NIST/NBS FIRE RESEARCH AND FRCA: 25 YEARS OF PROGRESS

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NIST/NBS Fire Research and FRCA:
25 Years of Progress

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INTRODUCTION

1973 was a significant year for fire safety in the United States. The National Commission on Fire Prevention and Control delivered its report, *America Burning*, to the President. The report documented the severity of the U.S. fire problem and the indifference with which Americans confront it. Their message was that the public needed to be protected from unwanted fires and recommended steps to do this. One of the outcomes of this was the Federal Fire Prevention and Control Act of 1974, which established the Center for Fire Research (CFR) at the National Bureau of Standards (NBS). Fire research has undergone a significant evolution since then. Organizationally, NBS has become the National Institute of Standards and Technology (NIST); and fire research has become part of the mission of the Building and Fire Research Laboratory (BFRL). Philosophically, however, a continuing theme has been a close relationship with materials manufacturers and their associations in helping to accelerate the acceptance of materials and products with improved fire safety performance. This paper will describe the NBS/NIST role in some seminal advances in materials fire research during the past quarter century and conclude with a view of what lies ahead.

A second occurrence that year was the formation of the Fire Retardant Chemicals Association. The timing relative to the release of *America Burning* could not have been better. The fire hazard of products continues to be poorly understood by the buying public. The level of fire safety called for in the report would depend on improved fire standards for materials and the products made of them. Fire retardant additives have become the method of choice for enabling inherently flammable products to be used to achieve a desired measure of safety.

NBS AND THE FIRST GENERATION OF FIRE TEST METHODS

The National Bureau of Standards was founded in 1901, an outgrowth of the little Office of Standard Weights and Measures. It reflected the dramatic rise of science and inventions, and the burgeoning need for ways to measure the properties and performance of products in the new American life style.

Just three years later, the fledgling NBS was given its first assignment in fire safety. Earlier that year, a major deflagration had destroyed one-fourth of the city of Baltimore. While there was a sufficient supply of water to have doused the flames well before this damage occurred, the fire vehicles from the surrounding municipalities were unable to connect to the city water system because their hoses did not match. NBS was quickly charged with developing a standard set of hose couplings. This early accomplishment was just the beginning of a number of fire safety assignments given to NBS by the Congress.

The most enduring contribution of NBS was initiated by the Congress in 1914. With the country faced with fire losses ten times that of any country in Europe, NBS was charged with determining the fire resistance properties of building materials. This was also a landmark program in that it was the first partnership with the young National Fire Protection Association and Underwriters Laboratories, both founded in the 1890s. The methods, especially what became ASTM E119, and data developed over the next 35 years in that joint effort are still the mainstay of fire safety in the U.S.

World War II and the years immediately following saw NBS begin work in a variety of aspects of fire safety. The war effort led to the start of NBS work on the flammability of organic materials. Products ranging from combat garb to aircraft housings needed to be functional yet fire safe. In 1950, the Department of Defense asked NBS to develop a method for determining the susceptibility of materials to thermal radiative ignition. Their concern was with the aftermath of a nuclear blast. However, as is often the case, this work laid the foundation for a number of eventual radiant exposure tests, such as ASTM E162. About the same time, NBS became involved in testing the effectiveness of fire extinguishers in conjunction with DoD and the Coast Guard. The results led to the Navy studying the use of potassium bicarbonate, still a mainstay of fire suppression, known as "Purple K." Other work sponsored by the Air Force led to the NBS development of principles for fire detectors based on spectral radiation as well as rapid flame flicker.

In 1953, the Congress passed the Flammable Fabrics Act; and in response, a new NBS team of researchers with expertise in both fire and textile properties was assembled. Over the next 20 years, their research led to test methods and enabled standards that have had major impacts on fire safety for the American public: children's sleepwear, upholstered furniture, mattresses, etc. These created an enlarged market for fire retardant additives, and eventually was a factor in the founding of the Fire Retardant Chemicals Association.

Concerned about the smoke measurements being derived from the Steiner Tunnel, in the 1960s NBS began research on an improved approach pioneered by Rohm and Haas. This became ASTM E662 and NFPA 258, known as the "NBS smoke chamber."

Thus, as the initiation of the Fire Prevention and Control Act of 1974 approached, the several NBS fire programs had begun to make contributions in the range of fields instrumental in improving fire safety.

