A Fireproof Future?

Plastics that don't burn could stop a fire in its tracks

By CORINNA WU

In Greek mythology, the Titan Prometheus stole fire from the gods and gave it to humankind—an act of insubordination for which Zeus punished him horribly. To us mortals, Prometheus' gift is both a blessing and a curse.

Fire provides warmth and light, but when it rages uncontrolled, it also causes devastating losses of life and property. Each year, fires destroy property valued at billions of dollars. Total expenses attributable to fires also include the huge costs of insurance, fire-protection systems, and lost wages.

Smoke detectors provide some warning of uncontrolled fires. Although they can be found in three out of four dwellings in the United States, when there's a fire, there is only a 20 percent chance that there will be a working detector present, says Richard G. Gann, chief of the fire science division at the National Institute of Standards and Technology (NIST) in Gaithersburg, Md. Even the most advanced detection and suppression systems currently available aren't foolproof.

One strategy to lessen the toll taken by fires is to make things out of materials that are less liable to burn—or even that don't burn at all. The Federal Aviation Administration (FAA) is avidly exploring this approach, setting itself a long-term goal of achieving a completely fireproof airplane cabin.

Right now, no commercially available materials, except for metals, are sufficiently flame resistant, says Richard E. Lyon, a polymer scientist and manager of the fire research program at the FAA's William J. Hughes Technical Center at the Atlantic City International Airport in New Jersey.

At the 1998 Annual Conference on Fire Research held at NIST in November, scientists presented their recent work on new fire-retardant materials, focusing on plastics. Gann says, "The science in that area is moving very, very nicely."

One promising candidate may be available to airplane manufacturers by the end of the year, says Lyon. Researchers are uncertain, however, whether cost and demand will drive such materials into construction and consumer goods.

FAA

The Federal Aviation Administration sometimes tests the flammability of materials and equipment by building a mock airplane cabin and setting it on fire.

Scientists began studying the flammability of materials in earnest after World War II, when U.S. residents enjoying newfound wealth began living in larger homes with more furnishings. "At about the same time, the plastics industry took off," Gann says, "and the fire problem took off, too."

Plastics' combination of low cost, moldability, strength, and flexibility make them ubiquitous as industrial materials. However, many plastics burn easily being composed primarily of carbon.

Airplane cabins, for example, consist mostly of plastics, or polymers. An all-metal airplane cabin would be impervious to flame but impractically heavy, not to mention uncomfortable.

Because of the heightened dangers of fire in an enclosed cabin surrounded by jet fuel, much fire-retardant research has focused on materials for the seats, walls, and carpets in airliners. The plastics currently in airplane cabins have an overall fire potential comparable to that of an equivalent weight of aviation fuel. Once they are burning, the materials give off the same amount of energy per kilogram.

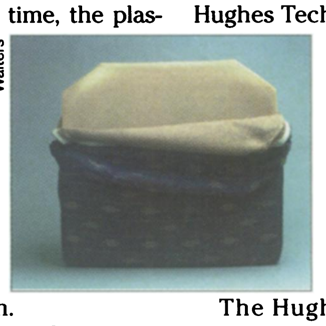
To reduce the risk of fire, materials in airplanes must pass strict flammability tests. Airplane manufacturers "are using the best materials they have now," says Lyon, "and they're still not good enough."

Scientists consider several characteristics of a material to assess its flammability: how long it takes to ignite, how hot and how fast it burns, and the types and amounts of toxic gases it produces in a flame.

FAA hopes to find cabin materials by 2002 that, when burning, release heat half as fast as the materials used today. The heat-release rate is the primary measure of a material's flammability, and a lower rate translates into more time for a person to escape a fire. By 2009, the agency hopes to have materials that release no heat, essentially not burning at all.

For the past 2 years, a consortium of universities and companies has been working with the FAA toward these objectives. The fire-research group at the Hughes Technical Center acts as a clearinghouse for the consortium. "Universities send us samples, and we run all the tests," says Lyon.

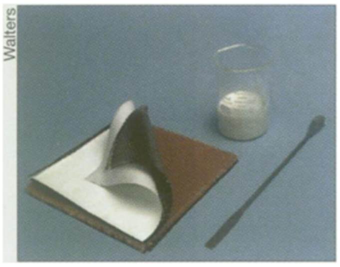
Walters



A layer of fireproof Kevlar encloses the flammable polyurethane in an airplane seat cushion.

The Hughes researchers test samples ranging in size from a few milligrams to thousands of kilograms. The standard device for testing materials' flammability is a cone calorimeter. It measures the heat, smoke, and gases given off as a flat, hockey puck–size sample is heated and burned.

Even tests on tiny samples, which may be all that are available, can provide a good picture of how materials will behave in a large fire, Lyon says. The Hughes researchers also do full-scale


Walters

A melted polymer is mixed with a layered silicate clay called montmorillonite to form a strong, fire-resistant composite material.

tests. For example, they can build a whole airplane cabin of test articles and set it on fire.

