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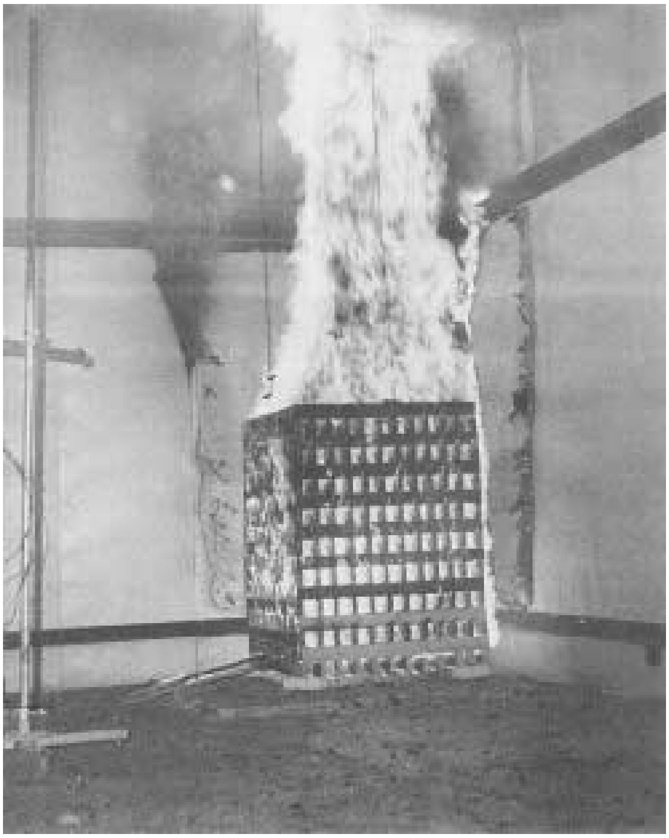

The testing industry is responding to the challenges of foam plastics with new tests. The corner test, shown above, aims to model actual fire growth in a room—using a three-panel corner and a burning crib of wood.

FIRE CODES *and* FOAM PLASTICS

The Test Results Are In, But the Jury's Still Out On Foam-plastic Safety

by William Rose

Fire-safety regulations are established to guarantee an acceptable measure of fire safety in buildings. Sandwich-panel construction—whether of polyisocyanurate or expanded-polystyrene (EPS) cores—can comply with current fire regulations in the model codes. So a builder can put up a house with sandwich panels and be sure that it is fire safe. Right? Well, not exactly...

In a recent article in *Progressive Architecture,* Richard Rush wrote: "Most fire-protection engineers agree that the code is the last thing they look at when they help design the fire protection of a building." Many fire researchers feel that ASTM tests E-84 and E-l 19—the standard measures of foam-plastic safety—are outdated. In fact, it was foam-plastic test results that prompted a flood of second thoughts about these tests.

The purpose of this article is to give some background on fires and fire-safety regulations. We can't cover all aspects—first, because fires have a notorious habit of defying even the best theories and, second, because the fine print and politics of fire regulations are mind-boggling. So the message to the builder who really wants to know the fire performance of a building is this—you'd better look beyond the building codes.

Residential Fires

Fires go through two phases: fire growth and developed fire. Fire growth starts with ignition. According to Sue Womble of the Consumer Product Safety Commission, we could cut the number of house fires in half by making upholstery more fire resistant. The cigarette/mattress connection is responsible for more house fires than any other source.

During fire growth, a fire can be extinguished. In fact, "housewives" put out more fires than firemen do, according to Paul Morrison of the Fire Service Institute. Fires with a two-foot flame may self-extinguish or can often be extinguished. Flames higher than that will probably grow and spread.

The rate at which a fire grows is critical. It depends on three factors: fuel, heat, and oxygen, one of which will limit the rate. (Fuel and heat are related in that heat releases combustible gases from the materials, making them available as fuel.)

Fires in older, leaky homes usually have unlimited air but are fuel starved. The fuel is limited because uninsulated walls allow the heat to dissipate. The fire usually spreads through cavities, which carry flames.

