the fire was greater than that usually observed in a normal burning fire of this type of structure"*.[xii]

**Todd Willingham**
The fire occurred on December 24, 1991, and was investigated on December 30 by Texas Fire Investigator Manual Vasquez. His fire investigation report cites several burn patterns in the hallway, bedroom and front porch that indicated the presence of a liquid accelerant:

> *"The burn trailers, pour patterns, and puddle configurations were followed from the west door into the northeast bedroom…The entire floor disclosed burn trailers, pour patterns, and configurations. In the center of the bedroom several puddle configurations disclosed that the fire had burned through 3 layers of floor material and then charred the wooden floor. In the center of the floor a liquid accelerant flowed under the tile squares and burned. The burn trailers, pour patterns, puddle configurations, burning under the tiles, and the charred wooden floor is evidence that the floor of the Northeast bedroom was poured with a combustible liquid accelerant and was ignited."*[xiii] (Vasquez Fire Investigation Report, page 4)

Later in his court testimony, Vasquez explains and defines the terminology used repeatedly in his fire report:

> *"Burn trailers is like a trailer, you know, like a little path, a burnt path. A pour pattern, which is a pattern like somebody put some liquid on the floor or wherever; and, of course, when you pour liquid, then it creates a puddle. Liquids creates puddles. When it rains, you get puddles. When the baby drops it's milk, you create puddles. If you ever drop a coke, you create puddles. All this area has that, has the burn trailer pour patterns and configurations…And a pour pattern and trailer is an indication that somebody poured something, you know, either going in or out."*[xiv] (Vasquez Testimony, pages 238,239)

**George Souliotes**
Fire investigators Tom Reuscher and Robert Evers relied heavily on fire pattern analysis in their determination that an ignitable liquid was present in the garage, kitchen and family room of the fire building, leading to their shared conclusion that the fire was intentionally set. The specific fire patterns sited by Reuscher and Evers were the presence of: pour patterns and low burning in the garage, kitchen and living room; vinyl kitchen tiles with separation and curled edge; and holes burned through the living room floor.

## <u>Specific Burn Patterns Analysis</u>

### *Low Burning and Pour Patterns*

**Ed Graff:**
Fire Investigator Porter's examination of fire scene photographs revealed burn patterns that he described as *pour patterns* which he attributed to an ignitable liquid. He described a photograph of the plywood flooring: *"The first thing it tells us is that we have a definite pour pattern of an accelerant along the edge of the plywood."* (Porter Testimony, page 966, referring to states exhibit #6) *"The only thing that can cause the fire (pattern) to change from a solid, charred pattern to an area where you just have discoloration for that large an area is going to be if an accelerant's is present in that area."*[xv] (Porter Testimony, page 968)

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| **Photo 1: Low burning to plywood flooring at Graf fire (Exhibit 6)** | **Photo 2: Overall fire damage to the shed at Graf fire (Exhibit 9)** |

**Todd Willingham:**
Fire Investigator Vasquez testified that low burning and "pour patterns" led him to believe an ignitable liquid was present: *"Puddle configuration, pour patterns, low char burning, charred floor, the underneath burning of the base board… puddle configurations, in that area, and the total saturation of this floor is indicated with pour patterns, because that's all I'm doing is looking at the facts, at the evidence. That's all I'm using. That's exactly what it is, and the fire was contained to the bedroom and to the hallway…That's some of the indicators that I came up with." (255/256)*

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| **Photo 3: Low burning to floors and baseboards at Willingham fire.** | **Photo 4: Low burning to floors and baseboards at Willingham fire.** | **Photo 5: Low burning to floors and baseboards at Willingham fire.** |

Furthermore, Investigator Vasquez found it suspicious that the windows of the northeast bedroom broke during the fire. He called this "auto-ventilation": *"…The first incinery (sic) indicator is the auto ventilation. The inconsistence of the fire going out of this (bedroom) window and the fire going out of the (front) door and this (bedroom) window here. That's inconsistent with fire behavior. That's an indicator that it's a possible incinery (sic) fire."(255)*

| Photo 6: Floor burn patterns to vinyl tile in the Willingham fire. | Photo 7: Floor burn pattern to vinyl tile and front door threshold in the hallway of the Willingham fire. |
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**George Souliotes:**
Investigators Reuscher and Evers both testified repeatedly of the presence of *pour patterns* and *low burning* in the living room, kitchen, garage and rear patio that the investigators attributed to the presence of a flammable liquid. Neither investigator acknowledged flashover as a likely cause of the irregularly shaped floor patterns or low burning.

Evers testified that low burning between the wooden pieces that made up the hard wood floor was a particular indicator of an ignitable liquid. *"You can see the gap in the tongue and groove, the heavy charring to the wood, burning down into the subfloor. That's not a normal fire".*[xvi] (Evers Testimony, page 3003)

**Photo 8: Floor burn pattern to hardwood floor in the living room of the Souliotes fire.**

Evers and Reuscher attributed the curled edges of kitchen tiles and the separation between the tiles to the presence of an ignitable liquid without additional chemical analysis to confirm their suspicions.

