Commentary

Fire, Water, and Soot—A Cautionary Tale

by Stanley H. Pine

What Happened

Black soot everywhere: on walls, ceilings, benches, equipment, papers, and books. Debris and puddles of water on the floor. The strong odor of a burn.

This is what I observed as I entered the seventh floor of our eight-floor Physical Sciences building two days after a fire had erupted on Sunday evening, August 9, 1998. Then I walked to the west end of the seventh floor where the fire actually began. Here several labs were completely gutted (a hazmat cleanup team had already begun their work) and burned benches, some remnants of walls and ceiling, and various sculptures of damaged wires and piping were all that was left.

The eighth floor appeared to be much cleaner, though a fine covering of soot was widely distributed. Several labs directly above the fire zone were damaged from fire and heat.

The fifth and sixth floors, below the fire zone, provided a different experience. Water was everywhere. Pieces of fiber ceiling tiles were on the floor, benches, desks, and equipment. There was evidence that the fire department had tried to protect property by using a sawdust type of material to dam the water flow and direct it into the stairwells. They even covered much of the equipment with plastic sheeting. The video I viewed much later, which was taken immediately after the Los Angeles City fire department released the building back to the university personnel on the night of the fire, showed water dripping from the ceilings like rain. The water came from fighting the fire as well as from broken water lines in the fire zone, which ran for more than two hours.

My initial response was one of thanks that nobody was injured. No students were working in the laboratories where the fire began and those in adjacent laboratory and office areas exercised great wisdom in realizing that the fire was beyond their ability to control. (I hope our regular student safety training provided some basis for this prudent decision.) They sounded the alarm and exited the building.

How and Why Did It Happen?

What was the cause of this major disaster in our Department of Chemistry and Biochemistry as well as lesser damage to the Departments of Physics and Astronomy and the Department of Geological Sciences that occupy floors two through five (floor five is a shared biochemistry/physics area)? I believe that several factors came together on that Sunday evening.

The laboratory in which the fire began was used for organic synthesis. It is actually a suite of two small rooms connected by an inner doorway. Four to six undergraduate and graduate research students usually occupy the space.

The weather had been very hot in Los Angeles—near 100° in the city and over 100° in the inland valleys. (Cal State Los Angeles is located in the northeast corner of Los Angeles city on a small hilly area overlooking downtown Los Angeles to the west and the San Gabriel Valley to the northeast.) There is strong evidence from students and faculty that the air system may not have been working that afternoon. Students working in the burned laboratories earlier in the day had portable fans set up to move the air. They turned off the fans and closed the corridor doors before leaving for dinner.

I believe that the fire resulted from a buildup of flammable vapors in the closed hot lab that did not have adequate venting. But what set off the vapors?

Three reactions were underway in the laboratory in which the fire started. All involved reflux of volatile solvents: tetrahydrofuran, methanol, and toluene. They were all being carried out in hoods; one building-vented hood and two nonvented (ductless) hoods. One of the students had observed that the solvent level in at least one of the refluxing systems had decreased during the day and actually added more solvent to make up the desired volume.

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Fire damage to laboratory work benches and walls was extensive.

Photos by Stanley H. Pine and William Wimberley

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But what set off the vapors? Each room of this laboratory suite had a drying oven and one room also contained a small under-counter refrigerator. I believe that one of those appliances provided a spark to begin the fire. During initial cleanup it was actually observed that one of the drying ovens had its door blown off. That was the probable source of the initiating spark.

Students working in laboratory–office rooms on either side of the fire zone reported that they heard a whoosh–thud noise, somewhat like the effect many of us have experienced when we wait too long after turning on the gas to ignite a Bunsen burner or gas barbecue. The "thud" led the students to believe that something heavy had fallen in the laboratories on the eighth floor above them. I believe that the force of the explosion moved upward into the utility plenum above the drop ceiling and then outward in both directions through that ceiling open space. That was the "thud" that the students heard. The ensuing fire within the two laboratories was then fed by solvents stored under the hood and lab benches as well as by reagents on open wall shelves. The heat was so intense that Pyrex drain pipes in the ceiling sagged, ring stand rods and utility handles bent, and at least one water line joint ruptured.

The heat of the fire traveled through the ceiling plenum area in both directions around the outer series of laboratories and offices. (The building is rectangular, with a center core of rooms and laboratories, and offices around the outer perimeter.) Considerable heat damage to the utilities in the plenum area, particularly electrical wiring conduit, extended through several laboratories in each direction from the fire zone.

