

**“PROGRESS” IN FIRE INVESTIGATION:  
MOVING FROM WITCHCRAFT AND FOLKLORE TO THE  
MISUSE OF MODELS AND THE ABUSE OF SCIENCE**

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**John J. Lentini, CFEI, D-ABC  
Scientific Fire Analysis, Big Pine Key, FL**

**Abstract**

This paper will present two old case studies, and two newer ones. The old case studies will reprise the now well-known investigations into virus that resulted in the conviction and capital sentencing of Ernest Ray Willis (1986-2004), and Cameron Todd Willingham (1991-2004). The newer cases are a capital criminal case alleging arson/homicide (2001-2010), and a civil arson case alleging the use of high-temperature accelerant (2001-2006).<sup>a</sup>

**The Old Mythology**

The old mythology was well entrenched, thanks in large part to the publication of the myths in respected textbooks. The following are quotes from the Fire Investigation Handbook (1980), published by the National Bureau of Standards.

Try to establish the lowest point of burning in the room. Look for definite patterns of fire travel upwards and outwards from this lowest point in the shape of a "V" on nearby or adjacent walls. If the fire began in the center of the room or area, there may be no "V" patterns. It will be helpful to look under furnishings, shelving, and window sills for evidence of fire damage as an indicator of low points of burning.

Crazed or irregular pieces with light smoke deposits indicate a rapid buildup of heat.

Floors seldom receive damage similar to that of ceilings, even in the case of total burnout, as the heat of the fire will be concentrated at the ceiling. In addition, as ceiling materials are damaged and fall, these materials protect the floor below. If, on the other hand, a large area of the Floor is extensively damaged, the use of accelerants may be indicated. Keep in mind, however, that plastics used in furniture, mattresses, drapes, and other interior decorations, can give the appearance of a flammable liquid burn and must be considered to avoid improper conclusions.

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-

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<sup>a</sup> The first year is the date of the fire, and the second year is the date of the resolution. Though some may argue that the Willingham case has yet to be resolved, any future resolution will be of no use to Mr. Willingham.

backed, shiny alligatoring. These observations apply, however, to unfinished lumber. Wood which has been painted or finished exhibits different characteristics depending upon the type of finish and thickness of the finish. Sometimes, taking a cross section of the wood exposed to a fire gives a clue as to the type of fire. A distinct line between the 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.

b) Spalling of concrete - indicates an intense, high heat fire. The spalling is caused by rapid boiling of the moisture trapped in the concrete.

c) Fire patterns - a wide angle or diffuse "V" pattern generally indicates a slowly-developing fire. A narrow sharply defined "V" pattern generally indicates a fast-developing, hot fire.

d) Ceiling damage - if the ceiling exhibits uniform damage, a slowly-developing fire is indicated. Extensive ceiling damage in one place indicates a rapidly-developing fire directly below the damaged location. [1]

With the exception of spalling, these were the myths used to convict Ernest Willis and Cameron Todd Willingham.

Ernest Willis was convicted and sentenced to die for setting a 1986 fire in Iraan, Texas. The prosecutor asked the jury to look at the “remorseless killer” sitting before them at his sentencing hearing, without bothering to mention that Mr. Willis had been drugged against his will. He also failed to mention that there was a “no future dangerousness” report from a state psychologist. The trial judge, learning of these abuses, recommended a new trial, but the Texas Court of Criminal Appeals did not agree. After 17 years on death row, a federal appeals court took into account the drugging, the Brady violations, and the fact that Mr. Willis’s lawyer was intoxicated for much of the trial, and granted him a new trial. The new prosecutor, Ori White, had the evidence independently reevaluated, and learned that the alleged multiple origins and alleged pour patterns were based on myths and folklore. He dismissed the case and Ernest Willis was freed.

The following are excerpts from the Willis trial testimony:

From the state’s main expert:

Q: Okay. Well, of all the burn patterns, what is the most significant to you, sir?

A: The most highly significant would be the low burning to the floor level on some of the walls, and the burn patterns that I observed on the floor itself.

Q: Low burning on walls?

A: Yes, sir.

Q: And the floor?

A: The burn patterns that I observed on the floor, yes, sir.

Q: Alright. Now let me make a note of that, sir. Low burning on walls, what does that indicate to you, sir?

