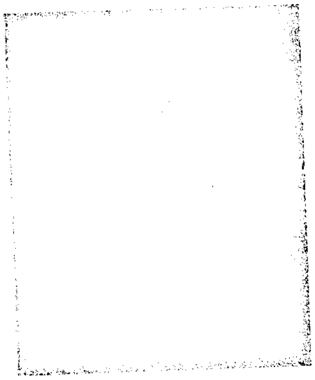
Nicholas
ANA-420, Bldg. 203



Cover: Test here is for smoke density—major cause of deaths in fires. (Photo, FMC Corp., Organic Chemicals Div.)

Flammability report

The issue of plastics and fire is as confusing as ever, but it promises to get top priority in the 70s

Since fire ranks third as a cause of accidental death in the U.S.—trailing behind auto accidents and falls—it has become the keystone in the push for safety legislation being led by Nader's Raiders and other consumer groups. And the control of flammability has become the focal point for both plastics industry technical development and R&D programs for the 70's.

But the situation remains in a state of flux. New standards are still coming up and the industry is rapidly improving present flame-retardant formulations to meet new requirements. Already DOT standards for automotive interiors, FAA regulations for aircraft passenger and crew compartments, and Department of Commerce standards for carpets have gone into effect, to say nothing of a spate of building code and certification group standards. And coming up are new tests that will be used by FDA to enforce the Child Protection and Toy Safety Act of 1970 and flammability standards for furniture that will probably be in effect by 1974. However, questions that have been raised about the ability of standard tests to predict actual conditions are casting doubts on the current direction of flammability regulations, and a possible move to sprinklered buildings may take some of the heat off plastics.

Getting technology there on time

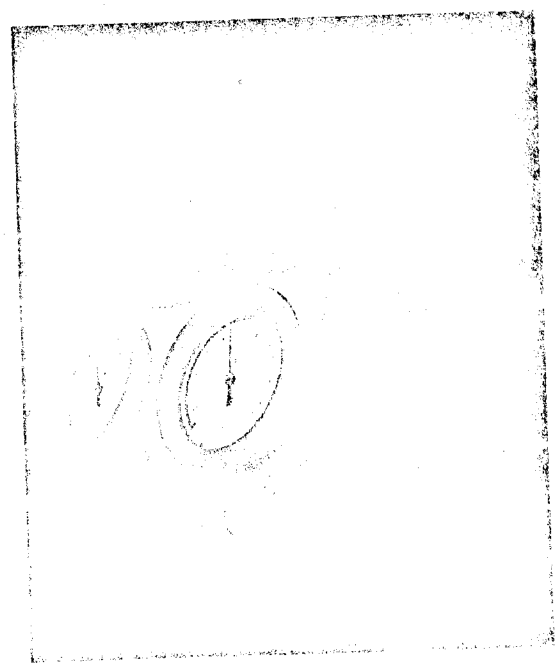
Right now, the market for flame retardants and flame-retardant resin formulations is keeping pace with regulatory activity. As new standards go into effect, consumption makes a quantum jump. In 1972, consumption of flame retardants is expected to finish out the year with 40% gains, but the long-range outlook is for flame-retardant markets to run at an average of 25% growth through the decade.

While meeting standards with present flame-retardant technology is possible, and in some cases even easy, meeting standards without affecting the properties of the finished product is another ball game, and research on flame retardants is concentrating on finding ways to get flame retardancy in without taking anything else out. At the present time it looks as if the additive approach will continue to get the emphasis. But the drawback of additives is that adding anything to a resin will have an effect on a resin's properties and on its processing characteristics.

The direction additive research is taking is to develop more efficient materials that can be used in lower concentrations to minimize their effect on the resin. The search is also for more stable compounds that can withstand long processing at high temperatures. Of particular importance are flame retardants for structural thermoplastic foams which would open up applications now held by metal that have an estimated volume of about 27,000 tons.

Right now the group of additives getting the attention are those based on aliphatic or aromatic bromine, which are generally about twice as effective as halogenated materials based on chlorine. A number of companies including Cities Service, Dow, Ethyl Corp., Great Lakes Chemical, and Michigan Chemical are involved, and products are starting to reach the market. However, most of the development work here has been on proprietary additives for incorporation into flame-retardant resin formulations, and a number of suppliers of PP, PE, polyester, and ABS are introducing resin grades with brominated flame retardants.

