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The Mythology Of Arson Investigation

John J. Lentini, B.A.
Scientific Fire Analysis, LLC
32836 Bimini Lane
Big Pine Key, FL 33043
USA
Scientific.Fire@yahoo.com

Abstract: Unlike in many other fields of scientific inquiry, progress in fire investigation is held back by the burden of an entrenched mythology. Despite the fact that it has been fifteen years since NFPA 921 was first published, some fire investigators still rely on "misconceptions" about the meaning of various fire effects and fire patterns.

This article will explore the development and promulgation of the mythology of arson investigation. Certainly, there is no reason to believe that anyone ever set out to promulgate something that was not true. It is likely that many myths came about as a result of unwarranted generalizations. For example, an investigator might observe a pattern of spalling around the remains of a gasoline container and make an association of gasoline with spalling. The next time that spalling is observed, gasoline is inferred.

Some myths arose because of intuitively "obvious deductions." The notion that gasoline burns hotter than wood is an appealing one, as is the notion that a narrow V-pattern indicates a "rapid fire." The problem is that the term "rapid" is never defined, thus making it impossible, in many cases, to actually design an experiment to test a particular hypothesis about the significance of a

particular indicator. Even when an indicator can be shown by direct evidence to be of no value, resistance to change and a culture of "circular citations" allow the myth to live on.

Many of the myths were gathered by the Law Enforcement Assistance Administration (LEAA) and published in *Arson and Arson Investigation Survey and Assessment* (1977), and although they were reported with appropriate cautionary language, the cautions were not heeded. And when the "indicators" were listed by what should have been the ultimate authority, the cautions were lost. No less an authority than the National Bureau of Standards (NBS then—now NIST) published a *Fire Investigation Handbook* (1980), which stated that crazed glass meant rapid heating, shiny alligator blisters meant that a fire burned "faster than normal," and narrow V's indicate "fast-developing, hot fires."

In the 1980s, one American text after another referred to the NBS publication or to another publication that cited the myths published in the LEAA report. These circular citations continue in books still in print. Interestingly, many of the myths never gained much credibility in the United Kingdom because the major "go to" textbook, Cooke and Ide's *Principles of Fire Investigation* (1985), either did not repeat the myths, or provided an accurate interpretation of the significance of indicators such as crazing and spalling.

In 1985, when the National Fire Protection Association (NFPA) Standards Council became sufficiently concerned about the validity of fire investigations, it appointed a Technical Committee to address the issue. Seven years later, the Committee and NFPA produced the first edition of NFPA 921, *Guide for Fire and Explosion Investigations.* The howls of protest from

fire investigation “professionals” were deafening. If what was printed in that document were actually true, it meant that hundreds or thousands of accidental fires had been wrongly determined to be incendiary fires. No investigator wanted to admit to the unspeakable possibility that they had caused an innocent person to be wrongly convicted, or a family to be wrongly denied their life savings. The profession was in denial.

In 1998, the Technical Committee on Fire Investigations, responding to public pressure, removed the word “misconception” from the titles of several paragraphs in the chapter on pattern development in the optimistic but mistaken belief that previous editions of the document, which was still not accepted in many quarters, had relieved the profession of these misconceptions.

The myths are slowly dying out (or being *“Dauberted”*out), but there are still practitioners who use them today, with disastrous consequences. Examples of the continued promulgation and application of the mythology since 2000 will be presented, as will the debunking of the myths as set forward in NFPA 921.

The Development And Promulgation Of Myths

The introduction and persistence of mythology in arson investigation is an unfortunate part of the history of the discipline, and is a subject that many fire investigators do not like to think about. Some would like to pretend that the myths have died, in the hope that people would gradually forget about them and they would not be a problem anymore. It is this failure to address a serious problem in the training and education of fire investigators that causes the myths to persist. The unfortunate consequence is that innocent lives are destroyed by well-meaning but ignorant

investigators. The purpose of this paper is to expose those myths, and to the extent possible, attempt to understand why they came into being, and why some of them still persist. The hope is that new investigators, or those considering entering the discipline, may be spared the necessity of having to "unlearn" things that are simply not true.

Just as has been learned from the study of Greek or Roman mythology, no single reason exists to explain why a myth develops. Certainly, no reason exists to believe that any investigator deliberately set out to promulgate something that was not true. It is likely that most myths came about as a result of unwarranted generalizations. For example, an investigator might observe that in a garage fire, a pattern of spalling surrounds the remains of a gasoline container, and makes an association of gasoline with spalling. The next time he sees spalled concrete, he infers that gasoline must have been involved.

Some myths arise because of "intuitively obvious deductions." The notion that gasoline burns at a higher temperature than wood is appealing. As anyone who has ever started a wood fire knows, it is much easier to start it with liquid fuel. And certainly after a short time, a fire started with gasoline, is throwing off much more heat than the fire burning wood only. Therefore, the flame temperature must be higher, right? Wrong! But even Paul Kirk, one of the leading forensic scientists of his time, bought into this notion. In the first edition of Kirk's *Fire Investigation* (1969) he described the utility of examining melted metals.

> Whenever any residues of molten metal are present at the fire scene, they will reliably establish a minimum temperature for the point of their fusion in the fire.

> The investigator may use this fact to advantage in many instances, because of the differences in effective temperature between simple wood fires and those in which extraneous fuel, such as accelerant is present. [1][1]

To this day, investigators sometimes infer the presence of accelerants when they observe a melted aluminum threshold.

The notion that crazed glass indicates that the glass was rapidly heated was appealing enough that Brannigan, Bright and Jason, three respected fire researchers at the National Bureau of Standards (now NIST), allowed it into the *Fire Investigation Handbook* (1980). Some authors have declared that crazed glass is sufficiently useful that the size of the crazing cracks can indicate proximity to the area of origin. [2][2.]

It is the **publication** and continued promulgation of myths that ensures their longevity. If an "arson school" decides to use a text containing the mythology in its training courses, hundreds of investigators can be exposed to this false "gospel." Those who take few refresher courses, fail to keep up with the literature, and attend few meetings may never be exposed to updated ideas and new research.