A: The heat source that caused the burn pattern was at a low level.

Q: Okay. So that if you have one room that's burned floor to ceiling and another room that's not, what does that indicate to you?

A: Indicates that the heat level in the room that burned from floor to ceiling was at a much lower level in the room.

Q: Which might support the idea that was liquid combustibles there?

A: That's true.

Q: Alright. Now burn patterns on the floor. Burn patterns on the floor you say are another part of the significant burn patterns on which you are relying to base your opinion; is that correct, sir?

A: Yes, sir.

Q: Alright. What are those burn patterns on the floor? What do you think about those? What do they mean to you?

A: In this particular case they indicate to me the use of a flammable liquid.

Q: How much flammable liquid?

A: I have no idea.

From another state expert:

Q: Mr. [expert], why would fire necessarily want to come out of the top of the door? Why wouldn't it come out the bottom?

A: Well, it's based on the theory that fire goes up and seeks the nearest exit. So if it's near a door, it will go up and out the upper portions of the window or door.

Q: Is there instances where fire goes down?

A: There could be, but, generally, the pretty basic rule is it goes up.

Later the same expert said:

A: ... and, on the couch, it unusual that a piece of furniture will be that totally consumed. Usually the fire—a normal fire will burn off the top of the furniture and go down some, but you will have quite a bit left of the bottom frame. ... The significance of this is that on the south end of the couch toward the door, the springs were annealed. And when I say, "annealed," I mean that all of the tension was gone out of them. They were real flat. And that is generally only—that only occurs when you have intense heat on the springs of a couch....

And when I see a couch like that in a fire—you can see how flat the springs are. They have annealed, or lost their temper. That is generally an indication that an accelerant had been placed on there that caused this intense fire. Like I say, furniture generally will not burn like that. Furniture will burn the upper portions of it. And whenever an investigator sees a piece of furniture like this where the springs have been annealed, or distempered, then there is a very strong indication that an accelerant had been put on the couch.

Cameron Todd Willingham was convicted and sentenced to die for setting a fire that killed his three daughters in Corsicana Texas. Mr. Willingham's lawyer believed him to be guilty, and provided no defense. Despite a last-minute report in 2004, alleging for the first time that the fire was not, in fact, incendiary, Cameron Todd Willingham was executed by lethal injection on February 17, 2004. The same type of evidence that was used to convict Mr. Willis was also used to convict Mr. Willingham. A melted aluminum threshold, crazed glass, and irregular burns on the floor "proved" that the fire was set.

Here is just one example of the quality of the scientific evidence used to convict Mr. Willingham:

The pieces of broken window glass on the ledge of the north windows to the northeast bedroom disclosed a crazed 'spider webbing' condition. This condition is an indication that the fire burned fast and hot.

In addition to the bad science used by the fire investigators, the state also employed a psychologist and a psychiatrist in the sentencing phase of the Willingham trial. Neither of these individuals had met Mr. Willingham, but both were willing to opine on his future dangerousness. The psychologist found great significance in Mr. Willingham's placement of Led Zeppelin posters on his wall, and stated,

"And all of these are in fire, depicting—it reminds me of something like Hell. And there's a picture—a Led Zeppelin picture of a falling angel. . . . I see there's an association many times with cultive-type of activities. A focus on death, dying. Many times individuals that have a lot of this type of art have interest in satanic-type activities."<sup>b</sup>

The state's lead expert in Willingham, a Deputy State Fire Marshal now deceased, gave some truly remarkable testimony, which caused one reviewer to characterize his approach as "hardly consistent with a scientific mindset and is more characteristic of mystics or psychics."

"The fire tells the story. I am just the interpreter. I am looking at the fire, and I am interpreting the fire. That is what I know. That is what I do best. And the fire does not lie. It tells me the truth.

Both the Willis case and the Willingham case were evaluated by the Arson Review Committee, affiliated with the Innocence Project, [2] and by an independent fire protection engineer hired by the Texas Forensic Science Commission, Dr. Craig Byler. [3] Both studies, as well as other independent analyses, concluded that both convictions resulted from the use of invalid indicators of arson.

