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Fire Retardancy in 2001

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Chapter 1

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Fire is a world-wide problem which claims lives and causes significant loss of property. Some of the problems are discussed and the solution delineated. This peer-reviewed volume is designed to be as the state-of-the-art. This chapter provides a perspective for current work.

In the United States every 17 seconds a fire department responds to a fire somewhere in the nation. A fire occurs in a structure at the rate of one every 60 seconds. A residential fire occurs every 82 seconds. Fires occur in vehicles every 85 seconds. There is a fire in an outside property every 34 seconds. The result is 1.8 million fires per year attended by public fire departments. In 1999 those fires led to $10 billion in property damage and 3,570 civilian fire deaths (one every 147 minutes) and 21,875 injuries (one every 24 minutes). Some 112 fire fighters died in the line of duty. Fires have declined over the period 1977 to 1999, most notably structural fires, from 1,098,000 to 523,000. Civilian fire deaths in the home (81% of all fire deaths) declined from 6,015 in 1978 to 2,895 in 1999. While those declines are progress, the United States still maintains one of the highest rates of fire in the world. One of the remaining needs is to make home products more fire safe (1-4).

The higher rate of fire in the United Sates versus most industrial nations is

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likely a product of five factors: (1) The U.S. commits fewer resources to fire prevention activities; (2) there is greater tolerance in the U.S. for "accidental" fires; (3) Americans practice riskier and more careless behavior than people in other countries (use of space heaters for example); (4) homes in the U.S. are not built with the same fire resistance and compartmentation as in some other countries; and (5) perhaps most importantly, people in the U.S. have more "stuff" than those in other countries (i.e., higher fire load) as well as a higher number of ignition sources (higher use of energy).

Polymers form a major part of the built environment, of the materials around us. Fire safety thus, in part, depends upon those materials. Polymers are "enabling technology," thus advances in numerous technologies depend upon appropriate advances in polymers for success. While polymers are both natural and synthetic, this book largely focuses on the fire aspects of synthetic polymers. Consumption of the five major thermoplastic resins—low-density polyethylene, high-density polyethylene, polyvinyl chloride, polypropylene, and polystyrene—is over 100 million metric tons worldwide. These resins constitute 80% of thermoplastics sold and about 55% of all synthetic polymers sold, including thermoplastics, thermosets, synthetic fibers, and synthetic rubbers. The U.S. constitutes about 25% of worldwide plastics consumption, the European Union about 22%, and Japan about 9% (5). In Table I are presented plastics production statistics in the U.S. for 1999 (6). Table II provides major market application statistics (7). Figure 1 shows the growth in the use of plastics from 1994 through 1999 (8).

All organic polymers are combustible. They decompose when exposed to heat, decomposition products burn, smoke is generated, and the products of combustion are highly toxic, even if only CO and CO_2. Fire performance is not a single material property (if it is a material property at all). Fire performance combines thermal decomposition, ignition, flame spread, heat release, ease of extinction, smoke obscuration, toxicity, and other properties. A regulation utilizes those tests and assessments for materials and systems used in and appropriate to a particular application. Thus, for example, it is appropriate for small appliances to only worry about ignitability by a Bunsen burner flame or a needle flame, since from an internal point of view that is the size of source possible in real life appliance failures.

This volume is about the latest research in the field of fire and polymers. Much work continues focused on improving the fire performance of polymers through a detailed understanding of polymer degradation chemistry. New analytical techniques continue to facilitate that analysis. Creative chemists are at work developing new approaches and new, more thermally stable organic structures. Mathematical fire models are becoming more sophisticated and more broadly applicable. Tests are becoming better understood and some provide data directly usable in fire models. And we are beginning to see the development of science-based regulations for furniture and building materials (particularly in Europe).

Table I. U.S. Plastics Production—1999 vs. 1998 (millions of pounds, dry weight basis[a]) (6)

Resin	*U.S. Plastics Production*	
	1999	*% Chg 99/98*
Epoxy	657	2.8
Urea	2,691	4.3
Melamine	294	1.4
Phenolic	4,388	11.4
Total Thermosets	8,030	7.8
LDPE	7,700	1.6
LLDPE	8,107	12.2
HDPE	13,864	7.3
PP	15,493	12.1
ABS	1,455	1.6
SAN	123	0.8
Other Styrenics	1,644	-0.6
PS	6,471	3.8
Nylon	1,349	5.0
PVC	14,912	2.8
Thermoplastic Polyester	4,846	9.6
Total Thermoplastics	75,964	6.7
Subtotal	83,994	6.8
Engineering Resins[b]	2,765	0.0
All Other Resins	10,702	4.3
Total Engineering & Other	13,467	3.4
Grand Total	97,461	6.3

[a]Except Phenolic resins (reported on a gross weight basis).

[b]Includes: Acetal, Granular Fluoropolymers, Polyamide-imide, Polycarbonate, Thermoplastic Polyester, Polyimide, Modified Polyphenylene Oxide, Polyphenylene Sulfide, Polysulfone, Polyetherimide and Liquid Crystal Polymers.