In newer homes, the fires take on a totally different character. The insulation keeps heat in—releasing combustible gases—and the ventilation rate is low. The fire has plenty of fuel but is air starved. Combustion will continue but will create greater quantities of carbon monoxide and other toxic gases. Carbon monoxide craves *oxygen* atoms; this is what causes oxygen depletion in the lungs of fire victims, and it is what gives an explosive surprise to whoever opens the door into a burning room. A fuel-controlled fire spreads when explosive gases backdraft to the next room.

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Fire will grow in a compartment until the floor temperature is around 200°F and the ceiling is at 1000 degrees. Then *flashover* occurs, when everything in the space seems to ignite. Occupants rarely survive flashover. After flashover, the fire is fully developed. A fully developed fire poses temperature, toxicity, and structural problems that must be left to fire fighters.

Fire-Safety Regulations

First, let's meet the players.

The building-materials industry. Here's where the money is. In 1985, the construction industry did $345 billion in business. The light-frame chunk of this was around $150 billion. While overall construction costs have increased 50 percent since 1967, the cost of building materials has increased 200 percent. So manufacturers understand the importance of participating in standards writing and code review.

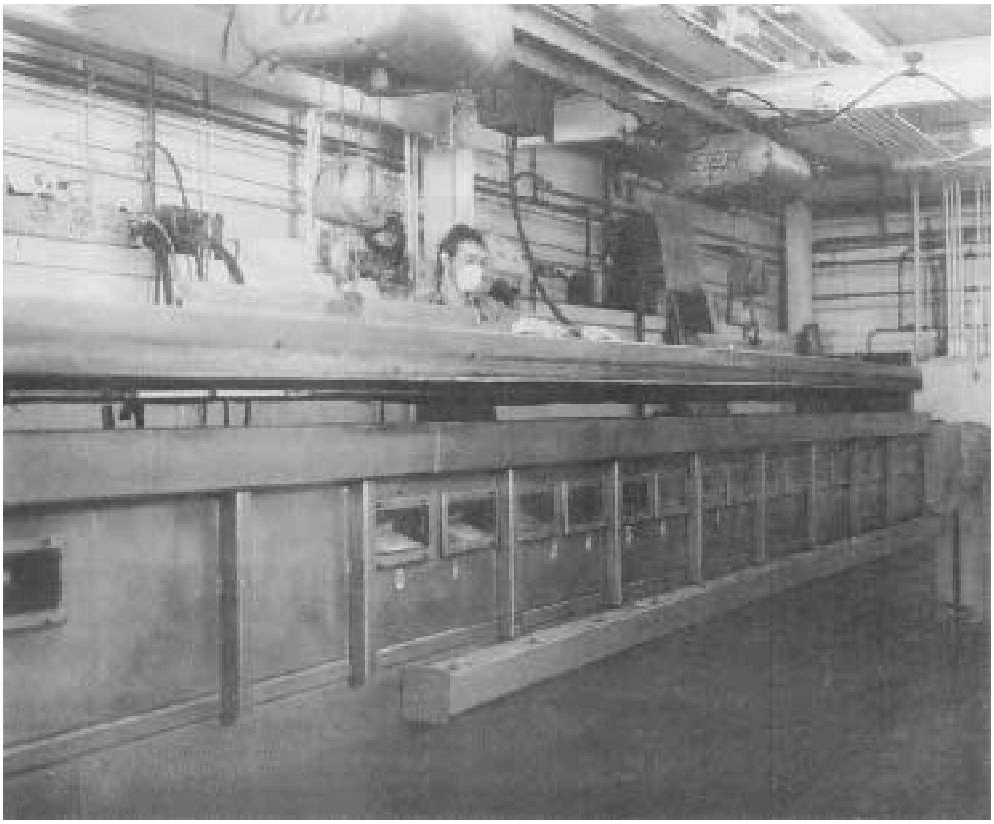
Standards associations. A "standard" is a description of an acceptable practice or product. Acceptable to whom? To whoever wrote the standard, and to whoever else chooses to adopt it—such as a code body. The literature that accompanies a product is one form of standard, describing acceptable installation. Industry associations, which represent various manufacturers, write standards to establish basic quality and performance guidelines among producers. Another type of standard describes how to test a product.