The Texas Forensic Science Commission has apparently decided that these convictions were obtained using flawed science, but because the myths were so widespread, the state investigators were not guilty of negligence or misconduct in their use of the faulty indicators. The Forensic Science Commission has yet to take a position on what responsibility investigators have to bring to the attention of prosecutors evidence that is no longer valid. The state's leading expert in the Willis case stated to a reporter shortly after Mr. Willingham was executed and Mr. Willis was freed, "At the time of the [Willingham] fire, we were still testifying to things that aren't accurate today," Cheever told Mills. "They were true then, but they aren't now." Cheever added, "Hurst was pretty much right on . . . We now know not to make those same assumptions."

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<sup>b</sup> This alleged expert was apparently unfamiliar with Led Zeppelin's song "Stairway to Heaven."

## **The New Mythology: Misuse of Modeling in the Case of Louisiana v Amanda Hypes**

After the turn of the century one would hope to see some progress, and indeed there has been. Many of the myths have been proven invalid to the satisfaction of the majority of the fire investigation community, (with the possible exceptions of irregular patterns on the floor and melted aluminum thresholds). Some of the old myths, however, have been replaced with new ones.

In a 2001 Louisiana fire, initial investigators were intrigued when they saw spalling on the concrete slab floor, and misinterpreted it as evidence of the use of an accelerant. The district attorney in charge of the case sought advice from senior investigators at both the state and federal level and he was told that no matter what the cause of the fire, the fact that the initial investigators pushed the house over to look for spalling after failing to properly document scene meant that the case could not be successfully prosecuted. They suggested that he confirm this with a leading authority on arson investigation.

Much to the surprise of the first set of reviewers, this national authority was able to “rehabilitate” the case, using timelines of dubious quality, assumptions of even more dubious quality, and his own “expectations” of the fire’s ability to spread in the allotted time. The expert’s first report stated, “Based upon the estimated fuel load of the rooms involved, the size of the rooms, and the reported rate of fire development, multiple points of origin or the use of an accelerant are very strongly indicated.” The Defendant was indicted on one count of arson and three counts of capital murder as a result.

Following a reliability challenge, the expert modified his report to remove the reference to the use of accelerants, but still stated that the fire “was the result of deliberate ignition of room contents in separate rooms - kitchen and master bedroom.” The second report relied heavily on hand calculations using fire dynamics equations, as well as more sophisticated computer modeling (CFAST). The defendant continued to be held without bond.

For the CFAST modeling, the state engaged a second expert, who used a “beta” version of the model. An analysis of the model’s output revealed that the temperature rose as one moved away from the fire, a violation of the laws of thermodynamics. The modeler was so focused on making the model “prove” what he wanted, that he failed to adequately scrutinize the output. What with the laws of physics being violated, the CFAST output lost any semblance of credibility. But it was the first expert’s “hand” calculations that showed how flawed the expert’s approach was.

Here is an excerpt from the expert’s report which used fire modeling equations to compare the heat release rate required to cause flashover to occur in a room, versus the “expected” heat release rate of the available fuel packages.

Using the computational tools in Fire Dynamics Tools (U.S. Nuclear Regulatory Commission, 2004), the QFO can be calculated using three different methods (assuming 5/8" drywall).

Master Bedroom QFO:  
McCaffrey: 1.25 MW  
Babrauskas: 3.4 MW  
Thomas: 2.4 MW

Living Room/Kitchen:

29' x 19' x 10' with 3' x 10' + 4' x 10' doors:

QFO = 3.1 MW McCaffrey

QFO = 8.5 MW Babrauskas

QFO = 6.25 MW Thomas

31' x 19' x 10' with two doors (same):

QFO = 3.0 MW McCaffrey

QFO = 8.5 MW Babrauskas

QFO = 5.8 MW Thomas

31' x 19' x 10' with three doors (8'):

QFO = 3.15 MW McCaffrey

QFO = 9.6 MW Babrauskas

QFO = 6.34 MW Thomas

The disparity between calculated values is dependent on different factors in each formula.

The numerical average of all three is the best approximation.