The question naturally arises as to why fire investigation espouses (or has espoused) such a wide variety of myths, whereas DNA analysis, a forensic discipline derived from molecular biology, has many fewer myths to expunge. To some extent, the answer lies in the nature of the practitioners. In forensic DNA, the leaders in the field are trained scientists. If someone told

them that crazed glass resulted specifically from rapid heating, they might remember an experiment in undergraduate chemistry lab that they tried to save from overheating by adding some water, only to watch the glass beaker craze when the water touched it. Thus they might consider an alternate explanation for the observation of crazing. During their education, it is hoped that scientists acquire what Carl Sagan referred to as a "baloney detector," otherwise known as natural scientific skepticism. However, one need not possess a science degree to be appropriately skeptical. Sagan wrote:

> The tenets of skepticism do not require an advanced degree to master as most successful used car buyers demonstrate. The whole idea of a democratic application of skepticism is that everyone should have the essential tools to effectively and constructively evaluate claims of knowledge. All science asks is to employ the same levels of skepticism we use in buying a used car. [3][3]

Presented with the notion that large shiny alligator blisters occur only on wood surfaces that have been rapidly heated, a scientist will say, "Show me the data!" while an apprentice fire investigator will absorb the "knowledge" from his experienced mentor. When someone with an advanced degree publishes the myth and maybe even an apparent explanation for why it is so (albeit with no real data), the apprentice internalizes the fallacy as fact, making retraining difficult. And once the investigator uses the myth to send someone to prison, he is extremely reluctant to question the myth's authority, lest he be forced to admit to an unspeakable error. Though rare, such admissions happen. A Texas fire marshal, commenting on the execution of Cameron Todd Willingham, stated the following in the Chicago Tribune: "At the time of the Corsicana fire, we were still testifying to things that aren't accurate today, **They were true then, but they aren't now**."

Much of the mythology about fire investigation was collected by the Aerospace Corporation, under a contract to the Law Enforcement Assistance Administration (LEAA) in a 1977 booklet entitled *Arson and Arson Investigation: Survey and Assessment.* To their credit, the authors of this survey pointed out, "Although burn indicators are widely used to establish the causes of fires, **they have received little or no scientific testing.**" They recommended, "a program of carefully planned scientific experiments be conducted to establish the reliability of currently used burn indicators. Of particular importance is the discovery of any circumstances which cause them to give false indications (of, say, a fire accelerant)." In a remarkably prescient statement, they added, "A primary objective of this testing would be to avert the formidable repercussions of a court ruling on the inadmissibility of burn indicators on the grounds that their scientific validity had not been established." Despite this prediction, serious challenges to the myths did not become common until NFPA 921 was published. Part of the reason for the acceptance of the mythology may be that no less an authority than the National Bureau of Standards gave its blessing to many of the myths. In section 1.1 of the *Fire Investigation Handbook*, which two National Fire Academy staffers are credited with contributing, most of the myths from the LEAA report were reprinted without a single caution of the type found in the original survey report. Having the imprimatur of such an august body as NBS, fire investigators and textbook authors believed (incorrectly as it turns out, but who knew?) that the myths had been scientifically tested.

The LEAA study provides as good a jumping off place as any for the study of the myths of fire investigation. Here is the list from the survey.

Alligatoring effect: checking of charred wood, giving it the appearance of alligator skin. Large rolling blisters indicate rapid intense heat, while small flat alligatoring indicates long, low heat. (This myth was repeated in the NBS *Handbook.*)

Crazing of glass: formation of irregular cracks in glass due to rapid intense heat—possible fire accelerant. (This myth was repeated in the NBS *Handbook.*)

Depth of char: depth of burning of wood—used to determine length of burn and thereby locate the point of origin of the fire.

Line of demarcation: boundary between charred and uncharred material. On floors or rugs, a puddle-shaped line of demarcation is believed to indicate a liquid fire accelerant. In the cross section of wood, a sharp distinct line of demarcation indicates a rapid, intense fire. (This myth was repeated in the NBS *Handbook.*)

Sagged furniture springs: because of the heat required for furniture springs to collapse from their own weight (1150^{o} F) and because of the insulating effect of the upholstery, sagged springs are believed to be possible only in either a fire originating inside the cushions (as from a cigarette rolling between the cushions) or an external fire intensified by a fire accelerant.

Spalling: breaking off of pieces of the surface of concrete, cement or brick due to intense heat. Brown stains around the spall indicate the use of a fire accelerant. [4][4]

In addition to the misconceptions listed in the LEAA report, the following myths have also been widely promulgated:

Fire load: Knowing the energy content (as opposed to the energy release rate) of the fuels in a structure was believed to allow an investigator to calculate the damage that a “normal” fire should produce in a given time frame.

Low burning and holes in the floor: Because heat rises, it was widely believed that burning on the floor, particularly under furniture, indicated an origin on the floor.

V-pattern angle: The angle of a V-pattern was supposed to indicate the speed of the fire. (This myth was printed in the NBS *Handbook.*)

Time and Temperature: By estimating the speed of a fire, or establishing the temperature achieved by a fire, it was believed that an investigator could determine whether it was accelerated.

The Overarching Myth

Before the discussion of the individual indicators used to determine whether a fire behaved "normally," we first consider the myth that makes all the rest of the myths plausible. This is the notion that accelerated fires burn at a higher temperature than unaccelerated fires. It is true that accelerated fires burn with a higher heat release rate (see the article on Fire Dynamics) but there is no measurable difference in temperature.

A corollary myth about accelerated fires is really about accidental fires. Accidental fires generally start small and slow. The myth is that even after a smoldering fire makes the transition to flaming combustion, it remains small and slow. This is simply false, as anyone who has watched a small cigarette fire on a piece of upholstered furniture can attest. After making the transition to flaming combustion, the sofa or chair can release sufficient energy to bring a room to flashover ion under 5 minutes.