The most prominent standards organization is the American Society for Testing and Materials (ASTM). ASTM is a private, nonprofit corporation that draws its membership from industry, government, universities, and testing laboratories. ASTM writes five kinds of standards: specifications, practices, definitions, guides, and test methods.

All ASTM standards are voluntary, consensual, and participatory. "Voluntary" means ASTM does not pay its members for their work. "Consensual" means that standards must be agreed on in full by all committee members. And "participatory" means that no committee can draw more than 30 percent of its members from any one group—including manufacturers.

In the world of standards writers, ASTM is considered to be among the organizations most free from the taint of self-interest. That's the reputation a standards writer needs to succeed. But ASTM does not work fast. It takes about three years to publish a standard from draft stage. It's an old-boy network, but it's been effective since 1893.

Interestingly, the National Bureau of Standards, which is part of the Department of Commerce, does not write standards. But it does conduct tests that help others write standards.



The Steiner Tunnel Test (ASTM E-84) rates how materials contribute to flaming and smoke production. All materials are compared to red oak, which is assigned flame-spread and smoke-developed ratings of 100. Researchers view the fire through the windows on the side of the chamber.

Testing labs. Testing is part of any product development. Products and processes need to be tested before getting code approval. There is an accreditation system for labs; nevertheless, the likelihood that a code organization will accept results hinges primarily on the credibility of the organization doing the test.

At one end of the spectrum are product tests conducted by the manufacturers themselves, or by an engineer they hire. More readily accepted are results from private laboratories, most of which have excellent reputations. The two most prominent are Underwriters' Laboratories (UL) and Factory Mutual, which test products for insurance companies. UL develops and conducts fire tests, which are essentially identical to ASTM tests. Testing is expensive.

Code organizations. In the U.S. there is no basic, uniform national code. Instead we have a number of model codes. The three primary residential building codes are the (Southern) Standard Building Code, published by SBCCI, the Basic Building Code, from BOCA, and the Uniform Building Code, from ICBO. The three code groups have only building officials as members, although industry groups lobby hard during review sessions,

Local building officials typically use one of the model codes as a basis for their local codes. Specific provisions can be kept or changed by local officials, and enforced with some discretion by local building inspectors. There is a remarkable amount of agreement among the model codes.

Sandwich-Panel Plastics

Both EPS and polyisocyanurate panels can comply with the model codes' requirements for plastic foams, although the two plastics behave quite differently in a fire. EPS begins to creep at around 175°F and melts at around 200 degrees. Liquid EPS flashes at around 800 degrees. Polyisocyanurate, on the other hand, chars when flames hit it, and the charring may protect the foam beneath. It flashes at between 800 and 850 degrees.

Both EPS and polyisocyanurate release carbon monoxide when they burn. Polyisocyanurate also produces hydrogen cyanide. However, J.R. Mehaffey of the National Research Council (NRC) of Canada claims "there seems to be no definite proof that under fire conditions, polyurethane foam insulation augments toxic hazards beyond the levels that already exist in building fires."

BOCA Code Requirements

Section 13 17.0 Foam Plastics contains these requirements:

1) The foam shall have a flamespread rating of not more than 75 and shall have a smoke-developed rating of not more than 450 when

Both EPS and polyisocyanurate panels can comply with the model codes, although EPS melts at around 200°F, and polyisocyanurate produces hydrogen cyanide when it bums.

tested for use in accordance with ASTM E-84;

2) All foam plastic shall be separated from the interior of the building by an approved thermal barrier of 1/2-inch gypsum wallboard or equivalent thermal barrier which will limit the average temperature rise of the unexposed surface [the back of the drywall] to not more than 250° after 15 minutes of fire exposure complying with the standard time temperature curve of ASTM E-119. The thermal barrier shall be installed in a manner that assures it will stay in place for a minimum of 15 minutes under the same test conditions.

Let's look at these two tests.

ASTM E-84

This is a test for surface flammability. It rates how materials contribute to flaming and to smoke production. Building codes use it to screen out materials that have no business being in homes in the first place.

