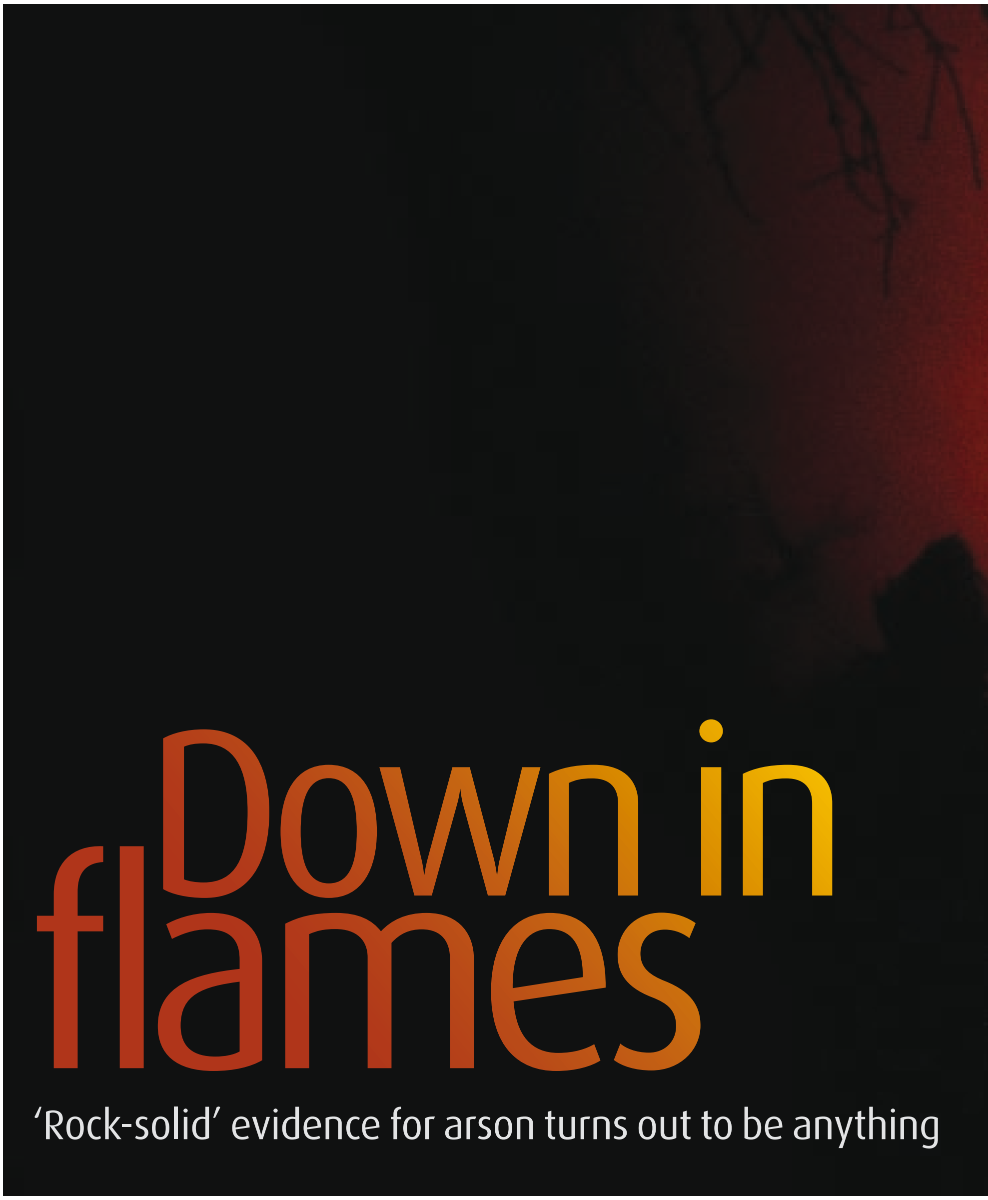


Down in flames

'Rock-solid' evidence for arson turns out to be anything

BRIAN GROVE wants to see his work go up in smoke. Inside a testing space the size of a warehouse at the Fire Research Laboratory in Beltsville, Maryland, he is looking at a full-scale recreation of a child's bedroom and the adjacent hallway. The room is furnished with a dresser and a wooden trundle bed. A SpongeBob SquarePants laundry bag hangs on the back of the door. On cue, a technician lights the bag and the blaze begins.

This set-up is a replica of a bedroom ravaged by fire in a suburban, Pennsylvanian home in February 2004. The blaze took the lives of Samantha Hirt's two children, Sarah, 3, and Matthew, 2, who died from carbon monoxide poisoning within minutes. The way this test fire develops will be critical to learning whether the original fire started accidentally, as Hirt claims, or was deliberately set in a malicious act that could earn her the death penalty.

