2. CENTER FOR FIRE RESEARCH IN THE 70s

2.1 CREATION OF THE CENTER FOR FIRE RESEARCH

Until the latter half of this century, the U.S. Congress had not shown much interest in the unwanted urban fire problem. (Unwanted fires denote those caused by accidental, natural and willful hazards, as distinguished from those desired and under control such as a fireplace fire to warm and cheer a room.) Then, beginning with passage of the Flammable Fabrics Act in 1953, this changed. During the next two decades, peaking in the Nixon years (1969-75), a number of pieces of legislation were enacted aimed at improving consumer health and safety, including fire safety. Notable among these were the Occupational Health and Safety Act, The Environmental Protection Act, the Consumer Product Safety Act, and three acts relating to a Federal role in reducing the losses due to unwanted fire. These three Acts - the amendments in 1967 to the 1953 Flammable Fabrics Act, the Fire Research and Safety Act of 1968 (PL 90-259), and the Federal Fire Prevention and Control Act of 1974 (PL93-409) constitute a considerable effort on the part of Congress to do something about fire losses in the United States. Each called for a major role for the National Bureau of Standards (NBS) in research and technology. So why this sudden attention to a problem that had traditionally been left to state and especially local governments?

Until the middle of the nineteenth century protection from the ravages of fire had been the province of private fire companies and insurance underwriters. As larger fractions of the populations moved into the cities and people were more crowded together, fires became a greater problem. In the big cities the fire companies were taken over by the city governments. Well-engineered water systems were placed so as to provide adequate pressure for fire fighting, and ordinances were passed concerning separations or fire barriers between buildings. These measures, taken mostly by city governments, were directed to preventing conflagrations that could and did involve large sections of cities - even, sometimes, entire cities.

Concern gradually shifted to preventing the loss of large, individual buildings. Still mostly city governments' work, building codes came into being, tests for fire worthiness were devised and required, organizations such as the National Fire Protection Association, the Underwriters' Laboratories, the American Society for Testing and Materials were established. The NBS was created in 1901 and one of its early experiences with fire standards came after the great Baltimore fire of 1904 in which it was found that fire hose couplings from different cities and towns could not attach to the Baltimore Fire Department's fire hoses and hydrants. NBS, working in collaboration with other organizations, created standards for fire hose couplings and for many years kept standard artifacts for adapters for the many different hydrants in the country.

For the first 50 years or so of NBS' history there was a steady progression of field and laboratory work on fire endurance. Fire endurance denotes the ability of building components to maintain their load bearing and separation functions for prescribed time periods when exposed to fire. Burnout tests were conducted in rooms and buildings to measure the temperatures produced in fires and their durations. Laboratory tests were developed and perfected for use in building codes. Many of these were for evaluating prolonged resistance to the stresses from prescribed fire exposures, usually in the form of standard time-temperature relationships, in a large furnace. The furnaces could be configured to test columns, floors, walls roof assemblies and ceilings. The code could then specify, according to occupancy and location in the building, a particular duration; e.g., 1/2, 1, 2, or even 4 hour ratings. Thus the lower structural members of a tall office building might be expected to resist fire exposure for 4 hours, giving the fire service time to gain control without collapse of the building. By the 1960s this work was mature and the Nation's building codes controlled fire safety in large buildings very well. Indeed, it was by then possible to say that in the United States we no longer lost towns and cities or large buildings when they were built and maintained according to code. Nearly all conflagrations or large building fires causing multiple deaths and major monetary loss could be attributed to "out-of-code" construction or use or to large natural disasters.

This seems no longer valid following the events of September 11, 2001. The disaster at the World Trade Center in New York City involved both severe impacts and severe fires ending with collapse of both towers. There now is concern that then applicable and current codes may not require sufficient evaluation of beam-column ensembles and beam to column connections. There also is concern that current temperature-time relations for fire testing do not adequately represent all potential fire exposures. New research is expected to improve test methods and code requirements.