Al Steiner of Underwriters' Laboratories developed the test. A specimen 24 feet long and 20 inches wide is installed as the ceiling in a tunnel made of firebrick. There are windows along each side for viewing the fire. At one end there's a flame source and air vent, and at the other end a smoke exhaust with a light and photocell to measure smoke density. The flame and vent openings are calibrated to a red-oak ceiling, which is the standard reference point for the test. The flame-spread index (FSI) of red oak is rated at 100, and the asbestos-cement ceiling has an FSI of 0.

The sample then is put in place, the flame is reignited, and operators watch through the windows to see how far the front of the flame advances. If it goes halfway between the cement-asbestos distance and the red-oak distance, the flame-spread rating is 50. In the same way, the smoke density of the sample is compared with the smoke densities of red oak (100) and asbestos cement (0).

A funny thing happened when they first put plastic foams through the tunnel test. The FSIs were very low. The polystyrene on the ceiling of the test tunnel melted as soon as the flames hit it, so the visible flame spread being measured was actually the spread against the backer board—the foam was gone from the ceiling. Polyisocyanurate, on the other hand, would char in place, but the flame spread was much lower than for red oak and much lower than the first operators expected.

The E-84 performance of foam plastics presented a real challenge to the standards groups, in particular, ASTM and UL. It called into question three things: how to treat smoke and flame from the test residue (material that melted and dripped to the floor of the test chamber), how the test results should be reported and, finally, whether it's an appropriate test at all for the fire safety of this type of material.

As some plastics melted, a lot of smoke was produced by the residue on the tunnel floor. Officially, the smoke number that matters is from the sample still on the ceiling. But how can one photocell distinguish between the smoke from two sources? And should it?

At present, Underwriters' Laboratories, with its test almost identical to E-84, reports two numbers: a "smoke produced" rating before the floor residue kicks in, and a "total smoke produced," which is reported as a footnote. For many foam plastics—including polystyrene—the smoke footnote figure is more than the 450 prescribed by code. The residue can also ignite, in which case the tunnel operator has to visually distinguish between ceiling flame spread and floor flames,

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The E-84 test standard calls for including in the final report of results any "observations of the burning characteristics of the specimen during test exposure, including delamination, sagging, shrinkage, fallout, etc." Many certificates of results include this information. However, that puts model-code bodies in a bind. At present, they only approve materials with an FSI of less than 75, and smoke-produced rating of less than 450. Committees at the code bodies are studying what to do about these darn footnotes.

ASTM E-119

The purpose of this test is to determine how an assembly retains its structural integrity during a *developed* fire. A furnace heats the exposed side of an assembly loaded for normal use. The heat applied rises to 1000°F in the first five minutes, then climbs until the assembly fails. Failure is when the assembly can no longer carry the load, or when the temperature of the unexposed side—facing 75-degree air in the lab—increases 250 degrees. The amount of time before failure is called the "assembly rating" (15 minutes, one hour, etc.).

The same test can be performed on finish surfaces, such as drywall, or combinations such as drywall and plywood. No load is applied, and the back of the finish material faces the room air. The time it takes for the unexposed surface to rise 250 degrees is the rating. Half-inch drywall has a 15-minute rating. Drywall and plywood together have a one-hour rating. The rating of surfaces takes on different names in different model codes: "finish rating" in the old editions, "thermal protection" in BOCA, and "thermal index" in the UBC.

Here's the point: A tested and rated surface will perform differently depending on what's behind it. With air behind the surface, temperatures on the back side will slowly climb 250 degrees. With insulation behind it, however, temperatures at the interface will climb quickly. So it's a myth that any assembly with a 15-minute rating of the finish material will last 15 minutes. Recognizing this, codes have been backing away from any implication that the finish rating indicates safety time for an assembly (thus the name changes).

