The night of November 28, 1942 was chilly in Boston, but that didn’t stop about 1,000 partygoers from jamming into the Cocoanut Grove nightclub on Shawmut Street, many of them celebrating the Holy Cross College football team’s victory. By 10 p.m., there were more than 1,000 people in the first-floor Broadway Lounge and basement-level Melody Lounge—about 400 more than the building could legally hold. Less than an hour later, 492 of them would be dead and 166 injured in a fire that started in the Melody Lounge, ostensibly after a busboy lit a match as he tried to replace a light bulb in an artificial palm tree.
Fifty-seven years later this fire still elicits passionate discussions about its cause and the speed at which it spread. The official cause of the fire is still listed as "undetermined," although many theories, from alcohol-laden air to residual insecticide vapor, have been proposed to explain both its ignition scenario and the devastation it caused. However, none of these hypotheses have the evidence to support them.

So what did start the notorious Cocoanut Grove fire? And how can any hypothesis be proven?

**The search begins**
The investigation into the cause and origin of the Cocoanut Grove fire began in 1996, when NFPA Fire Modeling Specialist Doug Beller began looking for a case study to demonstrate how fire models can be used to develop and verify performance-based fire protection designs. He knew a real fire would be easier for NFPA technical committees and authorities having jurisdiction to relate to than a fire he concocted and would give people an opportunity to compare thoughts. Beller also knew he'd have to use fewer assumptions when constructing the model, given the relatively large amount of information already known about the fire. And he knew that using the Cocoanut Grove fire as a case study would give people an opportunity to determine how effective some of the many code provisions adopted as a result of the fire would've been had they been in effect in 1942.

Having made the decision to use Cocoanut Grove as the subject of the case study, Beller began gathering data. Typically, the data is divided into three categories: geometric, physical, and miscellaneous.

Miscellaneous data consists of ambient conditions that existed before the fire began, such as air pressure and the specific heat of the air, and any other data that pertains to controlling the program. For example, one needs to determine how effective some of the many code provisions adopted as a result of the fire would've been had they been in effect in 1942.

Geometric data consists of the dimensions of the room of fire origin and the dimensions and locations of other rooms in the building. Locations and dimensions of vents, such as doors, windows, and ventilation outlets are also provided, as are the locations of the object that burned first and any other flammable items of interest.

In the case of Cocoanut Grove, the length of the foyer in which the fire traveled is a critical piece of geometric data. However, the foyer had a rounded ceiling, and fire models can't be used to simulate anything but rectilinear, or box-shaped, rooms with flat ceilings. To get around this obstacle, Beller converted the nightclub's rounded ceiling into an equivalent flat ceiling using some assumptions. Assumptions can sometimes prove burdensome because they must be subjected to a sensitivity analysis to determine their effect on the potential operation of the system. Fortunately, there's enough information available today to reconstruct the Cocoanut Grove nightclub accurately, at least in the computer. Beller held the foyer's length constant while he adjusted the room's height and width to provide the same cross-sectional area. The other rooms in the nightclub needed no adjustment.

The final category of data, physical, is usually the most troublesome, partly because it can be difficult to obtain. This type of data include the material properties of both the fuels that feed the fire and the building materials involved. How much heat energy does the burning fuel release, for example? How much smoke and other combustion products does it generate? When do additional fuels ignite? Since we know the construction and finish materials used in the Cocoanut Grove nightclub, representative material properties are readily available. But we don't know what fuel caused the devastation.

Beller didn't know one other important factor: where the fire actually started. In most historic fires, ignition location is known, as is the material that initially burned and its location in relation to other burnable items. The report that the fire was started in the Melody Lounge by a busboy with a match could never be substantiated, and it was just one of many hypotheses of varying degrees of plausibility that were proposed to explain the tragedy.

**The search for a culprit**
Because the bulk of computer fire model analysis depends on the burning characteristics of the fuel, it's important to identify it accurately. To do this, the researcher must first determine which fuels are plausible, and to do that, he or she must match evidence and eyewitness accounts with what's known about the burning behavior of the fuel.

Beller eliminated some of the hypothetical fuels because they didn't result in products of combustion that would cause the type of trauma seen in victims of the Cocoanut Grove fire. He considered only the three most plausible hypotheses: pyroxylin, refrigerant gases, and methyl chloride.

Pyroxylin, also known as cellulose nitrate, was used in the manufacturing of artificial leather present in Cocoanut Grove as wall lining material. Cellulose nitrate is also the basis for motion picture film, and one theory about the fire says that "a number of reels of cellulose

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Cellulose nitrate is flammable, and a sufficient quantity could explain the fire's behavior.