Several of the experimental materials they have tested come close to the FAA's goal of a 50 percent reduction in heat-release rate. At least two strong polymers called cyanate ester resins approach the FAA's long-term goal of total fire resistance.

One of these polymers, produced by Ciba Specialty Chemicals in Brewster, N.Y., is flame-resistant but prohibitively expensive to produce. In collaboration with the FAA, Ciba developed the second resin, which is inexpensive and has "almost zero heat release," Lyon says. "I think it will revolutionize the chemical industry." Ciba is filing a patent on the material and developing a marketing plan.

Richard N. Walters of Galaxy Scientific Corp. in Egg Harbor Township, N.J., who is testing the materials for the FAA, says that these cyanate esters might be used in composite panels and circuit boards in planes.

The technical challenge in making fire-retardant polymers is to reduce flammability while retaining the properties that make plastics appealing. The long carbon backbones that underlie these polymers' structure make perfect fuel for a fire.

"You're asking [polymers] that are organic . . . not to behave like an organic," says Jeffrey W. Gilman of NIST.

The kinds of plastic that do survive high temperatures are often brittle and hard to mold—not good choices for airplane seat cushions, for example. Seat cushions are now made from polyurethane, a stretchy polymer known as an elastomer. Although polyurethane is flammable, manufacturers comply with FAA fire regulations by wrapping the cushions in a fire-resistant fabric like Kevlar, the material used in bulletproof vests.

Adding flame-suppressing substances to the material provides another way to fireproof polymers. In the past, the additives of choice were halogen-containing molecules. They stop the chemical action of a fire by mopping up reactive molecules as they are released. Although halogens did this job well, they fell out of favor because they may release toxic dioxins when they burn.

Manufacturers make some polymers fire retardant by adding metal oxide hydrates, compounds that release water at high temperatures. The water absorbs the heat and cools down the fire. Such materials are common in wiring insulation.

Some polymers effectively fend off flames by actually getting scorched—but only on their surface. These materials form a layer of char that insulates the rest of the material from the fire, a process akin to searing meat on the grill to preserve the tender flesh inside.

At the NIST conference, Gilman described one such material: a nylon incorporating tiny, flat particles of a silicate clay called montmorillonite. Researchers were originally interested in this material for its ability to seal out water and for its high strength. Later, they found that the clay made the nylon less flammable.

"Typically when you add flame retardants, you tend to take away from the mechanical properties," says Emmanuel P. Giannelis of Cornell University, who is studying the material. However, incorporating 2 to 6 percent clay into a polymer such as nylon or polyamide reduces the heat-release rate 40 to 80 percent while doubling the strength, says Gilman.

Giannelis and his collaborators at NIST speculate that the nylon-montmorillonite composite provides flame resistance by producing a unique kind of char. "When the polymer burns away, the residue consists of alternating layers of silicate and carbon char," a combination that might have unusually good insulating properties, says Gilman. In contrast, pure nylon forms almost no char and is highly flammable.

Even though small amounts of the silicate improve the composite's strength, there's a limit to how much can be added without ruining the material's other mechanical properties. If too much layered silicate is included, "then we're talking about concrete, not a moldable polymer," Gilman says. The nylon containing 2 to 6 percent clay would still be workable in manufacturing, the researchers note.

The FAA is interested in the modified silicate for making molded airplane components. Scientists at Toyota Central Research and Development Laboratories in Japan have been considering the composite for use in heat-resistant engine parts, says Giannelis. It also works as packaging material, such as plastic wrap or bottles.

When an organic material like a polymer burns, the intense heat of the blaze causes a host of chemical changes. The material decomposes and releases carbon dioxide, water vapor, and other gases. Soon, all that's left is an unrecognizable lump of gunk.

Charles A. Wilkie of Marquette University in Milwaukee is taking those chemical transformations and turning them into an asset. His strategy is to make materials that harness the potentially destructive energy of a fire to provide fire resistance.

"We want to have something that is a normal polymer at room temperature. Then, when it's challenged by a fire, we

The windows and window shades on an airplane are made from molded plastic. Because they are small, they do not have to meet the same flammability standards that larger panels, ceilings, and partitions do.

want to have the polymer magically convert itself into something which is fire resistant," he explains.

Wilkie and his colleagues start with highly flammable polystyrene, best known as the Styrofoam of disposable coffee cups. Polystyrene is one of the most widely used plastics, forming the molded parts on many consumer goods. The researchers modify the plastic by adding a second polymer, called para-vinylbenzyl alcohol, and a catalyst. A new polystyrene forms with a network of bonds, or crosslinks, between polymer molecules.

To preserve the mechanical properties of the polystyrene, the chemists add only low concentrations of the second polymer. Wilkie and his team have found that use of a specific catalyst, phosphate ester, reduces the peak heat-release rate of the plastic to less than 40 percent of that of pure polystyrene.