THE CENTER FOR FIRE RESEARCH

On October 29, 1974, President Gerald Ford signed into law the Fire Prevention and Control Act of 1974. Sec. 16.(a) of this Act "established within the Department of Commerce a Fire Research Center which shall have the mission of performing and supporting research on all aspects of fire with the aim of providing scientific and technical knowledge applicable to the prevention and control of fires." The content of this program was to include:

"(1) . . . basic and applied fire research for the purpose of arriving at an understanding of the fundamental processes underlying all aspects of fire. Such research shall include scientific investigations of --

(A) the physics and chemistry of combustion processes;

(B) the dynamics of flame ignition, flame spread, and flame extinguishment;

(C) the composition of combustion products developed by various sources and various environmental conditions;

(D) the early stages of fires in buildings and other structures, structural subsystems and structural components in all other types of fires, including, but not limited to, forest fires, brush fires, fires underground, oil blowout fires, and waterborne fires, with the aim of improving early detection capability;

(E) the behavior of fires involving all types of buildings and other structures and their contents (including mobile homes and high-rise buildings, construction materials, floor and wall coverings, coatings, furnishings, and other combustible materials), and all other types of fires, including forest fires, brush fires, fires underground, oil blowout fires, and waterborne fires; . . .

(H) such other aspects of the fire process as may be deemed useful in pursuing the objectives of the fire research program;

(2) research into the biological, physiological, and psychological factors affecting human victims of fire, and the performance of individual members of fire services, including --

(A) the biological and physiological effects of toxic substances encountered in fires; . . .

(C) the development of simple and reliable tests for determining the cause of death from fires. . . "

Further, "The Secretary (of Commerce) is authorized to encourage and assist in the development and adoption of uniform codes, test methods, and standards aimed at reducing fire losses and costs of fire protection."

The United States now had its first formal, modern fire research program. This was further augmented when the National Science Foundation transferred its fire research grants program to the new Center.

The initial emphasis of the Center for Fire Research was on intervention in those fire scenarios that resulted in the largest loss of life and number of serious injuries. From this effort emerged a series of new fire test methods related to engineering materials and textiles. Some of the most important are:

- Cigarette ignition test for upholstered furniture. This mock-up test became standardized as ASTM E1352 and NFPA 261. It was adopted by BIFMA as a standard for institutional furniture.

- General wearing apparel. The method was transferred to the new Consumer Product Safety Commission.

- Ignition of thermal insulation materials, a hazard that rose to serious levels during the energy crisis of the 1970s.

- Rate of heat release. NIST pioneered the use of oxygen consumption calorimetry for measuring the rate of heat release at both bench- and full-scale. The development of the device known as the Cone Calorimeter (ASTM E1354) was just one part of an extensive research effort that showed that rate of heat release is the single most important characteristic of fire growth.

- Ignition and Flame Spread. This method, ASTM E1321, commonly referred to as the LIFT (Lateral Ignition and Flame Travel), produces data that are tied to the theory of product fire behavior.

- Room Fire Testing. NIST performed substantial testing and analysis that enabled ASTM to produce its Standard Guide for Room Fire Experiments, ASTM E603. Most full-scale fire tests are currently performed following this protocol.

In 1974, 25 organizations involved in the manufacture or sale of cellular plastics and their components signed a consent agreement with the Federal Trade Commission. The resulting trust fund supported a 5-year program centered in CFR to provide improved practices for testing and use of these products. In better defining the fire behavior of these materials, the results furthered the intelligent use of fire retardant chemicals.

In addition to these engineering efforts, the Center sponsored fundamental research on the chemical mechanisms of fire spread and retardancy:

- Gas-phase effectiveness of phosphorus-based retardants.
- Gas-phase chemistry of halogenated flame inhibitors.
- Condensed- and gas-phase mechanism of the antimony-halogen system.
- Ignition, flame spread and retardation of cellulosic fuels.
- Suppression of smoldering of cellulosic materials.

In the early 1980s, CFR initiated research into the links between the detailed polymer chemistry of a material and its fire behavior. After several years of fundamental investigation, applications of this science to practical products is evident. This will be discussed further in the next sections.

In 1989, CFR released HAZARD I, a methodology for quantifying the hazards to occupants of buildings from fires and the relative contributions of specific products to those hazards. For the first time, it became possible to predict the effects of changes in the fire properties of commercial products on life loss in fires. Over the next decade, significant improvements were made to expand the range of applicability of the method and in the computer software. HAZARD I has seen applications ranging from product development to fire reconstruction.

HAZARD I was also the first vehicle for the use of materials property measurement methods. The conventional use of fire test apparatus had been (and still continues to be) determination of whether a product sample meets a specific pass/fail criterion. In this new environment, a value of the property, e.g., rate of heat release, is measured. It's specific value, relative to that for a different product for the same use, affords an improvement or decrement in the continuum of fire safety.

During the period from 1984 to 1988, FRCA and CFR designed and conducted their first collaborative project. At issue was the toxicity of the smoke from fire-retarded (FR) products relative to that from non-fire-retarded (NFR) equivalents. The fire science community had held that a smoke toxicity measurement was only one component of the data set needed to evaluate the threat to life safety. The project results showed that the smoke yield from the FR and NFR products was comparable. Moreover, because of the more difficult ignition and the reduced burning rate of the FR products, less heat and smoke were produced. This greatly increased the time available for escape. These conclusions demonstrated the value of using both fire retardant products and modern fire hazard analysis.