Bob Evers, describing heat damage to tiles in the kitchen: *"The tiles had been subjected to extreme heat, too. And they were curling at the edges where they meet…I have experienced that before with a flammable or ignitable liquid being poured on them, that they get hot and curl in."* (Evers Testimony, page 8499)

Tom Reuscher, describing fire patterns left by ignitable liquids on vinyl tile: *"Well, when an ignitable liquid is poured on tile like that, the liquid will go through the small cracks and seep in underneath the tile, and then when it burns, that's where it's going to come out, and you'll have shrinkage of those tiles that erode and crack lines. You'll have irregular tile shapes such as this, and it will leave a corresponding pattern on the floor below…"*[xvii] (Reuscher Testimony, page 6614)

During cross-examination Reuscher was asked if this type of damage to vinyl tile could occur in "any kind of fire" and he responded: *"It's an indicator to me that there was a liquid poured there…That occurred primarily at the seams and then deteriorated, burned away at the edges and distorted the size and dimension of the tile" (Reuscher Testimony, page 6866)*

**NFPA 921:**
*NFPA 921* warns against attributing low burning to the presence of an ignitable liquid:

> *"Burning between seams or cracks of floorboards or around door thresholds, sills, and baseboards may or may not indicate the presence of an ignitable liquid." (2011 6.3.3.2.3)*

*NFPA 921* specifically acknowledges flashover conditions, long extinguishing times and building collapse as direct causes of fire patterns on the floor.

> *"Irregular patterns are common in situations of post flashover conditions, long extinguishing times, or building collapse" (2011, 6.3.7.8.2)*

*NFPA 921* contains specific warnings of the danger of attributing an irregularly shaped floor pattern to the presence of an ignitable liquid and cautions investigators not to use the term "pour pattern" when describing these patterns.

> *"Irregular, curved, or "pool-shaped" patterns on floors and floor coverings should not be identified as resulting from ignitable liquids on the basis of visual appearance alone. In cases of full room involvement, patterns similar in appearance to ignitable liquid burn patterns can be produced when no ignitable liquid is present" (2011, 6.3.7.8); and*

> *"Because fire patterns resulting from burning ignitable liquids are not visually unique, the use of the term pour pattern and reference to the nature of the pattern should be avoided. The correct term for this fire pattern is an irregularly shaped fire pattern. The presence of an ignitable liquid should be confirmed by laboratory analysis. The determination of the nature of an irregular pattern should not be made by visual interpretation of the pattern alone." (2011, 6.3.7.8.5)*

*NFPA 921* recognizes the type of damage to vinyl floor tiles described by Evers and Rouscher in any post-flashover fire, regardless of flammable liquids, and the importance of confirming any suspicion of the presence of a flammable liquid with laboratory analysis.

> *"Fire-damaged vinyl floor tiles often exhibit curled tile edges, exposing the floor beneath…In a fire, the radiation from a hot gas layer will produce the same patterns. These patterns can also be caused by ignitable liquids, although confirmation of the presence of ignitable liquids requires laboratory analysis. (2011 6.3.3.2.6)*

**Live Burn Results:**
Live burn research has shown that temperatures in excess of 1200 degrees Fahrenheit are common at floor level during flashover, with temperatures spiking above 1500 degrees in areas of greater ventilation. These high temperatures created burn damage throughout the room, from floor to ceiling, including low burning and heat damage to floor surfaces resulting in irregularly shaped fire patterns and deep charring to hardwood flooring causing gaps to be formed in the tongue and groove seams between the pieces of hardwood flooring.

Comparisons of the floor burn patterns throughout each of the four burn cells confirms that flashover conditions are the prime factor in creating irregularly shaped burn patterns on the floor and low burning throughout the room. Ventilation patterns are a major contributor to the location and the severity of burn damage in a flashover environment.

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| **Photo 9: Floor burn pattern to hardwood floor in burn cell #1.** | **Photo 10: Low burning to furniture and floor burn pattern to vinyl tile and carpet in burn cell #4.** |

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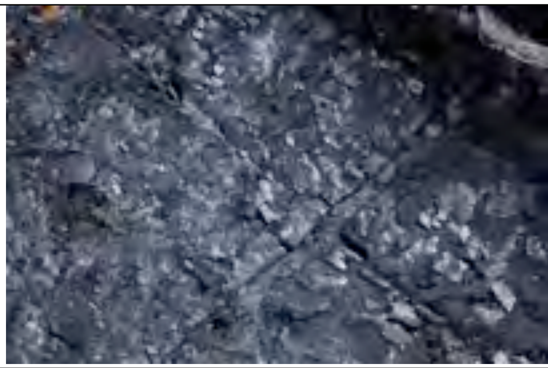
|  |  |
| **Photo 11: Vinyl tile in burn cell #2.** | **Photo 12: Vinyl tile in the door way of burn cell #4.** |

In a flashover fire, and the resulting full room involvement, deep charring to baseboards throughout the room is a common occurrence. The irregular shapes found in floor burn patterns are caused by the irregular and dynamic nature of ventilation through the burn room, not by poured liquids.