Still, the fire losses in this country had become large and politically sensitive. America Burning [1] cited annual deaths approaching 12,000 and annual costs conservatively exceeding $11 billion. What had happened? Review of the fire loss data suggested that, to make further reductions in our losses, we had to shift focus from large commercial and multi-occupancy buildings to residences and from fire spread to ignition. We also had to think of preventing individual life loss. Thus we had to look at the products brought into the residence and their behavior both as ignition sources and as agents for the growth and spread of fire within the space of fire origin.

2.1.1 THE FLAMMABLE FABRICS ACT

One of the early expressions of concern by the Congress was passage of the Flammable Fabrics Act in 1953. This Act was directed to removing from the market certain textile products that became known as "torch sweaters." The material was unusually combustible and a simple vertical flame exposure (in a voluntary standard method of test based on work done at NBS) served as the test. The immediate objective was achieved. By the 1960s, new fabrics and fabric constructions were on the market and studies began to show new problems with flammability. In 1967 the Congress amended the Flammable Fabrics Act and established responsibility among three agencies: the Department of Commerce was to establish test standards and requirements, the Department of Health, Education, and Welfare was to investigate reports of fire injuries and deaths, and the Federal Trade Commission was to enforce the Act. The Commerce Secretary assigned the standards development work to NBS. A Flammable Fabrics Section was set up under James Ryan and subsequently an Office was established under the Institute for Applied Technology (IAT) at NBS.

2.1.2 THE FIRE RESEARCH AND SAFETY ACT OF 1968

In 1968 the Congress expanded its concerns to all sources of losses from unwanted fire and enacted the Fire Research and Safety Act. This Act authorized a new National Commission to see why the U.S. had such high fire losses and what might be done to reduce unwanted fires and to mitigate the effects of those that do occur. The legislation further enhanced the technical role of the NBS by setting up a second office called the Office of Fire Technology. This group was charged with looking at ways to utilize modern technology both in fighting fires and in assisting the fire fighter by improving the tools and equipment available. So by the end of the decade NBS found itself with three essentially independent entities, all looking at some aspect of unwanted fire: the fire section in the Division of Building Research, the Office of Flammable Fabrics, and the Office of Fire Technology. The division and both offices were under the direct supervision of the Institute of Applied Technology.

2.1.3 THE AD HOC PANEL ON FIRE RESEARCH AT NBS - THE NATIONAL RESEARCH COUNCIL

This somewhat fragmented situation caused NBS management to request of the National Research Council (NRC), an ad hoc Panel on Fire Research specially chartered to evaluate fire research at NBS and to make recommendations on how to improve the quality of work product. This panel, chaired by Professor Howard Emmons of Harvard University and made up of an eclectic mix of professional interests drawn from around the country, made an in-depth study of what NBS was doing and wrote, in 1972, a detailed review with 34 numbered recommendations. The report called for a careful analysis of the National needs followed by a selection of those challenges that NBS could appropriately handle - a comprehensive plan. The report emphasized the need to think about the fire problem in a fundamental way and urged that fundamental work at NBS be expanded. It also urged that NBS' work on fire be tightly coordinated. The succeeding 1973 NRC report praised NBS efforts to pull fire research together, urged creation of a fire dynamics group, worried about hazards from new materials; e.g., plastics, and said that the work on smoke and toxic gases needed strengthening. The panel felt studies of smoke and fire detectors were going well. The need for better large-scale fire test facilities was emphasized. The ad hoc panel was converted to a regular, recurring panel soon thereafter and reported annually.

2.1.4 THE FEDERAL FIRE PREVENTION AND CONTROL ACT OF 1974

This legislation created the National Fire Prevention and Control Administration, the National Fire Academy, and a Fire Research Center at NBS. The intent was to come to grips with the National fire problem and to define a Federal role to work in tandem with the States and municipalities and the various groups in society already at work. Some NBS functions for fire fighter's equipment and training were transferred to the newly created U.S. Fire Administration and the U.S. Fire Academy. The new Consumer Product Safety Commission was just getting under way at this time and NBS transferred part of the effort on flammable fabrics, retaining the standards development work but transferring the evaluation of fire data on burns. Thus the area of work for the NBS was made clear. In fact it was spelled out in more detail than any other part of the Bureau.