It is one thing to use a fire model inappropriately, for example, using it to attempt to resolve an issue involving close tolerances. Despite the appearance of three or even four significant figures in some equations, fire models are properly used to provide order of magnitude approximations of times, temperatures, species concentrations etc. It is quite something else to make a statement such as, "the numerical average of all three is the best approximation." In this author's opinion, **this sentence is among the most outrageous ever written by a forensic scientist.** These flashover calculations are rough approximations, and the fire investigation profession has clearly stated that they should be used as **bounding** approximations. An appropriate use of the predictions of these three equations would be to state that the **range** of flashover requirements is from 3 to 10 MW. Nowhere in any peer-reviewed scientific literature does any fire protection engineer suggest averaging the three flashover equations. The appropriate use of the equations is not to find one "best approximation," but to define a range of possibilities. The expert's approach in this and other fires is sure to produce plenty of indictments, but it is completely invalid.

This expert also relied on the failure of the passerby to see fire at the residence 10 minutes before a large fire was discovered. He opined on the unlikelihood of a six-year-old boy playing with fire. He opined on the description of events given by the mother who entered the house in an attempt to save her children, and got soot on her clothes, but not sufficient soot to meet the experts "expectation" of how much that she should have received had she been exposed to the fire that this expert "expected." In fact he stated that the mother's description of events was not possible.

More than five years after the fire, after spending four years in jail, the defendant moved for a bail hearing and presented evidence that the fire was not really a set fire, and also that the prosecutor provided grand jury testimony to his experts in violation of state law. The judge granted bond, stating, "the defendant has met her burden of showing both proof is not evident and the presumption is not great that she is guilty." He then dismissed the indictment.

After two appellate courts upheld the dismissal, the prosecutor sought to re-indict, and requested a new report from his expert. Much to his surprise, the third report, issued in late 2008, stated, “Due to the limitations of the evidence and analytical methods, the original conclusion of the undersigned that this fire was ignited in several areas and spread to the extent observed by Mr. Taylor in 10 minutes cannot be defended to a suitable degree of scientific certainty.”

Still seeking his pound of flesh, the prosecutor filed a criminal information charging the defendant this time with three counts of cruelty to juveniles, carrying a maximum of 40 years per count. The defendant finally, some nine years after the fire, agreed to plead guilty to three counts of negligent homicide (for leaving her children home in the charge of her ten-year old daughter), provided that her sentence would not exceed time already served. Thus this travesty of justice was brought to an end.

### **Misuse of Science in the Case of Stark County Port Authority v Railway Properties**

The final case to be discussed involves another review by the same expert, who relied on a photograph of a spectacular plume that developed one hour after the fire was detected, the use of an inaccurate computer model and an “imaginative” interpretation of post-fire chemistry to conclude that at least five separate 50-pound packages of high-temperature accelerant (HTA) had been used to set a large fire.

Several million dollars were at stake in this case involving an insurance claim for a fire that destroyed a large warehouse. Approximately one hour into the fire, there was a very energetic event that resulted in the production of a tall plume of what appeared to be white fire (although it is not clear that the photograph of this plume was properly exposed). In any case, the damage was so extensive that none of the initial fire investigators were able to determine either the origin or the cause of the fire. Enter the national expert.

Based on his review of this **one photograph**, he developed a hypothesis that the energetic event was the delayed ignition of a container of high-temperature accelerant. High-temperature accelerant (HTA) fires are a mysterious phenomenon that first appeared in the period of 1981-1991 in the Pacific Northwest. Nobody was ever able to determine exactly what the accelerant might have been, although there were several hypotheses. Basically, these fires were energetic enough to take down large timber structures containing almost no fuel, and left no identifiable residue behind. HTA was blamed for several fires over the next decade, but no one ever produced credible proof of what the real cause of any of the fires was. HTA became a convenient excuse for people who could not determine the cause of the fire.

As a result of this kind of questionable determination, which most fire investigators viewed as invalid, the National Fire Protection Association's Technical Committee on Fire Investigations inserted a paragraph on high-temperature accelerant's into its document entitled NFPA 921, *Guide For Fire And Explosion Investigations*. The paragraph on "exotic accelerants" first appeared in the 1998 edition of the document. Here is what the general consensus of the fire investigation community was in 1998, and remains today:

#### 17-2.4\* Exotic Accelerants.

Mixtures of fuels and Class 3 or Class 4 oxidizers (see NFPA 430, Code for the Storage of Liquid and Solid Oxidizers) may produce an exceedingly hot fire and may be used to start or accelerate a fire. Thermite mixtures also produce exceedingly hot fires.