NIST and BFRL

In 1988, the Omnibus Trade and Competitiveness Act revised the NBS enabling legislation and transformed the Bureau into the National Institute of Standards and Technology. The intent of the bill was to strengthen the support of the institution for industry and to help bring to commercial fruition new and emerging technologies. Soon thereafter, in 1990, the Center for Fire Research and the Center for Building Technology merged into today's Building and Fire Research Laboratory.

The new organization continues to carry out a full research program in fire science and engineering, with a focus on measurement methods and predictive tools. A major component of this program is to produce materials-related fire performance measurement methods and technology, often working closely with industry and Federal government agencies. Some examples are:

- Smoke Toxicity. With sizable support from U.S. industry, we at long last have a validated method for determining the toxicity of smoke from burning products and for putting it into the context of fire hazard. This method is now designated NFPA 269 and ASTM E1678.

- Carpet Flammability. It appeared that the repeatability of ASTM E648 had deteriorated to the point where the test was not serving its intended purpose. NIST worked with the Carpet and Rug Institute to identify the sources of the scatter and restore the utility of this method.

- Transportation Vehicles. NIST has worked extensively with the agencies of the Department of Transportation to appraise current methods and develop new approaches for assessing the flammability of materials used in the interiors of airplanes, buses, rail cars, and mass transit vehicles.

Concurrently, NIST staff have been studying the molecular level processes by which materials, with and without additives, burn. The new understanding is already leading to:

- ways to modify host polymers to improve their flammability,
- guidance for optimal use of fire retardant additives,
- new, scientifically based flame retardant principles for reducing the flame contribution of commodity polymers,
- new additives for reducing the rate of heat release,
- prediction capability for the flammability performance of materials in a bench-scale test from their nanoscale and microscale composition, and
- prediction capability for end-product flammability from bench-scale materials performance.

The interaction between FRCA and the NIST Fire Research Program has become continuous. NIST staff are frequent speakers at FRCA conferences. At the 1994 Conference, NIST staff presented a tutorial on the fire behavior of materials and products. Over the past few years, FRCA has sponsored Nametz/Humphrey students whose research at NIST has included:

- combustion gas analysis using Fourier-transform infrared spectroscopy,
- tomographic analysis of combustion products from flames, and
- char yield from cyanate ester resins.

This summer an FRCA student will work on a project that will enable the quantitative measurement of smoke yield in any medium- or large-scale fire test facility. We can obtain this from light extinction measurements, and our recent work has shown that fuel chemistry has little effect on the specific extinction coefficient for pre-flashover burning. The student will assist with the installation of a smoke meter on the NIST Furniture Calorimeter, testing of its performance, and writing software needed for taking data.

THE FUTURE

The next decades will see unprecedented changes in the way fire safety is provided.

Performance-based Fire and Building Codes. There is a worldwide effort to replace codes that prescribe the performance of each component of a building and its contents with codes in which the ensemble meets the stated objectives of the owner and regulator. An example of such an objective is that occupants have enough time to exit a building before their survival is threatened by the fire. This could be met by a number of combinations of components: low flammability contents and interior finish, effective and early alarm, early flame suppression, etc. Cost, of course, will continue to drive the selection of approaches. Very large savings can be realized by demonstrating that one or more of the components are unnecessary. There will thus be value realized for the degree of fire mitigation provided by a component. For materials, pass/fail ratings will be replaced by performance numbers, perhaps using the same test device. The burden will be on the proposer to assure the specifier that the approach does provide the desired degree of fire safety.

Improved Detection. The concept of smart detectors is not new. These are devices that sense more than one characteristic of a fire and intelligently combine the information to recognize a fire far earlier and surer than the 30-year-old detector technology of today. Adding recognition of the signatures of nuisance alarms further enhances their reliability. Such sensors are already poised for the commercial market.

Clean Fire Suppression. The halons had shown promise for quenching flames with no harm to people and no residue. However, their ozone-depletion chemistry has led to their being removed from production and their being used only in the most critical applications. The search is on for replacement chemicals, with some already being marketed for commercial facilities. It remains to be seen whether one of these chemicals will find acceptance for the large residential market.

New Polymers and Additives. The fire performance of materials and products will undergo significant improvement in the next decade. Pressures for plastic products to be readily recyclable will drive changes in polymer chemistry and product formulations. There are also likely to be environmental demands on the processing of materials, producing reduced heat, carbon dioxide, etc. Competition among polymers and competitors will result in improved properties that the buying public will appreciate. There is a risk that the new products will pose a different level of fire threat.

As always, change presents opportunities, and those for fire retardant additives are enormous. We at NIST will continue to work with manufacturers and associations in helping to meet the challenges of these changes and to accelerate the acceptance of improved fire safety materials and systems.