As the test structure burns, Grove, lab chief Rick Tontarski and the rest of the engineering team keep at a safe distance of 10 metres or so. They don protective masks and watch the progress on video monitors, including infrared footage that penetrates the dark smoke in the bedroom to show the fire's exact position.

The lab is the largest and most advanced fire-testing facility in the world, and the first dedicated to arson investigations and re-enactments. Full-scale simulations like Grove's represent a new, systematic approach – one that relies on scientific evidence rather than assumptions and requires a higher standard of proof. Studies and tests like this have revealed, surprisingly, that most of what used to pass as evidence of arson is nothing of the sort, and that conventional wisdom is often plain wrong.

It is a long-standing problem. There are approximately 500,000 structural fires in the US each year, with 10 to 15 per cent deemed suspicious. "That's 70,000 chances to screw up," says John Lentini, a former crime-lab analyst who manages fire investigations for Applied Technical Services in Marietta, Georgia. More than 5000 people are currently in prison in the US for arson, and only recently have defendants had any hope of seeing their stories tested by rigorous experiments (see "A tale of two fires", page 45).

Fire investigation has always been more art than science. In the US, especially, it has been based largely on observations handed down through generations of firefighters and investigators. The hallmarks of arson have been thought to include extreme heat, complex patterns of cracks in windows and irregular burn marks on walls and floors, the latter suggesting the use of accelerants like gasoline or multiple points of origin. Yet until a couple of decades ago, there had been no studies of accidental fires, so there was nothing with which to compare suspected arson fires. Instead, proving arson fell to the experience of long-serving fire investigators. They routinely told juries that fires were too hot, too big or too fast-moving to be accidental.

"Arson murder is the only crime that can land you on death row based on the testimony of an expert witness who may not have attended college," says Lentini. For years, no one seemed to question the assumptions. Everyone accepted that fires that had been started intentionally with accelerants burned hotter than accidental fires, and that the depth of charring in wood revealed how fast a fire had burned, among other things. Never mind that there was no scientific research to support any of these beliefs.

All this began to change in the mid-1970s when a handful of fire experts started to look at the science. "We quickly realised that some of the things that were said in the books, and were being taught and used by investigators, didn't hold up," says John DeHaan, author of *Kirk's Fire Investigation*, a widely used text. "Fire scientists knew a lot about fires, fire engineers knew a lot about preventing them, fire investigators knew a lot about the aftermath, but the three groups never really talked to each other."

By the early 1990s, experts like Lentini and DeHaan were regularly debunking old myths through experiment. In October 1991 a massive brush fire in Oakland, California, killed 25 people and destroyed more than 3000 homes. The burnt-out buildings

JOHN KELLY/GETTY

presented Lentini and his colleagues with numerous accidental fire scenes. They studied the remains of 50 houses and could find no scientific basis for several traditional indicators of arson.

Take a phenomenon called crazed glass – windows marked with a distinctive web of tiny, tightly spaced, random cracks. The effect was thought to result from the intense, rapid heating of an accelerated fire. However, Lentini's team discovered it in 12 of the 50 Oakland homes. It appeared most often on the fire's periphery, suggesting that it resulted from contact with water from firefighters' hoses rather than rapid heating.

Lentini then performed lab tests, subjecting glass to slow and rapid heating sources, including an 800 °C propane flame. He found that spraying cool water on glass that had been heated to over 500 °C reliably produced crazing, while rapid heating never did. It turns out the effect results from thermal shock: as the glass cools it contracts too rapidly to adjust smoothly. Lentini published his results in 1992, but even today some diehard investigators remain reluctant to accept it. "I still run into cases where they used crazed glass as an arson indicator," says chemist and fire consultant Gerald Hurst of Austin, Texas.

Meanwhile, understanding a phenomenon called "flashover" has also shed light on the true behaviour of fires (see Figure, page 44). Flashover occurs when a fire becomes so intense – approximately 600 °C – that all the flammable materials that are present ignite simultaneously. Hot, deadly smoke billows, windows are blown out and flames gush from windows and doors. Flashover requires sufficient ventilation, but it can happen terrifyingly fast. A single burning armchair can bring a room to flashover point in less than five minutes. It also irrevocably alters the evidence a fire leaves in its wake, making it hard to tell arson from accident.

In 1991, Lentini was asked to test the

"We quickly realised that some things being taught and used by fire investigators didn't hold up"

Fire investigators' findings can make the difference between life and death for someone accused of arson

story of Gerald Wayne Lewis, who was about to stand trial accused of setting a fire that killed his pregnant wife and four children in Jacksonville, Florida. Lentini got permission to burn a similarly constructed, condemned house next door to Lewis's. The experiment became known as the Lime Street fire. After recreating the Lewis home's furnishings, Lentini and DeHaan started a fire on the living room couch, without using accelerants. They predicted it would take 15 to 20 minutes to reach flashover. It took just 4 minutes.