Water damage was serious in the portions of the building below the fire zone. But even the seventh floor suffered considerable damage as water flowed down the hallways and through the laboratories and offices. My own office, about 30 feet down the hallway from the fire zone, had a water and debris mark about two inches above the floor. Some electrical equipment was shorted because of this water.

Photo by Stanley H. Pine and William Wimberley

Extensive damage from soot and water-vapor condensation in a laboratory away from the actual fire zone.

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The smoke damage was most impressive. Most of the seventh-floor rooms in the outer perimeter were severely blackened. It appears that a cloud of hot steamy, soot, generated in part, I believe, from the fire-fighting efforts (we have no fire sprinkler system in this 1970-vintage laboratory building), engulfed the outer perimeter of the seventh floor and then condensed on walls, ceilings, and every other surface. The long side of the rectangular building measures almost 200 feet, and soot traveled the entire distance!

What we found on the eighth floor was surprising. Initial observations suggested that, other than in the area directly over the fire zone, there was very little soot on laboratory benches and equipment. However, once the laboratory cabinets and drawers were opened, a very different picture emerged. Everything in these closed units was even more soot-covered than what we found in the seventh floor (the fire floor) cabinets. In this case, the soot and hot gases that moved through the seventh-floor ceiling plenum area also flowed upward through holes for utility pipes that led into the eighth-floor laboratory cabinets. The failure of the building contractor to seal all of these passages 28 years ago markedly increased our cleanup costs (and increased the damage from laboratory water spills over the years.)

We learned that the chemistry of burning wood and plastic produces some very corrosive fumes. It was amazing to see stainless steel equipment in the laboratories that was pitted and marred from the residues of the fire.

What We Learned from It

So what have we learned and what advice can we give others as they plan, remodel, and just maintain their laboratory facilities and develop safe working procedures and emergency plans? Some laboratory safety issues are listed in the Box and discussed below.

We are all convinced that a major factor contributing to the fire was the very hot temperature in the laboratory. Though we have no specific records on the building air controls, there is strong evidence that the systems were sometimes turned off on weekends, probably for cost-saving. Although we continually complain about HVAC problems (doesn't everyone?), it might be prudent to limit the kinds of chemistry, if any, that can take place when systems appear to be malfunctioning. This would require students to make important safety decisions, usually without the guidance of a faculty mentor.

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Air flow and balance are critical to any building, but particularly laboratory facilities. When properly installed and maintained, they provide a pleasant and safe working environment. Modern laboratory buildings require very sophisticated (expensive) controls to ensure that air balance is maintained as hoods are turned off and on and doors opened and closed. Laboratory rooms are usually kept at a slightly lower pressure than connecting corridors or offices and classrooms so that vapors do not move from the laboratory to the rest of the building. Building planners must be continually reminded that laboratory air should not be recirculated. And most importantly, the systems must run continuously because even if personnel are not present, chemicals are stored and experiments may be in progress.

The ductless fume hoods in this laboratory suite were a compromise when hood space became short. We knew they were not ideal, but expected that careful monitoring and filter controls would be adequate. We also expected that the frequent air exchange provided by the building air systems would take care of any potential vapors leaking from these hood units. Since the time of their installation we have learned that ANSI (American National Standards Institute) suggests very strict limits on the use of ductless hoods in chemistry laboratories and the NFPA (National Fire Protection Association) clearly prohibits them. We will follow the latter recommendation in the future!

Guidance to students doing chemical syntheses can be improved. Students must be aware that water-cooled condensers don't do a very good job of containing very volatile vapors in a hot environment. A clue could have been the observation that the volume of the refluxing system had decreased. Those vapors must have gone somewhere! However, the reality is that normal air exchange in our laboratories is quite sufficient to minimize such dangerous vapor buildup—when the system is working.

The ignition source, which we believe to be a drying oven, is another focus of concern. Again, the vapors should not have built up to a dangerous level in the laboratory, but the presence of potential spark-producing equipment in a laboratory that uses considerable volatile and flammable solvents must be considered. Drying ovens and refrigerator controls are one potential spark source, but don't forget vacuum pumps and other equipment with electric motors.

A fire sprinkler system might have minimized damage. But our building was planned in the late 1960s when such fire-suppression systems were seldom installed in laboratories. Nor were they required by the City of Los Angeles or the State of California. We do have automatic carbon dioxide fire-suppression systems in the storeroom areas of the department. Today, we would be required to include sprinklers and other such systems during any new construction and in some cases during remodeling.