The Act of 1974 amended the organic act of the NBS to establish the Fire Research Center. It authorized a long list of research areas that were included in the organic act by amendment. These are:

"(1) basic and applied research for arriving at an understanding of the fun-

damental 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 under 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 … with the aim of improving early detection capability;

(E) the behavior of fires involving all types of buildings and other structures and their contents, … and all other types of fires, including forest fires … oil blowout fires …;

(F) the unique fire hazards arising from the transportation and use, in industrial and professional practices, of combustible gases and materials;

(G) design concepts for providing increased fire safety consistent with habitability, comfort and human impact in buildings and other structures; and

(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;

(B) the trauma, cardiac conditions, and other hazards resulting from exposure to fire;

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

(D) improved methods of providing first aid to victims of fires;

(E) psychological and motivational characteristics of persons who engage in arson and the prediction and cure of such behavior;

(F) the conditions of stress encountered by firefighters, the effects of such stress, and the alleviation and reduction of such conditions; and

(G) such other biological, psychological, and physiological effects of fire as have significance for purpose of control or prevention of fires; and

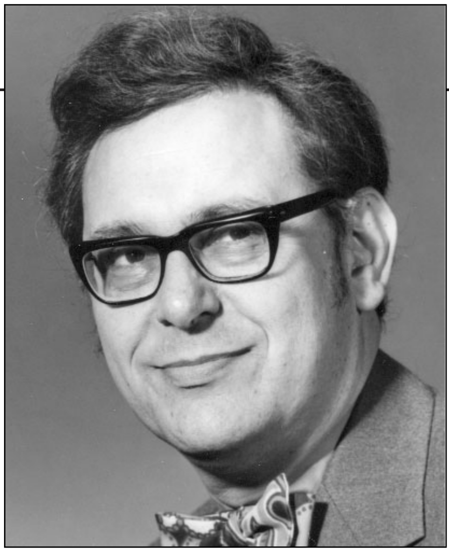
"(3) operation tests, demonstration projects, and fire investigations in support of the activities set forth in the section.

"The Secretary [of Commerce] shall insure that the results and advances … are disseminated broadly. He shall encourage the incorporation … in building codes, fire codes … test methods, fire service operations and training and standards. …"

John W. Lyons, a physical chemist, had been hired in 1973 to head the newly consolidated fire program. He arrived before the legislation was passed and became the founding director of the Center for Fire Research (CFR). Irwin Benjamin, an expert in uses of structural steel and the leader of the fire section within the Center for Building Technology's (CBT) Structural Division, joined CFR to become leader of its fire safety engineering work. Benjamin's personal commitment to fire safety, vision, skill in recruiting and mentoring his staff, insight into the best opportunities to improve fire safety, and knowledge of how to get improved practices accepted and applied in the fire safety community were key in CFR's achieving its goal to halve fire losses in a generation. Lyons hired Robert Levine from NASA to lead CFR's fire science activities. Levine came to CFR as a leading rocket scientist. He made strong contributions to CFR through his knowledge of combustion science and peer scientists worldwide, and his enthusiasm for good work in both fire science and fire safety engineering. Frederic Clarke, an organic chemist, joined CFR as assistant to the director.

CFR was established on October 29, 1974, when President Ford signed the Federal Fire Prevention and Control Act of 1974. NBS had anticipated this action and had in place a Programmatic Center for Fire Research headed by John Lyons and involving 110 federal employees.

John Lyons, founding director, Center for Fire Research during 1973 to 1977 when he became founding director of NBS's National Engineering Laboratory. Lyons' experience in industry, expertise in fire science and its applications, delight in strong technical work, and concern for people provided a strong start for CFR. His talents led to his promotions in 1978 to become the founding leader of the National Engineering Laboratory, and in 1990 to become director of the National Institute of Standards and Technology until 1993.