However, there doesn't appear to have been such a quantity. Furthermore, the fire was seen in the branches of the artificial palm tree near the ceiling at almost the same time it was seen traveling along the wall near the floor. If cellulose nitrate had been responsible for the rapid fire spread, it would've been near the floor and near the ceiling. Given the fact that it was present either as a wall covering or as reels of motion picture film, it doesn't seem likely that it was near the ceiling. Therefore, something else was to blame.

Having eliminated cellulose nitrate as a possible fuel, Beller's attention turned to the refrigerant gas hypothesis. According to Robert Moulton's 1962 account of the fire, air-cooling units in the Melody Lounge were served by a refrigerating unit behind the false wall, and after the fire, some of its tubing was found broken or melted. As Moulton notes, however, "none of the commonly used refrigerant gases are flammable, so this would seem to rule out any refrigerant gas as being in any way responsible for the initial flash."

Moulton also notes that, although some refrigerant gases used at the time were toxic, there wasn't any reason to assume that the refrigerating unit's tubing melted or broke to release the gas during the first minutes of the fire. "It thus appears," he said, "that refrigerant gas may be dismissed as a factor in the early stages of the fire when most fatalities occurred."

Or so it appeared in 1962. In 1993, however, David Arnold published an article in The Boston Globe that seemed to shed doubt on this conclusion. According to Arnold, "Methyl chloride is a flammable gas that was commonly used as a refrigerant during the war years. It replaced freon, almost all of which was allocated to the military. He goes on to say that, "it was common knowledge...that the Cocoanut Grove was cooling beer, food—and people in the summer—with methyl chloride in a system with a capacity of 10 to 15 tons." Apparently, "...investigators at the time thought the Cocoanut Grove was using freon or an older cooling chemical, sulfur dioxide." They didn't know about the methyl chloride, so it wasn't mentioned in their 1943 published report. No one noticed the omission because those who'd serviced the Cocoanut Grove cooling system never saw the report. They'd all gone to war.

Given that methyl chloride appears to have been on the premises at the time of the fire, Beller investigated its burning characteristics. When he asked Dr. Ed Clougherty, the Boston Fire Department's chemist, whether methyl chloride could've been at fault, Dr. Clougherty replied that, since methyl chloride gas is heavier than air, it couldn't explain the flames near the ceiling of the Melody Lounge.

At this point, the trail appeared to hit a dead end. Researchers considered all the plausible hypotheses, and none seemed to explain the spread of the fire or the resulting evidence. However, this didn't mean that a fire model of the Cocoanut Grove fire couldn't be developed.
Configuring the fire to produce the desired results

While it would've been nice to identify a specific material to explain the rapid fire spread, finding the ignition fuel isn't absolutely necessary when modeling a fire and its effects. One of the attributes of fire models is that they can be configured to provide a desired result. This is especially important for reconstructing fires because the model can be forced to predict an observed condition at a specific point in time.

For example, smoke started leaving the room of origin five minutes after the fire started, a fact that was used in the fire's reconstruction. Since there were so many eyewitness accounts, it was easy to input fuel properties that would allow the model to “predict” what the witnesses actually saw.

This “force to fit” capability is useful in answering “What if…?” questions posed by those developing structures using performance-based designs. For example, what conditions might have resulted if the fuel at Cocoanut Grove had burned less rapidly? To answer this question, a slower burning rate is used, with different effects predicted. Less smoke would've been generated in the same amount of time, therefore conditions would've remained tenable longer, giving more people time to escape.

To do this, Beller established a base case that depicted the fire as it actually occurred, with a burning rate of 100 percent. He then ran three more cases with burning rates of 50, 10, and 5 percent of the base case value. As expected, the three additional cases depict what conditions might result from less “severe” fuels.

Assuming materials are available that correspond to these burn rate values, a designer can specify material that best achieves the objectives of the proposed performance-based design.

After material burning rates were run, the modeling continued by establishing when smoke detectors and sprinklers would’ve activated, had they been present. The final step involved predicting evacuation time of Cocoanut Grove patrons. This last step involved putting anything more than a relative measure of how long people would need to evacuate safely.

The end of the story…?

At this point, Beller had a fairly realistic fire model of Cocoanut Grove in terms of time and fire spread, that could demonstrate performance-based design concepts when using limited zone models.

Given these limitations, sophisticated computational fluid dynamics (CFD) models could be applied to the Cocoanut Grove model. Beller asked Doug Carpenter of Combustion Science and Engineering to construct a CFD model of the Cocoanut Grove fire.

Carpenter felt an investigation using NFPA 921, Fire and Explosion Investigations, was more appropriate. Beller's staff, including Jennifer Sapochetti, looked into questions Carpenter raised, such as “What fuel when burned in a fire could explain the evidence?”

Investigations: then and now

In 1942, fire investigators relied on instinct and experience, not science, to base their conclusions about the cause and origin of a fire. There are, and may always be, missing links of information necessary to determine what really happened on that cold November night. While this project wasn't intended to determine the cause and origin of the Cocoanut Grove fire, could 57 years of scientific advances shed light on some unanswered questions?