During the live burn research conducted by The Arson Research Project, irregularly shaped fire patterns on the floor and deep burn damage to baseboards and furniture at floor level were observed in every burn cell, regardless of the presence of a flammable liquid.

Vinyl tiles (in Burn Cells #2 and #4) exposed to flashover conditions experienced the type of burn damage and post-burn characteristics described by Evers and Reuscher. The shrinkage, separation and curled edges were present wherever the tiles were exposed to high temperatures, both in the presence and in the absence of a flammable liquid. The burn damage to the vinyl tile documented during the live burn tests was identical to and indistinguishable from the damaged kitchen tiles in the Souliotes fire.

As a result, any correlation between damage to vinyl tile in a post flashover fire and the presence of a flammable liquid is not scientifically valid and is in direct conflict with the standard of care contained in *NFPA 921* as it existed in 1997 and as it exists today.

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| **Photo 13: Low burning to baseboards and vinyl tile in burn cell #4.** | **Photo 14: Low burning to furniture and vinyl tile in burn cell #2.** |

A visual comparison between the low burning and irregularly shaped fire patterns to the floors observed in each of the fire cells burned during the live fire testing and the low burning and irregularly shaped fire patterns to the floor shown in photographs of the case studies show that the patterns and burn damage are visually indistinguishable.

In the Willingham and Souliotes cases, all of the *pour patterns* described by fire investigators were located in major ventilation paths; between the northeast bedroom and the front door on the north side of the house (Willingham); between the garage door on the south side of the fire building and the sliding glass doors on the north side of the living room (Souliotes). These patterns are the expected results of a flashover fire with these ventilation paths.

"Auto ventilation", or the breaking of windows in the fire room due to the heat of a fire, described by Investigator Vasquez as *"The first incinery (sic) indicator"* was created in every burn cell. Flashover conditions *always* result in the failure of windows exposed to full room involvement.

Any attribution of these patterns or "auto ventilation" to the presence of a flammable liquid is in conflict with general knowledge regarding flashover and ventilation, is inconsistent with *NFPA 921* and recent live fire research, and is scientifically invalid.

***Holes Burned Through Floors***

**Ed Graff:**
Fire Investigator Porter testified to the presence of two holes in the flooring of the shed that were visible in scene photographs and implied they were the result of an ignitable liquid. (Porter Testimony, pages 1104, 1105)

**Photo 15: Low burning and hole in plywood subfloor at Graf fire (Exhibit 71)**

**Todd Willingham:**
Burn patterns to the floor in the center of the northeast bedroom included burning through the carpet, vinyl tile and plywood sheeting, exposing a wooden subfloor material, without completely penetrating the floor.

**Photo 16: Burn damage to floor in the northeast bedroom of the Willingham fire.**

**Photo 17: Burn damage to floor in the northeast bedroom of the Willingham fire.**

**George Souliotes:**
Both Investigators Evers and Reuscher harbored the false belief that a hole burned through a floor is prima facia evidence of the presence of an ignitable liquid.

Bob Evers described a photograph depicting several holes burned through the living room floor: *"In my experience this is a classic example of an ignitable liquid being poured on the floor, the damage that you see". (Evers Testimony, page 8488)*

Reuscher described holes burned in the living room floor as *"…an indication of flammable liquids being poured on the floor used as an accelerant"*. (Reuscher Fire Investigation Report, page 8)

**Photo 18: Hole burned through the living room floor of the Souliotes fire.**

**NFPA 921:**
Since its first edition in 1992, *NFPA 921* has recognized holes burned through floors as a common result of flashover:

> *"Holes in floors may be caused by glowing combustion, radiation, or an ignitable liquid….Evidence other than the hole or its shape is necessary to confirm the cause of a given pattern". (2011 6.3.3.2.5)*

**Live Burn Results:**
The live fire burn cells were burned for up to two and one half minutes past the onset of flashover, creating floor temperatures in excess of 1500 degrees Fahrenheit in the primary ventilation paths. These high temperatures created deep charring to flooring. If allowed to burn for a longer period of time it is clear that burning would have penetrated the floor, creating holes in the floor indistinguishable from the holes presented in the case studies.

Holes in floors are a common result of flashover conditions. The greatest influence on the location and size of these holes is the ventilation path, leading to increased floor temperatures, and the length of time the fire burns beyond flashover before being extinguished. The presence of an ignitable liquid plays little role in the creation of these holes.

All of the holes in the living room floor at the fire in the Souliotes case were found in the center of the living room and immediately adjacent to the sliding glass door on the north side of the living room, in the main ventilation path between the garage door on the south side, and the sliding glass door to the north (one notable exception was a small hole found adjacent to the frame of the sliding glass door, likely caused by molten aluminum coming in contact with the wood floor).