Irwin Benjamin, initial leader of Fire Safety Engineering.

Robert Levine, initial leader of Fire Science.

2.1.5 A LONG-RANGE PLAN FOR NBS FIRE RESEARCH - FIRE SCENARIOS AND INTERVENTION STRATEGIES

The detailed listing of the 1974 Act would seem to leave nothing to chance; it certainly authorized NBS staff to study whatever seemed necessary. However the list was only authorized, not mandated. Given the resources then available or likely to be, a host of choices had to be made to plan and execute the actual research program. Soon after the legislation was signed into law, the director of NBS requested of the director of the Center for Fire Research a detailed long-range research plan with a rationale for the proposed work [2]. In response the managers of CFR and some of the key research staff spent much time meeting together to develop an approach that took into account what was then known about the etiology of unwanted fires, the sequences by which the fires moved from ignition to growth and spread, and the ultimate cause of the losses through death, injury and destruction of property [3]. They called these sequences fire scenarios.

The NRC reports had prepared the way for carrying out the subsequent provisions of the Federal Fire Prevention and Control Act of 1974. The report of the Federal Commission on Fire Prevention and Control (1972) had declared that it should be possible to reduce the Nation's fire losses by half in about 14 years. The CFR planners took the 50 percent figure but stretched the timing to some two decades and then sought to define the technical work that would be needed to underpin the various interventions that would be required in those key scenarios that accounted for most of the fire losses. The goal for CFR became:

> *To insure the development of the technical base for the standards and specifications needed in support of the National goal to reduce fire losses by 50 percent over the next generation.*

The CFR staff took it as their responsibility not only to conduct and publish the technical work but also to see to it that the results were widely promulgated and adopted by the community at large. There was some concern by some staff that such objectives went beyond the ability of the staff to control outcomes. While this was certainly true we felt strongly that the Congress was funding the work for the change in fire losses, not for publications, however important.

2.1.6 TECHNICAL CHALLENGES FOR FIRE RESEARCH

A large number of technical challenges faced CFR.

Challenges deemed important by management were:

1. **Lack of tests that are scientifically based to meet legal challenges to imposing tests in regulations and codes. For instance, one cannot test at one irradiance if one wants to take into account the heat from the material's combustion in addition to that from the exposing flame or source; the use of a simple flame or single exposure is useful only for ignition tests.**
2. **Lack of tests at bench scale that correlate closely to performance in full-scale fire tests - hence the costly need to "build it and burn it."**
3. **Lack of mathematical models good to within 10 percent or so for predicting key events: e.g., flashover, toxic levels of gases. Fires are turbulent, reacting, buoyant flows with low symmetry - no two fires are the same.**
4. **Lack of first principles models to provide credibility for simplifying assumptions in zone models.**
5. **Lack of thermo-chemical and thermo-physical data on modern materials and composite structures for input to mathematical models.**
6. **Dearth of information on toxicity of combustion products - the predominant cause of death in fires: no standard test for toxicity, no tie between testing for toxicity and for ignition, spread, and growth.**
7. **No reference materials for calibration of instruments.**
8. **Lack of understanding of the molecular details of combustion such as soot particle formation and its effect on flame radiation and heat transfer.**
9. **Lack of rugged, calibrated instruments for looking into fires, and thermal lag in thermocouples.**

2.1.7 ORGANIZING THE RESEARCH

After transferring those pieces of the work that more properly fit the missions of the Consumer Product Safety Commission and the Fire Administration, there remained the task of putting together the new Fire Research Center, or in NBS custom, the Center for Fire Research (CFR). The programs involving fire then in the Center for Building Technology were moved into CFR and combined with the remaining parts of the flammable fabrics work and the fire research and safety functions. The several analyses and plans referred to above led easily to a new emphasis on the fundamentals and the creation of the Fire Science Division in which were chemistry, physics and dynamics, and an office of information and hazard analysis. In a short time chemistry became chemistry and toxicology, and a few months later this group split into two groups emphasizing the growing importance placed on the toxicity of combustion products. The engineering-oriented work was placed in a Fire Safety Engineering Division with groups on fire prevention - products (flammable fabrics and related ignition work), fire control in construction, fire control in furnishings (growth and spread of fire), fire detection and control (detectors and sprinklers), and new design concepts. This two-division structure worked well for a number of years. There were some permutations and the transfer of the National Science Foundation's fire research grants to CFR caused some adjustments.