A counter trend based on possible questions about the toxicity of brominated flame-retardant compounds has been to develop effective flame-retardant systems using phosphorus, nitrogen, and sometimes very small quantities of bromine. American Cyanamid recently has introduced materials in this category and Stauffer has flame retardants that contain no halogen but are intended for blending with halogenated types. Questions about toxic combustion products of flame retardants persist, but are no longer an issue. It has been satisfactorily demonstrated that before toxic concentrations of flame-retardant products can build



Oxygen index test, which measures ease of ignition, may become most important flammability test. (Photo, Du Pont)

Standards *(are there too many?)* retardants *(are there enough?)*, and solutions *(are they in sight?)*

up, death would have already occurred from a combination of heat, oxygen deprivation, and carbon monoxide (which is produced in all fires). One area that promises to become more important, and may even come under government scrutiny, is the toxicity of flame-retardant chemicals themselves. Already one group of brominated materials—brominated biphenyls—has fallen by the wayside after animal tests at Du Pont's Haskell Laboratory indicated that the materials were very toxic.

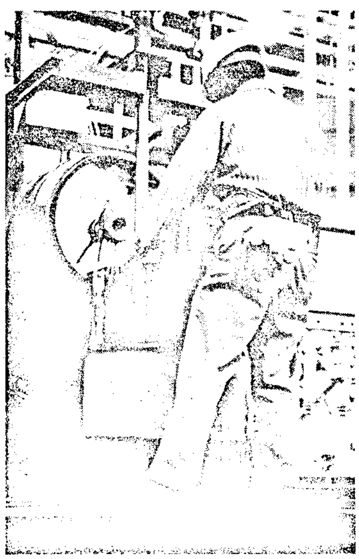
Work on reactive systems is by no means at a standstill, however, although reactives are best suited to urethanes and polyester which have readily available bonding sites to attach the flame-retardant group. Reactives are easier to develop for rigid urethanes and polyesters where several materials are available.

Other approaches to avoiding interference with the material properties also are getting attention. One is flame-retardant coatings which promise to become more important in the future. Because they are not incorporated into the resin, they don't alter properties or processing, although they do have the drawback of affecting surface finish. But improvements are on the way. Cities Service is getting ready to introduce what it says is the first clear, water-insensitive intumescent coating.

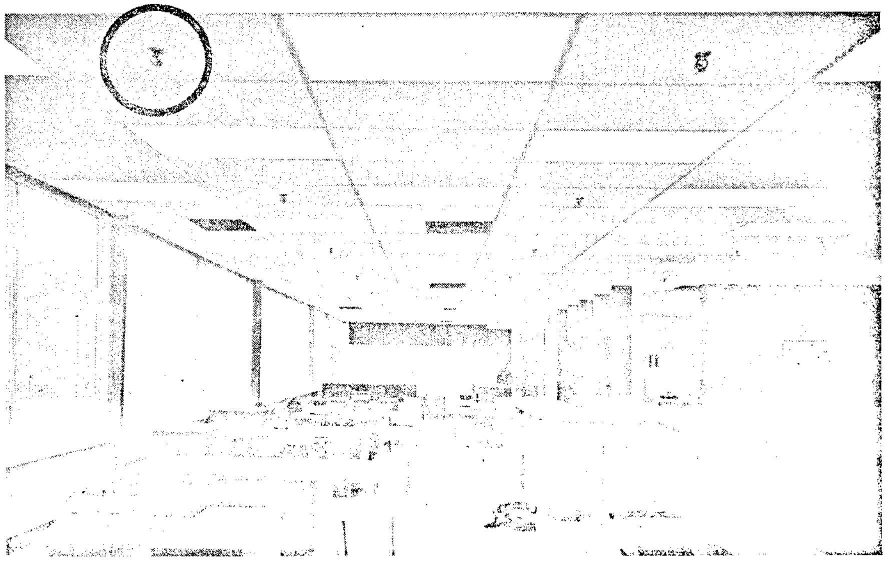
In another development, National Cash Register Co., Dayton, Ohio is experimenting with microencapsulation of chlorides and bromides in heat-degradable wall materials. The materials are encapsulated in gelatin-phenolic and PVA-phenolic wall materials that degrade in the presence of heat and release flame retardant. They are being tested in PS and urethane foams.

The testing boondoggle

But despite the rapid development of flame-retardant technology and the almost daily introduction of improved formulations, the market for flame-retardant plastics has failed to live up to the predictions of several years ago. Current estimates for the total amount of plastics containing some flame-retardant system range from a conservative 4% to an optimistic 10% of 1972 resin consumption. The fact is that the market is moving only as fast as regulations force it to move. Producers are voicing a reluctance to anticipate regulations because of the confusing maze of test methods now being employed. As one processor put it, "I know I'll have to go to flame retardancy soon, and I can formulate so that a product will pass a number of existing tests. But chances are that if I go to a lot of expensive testing now, my products won't pass the test that's finally required." This is backed up by a product manager for flame-retardant resins who says, "Everyone wants to see



As new regulations come in, flame retardant technology is keeping pace. (Photo, Nopco)



Increased interest in sprinklers may ease the test confusion by making propagation and endurance less important. Ignition tests will take precedence.