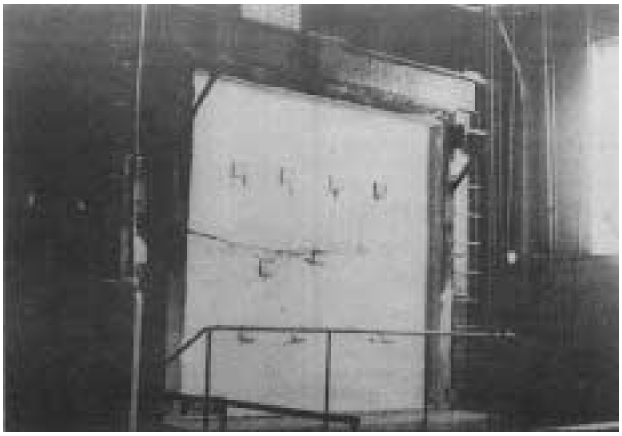
It's a myth that any assembly with a 15-minute rating of the finish material will last 15 minutes in a fire.

Assembly tests for every type of foam-core panel would be handy, except that with the hundreds of formulations of plastics and numerous facings, we would need thousands of assembly tests. So for practical reasons, the model codes require only that the *finish materials* on wall and ceiling assemblies be fire rated—not the assemblies themselves. In effect, this allows you to certify the safety of a foam-plastic assembly based on a test of the drywall finish.

Assembly tests have been conducted on panels with polyisocyanurate cores. The results show the stability of the assembly on the order of 15 to 20 minutes. Assembly tests are not conducted on EPS-core panels. Ken Rhodes of UL says that nobody would ever submit one. An EPS panel would melt right away.

Other Tests

Thanks mostly to the anomalies and confusion that plastic foams present to the testing industry, new tests are being developed with the aim of more closely modeling actual fire growth in a room. Most tests use a standard fire source—such as a regulated volume of gas, or a burning crib of wood with specified dimensions, layout, moisture content, and species. *Corner tests* use three sample panels as a wall and ceiling assembly. *Room* tests create a confined space with specified openings.



Using a king-sized furnace, the ASTM E-119 test measures the performance of a material or assembly (such as a foam sandwich panel) in a developed fire. This yields the familiar "finish ratings" assigned to drywall and other panel products.

Factory Mutual uses a 25-foot corner test for commercial and an 8x12 room test for residential. ASTM is developing a standard room test of 8x8x8. Other test configurations have been developed by Owens-Coming Fiberglas, Olin Corporation, the National Bureau of Standards, and the NRC of Canada. One set of corner tests conducted by the NRC of Canada shows a roughly similar performance of protected polystyrene and polyurethane.

There is little agreement as to what is the appropriate configuration for correct modeling. Remember that air-starved fires have little in common with fuel-starved fires. And remember that reflected heat within a compartment helps to release fuel from combustible surfaces. Which is the correct model for code acceptance? The jury's out.

Nonconclusions and Conclusions

A good builder should not rely on code compliance as a guarantee of the fire safety of a building. Surface ratings are helpful, but they poorly predict the performance of the assembly as a whole. And tunnel test results have not been reported consistently.

Also, the model codes waive the 15-minute thermal-protection requirement for roof assemblies, and require only 1/2-inch plywood or a "performance equivalent" on the interior surface. I am waiting for a satisfactory explanation of this, since roofs face higher temperatures than walls when the underside of the roof is the finished ceiling.

Why do model codes waive the 15-minute rating for roof assemblies?

The fire-safety provisions of most model codes are at an interim stage. I expect we will see references to room or corner tests in the model codes, but not tomorrow. These things take time.

Meanwhile there are these recommendations for builders:

- Insist on full test reports from suppliers. Understand how the tests were conducted and what the results mean. Read the fine print.
- If you are considering using foam-plastic panels, talk to your fire marshal. Share what information you have. He may not have better information than you and he may resent innovation. But respect the fact that his people have to put the fire out.
- Insist on repair procedures from suppliers. Steve Nolan of State Farm Insurance points out that home owners will not likely be denied home owner's insurance if their house meets local code requirements. But if the system appears hard to repair, the home owner will have to pay a surcharge, such as log-home owners have to pay in many areas.
- Spend some time envisioning how a fire would grow and develop in the house. Imagine the structural consequences.

And remember—build lots of convenient storage to reduce clutter. ■

William Rose, who is an ASTM member, researches residential building practices at the Small Homes Council, in Champaign, Ill., and teaches architecture at the University of Illinois.