NFPA 921 suggests that basic fire investigation should rely on a systematic approach, like that used in physical sciences, giving attention to all relevant details. A principle of inquiry, the scientific method forms the basis for legitimate scientific and engineering processes, including fire incident investigation. The use of a systematic approach often uncovers new factual data for analysis, which may require reevaluation of previous conclusions.

There are six steps to the scientific method. First, identify the problem or need for investigation. In this case, no official cause has been determined even after all these years. Next, define and investigate the problem. Many articles, books, personal accounts, artifacts, and photographs are available on the Cocoanut Grove fire, though investigators had to rely on the work and word of others due to the passage of time.

With the background in place, the third step is collecting data.
Medical advances in burn treatments

Some of society’s most notable advances were conceived in times of tragedy, hardship, and strife. The Cocoanut Grove fire remains one of the United States’ most tragic domestic conflagrations. Approximately 492 lives were lost, however, the death toll might have been much higher if it weren’t for medical breakthroughs occurring at the time.

Before the fire, the standard way of treating a burn was to “tan” it, which involved scrubbing the burned area clean before applying harsh chemicals, mainly tannic acid, to the burn. The theory was to keep the area clean and free of infection by allowing a hard scab to form, regardless of the terrible pain experienced by patients. Before the fire, Massachusetts General Hospital’s Dr. Oliver Cope and others developed an alternative treatment that didn’t involve chemicals or scrubbing extremely tender skin. Instead, the burn was covered with a salve of boric petroleum and wrapped in gauze. The patient was also given plasma transfusions to replace lost fluids.

Although this new method had only been used on a couple of patients before the Cocoanut Grove fire, it was a great success. Boston hospitals were overwhelmed with victims, and the new method saved many lives.

In addition to this new surface treatment, the Cocoanut Grove fire also fostered the advancement of respiratory therapy. Before the fire, the extent and dangers of internal burning weren’t well known. Many victims suffered burns inside their nasal passages and throats from breathing in super-heated gases, the effects of which were intensified by the presence of other gases such as methyl chloride. As a result many victims died from pulmonary edema even though they didn’t suffer external burns.

The number of lives saved over the years as a result of the medical advancements made during and after the Cocoanut Grove fire are unknown. What’s known is that significant research was made possible by the tragedy and the treatment of burn victims changed forever.

Everything must be carefully examined with notations of anything that offers a description or condition linked to the fire. In this investigation, several accounts of survivors’ stories related how they escaped and survived. Clues were extracted from these descriptions of where the person was in the club, how they became aware of the fire, and how they escaped. One clue was that many survivors recalled a sweet smell to the smoke. Another survivor said he held a wet towel to his mouth as the fire passed through the Melody Lounge, the point of origin. Since many people in that room were overcome by gas and smoke, dying before they could even leave their seat, why was he able to walk away? Clues lead to questions and questions lead to further investigation.

Analyzing such data is the next step in the process. Answering questions raised by the clues led to reviewing medical research documented by the doctors and interns who cared for Cocoanut Grove survivors. Three doctors at Boston City Hospital studied the recovery of patients with internal burn and pulmonary complications and concluded, “The exact cause of the pulmonary lesions in the victims of the Cocoanut Grove fire wasn’t determined. At the time of that disaster, the rapid development and severity of the respiratory symptoms, diffuse rales heard in the chests of many of the patients, and the number of deaths resulting from the pulmonary complications within the first few hours all suggested the possibility of a pulmonary irritant such as phosgene.”

This was just one of the many medically related links. However, such a link coupled with a report mentioning the use of methyl chloride as a refrigerant, the accounts of sweet smelling gas, and the story of the man who held a wet towel to his face can be pulled together to form a hypothesis, which is the next step in the scientific method.

Several hypotheses should be developed and tested. For example, further investigation has shown that methyl chloride, the assumed refrigerant, releases the toxic gas phosgene when it burns. It’s also described as having a sweet smell at certain concentrations and is water soluble. The effects of phosgene on the human body could cause the symptoms many patients displayed. The solubility of methyl chloride could explain why the man with the wet towel wasn’t overcome.

The last step in the scientific method is testing and selecting a hypothesis, which can only be done after carefully testing each hypothesis for validity. The methyl chloride hypothesis used as an example has yet go through this rigorous process, which is why it remains only one of many speculated theories.

Exactly what occurred the night of November 28, 1942 may never be fully known. But with fire models and the continued use of scientific methods in the investigation process, mysteries such as the Cocoanut Grove fire may finally be put to rest.

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Doug Bellier is a NFPA fire modeling specialist involved in NFPA’s performance-based codes and standards initiative. Jennifer Sapochetti is a fire protection engineer with R.G. Vanderweil Engineers, Boston, Massachusetts.

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