As a result, any conclusion regarding the presence or absence of an ignitable liquid due to the presence of holes in floors in a post flashover setting, especially holes located in the primary ventilation path, are scientifically indefensible, inconsistent with *NFPA 921* and recent live fire testing, and not in keeping with generally accepted practices within the field of fire investigation.

***Abnormally Hot Fire***

**Ed Graff:**
Investigator Porter attached value to the presence and size of "alligator" type burn patterns in determining the heat of the fire:

> *"A charring pattern takes on a peculiar shape because of the very nature of the fire. And you have what we call alligatoring...It tells us quite a bit of information by being able to examine the alligatoring just by examining its formation, the size of the squares that are involved in it, and the direction that the squares take when we examine them… Now, depending on the amount of heat that's involved than that tells you what size that alligator charring is going to be. The hotter the fire is, the larger the bubbles are going to be. The cooler the fire is or the slower burning the fire is, the smaller those are going to be…The size of the pattern gives us an idea of how hot that fire was. How much temperature was involved. That allows us in turn to look at the fire load in the building or the amount of combustible materials in the building in determining whether or not those combustible materials could create the heat necessary to have the alligatoring of the size that we're observing." (Porter Testimony, page 949)*

Porter also described the abnormal heat of the fire in terms of the fire's intensity:

> *"From the obvious char patterns on this front board along here and from the char patterns that are on this floor joists here, the only way that fire could have progressed at the intensity that it did and the speed that it did from top to bottom was for there to have been an accelerant present in this area." (Porter Testimony, page 962)*

**Todd Willingham:**
Investigator Vasquez interpreted the melted aluminum of the front door threshold as a clear sign that the fire burned abnormally hot:

> *"And aluminum melts at 1200 degrees normal. Wood fire does not exceed 800 degrees. So to me, when aluminum melts, it shows me that it has had a lot of intense heat. It reacts to it. That means its temperature is hot. The temperature cannot react. Therefore, the only thing that can cause that to react is an accelerant. You know, it makes the fire hotter. It's not normal fire." (Vasquez Testimony 249)*

**George Souliotes:**
Investigators Reuscher and Evers interpreted statements by firefighters that the fire was abnormally hot to indicate the presence of an ignitable liquid accelerant.

Investigator Reuscher claimed never to have seen a non-accelerant fire burn with such intensity: *"I've never seen a fire in a residential structure where common combustible were involved that had the kind of devastation." (Reuscher Testimony, page 6709)*.

Reuscher's fire report stated that the fire's abnormal intensity "*was an indication that an abnormal fuel source should be looked for, most likely in the form of flammable liquids."* (Reuscher Fire Investigation Report, page 1) His fire report also implied that melted aluminum framing of the living room sliding glass door was the result of an abnormally hot fire, resulting from the presence of an ignitable liquid. (Reuscher Fire Investigation Report, page 1)

Bob Evers testified that in a "normal accidental structure fire" extreme damage to the living room, kitchen and garage area would be unusual, and that the amount of damage he observed on Ronald Avenue was a strong indicator that a liquid accelerant was present:

> *"To me that's a red flag that there was an accelerant used to get that kind of intensity out of it" (Evers Testimony, pages 8483, 8484)*.

**NFPA 921:**
*NFPA 921* clearly states that maximum temperatures in a room fire are not determined by the presence or absence of an ignitable liquid.

> *"Wood and gasoline burn at essentially the same flame temperature. The turbulent diffusion flame temperatures of all hydrocarbon fuels (plastics and ignitable liquids) and cellulosic fuels are approximately the same, although the fuels release heat at different rates. (2011, 6.2.2.2)*

*NFPA 921* specifically addresses *alligator charring*:

> *The presence of large shiny blisters (alligator char) is not evidence that a liquid accelerant was present during the fire, or that a fire spread rapidly or burned with different types of fires. There is no justification for the inference that the appearance of large, curved blisters is an indicator of an accelerated fire" (6.2.4.3)*

**Live Burn Results:**
Fire Investigators Porter, Velasquez, Evers and Reuscher were under the mistaken impression that an accelerant fueled fire burns hotter, and therefore causes more damage, than a fire fueled by common combustibles.

Room fires with contents consisting of the wood and plastics present in a house or storage shed normally reach post-flashover temperatures in excess of 1200 degrees Fahrenheit, and significantly higher temperatures are reached in areas of high ventilation. The presence of an ignitable liquid does not influence this maximum temperature.

All of the burn cells reached floor and ceiling temperatures in excess of 1500 degrees Fahrenheit, both in rooms with and without liquid accelerant. The maximum room temperatures (all in excess of 1700 degrees Fahrenheit) in each of the burn cells were virtually identical. The only significant difference between the temperature measurements was that the burn cell ignited with a liquid accelerant (burn cell #2) reached its maximum room temperature more quickly than the burn cells ignited without an accelerant (burn cells #1, #3 and #4). The accelerant in burn cell #2 merely *accelerated* the rate of temperature increase, but did not increase the fire's maximum temperature.