The organization and key people as of 1975 became:

Fire Science Division, *R. Levine, Chief*
- *Project Manager for Arson, B. Levin*
- *Office of Information and Hazard Analysis, B. Buchbinder*
- *Program for Chemistry, C. Huggett*
- *Program for Toxicology of Combustion Products, M. Birky*
- *Program for Physics and Dynamics, J. Rockett*

Fire Safety Engineering Division, *I. Benjamin, Chief*
- *Program for Fire Prevention-Products, J. Winger*
- *Program for Fire Control-Construction, D. Gross*
- *Program for Fire Control-Furnishings, S. Davis*
- *Program for Fire Detection and Control Systems, R. Bright*

2.1.8 CFR ACQUIRES NSF'S FIRE RESEARCH PROGRAM

In the late 1960s and early 1970s the National Science Foundation (NSF) program called Research Applied to National Needs was managing a set of research grants awarded primarily to universities, but also to private and commercial research institutions with close ties to universities. NSF had about $2 million a year invested in fire related research. The program was of the highest quality. The Congress decided that a better place for this effort was at the CFR; thus in 1975 they transferred the authority and budget to NBS. This move caused some concern at the Bureau. Some thought it a poor idea to mix in-house work with management of grants or contracts externally. The belief was that the added management role would dilute attention to NBS' laboratory work and that perhaps both would suffer. (This argument returned again both under the Carter Administration, when centers for cooperative technology development were proposed to be located at NBS with major components from the private sector, and later when the Advanced Technology Program, the Manufacturing Extension Program, and the Baldrige National Quality Award were in fact enacted and given to NBS to manage.) However, the choice to accept the NSF grants or not was not NBS' and we went forward with the transfer. The decision was a good one.

A key decision was to assign the oversight of the external work to the individual research groups in CFR. Thus the dynamics work at Harvard/ Factory Mutual, California Institute of Technology, Notre Dame etc was closely followed by the fire physics and dynamics group at CFR and the toxicology work was overseen by the CFR toxicology group. Recommendations as to changes in the work or renewals came from the in-house group leaders. This internal management was made possible through the use of cooperative research agreements as opposed to grants or contracts. The cooperative agreements had recently been authorized by Congress to enable closer cooperation and integration between in-house and extramural work throughout government. In CFR's experience the mechanism worked effectively. It was not long before the interactions became very close and we could consider all of the work - in-house and extramural - as one large integrated program. The benefits to all were great.

2.1.9 1975 ACCOMPLISHMENTS

Accomplishments in 1975 included:

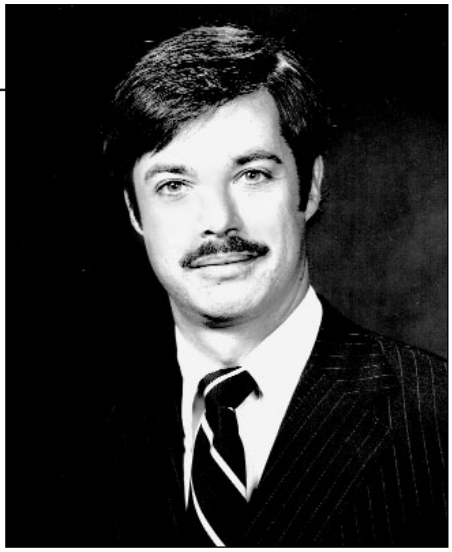
- The pilot implementation of the National Fire Data System was completed and turned over to the National Fire Prevention and Control Administration.
- A relationship was established between flammability limits in premixed and diffusion flames.
- The capability was developed for measuring particle size distribution and mass concentration in smoke.
- A proposed standard for the flammability of upholstered furniture was developed and recommended to the Consumer Product Safety Commission.
- The fire safety of interior components of AM General buses and Metro subway cars was evaluated for the Washington Metropolitan Transit Authority.
- Reduced scale and analytical modeling techniques were developed and tested for predicting fire growth in rooms.
- Recommended performance standards for single-station smoke detectors were adopted and published by Underwriters' Laboratories, Inc.