Many of the myths about fire investigation were addressed in the first two editions (1992, 1995) of NFPA 921. In the chapter on fire patterns, there were several paragraphs entitled "Misconceptions about_____(char, spalling, v-patterns, inverted cone patterns)." While the Technical Committee felt it important to shine a spotlight on these myths, many in the fire

investigation community railed against the notion that any of them had ever harbored any misconceptions about anything. They insisted, and the committee acquiesced to a change in the 1998 edition, that section titles be changed to "Interpretation of _____," as if removing the **word** "misconception" would remove the misconception.

ALLIGATORING

The *Fire Investigation Handbook* contains some useful information, but it starts out with a myth-filled chapter on how to determine origin and cause. Chapter 1 of the *Handbook*, states:

> In determining whether the fire was a slowly developing one or a rapidly developing one, the following indicators may be used: a) Alligatoring of wood—slow fires produce relatively flat alligatoring. Fast fires produce hump-backed shiny alligatoring. [5][5]

The 1982 IFSTA (International Fire Service Training Association) manual unequivocally states:

> If alligatoring is large, deep, and shiny, the fire spread extremely rapidly. Large alligatoring should be considered an indication of the nearby presence of a flammable or combustible liquid. [6][6]

Nowhere is it stated what the difference is between a "fast" fire and a "normal" fire. The lack of a definition of these subjective words not only renders the "indicators" of a fire's progress meaningless, it also makes it nearly impossible to design an experiment that tests the indicator's usefulness. The U. S. Army's Field Manual 19-20, *Law Enforcement Investigations* provides a slightly different interpretation of alligatoring when it states:

> When wood burns, it chars a pattern of cracks which looks like the scales on an alligator's back. The scales will be the smallest and the cracks the deepest where

> the fire has been burning the longest or the hottest. Most wood in structures char at the rate of 1 inch in depth per 40 to 45 minutes of burning at 1400° to 1600 °Fahrenheit — the temperature of most house fires. *(Thus combining three misconceptions in a single paragraph!)* [7][7]

O'Connor's *Practical Fire and Arson Investigation* (1986) stated:

> Deep alligatoring (large rolling blisters) on an exposed wooden surface ordinarily indicates an intense, rapidly moving body of flame. This condition may be associated with the use of an accelerant. [8][8]

The second edition of the book (1997) is far more cautious, the authors having been brought up to speed on this subject. The newer text states:

> It has been suggested that the presence of large shiny blisters (alligator char) and the surface appearance of char, such as dullness, shininess or colors have some relation to the presence of liquid accelerant as the cause, but no scientific evidence substantiates this. The investigator is advised to be very cautious in using wood char appearance as an indicator of incendiarism. [9][9]

They have not completely given up on the myth, however. The 1997 text shows a photo of "a heavy rolling char…caused by the rapid intense movement (extension) of heat and flame."

Randall Noon, in his 1995 *Engineering Analysis of Fires and Explosions*, wrote:

> In the same way that a hunting guide interprets signs and markers to follow a trail of game, a fire investigator looks for signs and markers which may lead to a point of origin. For example, a fast, very hot burn will produce shiny type wood

> charring with large alligatoring. A cooler, slower fire will produce alligatoring with smaller spacing and a duller appearing char.

Noon then goes on to explain "scientifically" why this is should be so.

> As heat impinges on the piece of wood, the water in the surface material will evaporate and escape from the wood. The rapid loss of the water at the surface is also accompanied by a rapid loss of volume, the volume which the water formerly occupied. The wood surface then is in tension as the loss of water causes the wood to shrink. This is the reason why wood checks or cracks when exposed to high heat or simply dries out over time. Of course, if the heat is very intense, more of the water "cooks" out, and the cracking or alligatoring is more severe. [10][10]

The scientific-sounding explanation (though it is rubbish) lulls the reader into believing that the author actually knows what he is talking about. This kind of exposition in many books that repeat the myths has enhanced their credibility and thus their longevity.

The final word on this and most other myths may be found in NFPA 921. Here is what it says about alligatoring:

> **6.5.5 Interpretation of Char.** The appearance of the char and cracks has been given meaning by the fire investigation community beyond what has been substantiated by controlled experimentation. It has been widely stated that the presence of large shiny blisters (alligator char) is proof that a liquid accelerant was present during the fire. This is a misconception. These types of blisters can be found in many different types of fires. There is no justification that the appearance

of large, curved blisters is an exclusive indicator of an accelerated fire. Figure 6.5.5, showing boards exposed to the same fire, illustrates the variability of char blister.

6.5.5.1 It is sometimes claimed that the surface appearance of the char, such as dullness, shininess, or colors, has some relation to the use of a hydrocarbon accelerant or the rate of fire growth. There is no scientific evidence of such a correlation, and the investigator is advised not to claim indications of accelerant or fire growth rate on the basis of the appearance of the char alone.

The referenced figure is a photograph taken by Monty McGill, which was first shown in *Kirk's Fire Investigation,* Second Edition. It is the definitive evidence that debunks the myth of the shiny alligator. For our friends in the UK, we note the fact that Dougal Drysdale prefers the term "crocodiling." Figure 1 shows a fire damaged wood wall that exhibits three different kinds of alligatoring, all the result of exposure to the same fire.

CRAZED GLASS

It is unclear why anyone ever thought that crazing of glass indicated rapid heating. Perhaps a piece of crazed glass was observed near the known origin of a fire, and one influential investigator reached the wrong conclusion and repeated it to a large group of seminar attendees. However the notion began, it achieved widespread acceptance. Unlike most myths, this one has proved especially amenable to testing, but until 1992, nobody bothered to make the effort.

The NBS *Handbook* stated, "Window glass fragments in large pieces with heavy smoke deposits usually indicates slowly developing fires. Crazed or irregular pieces with light smoke deposits indicate a rapid buildup of heat."[11] Both statements are false, but crazing is our focus for now.