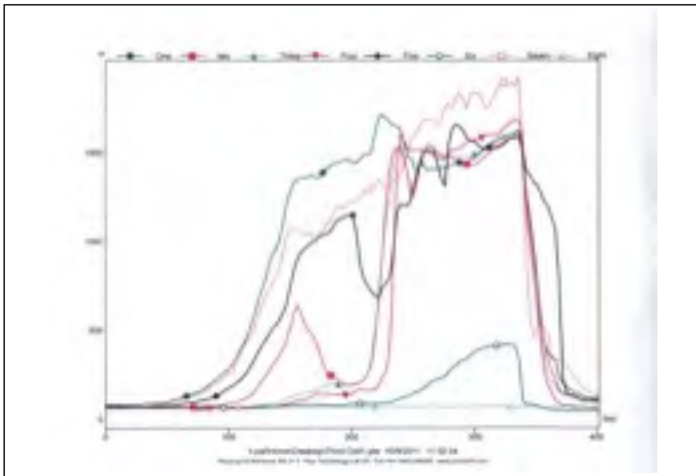

**Fig. 1: Burn Cell #1 (common combustibles)**

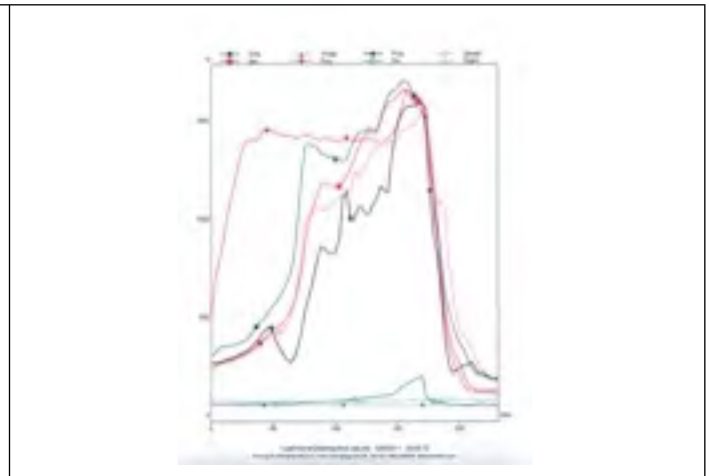

**Fig. 2: Burn Cell #2 (flammable liquid and common combustibles)**

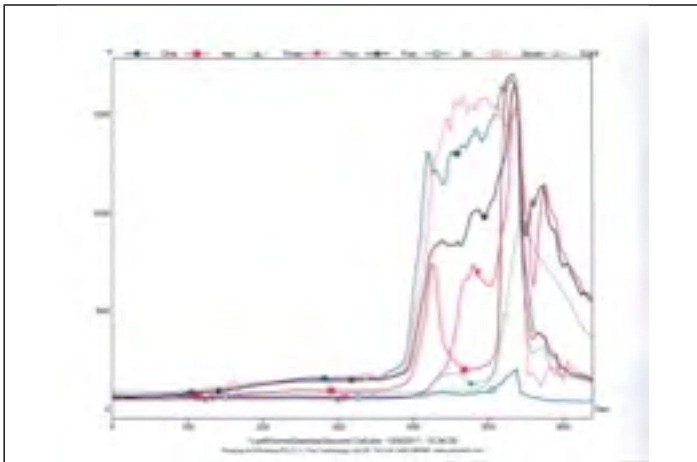

**Fig. 3: Burn Cell #3 (common combustibles)**

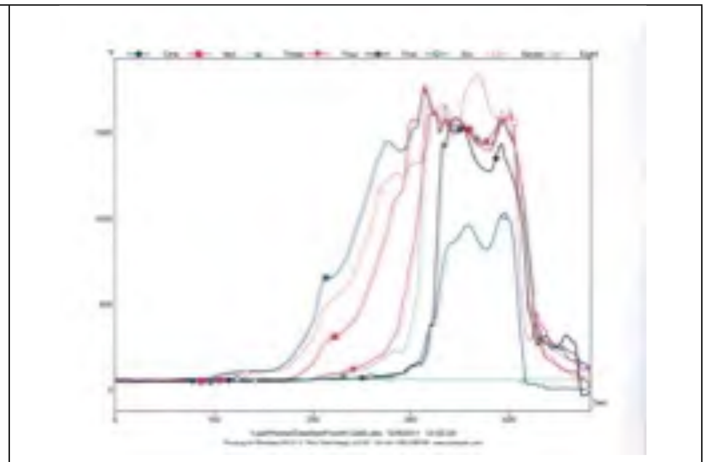

**Fig. 4: Burn Cell #4 (common combustibles)**

The melting temperature of aluminum is approximately 1220 degrees. During live fire research temperatures in excess of 1500 degrees Fahrenheit were measured at floor level, including in doors and windows, well beyond the heat necessary to melt aluminum.