Test	Procedure
[illegible] ... materials	[illegible]
UL Hot Wire Ignition *Materials:* Plastics *Use:* Plastics parts in electrical applications certified by UL	Bar-shaped sample is wrapped with resistance wire which is heated electrically to red heat. Time for sample to ignite is measured
UL High Current [illegible] ... electrical applications certified by UL	Electrodes resting on sample are [illegible] ... required to ignite sample is recorded
UL High Voltage Arc Ignition Test *Materials:* Plastics *Use:* Plastics parts in electrical applications certified by UL	Two electrodes rest on surface of sample 4.0 mm. apart. Current is supplied to cause a continuous arc. Time required for ignition is measured
ASTM D2859 [illegible] ... *Use:* For compliance with DOC standard for carpets exceeding 24 sq. ft.	Methenamine pill is ignited on sample and allowed to burn out [illegible] ... also measures flame propagation; see below)
Flame propagation tests ASTM D635, FTM 2021 *Materials:* Plastics sheet *Use:* Burn rate of 2.5 in./min. for approval under BOCA, SPI Model Code, and other building codes	Horizontal sample is exposed to bunsen burner flame for 30 sec. and allowed to burn until fire goes out or sample is consumed. Rate is measured in in./min.
ASTM 1692, UL subject 94 *Materials:* Plastics foams *Use:* Testing foams for building and furniture applications	Horizontal sample is exposed to bunsen burner flame for 60 sec. In UL 94, cotton is placed under sample. Burn rate is measured and flaming droplets must not ignite cotton
ASTM E84, UL 723, NFPA 255, 25-ft. Tunnel Test *Materials:* All *Use:* Most widely used test for building materials. Model codes require a rating of 25 for interior finishes in stairwells, 75 in exit areas, and from 75 to 225 in rooms	Sample is mounted along ceiling of 25-ft.-long tunnel and ignited by burner at front end of tunnel. Burn distance is noted, and compared to red oak which is set at 100. (Test also measures heat contribution and smoke generation; see below)
[illegible]	Vertically oriented sample is [illegible] ... Self-Extinguishing, Group 0. If time [illegible] ... Self-Extinguishing, Group I [illegible]

what I've got, but no one is buying until they have to."

The processor is caught in a crossfire of proliferating standards that are written by a large number of unrelated organizations, each with its own test method and test conditions. And while the tests are designed to give a relative ranking of the flammability of various candidate materials, a material that passes one test with flying colors can very well fail another miserably.

The flammability tests that are currently in use analyze specific burning parameters of materials. Ignition tests determine what is required to get a material to ignite. Others are aimed at measuring the propagation of fire on burning materials to determine which materials will contribute to the spread of fire in a building. Large-scale tests measure how long a particular type of building construction can stand up to a fire and provide a measure of ability to contain a fire. Another group of tests measures the amount of heat contributed to a fire by the combustion of various materials. Other tests measure the amount of smoke generated by various materials and screen out materials that generate so much smoke that exits would be obscured.

But while all these tests are very scientific, they fail in one of the most important criteria of a test: they do not predict what will happen in real fires. All they can do is provide a relative ranking of the behavior of materials under the conditions of that test. The reason is that there are so many variables in fires that controlled conditions cannot possibly account for all of them. Fire is a complex set of chemical reactions that depend on the materials present, the amount of oxygen available to the fire, the location of the fire, the velocity and direction of air flow, and many other factors. Changing a single condition can mean the difference between a harmless burnout and a full-scale conflagration.

This was confirmed by a series of full-scale tests funded by SPI at Illinois Institute of Technology Research Institute (IITRI). The purpose of the IITRI tests (see Oct. 1971 MP, p. 80) was to determine correlations between currently used tests and actual building fires. None were arrived at. In fact, the tests showed that a change in conditions such as the position of the sample could completely alter the ranking of various materials. It also appears that some of the tests have very little reproducibility. Recent round-robin testing of the existing ASTM-E84 tunnel tests failed to correlate between tunnels.

In light of these results, the only legitimate use of present fire tests would appear to be to eliminate the extremely hazardous materials. And the present state of flammability legislation seems more a matter of passing a test than providing a known quantity of fire protection.