Such accelerants generally leave residues that may be visually or chemically identifiable.

Exotic accelerants have been hypothesized as having been used to start or accelerate some rapidly growing fires and were referred to in these particular instances as high temperature accelerants (HTA). Indicators of exotic accelerants include an exceedingly rapid rate of fire growth, brilliant flares (particularly at the start of the fire), and melted steel or concrete. A study of 25 fires suspected of being associated with HTAs during the 1981-1991 period revealed that there was no conclusive scientific proof of the use of such HTA.

In any fire where the rate of fire growth is considered exceedingly rapid, other reasons for this should be considered in addition to the use of an accelerant, exotic or otherwise. These reasons include ventilation, fire suppression tactics, and the type and configuration of the fuels.

A-17-2.4

See Carman, "High Temperature Accelerants, A Study of HTA Fires Reported in the United States and Canada Between January 1981 and August 1991."

Thus, if an investigator is to follow valid methodology, one would expect him to observe **at least one** of the four indicators of exotic accelerants, i.e., an exceedingly rapid rate of fire growth, brilliant flares (particularly at the start of the fire), melted steel or melted concrete. As stated in the standard, there is actually no conclusive scientific proof that HTA was ever used in any fire, so again, one would expect a great deal of caution on the part of any fire investigator examining a fire suspected of being started with HTA.

The following are excerpts of the deposition given by the expert in the *Railway Properties* case

Q: So in your 35 years of experience, this is the one case in which you have given an opinion and want to proffer an opinion to a jury, that an HTA was used, correct?

A: That's correct.

Q: What evidence do you have that there was an exceedingly rapid rate of fire growth here?

A: I don't.

Q: What evidence do you have that there was a brilliant flare at the start of the fire?

A: I have the observations of the firefighters, in this case, of an event, highly energetic event, occurring while they were on site, and we have the photograph.

Q: And that occurred more than an hour after they were on site?

A: That's correct.

Q: So there's no observation at the start of the fire, for a brilliant flare, is there?

A: That's correct.

Q: Any observation of melted steel?

A: There are sections of -- well, there are residues of molten iron found on -- near or in samples from "B" and "D," that indicated extremely high temperature.

Q: I'm talking about melted steel, not melted iron. Any evidence of melted steel?



*Here is the photo.  
Note that there was at  
least one propane  
cylinder stored near  
the base of the plume.*

A: No, not that I can recall.

Q: Any evidence of melted concrete?

A: No.

Q: **So the four indicators of HTA, ... you don't have any of them here, do you?**

A: **That's correct.**

Later in the deposition, the following exchange appears:

Q: My question was, "What do you think somebody brought into this building," and your answer was: "I could do it this way." I don't want to argue with you about semantics. I just want you to try and listen to my question and answer the question that I am asking.

Q: What are you going to tell the jury that you think an arsonist brought into this building, in terms of volume?

A: At least 50 pounds of fuel oxidizer mixture for each location.

Q: For each of these five areas?

A: Yes.

Q: At least 50 pounds?

A: That's right.

Q: In what form would that 50 pounds be?

A: It would be a dry solid.

Q: So it was something that they can bring in, in a bag or a pack or a canvas? You know, what would the mechanism be?

A: It can be anything. It can be a cardboard – cardboard box. It could be a plastic bucket. Anything that will hold 50 pounds or more, of powder.

Q: How do you come to the conclusion that at least 50 pounds of powder was used to ignite each one of these five areas?

A: Because of the tests that I've conducted, I know how much heat I can generate from small and medium sized amounts of similar material, and that's the basis for it.

Q: Is there any guarantee that somebody did not use more?

A: No, there isn't.

Q: Is it your belief that they could not have accomplished this result using less?

A: I'm sorry?

Q: Less than 50 pounds per location?

A: It would be highly unlikely.

Q: So a person, or persons unknown, brought in a minimum of 250 pounds of fuel, correct?

A: Yes.

Q: You have already told me, I believe, that you can't tell me what they used to ignite it; is that correct?

A: That's correct.

Q: Do you have an opinion, or do you intend to offer an opinion, as to whether or not there was some mechanism used to ignite it as opposed to an open flame, or whether they used some mechanical device?