The Army's Field Manual, *Law Enforcement Investigations*, states, "As a general rule, glass that contains many cracks indicates a rapid heat buildup. Glass that is heavily stained indicates a slow, smoky fire."[12]

IFSTA's *Fire Cause Determination* stated:

> A window with small crazing (minute cracking), and perhaps with light smoke accumulation, is probably near the point of origin, its condition suggesting intense and rapid heat buildup. Large crazing and a heavy smoke accumulation suggest slow heat buildup and remoteness from the point of origin.[13]

The IFSTA manual may have been the source used in *Practical Fire and Arson Investigation*, (O'Connor, 1986 and O'Connor and Redsicker, 1997), which repeats the notion that crazing implies a "rapid and intense" heat buildup, and that if the crazing is "small," it is close to the area of origin. A larger crazing pattern, on the other hand, "implies that it may have been located in an area some distance away from the point of origin." The misconception about crazing follows an extensive discussion of the types of glass that an investigator may encounter, complete with softening points, chemical compositions and applications. The reader thus is led to believe that the writers know all about glass.

DeHaan, who today warns against reading anything into a finding of crazed glass and lists it under "Myths and Misconceptions," still believed the myth in 1991. He stated, "Crazed glass, where the fractures or cracks resemble a complex road map in the glass, is certainly indicative of a very rapid buildup of heat sometime during the fire." [14] Getting closer to an understanding of the true cause of the phenomenon, he went on to state, "Small cratering or spalling of the glass is more likely due to a spray of water hitting a hot pane of glass during suppression." By the time the fourth edition of *Kirk's* was published, in 1997, DeHaan acknowledged the work by this author that proved that crazing is **only** the result of rapid cooling.[15]

In the study conducted by the author following the urban wildland fire in Oakland, CA in 1991, crazed glass was one of three "indicators" examined. We observed that all of the crazing occurred at those parts of the fire where there had been active suppression efforts, suggesting that water was associated with crazing. Later, in a series of laboratory experiments conducted by the author, we demonstrated that crazing is never caused by rapid heating, and can only be caused by rapid cooling.[16]

It is interesting to note that crazing of glass as an indicator of rapid heating is a myth that never caught on in the United Kingdom. This is almost certainly because in the UK, the most widely read fire investigation text, *Principles of Fire Investigation,* correctly identified "the appearance of many small conchoidal fractures on one surface of the glass," as being the result of rapid cooling from extinguishment water.[17] The authors of that text did not use the term "crazing." The absence of the crazing myth in the UK lends credence to the proposition that it is **publication** in

apparently respectable texts that is responsible for the perpetuation of the mythology of arson investigation.

DEPTH AND LOCATION OF CHAR

In 1979, Aetna Life & Casualty published a brochure-style handbook, authored by John Barracato, which espoused as many myths as any publication ever printed on the subject. On the subject of depth of char, the booklet entitled *fire…is it arson?* states:

> The speed at which a fire burns is an important indicator of its cause. A fire not involving accelerant (such as gasoline or other flammable liquid) burns at the rate of 3/4 inch per hour into pine wood. The investigator should ask the fire department how long and intensely the fire burned, then carefully inspect any charred wood to see if there is a reasonable correspondence between the length of time the fire burned and the degree of damage it caused.[18]

Exactly this type of analysis was put forward in the case of *Commonwealth v. Han Tak Lee*. (1989). The investigator in that case made the following observations:

> (a) the fire burned for a total of 28 minutes,
>
> (b) fire burns one inch in 45 minutes (note: this is a more commonly cited charring rate than Barracato's 3/4 inch per hour), and
>
> (c) 2 by 10s, were completely consumed.

Therefore, the fire **must** have been accelerated because it would take 4.5 hours to burn through a 2 by 10. This of course, assumed that the fire would only burn in one dimension, as opposed to attacking the wood from both sides. He estimated the time required to burn a 2 by 4 at 1 hour 43 minutes at 1780^{o} F.[19] The investigator was misled by two myths, one, that the depth of char could be used to determine reliably the time of burning, and two, a uniquely-held belief that only one dimension of the wood would be attacked by the fire. If we assume, for the sake of argument, that fire burns one inch in 45 minutes, then it should take only 34 minutes to burn through a 1 1/2 inch piece of wood, assuming it is attacked from both sides. This investigator had both his premise and his implementation of that premise wrong. NFPA 921 states unequivocally that depth of char measurements should not be relied on to determine the duration of the burning.

LINES OF DEMARCATION

This is one of the more complex myths in fire investigation because, in some instances, lines of demarcation can be used to tell exactly what happened, whereas in other instances, lines of demarcation are just lines. The threshold question is whether the compartment where the lines occur experienced full room involvement. Let us be clear. There are times when a fire pattern is so obviously caused by an ignitable liquid that further analysis truly is “the icing on the cake,” to coin a phrase. Once a fire progresses to full room involvement, however, it is no longer valid to make a determination using visual cues alone, and there are some who maintain this should never be done. Sharp, continuous, irregular lines of demarcation between burned and unburned areas are frequently cited as evidence of the use of ignitable liquids. It is true that ignitable liquids can

produce such patterns on carpeting, and many arson seminars include staged fires that are extinguished early, so that investigators can learn to recognize “pour patterns.” What is not evident from these incipient test fires is what happens after the room becomes fully involved.

Lines of demarcation can occur for no apparent reason. The intensity of radiation falls off as the square of the distance from the source to the target, so at some point, perhaps a sharply defined point, insufficient energy exists to maintain combustion. This property, as well as the random nature of some burning, can result in sharp lines of demarcation.

Protection patterns can be produced by irregularly shaped pieces of gypsum drywall, which fall from the ceiling and provide protection to whatever floor they land upon. Clothing on the floor has also been known to produce alternating areas of exposure and protection.

In a ground-breaking study of burn patterns caused by burning pools of gasoline and kerosene, Putorti demonstrated that even on wood and vinyl floors, the edges of the patterns produced are not necessarily all that sharp.[20] The only definitive pattern he found that could reliably be associated with the use of ignitable liquids was the “doughnut” pattern on carpeting, caused by protection at the center of the pattern by the presence of liquid fuel that had not yet evaporated.