2.2 EVENTS AND PROGRESS THROUGHOUT THE 70S

In the early 1970s some disastrous fires had been occurring in rooms lined with fire retardant treated cellular plastics. These plastic foams had been deemed to be fire-safe by the bench scale fire tests in use at that time and also by the ASTM E84 tunnel test that is the standard test for interior finishing materials. As a result, the Products Research Committee (PRC) with John Lyons as its chairman, was created in 1974 as a free standing charitable trust in an agreement to a consent order signed between the U. S. Federal Trade Commission and 25 manufacturers of cellular plastics.

Thus, a large investigation was launched to determine: 1) why the existing tests failed; 2) if they could be fixed; and 3) if new tests needed to be developed for these materials. The Products Research Committee members came from industry, testing agencies, government and academia. The committee supported relevant research in a number of organizations including NBS. The funds were provided by the cellular plastics industry.

This work showed that thermal radiation reinforcement by the enclosure was a critical factor in the growth of fire in a room. The building codes now require that cellular plastics be covered by safer materials, or pass a standard room fire test with a substantial ignition source in one corner. A standard



Frederic Clarke, 2nd director of the Center for Fire Research.

room fire test was developed in the civil engineering department at the University of California on a research grant from CFR. William Parker, the project monitor from CFR, worked with Brady Williamson at UC on the design and incorporation of an oxygen consumption system for measuring the heat release rate in the room fire.

John Lyons, beginning in October 1977, organized and directed the new National Engineering Laboratory (NEL). NEL replaced the Institute for Applied Technology (IAT) as the parent organization for CFR and CBT. Frederic Clarke, who had served as Lyons' special assistant for planning and communications, became acting director of CFR and its permanent director in October 1978. Clarke, still in his 30s, showed outstanding scientific and analytical skills, commitment to CFR's goal, and strong interpersonal skills.

The report of the September 1978 Annual Conference on Fire Research [4] summarized the major activities and accomplishments of CFR in fiscal year 1978.

Benjamin Buchbinder's Program for Information and Hazard Analysis described, with the example of upholstered furniture, how Decision Analysis provided the analytical framework for combining loss and cost estimates for alternative strategies for addressing particular fire problems and selecting the most cost effective strategy. The Fire Research Information Services (FRIS) was described as one of the world's foremost collections of fire research documents.

Richard Gann's Program for Chemistry was seeking a scientifically based susceptibility index for spontaneous ignition, and determining the fire potential of dielectric fluids that could be substituted for the environmentally harmful polychlorinated biphenyls (PCBs) that had been banned as insulating fluids for transformers and capacitors by the Environmental Protection Agency. Oxygen depletion by combustion was shown to be a sound quantitative measure of rate of heat release, and mass spectroscopy was showing valuable capabilities for studying temperatures and chemical processes in flames.

John Rockett's Program for Physics and Dynamics progressed with zone models for the spread and growth of fires and computational fluid dynamics models for flow phenomena in fires. James Winger's Product Flammability Program worked for the Department of Energy to develop methods and procedures to assure adequate fire safety when wood is used for a fuel in residences. William Parker's Construction Materials Program produced a new heat release rate calorimeter and worked on fire hazards of insulations in residential occupancies for the Department of Energy.

Edward Budnick's Fire Detection and Controls Program worked on test methods for smoke and fire detectors and performance of detection systems in health care facilities and mobile homes. Laboratory studies were conducted on the performance of sprin-

John Rockett, leader of Physics and Dynamics, is performing an experiment to model smoke growth and flow in corridors. Rockett had played a leading role in NBS's fire research since the 60s and contributed strongly to the development of CFR.

klers in health care facilities and in open stairways.