Table II. Resin Sales by Major Markets (millions of pounds) (7)

Major Market	*1999*	*Compound Growth Rate 1995-1999*
Transportation	3,836	3.2%
Packaging	21,270	5.6%
Building & Construction	19,072	8.9%
Electrical/Electronic	3,256	3.2%
Furniture & Furnishings	3,587	3.0%
Consumer & Institutional	11,802	7.2%
Industrial/Machinery	1,043	6.7%
Adhesives/Inks/Coatings	2,065	3.6%
All Other	10,446	8.9%
Exports	8,622	4.7%
Total Selected Plastics	84,999	6.4%

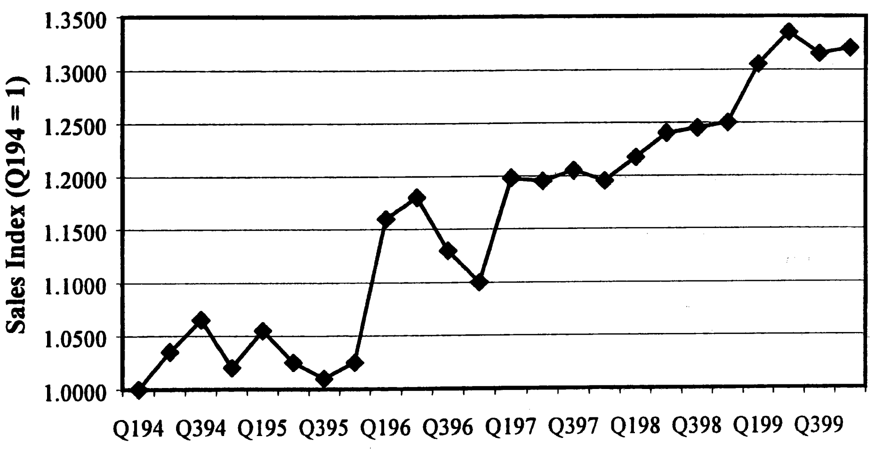

Figure 1. Six-Year Growth Graph: Trend of Sales and Captive Use for Major Plastic Resins (8)

NOTE: Graph represents total sales and captive use of all thermoset and thermoplastic resins. The graph is an index, only meant to display performance of the industry, using 1994 as a base.

There are many diverse approaches to enhancing the fire stability of polymers; in the past the most common approach has involved the addition of additives. Ten years and more ago halogenated fire retardants, synergised by antimony oxide, were the method of choice to enhance the fire retardancy of many polymers. At this time there is a strong emphasis on non-halogenated fire retardants.

As one looks at previous *Fire and Polymers* volumes, topics have clearly changed. In 1990 fire toxicity was the first section with six papers (9). In 1995 there again was a section on fire toxicity with seven chapters (10). In this volume there is but one paper, Chapter 25. This represents the growing recognition that carbon monoxide is clearly the primary toxic gas in real fires, and its concentrations are more dependent upon the scenario than on the materials present. In 1990 there was a section on fire and cellulosics; again, in this volume there is only one chapter on wood, Chapter 28. In the 1995 volume there were twelve chapters on tests and regulation. In the current volume there are really only two. In the current volume the heart of current research is in the area of non-halogen approaches to flame retardancy, including additives and intrinsically fire-retardant polymers (fire-smart polymers). The topic of greatest interest is nanocomposites, although work has yet to get beyond decreases in heat release rates. With a considerable interest in "ecofriendly" materials, the need for new approaches to flame-retardant polymers has increased. That need is represented by half the papers in this volume. That is not to say, however, that very traditional materials are not recyclable; see Chapter 22. This peer-reviewed volume is designed to represent the state of the art.

References

1. Karter, Jr., M. J. *Fire Loss in the United States During 1999;* National Fire Protection Association: Quincy, MA, September 2000.
2. *The National Fire Problem;* United States Fire Administration National Fire Data Center; http://www.usfa.fema.gov/nfdc/national.htm.
3. *Residential Properties;* United States Fire Administration National Fire Data Center; http://www.usfa.fema.gov/nfdc/residential.htm.
4. *The Overall Fire Picture–1999;* United States Fire Association National Fire Data Center; http://www.usfa.fema.gov/nfdc/overall.htm.
5. Nelson, G. L. The Changing Nature of Fire Retardancy in Polymers. *Fire Retardancy of Polymeric Materials;* Grand A. F.; Wilkie, C. A.; Eds; Marcel Dekker: NY, 2000, pp 1-26.
6. APC Plastics Industry Producers' Statistics Group, as complied by Association Survey Resources, LLC. APC estimates. http://www.american plasticscouncil.org/benefits/economic/pips_99_sales_production.html.

7. American Plastics Council; http://www.americanplasticscouncil.org/benefits/economic/pips_resin_markets_sales.html.
8. American Plastics Council; http://www.americanplasticscouncil.org/benefits/ economic/pips_six_year_graph.html.
9. *Fire and Polymers, Hazards Identification and Prevention;* Nelson, G. L.; Ed.; American Chemical Society: Washington, DC, 1990.
10. *Fire and Polymers II, Materials and Tests for Hazard Prevention;* Nelson, G. L.; Ed.; American Chemical Society: Washington, DC, 1995.