Lines of demarcation in the cross section of charred wood have been cited since 1980 as an indicator of the speed of a fire. The *Fire Investigation Handbook* stated, “A distinct line between charred and uncharred portions indicates a rapidly developing fire. Lack of a distinct line usually indicates a slow, cooking process, thus, a slowly developing fire.”[21] O’Connor (1986) and

O’Connor and Redsicker (1997) both provide a diagram of a cross section of a piece of lumber showing a sharp line of demarcation indicating a rapid spread, and a gradual line of demarcation indicating a slow-burning fire. DeHaan (2002) states, “One indicator that is more reliable [than the surface appearance of char] is the appearance of the charred wood in cross section. When a charred beam is cut crosswise, the gradation between the charred layer and the underlying undamaged wood is more gradual with a slowly developing fire.” He then goes on to provide a perfectly reasoned analysis of why this should be so, but, like O’Connor, provides neither data (though he also provides a drawing), nor a definition of what is meant by “sharp,” “gradual,” “fast,” or “slow.” It seems to be a case of “I know it when I see it.” To his credit, DeHaan cautions that a fast-developing fire may or may not be accelerated. Nonetheless, this is the type of “data” that an investigator may use to incorrectly “eliminate” a smoking fire, since smoking fires are not “fast-developing.” (Actually, once a smoldering fire started by a cigarette makes the transition to flaming combustion, the speed of fire growth is not distinguishable from a fire ignited by an open flame.)

Some of the more frequently debated sections of NFPA 921 deal with determinations made by observing lines of demarcation. While it is silent on the observation of cross sections, the document contains a whole section devoted to caution in the interpretation of burn patterns on the floor. **NFPA 921 contains more cautions on this subject than on any other.** The reason for the abundance of cautions on the subject of interpreting lines of demarcation is simple—the errors caused by this particular misinterpretation have been legion.

SAGGED FURNITURE SPRINGS

The Aetna booklet *fire…is it arson?* (1979) advised fire investigators to photograph furniture springs, "because their appearance can help the investigator document the area of origin. Severely sagging springs can indicate that a flammable liquid was involved and created heat intense enough to cause the springs to sag."[22] Carter, on the other hand, writing in *Arson Investigation* (1978) stated that collapsing all or part of a coil spring was an indication of a cigarette starting the fire.[23]

In the Han Tak Lee case, smoking in bed was ruled out because the bedsprings had lost their temper. Clearly, this is an area of much confusion. In 1989, Tobin and Monson, two FBI laboratory scientists, subjected furniture springs, both loaded and unloaded (with and without weights on them), to different fire conditions, and basically concluded that the condition of the springs is of little probative value in fire investigation.[24] DeHaan correctly states that varying degrees of spring damage can provide some insight about the progress of a fire but cautions that the collapse of springs cannot be reliably used to determine whether a fire was incendiary.[25] NFPA 921 states that the value of analyzing the furniture springs is in comparing the differences in the springs to other areas of the mattress, cushion, or frame. Comparative analysis of the springs can assist the investigator in developing hypotheses concerning the relative exposure to a particular heat source.

SPALLING

There exists no more misunderstood and misused indicator than concrete spalling. It has been the pivotal "indicator" in many major fire cases, and has been the subject of numerous contentious articles in the *Fire and Arson Investigator*. To this day, arson cases are made on the basis of spalled concrete. Kennedy's "Blue Book,"(1977) had the following comments on spalling:

> Spalling caused by flammable liquids burning is usually found at low levels because the flammable liquid vapors are heavier than air and tend to go down.
>
> … Regardless of the composition of the concrete or brick, the indicator is the spalled area or areas indicating the burning of accelerants….
>
> …The spalling temperatures are usually much higher than the temperatures found in the normal dwelling or commercial building fire. Therefore, we know that accelerants were used.[26]

IFSTA's *Fire Cause Determination* provided the following statement on spalling in 1982:

> Concrete floors and assemblies that have spalling should be examined closely. The spalling may be an indicator of the use of accelerants. If the accelerants had adequate time to soak in before ignition, the spalling will follow the flow pattern of the liquid. Spot spalling is not a clear indicator of the use of accelerants. Further, it is not unusual for spot spalling to result from severe fire exposure.[27]

This semi-cautious language is typical of what has been written about spalling. Skeptics have always questioned the relationship between ignitable liquids and spalling. These include Harvey

French in 1979, Fred Smith and Jack Mitchell in 1981, Bruce Ettling in 1984, Charles Midkiff in 1990 and Bernard Beland in 1993. Some fire investigators simply ignored all these skeptics, and ploughed on with their case making.

One of the largest insurance bad faith awards in Alabama history was the result of a fire investigator, who relied on a "trail of spalling" in addition to other "indicators" to conclude that the cause of a fire was arson. It did not help that the fire chief stood on the "trail" before the fire reached the basement. Nor was the court impressed with the shape of the "trail" when it learned that its shape resulted from the investigator shoveling a trail.[a] When the slab was completely cleared, it was found that the entire slab had spalled, and no "trail" of any kind had ever existed.[28]

Fire investigators have argued endlessly about the characteristics of an accelerant-induced spall versus a naturally occurring one. A brownish, or pinkish halo around the hole was thought to indicate the presence of burning hydrocarbons[b]. Numerous slides and photos were exchanged, but in the end, the consensus was that the skeptics were right.

The evolution of DeHaan's thinking is instructive. In 1991 he wrote, "As a fire indicator, spalling can indicate the presence of such suspicious sources of localized heating as a chemical

[a] The court's characterization of the testimony of the investigator is instructive. "The court concludes that not only is [the investigator's] testimony as a whole completely void of credibility, but the presentation of his testimony borders on the perpetration of a fraud upon this court. For [the investigator] and [the insurance company] to present to this court a case so heavily dependent upon "spalling" as this case, when it is indisputable that [the investigator] selectively cleared only those areas of the floor which supported this incredulous theory is reprehensible."