The winds of change

There are indications that developments in the next few years may very well bring a reduction of the dependence on tests for building fires which will take a lot of the pressure off the plastics processor. Instead of relying solely on the reduced flammability of materials, other methods of extinguishing fires may become increasingly important. The emphasis in material testing will be on ignition characteristics, with the main criteria being self-extinguishing, particularly for thermoplastics in electrical applications.

The trend right now is toward smoke detection equipment and sprinkler systems in buildings, an area in which the U.S. has lagged. Sprinkler systems have been designed that are capable of putting out fires almost as soon as they start. And if materials are used that are difficult to ignite, the other flammability characteristics of materials become relatively unimportant.

This is a development favored by insurance companies. They have long argued against the widespread use of the tunnel test in building code specifications because of its inability to predict behavior of a material in actual fires. On the other hand, there has never been a human death in a fully sprinklered building. In New Zealand, where sprinklers are required in all code-regulated buildings, there have been no deaths due to fire in eight years.

The 105-story Sears building in Chicago was the first high-rise structure in the U.S. to be fully sprinklered. And, Florida's Disney World which probably has more plastics and more people to protect than any building of its size in the world, went to sprinklers, smoke detection equipment, and automatic smoke exhaust vents, and realized a reported saving of $2 million in reduced construction costs and insurance.

Of course, at this point the only thing that could turn around the current trend in fire safety regulation is action by the federal government, but that is not totally beyond the realm of possibility. The General Services Agency is pushing a concept of total building design in which flammability would be designed out of a building at the architecture/engineering stage. New federal regulations for nursing homes now require sprinkler systems and the National Fire Protection Association recently issued a standard for sprinkler and detection devices for residential use. Also, the National Commission of Fire Prevention and Control will publish recommendations and propose a set of new standards in the spring. It is currently examining sprinklers and has scrutinized U.S. fire-fighting practices and training, an area in which improvement could further alleviate fire losses.

The other alternative is to continue the testing game until it includes not only building structures but the contents of the building as well. An early move in this direction was made by New York's Port Authority which established stringent standards for furniture in its new World Trade Center. However, the standards reportedly are so stiff, and push furniture costs up so high, that the Port Authority reportedly is not enforcing them. But the real impracticality of the move rests on the fact that, when a fire gets started, even the best flame-retardant materials will burn and, in a high-rise building where it takes a long time for firemen to reach the scene of a fire, sprinklers are decidedly safer.

However, industry groups are pushing for regulation on the Federal level to head off other possibly unrealistic and contradictory regulations at the state and local level. Furniture is likely to be the next regulatory area for plastics, and representatives of the furniture industry currently are working with NBS to develop a workable test for a standard that is likely to go into effect by 1974. And at NBS at least, attempts are being made to develop tests that more closely simulate real conditions. The probable test for mattresses involves a lighted cigarette, based on the fact that careless use of cigarettes is a major cause of mattress fires. A similar test probably will be used for furniture.—ALAN HALL

[illegible]

Tests	Procedures
MVSS302 Horizontal Burn Test *Materials:* All *Use:* Adopted by Dept. of Transportation for all materials used in automotive interiors	Horizontal specimen is ignited by a 15-sec. application of a bunsen burner flame. When flame has burned 1½ in. of the sample, time is measured until material ceases to burn or until burning has progressed 10 in. and rate must not exceed 4 in./min. to pass
[illegible] Vertical Test [illegible] components of [illegible] compartments	Bunsen burner flame is applied to [illegible] flame time must not exceed [illegible] out before [illegible]
FAA Horizontal Test *Materials:* All *Use:* Required by FAA for components of aircraft	Same conditions as above except samples are horizontal. Maximum acceptable burn rate is 2½ in./min. for acrylic windows, instrument assemblies, seat belts, and shoulder harnesses. Small molded parts are acceptable if burn rate is less than 4 in./min.
[illegible]	[illegible] time limits
Bureau of Mines Flame Penetration *Materials:* Plastics foams *Use:* Materials used in mines	Time required to burn through a 1-in.-thick layer of foam exposed to a continuous flame from a propane torch, temperature of 2150° F.
Heat contribution [illegible] Calorimeter [illegible]	Sample is burned in a gasoline-fired furnace and time-temperature curve is recorded. A non-[illegible] and time-temperature curve is [illegible] gives value of sample
Smoke generation ASTM D2843, Rohm & Haas XP2 Smoke Density Chamber *Materials:* Plastics *Use:* Testing for compliance with building codes	Sample is placed in a chamber and is ignited by a propane flame, and smoke density is measured by a photocell across a horizontal 12-in. light path. Most building codes permit materials if maximum light absorption is less than 50%. Uniform Building Code accepts up to 75%
[illegible]	[illegible]