On a rainy spring morning in eastern Kentucky, Greg Gorbett prepares to commit arson. His target is a tidy but cheerless one-bedroom apartment with the kind of mauve-colored carpet, couches, tables, and lamps you would find in a cheap motel. Gorbett is not the only one eager to see the place burn. A handful of other fire scientists and grad students from Eastern Kentucky University (EKU) are checking equipment in the test room as well. They have gathered at the EKU fire lab, a concrete structure in an open meadow as close to nowhere as possible, to document in exacting detail the life cycle of a blaze.

Gorbett scans the setup one last time. A foil-covered wire studded with metal probes—a thermocouple array—crosses the ceiling and hangs down the center of the space; it will measure the temperature at one-foot intervals every two seconds. A radiometer shaped like a soup can will detect changes in radiant energy. Bundles of yellow wires will carry the data to a computer-equipped truck sitting out back. There is also a man lying on the floor: James Pharr, a former fire investigator from Charlotte, North Carolina, wearing a fire-resistant suit and oxygen mask, who will record the event with a thermal-imaging camera.

Gorbett lights a pan of flamable heptane under an end table and then quickly exits the room. The fire begins as a glowing ball and then reaches up and curls around the tabletop like a claw. Quickly it moves to the adjacent couch, which bursts into flames. Modern cushions are made of polyurethane foam, and despite their fire-resistant-covering (introduced in the 1970s to protect against smoldering cigarettes), they are basically solidified petroleum. A
modern couch can release the heat equivalent of a 3 million bulb.

The fire doesn’t burn the couch so much as melt it, like a marshmallow over a campfire. The fire, although no other source of heat, “Gorbett explains. The room is obscured from the only possible cause. Liquid accelerant poured on the concrete surface and lit. REALITY: Patterns can result from a number of factors, including ventilation, air currents, location of fuel, and the moisture-bearing objects and furniture. These patterns are not caused by an accelerant.

7. Sharply angled blisters seen on a wall indicate a fast burning fire that must have been started with a liquid accelerant. REALITY: Patterns can result from a number of factors, including ventilation, air currents, location of fuel, and the moisture-bearing objects and furniture. These patterns are not caused by an accelerant.

A typical fingerprint sequence: A fire starts on a sofa; the fire penetrates a hot gas layer, the hot gas layer combusts; and finally, everything ignites floor to ceiling (flashover), enveloping the room in a blaze.
After Cameron Todd Willingham was executed, the Innocence Project concluded that none of the evidence for arson in the case was scientifically valid.

The following year Lentini had another conversion experience in a fire that almost certainly was accidental as the Oakland Black Hole. A brush fire swept into that California city, killing more than two dozen people and destroying more than 300 homes. Willingham and his wife had burned materials in its natural habitat, Lentini and a crew of investigators moved in, examining 50 houses for postfire damage. They knew the fire had been accidental, yet they found classic signs of arson: large, shiny blisters on wood resembling alligator skin, chipping concrete, and melted metal doorway thresholds, all typically attributed to accelerator and accelerator runoff. Witnesses had reported flames exciting out the windows—the main indicator of a flashover fire. Scientists and some field investigators, such as Lentini, knew that flashover fires could char wood at the floor level, melt metal, and create burn patterns that might suggest poured flammable liquid. Yet that information had not reached or convinced the state’s deputy fire marshal, Manuel Vasquez (who died in 1994). In 1992 Willingham was found guilty of murder and sentenced to death.

Willingham lost one appeal after another. Finally, in 2004, just weeks before Willingham’s scheduled execution, Gerald Hurst wrote a report debunking the findings that had contributed to Willingham’s conviction. Hurst wrote that the blaze was almost certainly accidental, perhaps caused by a faulty space heater. Hurst concluded that there was no evidence of arson or that the fire had been set.

But even that would be difficult to prove, because the house had been shrouded out by investigators. “The cause of the fire should have been obvious,” Hurst said, “but even that was not the case.” The Texas Board of Pardons and Paroles disagreed and denied the petition. After Willingham was executed, the Innocence Project, a nonprofit legal organization focused on overturning wrongful convictions, assembled a team of leading arson investigators, who concluded that none of the evidence for arson in the case was scientifically valid. The project’s lawyers later filed an allegation with the newly formed Texas Forensic Science Commission alleging professional misconduct by the fire marshal’s office. The case was such an outrageous example of junk science and video evidence that the fundraiser after the execution. After that, results from exposure to intense heat. “We’re not just in the business of patterns, we’re measuring them,” Gorbets said.