[b] Cook and Ide (1985) reported that the color change was probably a result of the dehydration of yellow colored hydrated iron oxides, which turned pink or reddish brown at about 300 ^{o}C.

incendiary or a volatile petroleum liquid." In the next edition (1997), the language was moderated to the following: "As a fire indicator, spalling can indicate the presence of a significant fuel load of ordinary combustibles, as well as the presence of suspicious sources of localized heating as a chemical incendiary or a volatile petroleum liquid." By the fifth edition of *Kirk's* (2002), spalling had been relegated to DeHaan's list of "Myths and Misconceptions."

Most of what is written about spalling today wishfully refers to misconceptions formerly held. NFPA 921 has, since its inception, warned about misinterpreting spalling. Overall, 921 states that the importance of spalling to the fire investigator lies in the documentation and analysis of a heat source.

One way to tell whether an investigator is keeping up is to look at the way he spells spalling. Some people spell it "spalding" and some spell it "spaulding." The origin of the misnomer is probably the past tense of the word spall. One sees spalled concrete. People who don't know any better add the "d" and call the process spalding or spaulding. Such people have apparently never read a text or even an article on the subject, and are quite beyond hope.

FUEL LOAD

In one of the early attempts to bring a quantitative approach to the practice of fire investigation, French (1979) described a methodology by which a fire investigator could determine whether the fire behaved in a "normal" manner. He described the process as follows:

The heat energy production of fuels is extremely important to any competent fire investigator in determining fire load in the premises or equipment under investigation, again in respect to its potential in affecting temperature rise and spread and the time spectrum....

Fire load of any given space may be established by knowing the type of combustibles in storage, their calorific heat producing capacity in Btu's per lb., the total weight of the combustibles in storage, and the square-foot capacity of the space.

The formula is as follows: multiply the calorific contents in Btu's per lb. by the total weight of the contents or materials in pounds. Then, divide the result by the area in square feet. The answer is fire load per square foot.

National Bureau of Standards and American Standards as well as the National Fire Protection Association and British time/temperature curves are in general agreement as to what temperature rise may be expected in various occupancies, with known fire loads, particularly during the first two hours of combustion.

For example, with sufficient oxygen to support continuing combustion, fires in buildings may be expected to attain 1000 to 1200 °F during the first 5 to 10 minutes, accelerating on the curve to approximately 1500 °F in the first half hour and with temperatures reaching the order of 1700 °F at one hour.[29]

Carroll, writing in *Physical and Technical Aspects of Fire and Arson Investigation,* adopted a similar approach, but instead of fire load, urged investigators to use the flame-spread index described earlier in his text. The vaguely defined process was described in two paragraphs as follows:

> Using this flame spread index (available from Underwriters Laboratories, Inc.), a fire investigator can determine the comparative rate of how fast a fire should or should not have spread under normal circumstances by comparing the burning rates of known fires and the standard ASTM (American Society of Testing and Materials) time/temperature fire exposure chart shown in Figure 10.
>
> Figure 10 shows the temperature acquired as a function of time, which has been found to be the average temperature 8 feet off the floor.[30]

Carroll also wrote, "By knowing the fire load of the building, i.e., the material available for the creation of heat, a reasonable approximation of the highest temperatures attained can be made and compared with temperatures to be expected had an accelerant been used."

Neither Carroll nor French understood that the "Standard Time/Temperature Curve" had nothing to do with the behavior of any fire. The Standard Time/Temperature Curve describes the way a furnace should be operated in order to compare the fire resistance of various building assemblies. Unfortunately for many fire victims, including Han Tak Lee in Pennsylvania, this approach

resulted in numerous determinations of a fire behaving "abnormally," and this in turn resulted in wrongful prosecutions and convictions.

This particular misconception about fire behavior did not receive as much acceptance as some of the other myths, possibly because it involved math. There were enough practitioners using this "quantitative" approach that the NFPA Technical Committee on Fire Investigations felt the need to address the issue in NFPA 921 in the chapter on basic fire science:

> **5.4.1 General**. The term fuel load has been used to indicate the potential severity of a fire and has been expressed in terms of Btu (British thermal unit) or pounds of fuel per square foot of floor area. An example is provided in 5.4.1.1
>
> **5.4.1.1** The Btus were expressed in wood equivalent based on 8000 Btu per pound. The fuel load was determined by weighing the fuel in a room and converting the weight of plastic to 2 pounds of wood using 16,000 Btu per pound as a value for plastic (1 pound of plastic equals 2 pounds of wood). The total Btus (or pounds of fuel) were divided by the area of the room floor. While this approach can be a measure of the total available if all the fuel burns, **it does not depict how fast the fire will develop once it starts**. *(Emphasis added).*
>
> **5.4.1.2** The rate of fire growth as determined by witness statements is highly subjective. Many times witnesses are reporting the fire growth from the time of discovery, which cannot be directly correlated to ignition time. The rate of fire

growth is dependent on many factors besides fuel load, to include fuel configuration, compartment size, compartment properties, ventilation, ignition source, and first fuel ignited. The rate of fire growth as reported by witnesses is not reliable or supported independent evidence of an incendiary fire.

5.4.2 Heat Release Rate

5.4.2.1 Total fuel load in the room has no bearing on the rate of growth of a given fire in its pre-flashover phase. During this period of development, the rate of fire growth is determined by the heat release rate (HRR) from burning of individual fuel arrays. The HRR describes how the available energy is released. This quantity characterizes the power — energy released per unit time (Btu/sec or kilowatts) — and is a quantitative measure of the size of the fire. A generalized HRR curve can be characterized by an initial growth stage, a period of steady-state burning, and decay. The largest value of the HRR measured is defined as the peak heat release rate.

These values should only be considered as representative values for comparison purposes. Fuel items with the same function (e.g., sofas) can have significantly different HRRs. The actual heat released rate for a particular fuel item is best determined by test.

Despite this warning about fuel package variability, some allegedly scientific fire investigators insist on their right to estimate the HRR of an item of furniture, and then opine whether it will have sufficient radiant energy to ignite a nearby item. Usually the estimate is at the low end of the HRR scale, which may range from 500 to 2,500 kW for an armchair for example. The investigator then "deduces" that because the fire did spread, there must have been multiple points of origin.