"It doesn't burn as hot, and it takes about three times longer to reach that hotness," Wilkie says.

Unlike pure polystyrene, the new material forms a char, which provides additional protection from burning. Wilkie suspects that charring is related to crosslinking of the polymer. "We're trying to clarify it, but it's not easy," he says.

Wilkie and his colleagues have also modified another plastic to increase its fire resistance. ABS, or acrylonitrile-butadiene-styrene, is used to make computer cases and automobile body parts. The researchers have added a surface coating of sodium methacrylate, which in a blaze decomposes into a sodium carbonate char. Once charred, the material's rate of heat release drops dramatically, and the time it takes for the modified ABS to reach its peak heat-release rate increases from 9 to almost 19 minutes.

"You have twice as long to get away from a fire, [and that fire] is between a third and a fourth as intense," Wilkie notes.

These materials, though promising, are still a long way from commercialization, Wilkie cautions. For example, his group has looked only at ABS samples as large as a fingernail. "Maybe we will come up with something that is practical. We like to think that it's possible."

Fire-resistant materials will have to be very practical in order to supplant the inexpensive but flammable ones used today. Even in an area as important as airplane safety, the cost of a material plays a major part in whether manufacturers will adopt it.

"The problem with all this stuff is that fire behavior doesn't pull new products into the market," says Lyon. "They have to be fireproof but sell themselves in another way."

In the future, the FAA might upgrade its regulations to encourage the use of new fireproof materials, Lyon adds, but "it can't upgrade the regulations until the materials exist." Only then might passengers expect to sit on seat cushions that can not only serve as flotation devices in an emergency but can also squelch a flame. □

Behavior

Follow the rules, baby

Viewers of the movie *Look Who's Talking* hear the thoughts of a wisecracking baby who aims fully grammatical barbs at everything from loaded diapers to dimwitted adults. If real-life infants do the same, they're not telling. They have, however, given scientists a peek at how infants begin to make sense of all the gabbing that goes on around them.

Seven-month-old babies discern and remember simple rules for arranging speech sounds, an ability that may foster language acquisition, according to a report in the Jan. 1 SCIENCE.

In experiments directed by psychologist Gary F. Marcus of New York University, 7-month-olds developed an awareness of predictable patterns in three-syllable nonsense sequences that they heard.

Infants first listened to examples of a sequence in which two different syllables precede a repeat of the initial one. These included "ga ti ga" and "ni la ni." They then heard more versions of that sequence, such as "wo fe wo," and new sequences in which the second sound is repeated, such as "wo fe fe."

Babies looked much longer in the direction from which the sounds of a novel sequence came, reflecting surprise and curiosity about unexpected sound patterns. This reaction indicates that the tots had learned the rule that the first and third sounds are the same, the researchers contend.

Further trials showed that infants did not simply like the sound pattern of some sequences more than others or focus on particular syllables that occurred together more often in one sequence than another. Youngsters also distinguished between patterns such as "de ko ko" and "ji ji we," indicating that their insights were not based on whether sequences did or did not contain an adjacent pair of repeated sounds.

Other investigators have found that 8-month-olds detect the statistical tendency of certain spoken syllables to occur together (SN: 5/3/97, p. 276). They suspect that the ability to notice and generalize statistical regularities in speech ushers kids into the realm of rule-based grammar. Research on connectionist computer systems, which use simple arrays of processing units to learn past tenses of verbs and other linguistic conventions, has bolstered the notion that rule use emerges from statistical learning.

Marcus' findings lend support to the contrasting view that prewired brain circuits regulate grammar learning. A connectionist computer system devised by Marcus failed to recognize syllable sequences as the babies had done.

Yet using a different connectionist system, psychologist Jeffrey L. Elman of the University of California, San Diego says he has successfully simulated Marcus' infant findings. Grammar skills may indeed grow out of babies' recognition of statistical patterns in the talk that they hear, Elman proposes. *—B.B.*

Youth violence defies predictions

New crime statistics for 1997 underscore an ongoing drop in youth violence rates, which had surged during the 1980s. Close inspection of the data shows that recent predictions of an explosion of youth violence as the juvenile population expands were "demonstrably silly," argues criminologist Franklin E. Zimring of the University of California, Berkeley.

Zimring analyzes U.S. crime data from 1980 to 1997 in *American Youth Violence* (1998, Oxford University Press). Arrest rates for teenage rape, robbery, and homicide in 1997 were the same as or slightly lower than in 1980, Zimring says. Both adult and teenage rates of aggravated assault rose sharply during that period, primarily because police became more apt to make arrests in cases of domestic violence, he holds.

Juvenile violence often rises and falls in several-year cycles that do not coincide with the juvenile population size, Zimring maintains. "Over the long run," he adds, "we don't know what will happen to youth violence rates." *—B.B.*