In the Willingam and Souliotes cases, the fact that the aluminum threshold and framing experienced melting should not be seen as unusual. To attribute the melting to increased temperatures caused by the presence of an ignitable liquid is scientifically indefensible and in direct conflict with NFPA 921.

*Alligator char*, the burn pattern described by Investigator Porter in determining the presence of abnormal heat in the Graf case, was present in each of the four burn cells. Virtually every exposed wooden surface in each of the four burn cells experienced some amount of fire damage that would meet Investigator Porter's description of *alligator charring*.

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| **Photo 19: Floor burn patterns to plywood sheeting of burn cell #3.** | **Photo 20: Floor burn patterns to plywood sheeting of burn cell #2.** |

The size and depth of the char patterns varied between the cells and areas within each cell, regardless of the presence or absence of an ignitable liquid.

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| **Photo 21: Low burning to wooden table in burn cell #4.** | **Photo 22: Low burning and burn patterns to underside of wooden table in burn cell #4.** |

**Photo 23: Low burning to wooden chair in burn cell #4.**

**Photo 24: Low burning and burn patterns to underside of wooden chair in burn cell #4.**

There is no evidence to support the conclusion that the high temperatures encountered in any of the case study fires were caused by anything other than a flashover fire in the presence of a good ventilation path. Conclusions to the contrary are in direct conflict with *NFPA 921* and with independent research conducted by The Arson Research Project.

**Burn Pattern Study**

In November 2011, in conjunction with the California Conference of Arson Investigators (CCAI), thirty-three fire investigators participated in a study to examine the accuracy with which fire investigators are able to determine the presence or the absence of an ignitable liquid through visual examination of burn patterns obtained from compartment fires that burned beyond flashover.

Twelve floor samples taken from the four burn cells were transported to San Luis Obispo, California and displayed during the CCAI semi-annual training conference. The participant fire investigators were allowed to examine each burn pattern sample, along with scene photographs and diagrams for each cell, and asked to choose one the following three choices for each sample:

1. This burn pattern was created **in the presence of** an ignitable liquid.
2. This burn pattern was created **in the absence of** an ignitable liquid.
3. The presence of ignitable liquid **cannot be determined** through examination of this burn pattern and the associated photographs and diagrams.

Of the thirty-three completed questionnaires, one-third of the answers were #3 (the presence of an ignitable liquid cannot be determined through examination of the burn pattern). Two-thirds of the answers were either #1 (concluding that an ignitable liquid was present) or #2 (concluding that an ignitable liquid was absent).

Of the answers that were either #1 or #2, 49.9% correctly identified the presence or the absence of an ignitable liquid, and 50.1% incorrectly identified the presence or the absence of an ignitable liquid. Because the random chance of correctly identifying the presence or the absence of an ignitable liquid under these conditions is exactly 50%, the results of this study are consistent with a random guess.

The results of this study confirm the hypothesis that the presence or absence of an ignitable liquid in a post-flashover setting cannot be determined through visual examination of the resulting burn patterns. Any attempt to do so is no more reliable than a flip of a coin.

**Conclusion**

At the time of their initial training, Fire Investigators Porter, Velazquez, Evers and Rouscher attended fire investigation courses whose curriculums contained learning modules that endorsed fire pattern analysis as a method to determine the presence of an ignitable liquid. In the era prior to the publication of *NFPA 921*, no consideration was given to the effects of flashover on fire pattern analysis.

The study of flashover fires and the effects of ventilation in a flashover setting on burn pattern analysis is an on-going endeavor, and it is understandable that fire investigations conducted prior to the publication of *NFPA 921* would lack an understanding of the implications that flashover and ventilation present.

However, it has become clear since the 1992 publication of *NFPA 921* that flashover conditions cause low burning and irregular floor patterns; that holes burned in floors are the common result of fires in the absence of a liquid accelerant; that the presence of an ignitable liquid can only be confirmed by laboratory analysis and not fire pattern examination; and that the use of the scientific method in the practice of fire investigation is a fundamental requirement of remaining within the nationally recognized standard of care.

Fire pattern analysis in a post flashover environment is an unreliable method of determining the presence of an ignitable liquid. Fire patterns created by flashover or “full room involvement” are physically identical to burn patterns created by the presence of an ignitable liquid; these burn patterns cannot be differentiated by visual examination because there is simply nothing to differentiate.

Furthermore, it is now clear that maximum temperatures of a room fire are the result of ventilation patterns and flashover, not the presence of an ignitable liquid.

Not only were Fire Investigators Porter, Velazquez, Evers and Rouscher unable to differentiate burn patterns created in the presence of an ignitable liquid from burn patterns created in the absence of an ignitable liquid, thirty-three other fire investigators were unable to do so as well.