LOW BURNING AND HOLES IN THE FLOOR

A common misconception is that because heat rises, fire burns up and out and will not burn downward unless it has "help." This simplistic explanation of fire behavior has formed the basis of many an arson investigator's determination of incendiary cause and plays very well with a jury that has no knowledge of flashover.

In Carroll's 1979 text, he discusses multiple low points and states, "The discovery of a low point should not be considered the end of the search, since more than one low point may be discovered. This is particularly true in arson fires." He states further that, "Every effort should be made to determine whether multiple low spots are accidental or deliberate. If they have been set in an incendiary effort, these would be considered evidence of arson."

Carroll states, "Significant differences in char depths at two different low points would indicate an accidental low point."[31] If the low points or holes in the floor are all about equally charred,

the use of multiple holes to indicate multiple points of origin could arguably be justified by referring to this alleged learned treatise.

The IFSTA manual, *Fire Cause Determination*, espoused a similar misinterpretation when it stated, “Low levels of charring are good indicators of a flammable liquid having been used. For example, accidental fires are unlikely to burn the bottom edge of furniture or the bottom edge of the door.”[32]

The Army's *Field Manual* succinctly restates the popular myth

> Liquid accelerants leave evidence of low burn. That is, they show burning on the floor of the structure. A normal fire chars only the upper portion of a room. Floor damage in natural fires is usually limited to about 20% of the ceiling damage. Low burn, shown by complete charring of large areas of the floor or the baseboards, is not natural.
>
> Nor is fire burning downward natural. Fire burning downward is a prime indicator of the use of a flammable accelerant. Patterns burned in wood floors or holes in a floor may show that an accelerant was used.[33]

Kirk was one of several workers who disagreed with the notion that holes observed in a burned floor necessarily indicated the presence of an ignitable fluid. In 1969, he wrote:

> In many instances, the lowest burn is a floor surface or region directly under a floor. These points are sometimes difficult to evaluate and often lead to error in interpretation. For example, there is a whole burned in the floor in a region away from any walls or other objects that could carry a fire upward by providing fuel in the path of the flames. It is not uncommon for the investigator to assign the cause to the use of a flammable liquid. Such an interpretation is more often incorrect than otherwise. On a tight floor, it is always incorrect, unless holes or deep cracks are present. **Lacking such conditions, flammable liquids never carry fires downward.** (*Emphasis in the original).*[34]

NFPA 921 has dealt with this myth in a straightforward admonition:

> **6.17.2.2**. Like other areas of low burning, holes in the floor can be produced by the presence of ignitable liquids, glowing embers, or the effects of flashover or full room involvement.

It is this warning in NFPA 921 that drew the ire of many fire investigators who believed they had been properly trained to recognize artifacts indicative of the use of liquid accelerants, even in fully involved compartments. There is no doubt that they had been trained, but that training had no validity.

THE ANGLE OF THE "V"

The “V” angle myth has been published by many authors. It goes like this: The sides of a “normal” conical fire plume are angled 15 °From vertical. The faster a fire burns, the slower it will spread laterally and the closer the angles will be to vertical. Conversely, the slower a fire burns the further the angle will tilt from vertical. Like most of the myths presented in this paper, no scientific support exists for this myth, however, it is a deceptively appealing notion. The NBS *Fire Investigation Handbook* stated that the V pattern should be examined to determine whether the fire was a slowly developing one or a rapidly developing one. Without defining rapid and slow, the intent was apparently to let the indicator do the defining. The authors stated:

> Fire patterns — a wide or diffuse V pattern generally indicates a slowly developing fire. A narrow sharply defined V pattern generally indicates a fast developing, hot fire.[35]

The Army's 1985 *Field Manual* states,

> Fire burns up and out. It leaves a V-shaped char pattern on walls and vertical structures. A fire which is hot and fast at the point of origin will leave a sharp V pattern. A slow fire will produce a shallow V.

The new, allegedly updated, Army *Field Manual* (2005) repeats the same misinformation.[36]

Carroll took a more quantitative approach, at least as far as the angles were concerned:

> A normal fire, consuming wood, plastic or electrical insulation, would burn with a "V" pattern of approximately 30° measured vertically. If an accelerant was used, or if highly combustible material was involved, the "V" would be narrower as the temperature of the fire increased, due to the additional heat content of the accelerant or flammable liquid. This would cause a faster rise of heat and flame, resulting in a "V" pattern of approximately 10° depending on the heat flux generated by the accelerant.[37]

Noon (1995) devotes an entire section of his book to burning velocities and V patterns. This discussion is accompanied by equations to help the investigator determine the ratio of the upward burning rate to the lateral burning rate by finding the tangent of the angle of the V.

O'Connor (1986) and O'Connor and Redsicker (1997) repeat the story:

> The breadth or width of the V (also called the *funnel pattern*) is affected by (and hence, indicative of) the buildup, progression, speed and intensity of the fire. An intense rapidly moving fire produces a narrow the pattern whereas a slow, less intense fire produces a wide V pattern. The angles of the boundaries average between 10 and 15°.[38,39]

In the third edition of *Kirk's Fire Investigation*, DeHaan urged caution in the interpretation of the pattern angles when he stated, "Although it is sometimes claimed that the more vertical the sides of the V, the faster the initial fire (and therefore the more suspicious), one can appreciate that the

nature of any wallcovering and conditions of ventilation have important effects on the shape of the pattern, and must be taken into account."[40] By the fourth edition, he came right out and said, "The angle and width of the V are not dependent on the rapidity of ignition of the fuel."[41]
Since it was first published in 1992, NFPA 921 has contained a section on the interpretation of V patterns, and describes the equation of angles with speed as a "misconception." The current (2004) edition makes the following statement:

> **6.17.2.2.** The angle of the borders of the V pattern does not indicate the speed of fire growth; that is, a wide V. does not indicate a slowly growing fire, or a narrow V does not indicate a rapidly growing fire.