After extinguishing the blaze, the investigators found streaks on the floor similar to those found in Lewis's house that were being cited as evidence of arson. Known as "pour patterns", these irregularly shaped marks were thought to be caused by someone pouring an accelerant on the floor and lighting it. The assumption, which has since been proven false, was that a fire would burn hotter at the points where the liquid was.

What's more, separate floor marks were believed to show multiple points of origin and provide further "evidence" that a fire had been deliberately set – though it turns out they can result from melted furniture, for instance, after flashover. The only sure way to detect an accelerant in debris is if enough is still present to be properly identified in a chromatographic lab analysis.

Webs of cracks on glass were often used as evidence for rapid heating from a deliberately started fire

The Lime Street experiment proved that any fire that reached flashover could produce marks indistinguishable from those left by arson. Lentini calls it his biggest epiphany. As he puts it, "None of the old crap stands up." Some in the fire investigation community, however, were disgusted when Lewis was acquitted. "Like any scientific revolution, there is always a period of combat before the new paradigm takes over," says Hurst.

Fire testing continued and experiments have since confirmed that neither the temperature of a fire, nor the speed at which it spreads, is a valid indicator of arson. Prior to the opening of the Fire Research Laboratory in 2003, however, law enforcement authorities had nowhere to conduct large-scale experiments. In addition to cameras and other sensors, the lab's "burn rooms" also boast five stainless-steel calorimetry hoods that can measure a fire's heat output.

Which brings us back to the Hirt case from Pennsylvania. For his re-enactment, Grove needed to find furniture very similar to what was in Sarah's bedroom. What's more, it was crucial to use an identical SpongeBob laundry bag. Because the bag was more badly burned than the furniture across the room, investigators suspected it was where the fire originated. Grove found it had been discontinued, but tracked one down on eBay. He also acquired a small piece of the original carpet, which the team placed under the bedroom door for the test.

The original fire completely consumed the bedroom door and its wooden frame. All that remained was the doorknob lying on the floor. Yet no window or door had been open, so Grove would have expected the fire to die out quickly as thermal expansion of the gases in the room reduced the oxygen supply. He had to establish that it could have taken hold in that unventilated bedroom, as investigators theorised, then continued for long enough to cause all the damage found.

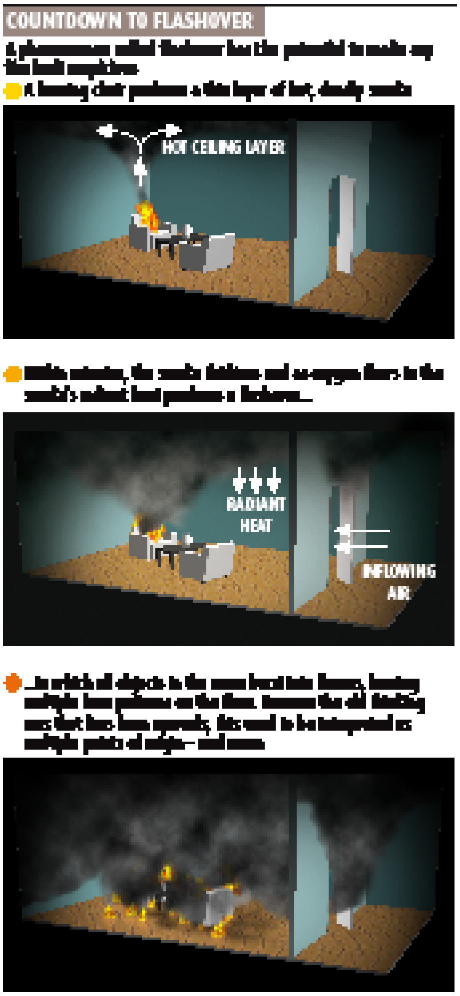
What he discovered was surprising and definitive. From the bag hanging on the inside, the flames passed underneath the threshold of the door by way of molten material falling to the floor. It then started burning on the hallway side, quickly boring a hole and consuming the door from the outside in. The damage was such an uncannily precise replication of what happened in the Hirt home, right down to the doorknob left on the

Virtual flames

Many fire engineers use computer models to investigate blazes. The results are not exact, but can provide useful estimates. "Zone models", for example, can help building designers assess fire hazards. They simplify the air inside a room into two uniform layers of gases: an upper layer of hot smoke and a lower layer of cold fresh air. Software calculates the changing distribution of heat, fire and gases over time. Enter the geometry of the room and the position of vents and the program will predict the overall movement of toxic smoke or the amount of time before the room will be engulfed in flames.