As a result, conclusions regarding the presence or absence of an ignitable liquid derived from fire pattern analysis, room temperatures and amount of fire damage in a post flashover environment are not scientifically valid; they are not in compliance with the standard of care established by *NFPA 921*; they are inconsistent with the current curriculum of the National Fire Academy; they do not meet the standards of generally accepted techniques and methodologies within the field of fire investigation; and they have been proven to be inaccurate and unreliable through independent research.

**About the Author**

Paul Bieber is the founder and director of The Arson Research Project. He is a Criminal Investigator specializing in indigent defense investigations and a member of the investigator's panel of the San Mateo County, California, Private Defenders Program where his assignments range from misdemeanors to complex felonies.

Paul is a certified fire and explosion investigator (CFEI) and has nine years of investigative experience with a concentration in fire cause and origin, death scene, and insurance fraud investigations, and an additional 15 years in fire suppression as a firefighter and paramedic. His professional experience includes conducting civil and criminal investigations as a fire investigator for EFI Global, Inc., as a Deputy Coroner for San Mateo County Coroner's Office and as a Criminal Fraud Investigator for California Department of Insurance, Fraud Division. He has conducted hundreds of accidental and incendiary fire cause and origin investigations, numerous death scene investigations, and has acted as the lead investigator on major fraud cases leading to criminal prosecution.

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[i] Kirk, P., *Fire Investigation,* Wiley, 1969.

[ii] Aerospace Corp. *Arson and Arson Investigation: Survey and Assesment*, National Institute of Law Enforcement and Criminal Justice, LEAA, USDOJ, 1977.

[iii] Brannigan, F., Bright, R., and Jason, N., *Fire Investigation Handbook*, NBS Handbook 134, 1980.

[iv] International Fire Standards and Training (IFSTA), *Fire Cause Determination*, First Edition, Fire Protection Publications, OSU.

[v] NFPA 921, Guide for Fire and Explosion Investigation, 2011 edition.

[vi] U.S. Dept. of Justice, Fire and Arson Scene Evidence: A Guide for Public Safety Personnel (2000), pg. 6.

[vii] Chester Valley Coach Works vs. Fisher-Price, Inc., Eastern District of Pennsylvania (2001), U.S. Dist. LEXIS 15902

[viii] McCoy vs. Whirlpool Corp. (2003), District of Kansas, U.S. Dist., LEXIS 6901.

[ix] http://www.usfa.fema.gov/applications/nfacourses/catalog/details/38

[x] NFPA 921 definition of "flashover": A transition phase in the development of a compartment fire in which surfaces exposed to thermal radiation reach ignition temperature more or less simultaneously and fire spreads rapidly throughout the space, resulting in full room involvement or total involvement of the compartment or enclose space (2011, 3.3.78)

[xi] NFPA 921 definition of "full room involvement": Condition in a compartment fire in which the entire volume is involved in fire. (2011, 3.3.85)

[xii] Texas State Fire Marshal Synopsis Investigation Report, Joseph D. Porter, Case no. 61-Sep-064-S

[xiii] Texas State Fire Marshal, Fire Investigation Report, Manuel Vasquez, 1/24/1992

[xiv] Testimony transcript, State of Texas vs. Cameron Todd Willingham

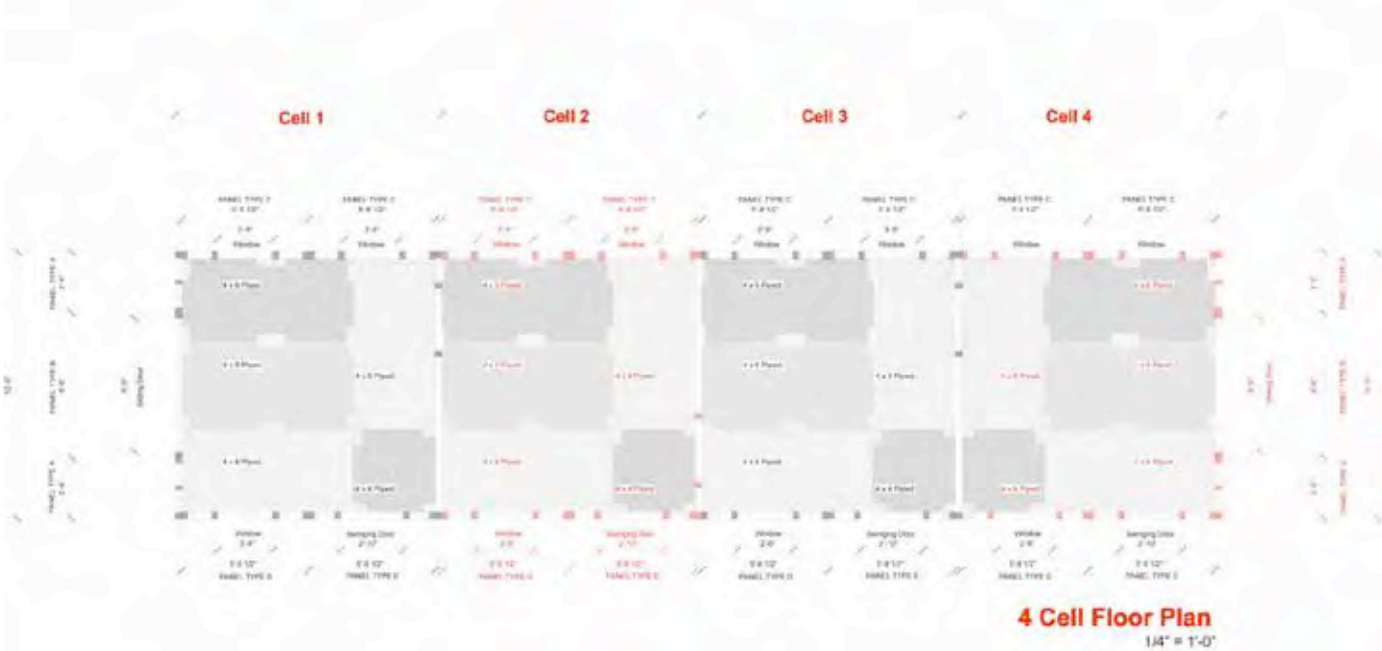
[xv] Testimony transcript of Porter, State of Texas vs. Edward E. Graf