Harold Nelson's Program for Design Concepts worked on closing the gap between scientific data and models and the "use system" of standards and codes. Fire safety evaluation systems were under development for health care facilities, group homes and multi-family housing.

Merrit Birky's Program for Toxicology of Combustion Products drafted, in consultation with experts from industry, government and academia, a test method for the identification of materials that produce unusually toxic combustion products. It involved measuring the mid-lethal concentration of combustion products for exposed rats. NBS management was very uncomfortable with on-site animal testing, but a major goal of this work was to reduce needs to conduct animal testing to determine the combustion toxicity of products.

The Third Annual Conference on Fire Research held on August 22-24, 1979, [5] does not describe management issues and cites few major accomplishments. James Winger's Program for Product Flammability Research reported a review of literature, model codes and tests for the fire safety of wood burning appliances in residents and small industries. Standards were recommended to the Consumer Product Safety Commission for cigarette ignition of upholstered furniture and for flammability of general apparel, and to the Federal Aviation Administration for flammability of flight crew uniforms.

The Fire Safety Engineering Division participated with ASTM in the introduction of new test methods and in the improvement of existing ones. These included:

1. Flooring Radiant Panel E 648 for Carpet Flame Spread.
2. Critical Radiant Flux for Flame Spread on loose fill insulation.
3. Smoldering Ignition test.
4. Mobile Home Project: factors affecting life safety given a fire in a mobile home and mitigation of the worst hazards.
5. New time-temperature curve for fire endurance of walls and floor assemblies in residential occupancies. Basement recreation rooms were especially dangerous because of the short time to flashover.
6. Smoke movement in high-rise buildings.
7. The Lateral Ignition and Flame Spread Standard Test (LIFT) apparatus to measure ignition flux and flame spread.

In addition, heat release rate (HRR) was recognized as a most important fire property of materials.

CFR issued its updated Research Plan in August 1979 [6]. The goal of CFR was expressed as:

> *The goal of the Nation is to reduce fire losses by 50 percent by 1995. The goal of the Center for Fire Research is to provide the needed knowledge for making rational and cost-effective choices among alternative strategies for this loss reduction, and to reduce fire as an obstacle to meeting of other national needs.*

The strategy for CFR was:

1. The Center research program will take several simultaneous approaches to reducing fire losses.
2. The Center's approach to improved fire safety is one grounded in an understanding of the fundamentals of fire science.
3. The Center's responsibility includes the conversion of research results into implemented fire safety measures.

Planning was based on the scenarios for fire losses [6] that related fire deaths in the U.S. to occupancy, item ignited and ignition source. Technical issues were identified to address the scenarios and from these action items were identified for fire research:

1. Improved standard test method for smoke detectors.
2. More economical design criteria and performance specifications for sprinkler operation and installation to the National Fire Protection Association (NFPA).
3. Design criteria for optimum use of smoke control/HVAC systems to NFPA and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).
4. Take systematic approach to achieve given level of fire risk with lowest cost combination of fire protection elements.

5. Standard test methods to ASTM International, NFPA for flame spread and rate of heat release of interior finishes.
6. Standard test methods to ASTM, NFPA, and Consumer Product Safety Commission (CPSC) for flame spread, rate of heat release of furnishings.
7. Proposed standards to reduce likelihood of ignition by electrical and heat producing products to Underwriters Laboratories Inc. (UL), Factory Mutual, and the Institute of Electrical and Electronics Engineers, Inc (IEEE).
8. Recommended practices to assess combustion product toxicity as component of life safety hazard.
9. Modeling design decisions to minimize full-scale assembly testing.
10. Design and formulation guide for improving ignition or smolder resistance of composite materials.
11. Specific structural fire resistance requirements based on experimental evidence.
12. Design requirements based on actual human behavior and needs.
13. Standard test method for detectors to NFPA, UL, which identifies detector capability to resist false alarms.
14. Arson detection methods for the National Fire Academy, state arson laboratories through US Fire Administration (USFA).