It is both amazing and disturbing that when the Army revised their *Field Manual* in 2005, and stated that the revision contained information from NFPA, they would continue to include the V angle myth despite the fact that NFPA 921 had disparaged this myth through five editions over 13 years.

TIME AND TEMPERATURE

A fire that burns "hotter than normal" or "faster than normal" is thought to indicate an accelerated fire. Actually, fire temperature and the perceived speed of the fire are not valid indicators of a fire's cause.

A major misconception underlying many false determinations of arson is that the temperature achieved by a particular fire can help an investigator evaluate whether a fire was "normal" or "abnormal," with an abnormal fire being attributed to incendiary activity. Higher than "normal" temperatures indicating a set fire is such an appealing notion that even Paul Kirk bought into it, as previously discussed. To this day, investigators sometimes infer the presence of accelerants when they observe a melted aluminum threshold.

Kennedy, discussing the fusion of copper, wrote:

> Copper fuses at 1980 °F, which is very high. Therefore, if we find fused copper or beaded copper wires, we are immediately alerted because we have an unusually high temperature that must be explained. The normal burning of a structure would not cause temperatures in the 2000 °F range, which is necessary to fuse or melt copper.
>
> What could cause copper to fuse or melt? The burning of an accelerant such as flammable liquids, natural or LP gases or electrical shorts or arcing are some of the causes for "high heat" — meaning excessive temperatures.[42]

Barracato (1979) summed up the time and temperature equation as follows:

> Fires which burn through entire floor sections, destroy large support beams in a relatively short period of time, or melt articles located in the area of origin such as

> metal, copper, aluminum or glass, are unusual. It takes tremendous heat to cause such damage and unless there is a rational explanation for the heat buildup — for example, if the room was used to store a highly flammable material — it's very probable that the fire was intentional and an accelerant was used.[43]

Carroll, as discussed previously under "fire load," presented the standard time/temperature curve from ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials,* and stated that it can be used as a basis in comparing the burning rates in structures. Carroll also stated, "if accelerant or other chemicals are present, temperatures can reach higher than on the standard fire curve."[44]

Based on research that began in the late 1970s and continues until today, it is now well understood that there is valid definition of "normal" fire spread and also that the ASTM time/ temperature curve has little relation to the behavior of a "normal" fire.

In the second edition of *Kirk's Fire Investigation* (1983), DeHaan somewhat moderated Paul Kirk's enthusiasm for interpreting melted metals, but still left readers with the suggestion that an abnormal fuel load, such as provided by an accelerant, will increase temperatures.[45]

Although the third, fourth, and fifth editions of *Kirk's* include a discussion of the fact that gasoline burns at essentially the same temperature as wood, it still states that temperature can be used to determine the presence of "enhanced draft conditions or unusual fuel loads," when the data support only the former. Nonetheless, the modern text of *Kirk's* at least recognizes what

blacksmiths and metallurgists have known for millennia: that increased ventilation, not a change in fuel type, causes increased temperatures.

NFPA 921, beginning with the first edition and continuing until today contains an admonition about placing too much stock in the perceived temperature of a fire. In the 2004 edition of the document, both temperature and speed of the fire are addressed, and investigators are warned to be cautious when interpreting temperature and speed. The following language appears:

> **6.8.2.2** 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.

The speed at which a fire progresses is frequently used to imply that the fire is incendiary. While it is true that an accelerated fire burns faster than an unaccelerated fire, at least in its initial stages, serious caution is required when confronted with information about how rapidly a fire spread. Most observations about the "speed" of a fire are provided by eyewitnesses, but there have been reported instances of an investigator looking at a destroyed structure and, knowing the time from alarm to extinguishment, opining that the amount of destruction could not have occurred in that timeframe unless the fire had "help." These conclusions are usually based on the misconception that the wood has a fixed burning rate, such as the often quoted "1 inch in 45 minutes."

A study by the editors of *Fire Findings*, published in 1995, revealed that witnesses might make very different observations about a fire, even if their sightings are only a few minutes apart.[46] This study, which involved the actual burning of a two-story house, resulted in the findings that fires may only appear to start rapidly and tended to dispel the widely held (but incorrect) belief that if a fire appears to start quickly, accelerants must have been involved. If an eyewitness only notes the existence of a fire at the point where it breaks out a window, the progress thereafter will be rapid indeed, regardless of the cause.

In the fifth edition of *Kirk's Fire Investigation*, DeHaan published a time/temperature curve for a fire in a "typical furnished room" with no accelerants that shows flashover occurring just 210 seconds (3.5 minutes) after ignition. This curve looks nothing at all like the "standard time/temperature curve" from the ASTM test method.[47]

Thus, while it is true that accelerants tend to make fires burn more rapidly, a rapidly burning fire does not necessarily indicate the presence of accelerants.

CONCLUSION

Fire investigation involves the comparison of the investigator's "expectations" with his perception of the behavior of the fire. If those expectations are not properly "calibrated," the result will be numerous errors. In the 17th century, when the scientific community was first getting organized, it was understandable that misconceptions about fire, such as the phlogiston

and caloric theories, should exist. What is surprising is that after three centuries of scientific examination of fire, myths have been added rather than dispelled.

Many of the myths have been taught to the individuals who are now in control of the fire investigation industry. These myths were promulgated by the National Fire Academy and by other entities involved in the training of fire investigators, and given the stamp of approval of one of the most prestigious and credible U.S. government agencies. To date, the misinformation has not been officially repudiated or "recalled." While most responsible training organizations no longer teach the myths, there are still plenty of fire investigators who have not been back to school since it was learned for certain that the "indicators of arson" that they learned were false. Further, the libraries of most fire investigators contain numerous texts that are filled with this misinformation. Even worse, there are still a few popular speakers and agencies training new investigators with the old mythology.

The sheer number of misconceptions, and their widespread publication in learned and not-so-learned treatises indicates that fire investigation, as a profession, still has very far to go.

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Figure Captions

Figure 1. Burned wooden wall exhibiting char blisters (alligatoring) of different size and different levels of gloss, all as a result of exposure to the same fire.

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