Laboratory Safety Issues

- Work with students to understand possible safety issues and contingency plans *before* beginning an experiment.
- Consider not only the experiment in question, but also other activity in the laboratory.
- Be cautious in the use of nonvented fume hoods.
- Ensure that adequate HVAC systems are operating.
- Store flammables in appropriate safety cabinets and minimize the stored quantities.
- Know the location of utility shutoffs for the laboratory.
- Close doors when leaving the laboratory.

The storage of bulk quantities of flammable solvents in the laboratory surely contributed to the extreme heat of the fire. Though many fire safety cabinets have been purchased for our department during the past 5–10 years, we still do not have enough to contain all the solvents that typically are stored. We must face this in several ways. Cut down on the quantities of bulk solvents stored in laboratories and ensure that they are all in fire safety cabinets, properly closed except when in use. The common practice of storing solvents in cabinets under the hood might now be modified to storing solvents in fire safety cabinets under the hood.

It was interesting to see how effective closed wooden cabinets, not specifically designed for fire safety, were in protecting flammable solvents. Gallon bottles of flammable solvents in closed cabinets in the less damaged of the two burned laboratories did not ignite even though the outer surfaces of the wooden doors were deeply charred. In addition to proper fire safety cabinets, I would suggest that all flammable chemicals be stored in closed (with wooden or metal doors) rather than open laboratory shelves.

Charred outer doors were effective in limiting fire damage within a closed wooden cabinet in which containers of flammable liquids were stored.

Photo by Stanley H. Pine and William Wimberley

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Laboratory side (burned, on left) and corridor side (right) show the effectiveness of fire safety doors. Note the safety viewing window.

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View from inside the burned lab looking toward the corridor shows how effectively the closed doors served to limit the spread of the fire.

Much of our building damage was from water, and much of that water resulted from the inability to get the building water shut off after heat had caused water lines to rupture. Access to clearly marked utility isolation valves and switches for buildings, individual floors, and in some cases specific laboratory areas, must be a part of building planning, remodeling and the overall emergency procedures of the institution.

Provision for fire isolation played an important role in limiting the spread and damage from the fire. Each laboratory is equipped with one or more two-hour fire safety doors. These were closed at the fire-zone laboratories and very impressively kept the fire from entering the corridor area and spreading more widely. The fire side of the doors was deeply charred, whereas on the outside (the corridor side), there was almost no evidence of fire. When we instruct people in fire safety, we always tell them to close the door as they leave the burning laboratory. That lesson was clearly emphasized by our experience. It is also a good reminder to close inner and outer laboratory doors when leaving the area.

Another feature in our laboratory safety doors is a small, 8×8-in. safety-glass window. We have a lot of trouble stopping students from covering the window with pictures or notes, but this experience emphasized the value of those windows. The students who first heard the ignition immediately ran toward the laboratory to see what had happened. But wisely they looked through the window and saw the room aglow in red. They did not open the door but sounded the alarm and rapidly exited the building—a very fortunate decision for their personal safety.

Photo by Stanley H. Pine and William Wimberley

A burned hood in the laboratory adjacent to the one in which the fire is believed to have started.

I am writing this four months after the fire. Though we are not yet back into floors seven and eight, much of the cleanup (and required asbestos abatement) has been completed. We were reminded that environmental concerns and regulations slow the pace of repairs even more than in our experience 11 years ago after a serious earthquake and fire. (For more on laboratory disasters see *J. Chem. Educ.* **1988,** *65*, A98.) Air-quality monitoring and testing for asbestos and other building materials of safety concern were required. Even the moving of laboratory chemicals so that cleanup can proceed has become a slow and costly process.

The disruption to the teaching and research program has been severe, and the cost enormous. We have spent nearly \$1.4 million and still have not faced the time and costs to rebuild the eight laboratories that were damaged. Reminders of the incident will be with us for a long time. The soot on books, papers, and equipment seems to continue to linger even after cleaning. Corrosion from the fumes is extensive and is continuing to show up in electronic components that at first seemed to work fine. I expect that we have a long haul ahead of us!

Stanley H. Pine is a member of the Department of Chemistry and Biochemistry, California State University, Los Angeles, Los Angeles, CA 90032; spine@calstatela.edu.