More complex programs use computational fluid dynamics and break the space into hundreds of thousands of cubes. "You apply basic laws of transfer of heat, energy, momentum and mass through each wall of the cube," says John DeHaan, author of *Kirk's Fire Investigation*. The models give a more detailed look at the way heat and smoke move through space, which helps predict survivability.

One program, the Fire Dynamics Simulator developed at the US National Institute of Standards and Technology, calculates temperatures and visibility and shows smoke and air movement caused by ventilation systems, wind or flames. A graphic interface displays the results as cartoon-like visuals. DeHaan sees these models as useful tools, but stresses the importance of conducting real-world experiments.



GEORGE HALL/CORBIS

American arson

In the US last year, arson destroyed an estimated 31,500 structures (excluding vehicles), causing 350 civilian deaths and $664 million in damage to property.

A tale of two fires

Fire science has come to the fore in the US in two cases championed by the legal group The Innocence Project. The cases involve two Texans, Cameron Willingham and Ernest Willis. Each was accused of arson murder – Willis for the deaths of two female acquaintances who died in a house fire in 1986, and Willingham for allegedly killing his three children, all under 3 years of age, in a fire at his home in 1991. Both men claimed to have woken to find the houses ablaze. Both were convicted and sentenced to death on the basis of expert testimony that the fires were started intentionally.

At Willingham's trial, investigators told jurors of 20 arson indicators in the debris, and claimed Willingham had used accelerants to start three separate fires in the home. In 2004, however, a month before Willingham's scheduled execution, the defence asked independent fire consultant Gerald Hurst to review the case. Hurst's report disputed every bit of trial testimony and dismissed as invalid all the arson indicators cited by the investigators. The list included crazed glass and burn patterns on the floor. All have been found in accidental fires, and experiments have reproduced them. In short, Hurst found no evidence of anything but an accident. His appeals to the court fell on deaf ears, however, and Willingham was put to death.

By contrast, Willis was lucky. In 1996, new lawyers secured a hearing to determine whether he deserved a second trial. A judge ruled in 2004 that Willis either be released or retried. A new district attorney asked Hurst to review the case. Again, he found no evidence of arson. Only months after Willingham's execution, Willis was exonerated and set free after 17 years on death row.

In January 2005, a panel of fire-science experts looked into these cases. Its report echoes Hurst's conclusions: arson testimony used against each man was based on obsolete assumptions. It calls for the criminal justice system to require those who testify in arson cases to have backgrounds in fire science. In May this year the report was sent to the Texas Forensic Science Commission. There has been no response yet, but if Texas is shown to have wrongfully executed Willingham, the state's lawyers will be the ones putting out fires.

Cigarettes don't kill

Despite what you see in action movies, dropping a lit cigarette onto a trail of gasoline won't ignite it, assuming normal oxygen levels and no unusual circumstances.

That's because the gasoline has limited contact with the hottest, glowing part of the ash, and X-ray thermography has shown that this is very localised. According to UK forensic scientist Robin Holleyhead, the outer ash layer is much cooler and prevents much heat from reaching the gasoline.

US fire experts say their lab tests have confirmed these findings. More recently, investigator John Malooley has conducted hundreds of similar tests with cigarettes and gasoline. Again, no ignition. So criminals tempted to say, "The cigarette did it" had better find a new excuse.

A warning, however: cigarettes can ignite gases such as hydrogen and acetylene.

Weekly UK arson toll

2 people killed

53 injured

20 schools damaged or destroyed

1402 cars damaged or destroyed

floor, that Grove was shocked. "It's the most consistent test I've ever conducted," he says.

Grove also explored whether Hirt could have started the fire accidentally. During interrogation, she offered the possibility that she had lit a cigarette while leaving the bedroom. Could a glancing contact between a butane lighter and the laundry bag have started the blaze? Using Hirt's lighter, Grove tested how long the flame had to be in touch with SpongeBob's pillowy head and the mesh of the bag itself to ignite either. A fleeting brush past was not enough, nor was a slower sweep. "The mesh bag lit rather easily," he says, "but it wouldn't self-sustain. It dripped, then went out." Ultimately, it took 4 seconds of direct contact between the lighter flame and the stuffed head to start a sustained fire.

These damning results gave the prosecution powerful ammunition to convince Hirt that they could convict her. She pleaded guilty but mentally ill on two counts of third-degree murder, thereby avoiding a trial. She is expected to serve between 12 and 30 years in a state prison.

With arson the resolution is rarely happy, of course, but at least now fire investigators' conclusions are more likely to be supported by science. "It's not enough for someone to say that they've been doing it for 30 years and you have to take their word for it," says DeHaan. "The catchphrase now should be, 'Show me the data.'" ●

Sue Russell is a writer based in southern California