A: No residues of a timing or delayed device would survive this thermal exposure. And so there were no identifiable residues of any such timing device found.

Describing why he thought only one plume was seen late in the fire, rather than five plumes at the outset:

Q: So would it be fair to say that you think four out of five plumes here occurred, and there were flames going up 35 to 40 feet high and nobody saw them. Is that what you believe?

A: I don't know if they had to be 35 feet high, but, yes, there were energetic plumes of some height, capable of reaching at least a portion of the roof structure, which is, I recall, started as low as 14 feet from the floor. But that's correct, no one outside the building saw it.

Q: And again, you think that the ignition happened at earliest, an hour ahead—before it was observed?

A: Yes.

Q: So is it your opinion that the arsonists or arsonist set five charges, and maybe more, and then left the building; and subsequently four plumes ignited, one ignited later. Is that your testimony?

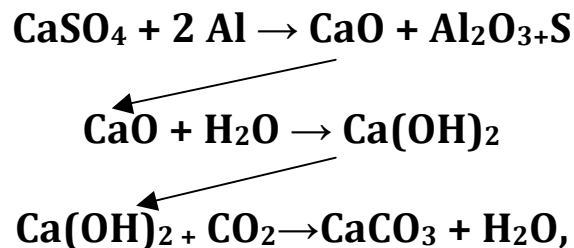
A: That's a likely scenario. However, there's no guarantee that somebody had to be out of the building when the devices function.

Q: Is it your opinion that the arsonists or arsonist could have ignited, say, Area A with the resulting plume, and then gone around and ignited the other locations?

A: Yes.

The photograph of the plume that occurred approximately one hour into the fire was not the only evidence upon which the expert relied, though his reliance on the chemical analysis was certainly misplaced. The chemical analysis found large quantities of calcium carbonate and small quantities of aluminum oxide. From this it was hypothesized that the HTA mixture was calcium sulfate (plaster of Paris) and metallic aluminum powder. No metallic aluminum was found, despite a diligent search. Some calcium sulfate was identified, but this is a component of wallboard, concrete and cinderblocks.

In consultation with a chemist, it was hypothesized that the following series of chemical reactions took place:



resulting in the presence of the calcium carbonate. While this complicated reaction is certainly possible, there was no evidence to support it, particularly when one considers that calcium carbonate constitutes approximately 25% of wood ash. A more appropriate interpretation of the finding of calcium carbonate would be the following chemical reaction:



A complete discussion of the relative merits of these two competing hypotheses explaining the presence of calcium carbonate was prepared by the author in the *Railway Properties* litigation. [4]

Elemental analysis of wood ash is not a common fire investigative procedure, but if one plans to rely on it to prove that a fire is somehow not "normal," one should at least conduct a literature search to find out what is actually "normal." Failing to do the literature search, and being presented with test results that were capable of being interpreted to the advantage of either side, the expert in this case chose to rely upon **only that interpretation favoring the side by which he was employed.**

The kind of interpretation put forward by the expert in the *Railway Properties* case is typical of fire investigations that reach incorrect conclusions: data that is commonplace is presented as evidence that something uncommon happened.

Modeling also played a role in the *Railway Transfer* case, though HTA fires are not exactly what the authors of the models had in mind, particularly not fires involving five separate 50-pound charges of exotic accelerant. In order to make the FDS model output match the desired result, the modelers were required to add several vents during the fire—vents which did not actually exist. Further, the modelers failed to include any of the combustible contents in their model. They did not adequately address the possibility that the fire had only one point of origin. So, they achieved the desired result of "proving" that the fire needed five points of origin in order to do the amount of damage that was observed.

When the defendant (insured) expert modeled the fire with no extraneous vents, and with appropriate contents, the model output was consistent with a single point of origin. [5]

This case was tried before an Ohio Common Pleas Court jury in February 2006. The jury returned a verdict in favor of the defendant. To date, there is no record of a jury anywhere finding that a fire was set using HTA.

## CONCLUSION

While the fire investigation profession can take a measure of pride in the way it has progressed over the last 25 years, we must continue to be vigilant, lest new “myths” creep in to our practice. Particularly with the use of models, it is important to make sure that they are being properly applied, and the output properly interpreted.

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