[xvi] Testimony transcript of Robert Evers, People vs. George Souliotes

[xvii] Testimony transcript of Tom Reuscher, People vs. George Souliotes

**<u>Burn Cell Construction and Configuration</u>**

The burn structure consisted of four 12’x12’ burn cells, built with 2”x6” floor joists, 2”x4” wall studs, 2”x6” ceiling rafters and 5/8” drywall. Each southern wall had a 32”x84” door and 2’x3’ window; each northern wall had one 4’x4’ window.




**Burn Cell 1**

Burn Cell 1 was furnished with a large couch along the east wall, and a reclining chair in the southwest corner. The flooring material was half hardwood floor, on the west, and half carpet with padding on the east. There was a 6’0” sliding glass door in the center of the west wall, and 4’x4’ window on the north wall. These window openings, along with the door and window on the south side, provided ample ventilation to create a robust flashover. The area of origin was in a trash container located immediately north of the couch, in the northeast corner of the room.

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| Photo 1.1: View of southwest corner of burn cell 1 | Diagram of burn cell 1 | Photo 1.2: View of northwest corner of burn cell 1 |

Photo 1.3: Burn cell during flashover

**Burn Cell 2**

Burn Cell 2 was the only room where an ignitable liquid (liquid accelerant) was present.  It had a twin mattress laid on top of wooden pallets in the northwest corner, and wooden cabinets along the east and south walls.  The floor was divided into quadrants: hardwood floor in the southwest, vinyl tile in the northwest, carpet with padding in the northeast, and bare 5/8" plywood subfloor in the southeast near the door.  The room had a 4'x4' window on the north wall, and a door and window on the south side.  Approximately 90 oz. of  ignitable liquid (paint thinner) was poured in the center of the room where the four flooring materials came together, and trailed onto the mattress and bedding material to the north.

Photo 2.1: View of north wall of burn cell 2



Diagram of burn cell 2

Photo 2.2: View of the northeast corner of burn cell 2


Photo 2.3: Burn Cell 2 during flashover

**Burn Cell 3**

Burn Cell 3 had the same window and door configuration as burn cell 2, with a bunk bed on the west side of the room and wooden cabinets on the east and the south.  The flooring was half carpet with padding on the west side, and 5/8" plywood subfloor on the east.  An area rug was laid in the center of the plywood flooring on the east side.  The area of origin was on the south portion of the lower bunk bed, in a pile of clothing shown on Photo 3.1.

Photo 3.1: View of northwest corner of burn cell 3


Diagram of burn cell 3

Photo 3.2: View of northwest corner of burn cell 3

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| Photo 3.3: Burn Cell 3 during flashover |

**Burn Cell 4**

Burn Cell #4 had couches on both the east and west walls.  The flooring was half carpet with padding on the west, and vinyl tile on the east.  The area of origin was in a trash container immediately north of the couch shown in Photo 4.1.

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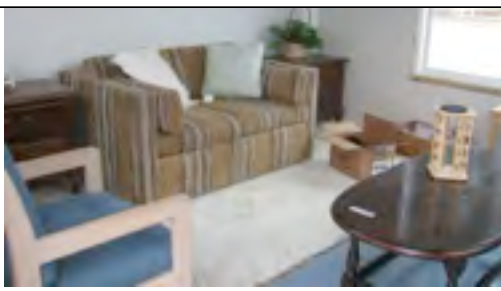
|  |  |  |
| Photo 4.1: View of northwest corner of burn cell 4 | Diagram of burn cell 4 | Photo 4.2: View of northeast corner of burn cell 4 |

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| Photo 4.3: Burn Cell #4 during flashover | Photo 4.4: Burn Cell #4 being extinguished |