At NIST, engineer Dan Madrzykowski employs a similarly painstaking methodology. In 2010 he turned a classic V-shaped burn pattern on a wall behind a chair. According to conventional wisdom, the markings indicated the chair as the source of the fire. By then the NIST team knew better, but they were still stumped. The chair had not been placed there, so even if the burn pattern showed several times and changing the location of the chair and the door. Eventually they noticed that the V-shaped burn patterns should always appear on the wall opposite the open doorway.

It was then that Madrzykowski and his colleagues had uncovered a new phenomenon in fire behavior. As the fire is burning and smoke rises, fire and air rushes in through the bottom of the open doorway. It then races across the floor and mixes with unburned gases. As it mixes, the fire is hotter and creates a classic V-pattern appears in a location that had neither fuel nor ventilation. This phenomenon has never been described in detail before. But Madrzykowski and his colleagues, along with the Chicago Fire Department and
The human body has proved another valuable source of evidence. Richard Roby and colleagues have used toxicology reports from the bodies of fire victims to help determine where a fire originated, what stage it reached, and how long it burned. Not all fire-related deaths are the same. Victims who collapse away from a fire generally die from carbon monoxide, which, pumped out in great volume by flashover fires, can kill in just a few breaths. But victims who die close to the fire perish either from edema (heat-caused swelling of the airways) or heat exposure, in which the organs shut down “like a system going into emergency,” Roby says.

Roby has been creating computer models of his findings in the hope they will one day make their way into the courtroom. One case that could benefit involves a woman who died in a trailer fire last year in West Virginia. Neighbors thought they saw her boyfriend, who had recently been released from prison, set a gasline fire in an outside corner of the trailer. But Roby has another theory. While the autopsy showed low levels of carbon monoxide in the woman’s blood, it also revealed extensive thermal injuries in her air passages and lungs. This meant that she must have been close to the fire source. Since the woman was a smoker, Roby speculates that a smoldering cigarette may have set her bed on fire and caused the damage documented in the autopsy report.

Assembling such elements can help investigators understand where a fire began and how it progressed, but even with current technology determining what started a fire—and whether liquid accelerant was used—remains challenging. One common theory is that accelerants, which we live in a petroleum-rich environment, fuel building materials, carpet, athletic shoes, and toothbrushes all contain petrochemicals. But to record their molecular signatures and upload the results to an online database, investigators who log on can compare chromatograms produced in their labs from fire scene samples with those in a reference collection of flammable liquids. If they find a match, or a near match, Sigman can send them a sample so they can analyze both liquids on their own lab equipment. This provides strong forensic evidence that can form the basis of expert testimony in court. “It’s preferable to saying, ‘This is how it smells,’” says Sigman.

Despite the surge in fire science, pseudoscience remains entrenched in arson investigation. Most states have no legal requirement for a person to become a fire investigator, although they prefer him or her to take in-person or online training courses and pass rudimentary tests. In some states, including Indiana, a private investigator’s license is enough to give you legal authority to investigate a fire and testify about its origins. In other words, some people who make his living spying on his clients’ spouses in hotel rooms can become an expert in fire investigation after an optional training period of just a couple of weeks. “It’s still the Wild West out there,” says Justin McSaine, a Harrisburg, Pennsylvania, attorney who has defended many arson cases. “You’ve still got people talking about crossed glass or using the most damaging as an invented technique that only hope that in ten to twenty years we get trained scientists doing these investigations.”

A few states are pushing for better fire science. In Indiana, anyone who wants to become a fire investigator for the state fire marshal’s office must earn a two-year associate’s degree in fire science or a related field, take an intensive training course, and continue supervised on-the-job training sessions for at least a year. Yet the problem is not limited to investigators. Despite legal precedents that courts should prohibit polyurethane as a defense, many judges remain unconvinced. One scientifically trained investigator, who asked not to be identified, testified last winter at the appeal hearing of a man who had been convicted of murder and arson based on a polyurethane-related defense confirmedatory laboratory results. Preparing for the case, the investigator replicated the man’s using the same kind of rug and horsehair carpet pad. He then reproduced the same pattern in his tests without using a flammable liquid. The judge denied the convict’s appeal anyway. “I don’t want to see arsonists go free,” said the investigator, “but I certainly don’t want to see innocent people going to jail.”

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In Indiana, someone who earns a living spying on cheating spouses can be certified to testify in arson cases after a couple of weeks.