The Plan then established the objectives for CFR. The Plan was developed just before CFR moved into an extremely difficult decade with unstable funding and funding cuts. Yet, this history will show excellent accomplishment of the objectives.

For Existing Resources

1. To develop a set of performance based design recommendations for automatic suppression systems, with submission of recommended design changes for automatic sprinkler systems to the appropriate authorities in 1983.
2. Develop performance guidelines for the design of both fire detection and smoke control systems; including recommendations regarding whether or not to develop a revised full scale protocol for smoke detection by 1980, and the development of an initial Mechanical Engineers Smoke Control Manual based on state of the art technology by 1981.
3. To identify the importance of combustion product toxicity as part of the overall fire hazard and to provide the test methods and recommended practices for predicting and reducing the hazard, with the development of a toxicity hazard assessment methodology by 1983.
4. To develop test methods for the fire properties of materials and products which can be related to fire hazard; with procedures for ignitability, flame spread, and rate of heart release for upholstered furniture to be completed by 1983.
5. To develop the capability to predict the effects of a fuel's physical characteristics and chemical composition on its fire behavior, with a mechanistic model for radiant ignition developed by 1982.
6. Develop technical background to support measures to reduce the likelihood of unwanted ignitions associated with the generation, distribution, and use of electrical energy and use of heat producing equipment or processes with recommendations to reduce ignitions from residential electrical power systems in 1983.
7. To develop a validated, physically based predictive method for describing the growth of fire in a building, with a documented validated room fire model by 1983.
8. To provide the full-scale fire test data needed to verify the physical and analytical fire growth models, to support the development of standard fire test and to assess the hazards of materials as exemplified by the development of a correlated reduced scale room fire test by 1981.
9. Develop and apply methodology for evaluating alternative strategies for reducing fire losses based on cost benefit considerations, with an initial analysis of residential fire loss reduction strategies by 1982.
10. Synthesize fire research, fire protection engineering, and human behavior technology into systematic technically based approaches to fire safety design, with the issuance of initial approaches to comprehensive design evaluation and cost effectiveness systems by 1983.

11. Establish by 1983, a battery of analytical methods and procedures for use in the field and laboratory detection of arson.
12. To transfer information on both fire research and the interpretation of fire research to various publics: e.g., designers, fire researchers, fire services, and standards organizations. An example of this transfer will be the incorporation of the NBS developed Fire Safety Evaluation System into the 1980 edition of the Life Safety Code.

For New Resources (which were not received)

1. To publish a home fire safety design manual and curriculum by 1985.
2. To develop the instrumental capability and technical competence to define the role(s) of oxygen in the various modes of fire-related combustion, with a model of the oxygen involvement in oxidative pyrolysis by 1982.
3. To exploit the mechanics of smoke and aerosols, and new fire detection sensor principles to eliminate false alarms by 1985.
4. To improve existing knowledge of the physiological effects of fire and to recommend methods of treatment by 1985.
5. Develop, by 1983, the competence to analyze and identify methodologies for controlling fire losses associated with storage and transportation of hazardous materials.

The Department of Commerce provided strong recognition for CFR's accomplishments in its awards of Gold and Silver medals:

- Gold to Alexander Robertson in 1976 for career accomplishments in improvements of fire safety standards.
- Gold to John Lyons in 1977 for leadership of CFR.
- Silver to Richard Bright in 1976 for his work in improving the performance of residential smoke detectors.
- Silver to John Rockett in 1977 for advances in fire modeling.
- Silver to Clayton Huggett in 1978 research in flame inhibition.
- Silver to James Winger in 1978 for research in fabric and furniture flammability.
- Silver to Irwin Benjamin in 1979 for the development and adoption in standards of the Fire Safety Evaluation System.

The National Bureau of Standards conferred its Rosa Award on Alexander Robertson in 1978 for development of standard flammability test methods.

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