Attacking the Fire Problem:
A Plan for Action

Kenneth Giles and Pamela Powell, Editors

Programmatic Center for Fire Research
Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

U.S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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PREFACE

On October 29, 1974, President Ford signed into law the Federal Fire Prevention and Control Act of 1974. This legislation, the direct result of the findings of the President's Commission on Fire Prevention and Control, reflects the Commission's findings that America's fire losses are disgraceful and totally unacceptable to a country whose level of technology and human resources is the highest in the world.

The Congress intended the Federal Fire Prevention and Control Act of 1974 to provide new impetus to solving the Nation's fire problem. Section 18 of the Act provides for the establishment of a Fire Research Center and, accordingly, amends the 1901 Organic Act of the National Bureau of Standards. The Fire Research Center is charged with understanding fundamental processes of fire, including its physics and chemistry; its behavior, spread and growth in buildings; the fire hazards uniquely arising from transportation of combustible fluids and materials; and design concepts for increased fire safety in the built environment. Further, the Congress authorized the Fire Research Center to carry out investigations into the biological, physiological, and psychological factors affecting the victims of fire. In particular, the biological and physiological effects of toxic substances on fire victims, and the psychological and motivational characteristics induced either by fire stress or fire trauma are to be systematically studied for the first time.

Thus, the Congress has created within the National Bureau of Standards a Fire Research Center with a broad mandate for understanding fire and its myriad effects, and for reducing the unconscionable losses which attend it.
Tools to reduce fire losses by 50%

Goals

Fire Safety Engineering

Fire Science

A Plan for Action

Attacking the Fire Problem
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Abstract

The mission of the Center for Fire Research is 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% over the next generation. A systems approach to accomplish this mission is described. The Center consists of three basic programs in the area of Fire Science and five applied research programs in the area of Fire Safety Engineering. Each applied program addresses an aspect of the Fire Problem, using fundamental information supplied by the basic research function. Active participation by staff members in voluntary standards organizations is the principal means of making this technology available for codes and standards need to reduce the Nation’s fire loss.

Key words: Building design; consumer protection; fire control; fire detection; fire research; fire spread; flammability.
Center for Fire Research

MISSION:

ATTACKING THE FIRE PROBLEM

The goal of the Center for Fire Research is 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% over the next generation.
Fire Problem
Attacking the
CONFRONTATION
Unwanted fire reaps a grim toll in the United States. Each year more than twelve thousand of our citizens die in fires and several hundred thousand more suffer serious burn injuries. In addition to this human suffering, property damage drains some eleven billion dollars from our economy. These figures, stark in themselves, are all the more shocking when they are contrasted with figures from other industrialized countries. For example, Japan reports 0.61 fires for each thousand persons as compared to 18.0 for the United States. Japan has 14.2 fire deaths for each million persons vs. 57.1 in the United States. Figures can be recited for several European countries to the same effect. While the statistical basis for these figures is less than perfect, the unfavorable position of the United States seems beyond dispute.

No one knows why our Nation's losses are so great, although some of the very characteristics which make the United States unique may also contribute to the problem. For example, our homes are generally of wood construction, as compared to the stone and concrete commonly used in Western Europe, and they are replete with plush furnishings. Further, there is some correlation between energy consumption and fire incidence. An important social factor is the attitudes people have: in the United States we view fire as a misfortune or an unavoidable accident, while Japan deals with the fact of having a fire as a felony.

Despite the fact that unwanted fires are complex phenomena with cause and effect poorly understood, simplistic solutions abound. Some call for intense public education as the only answer, on the assumption that most fires are caused by people. Others believe that using such devices as automatic sprinklers in all occupancies will solve the Fire Problem. Yet, both of these approaches have their limitations. For example, much of human behavior, especially that of infants, the very old, and the mentally handicapped, is uncontrollable. The victims of this behavior may be other innocent persons, perhaps asleep in neighboring rooms. We must deal with the problem on the assumption that people will, on occasion, be careless and that accidents will happen. Yet, life safety is often endangered well before a fire reaches the detectable threshold for sprinkler systems, however reliable they may be. Therefore, it should be clear that a single remedy for the entire scope of the Fire Problem does not exist or, if it does, it will only be uncovered by further research.

The National Bureau of Standards has been the Nation's fire research laboratory for over five decades;¹ our laboratory facilities for fire research are excellent. The staff cooperates closely with the individuals and groups at home and abroad who are working to decrease fire losses. The fire services, the Congress, various universities, the program on Research Applied to National Needs (RANN) at the National Science Foundation, the National Fire Protection Association, building code officials and voluntary standards organizations share with us the challenge to make our environment safer from the ravages of fire.

We are just now gaining a measure of quantitative understanding of fire phenomena. Fire technology is moving slowly from childhood to adolescence, but it is a long way from being a mature science. Nevertheless, action on fire cannot wait for a total understanding of the appropriate physical and chemical phenomena.² The world demands, now, criteria and recommended practices for controlling fire hazards. In short, an attack on the problem is needed!

Only a balanced approach will provide interim solutions that are both technically sound and immediately applicable. Fire science - its chemistry and physics - and statistical analysis of fire incidence serve as inputs and guides. Fire safety engineering transforms these inputs into the tools the Nation needs to reduce fire loss. The National Bureau of Standards (NBS) directs the results of all these activities to the agencies and organizations with authority to set standards and specifications.

While the urgency of the Fire Problem cannot be understated, its scope and complexity require that we take a sophisticated systems approach comprised of a balanced attack along a broad front of fire research. The following pages outline that approach and constitute a blueprint for action for the NBS Center for Fire Research.

Fire Research Center for Fire Problem Attack
Objectives: to characterize national fire hazard and loss...to identify problem areas, to provide a detailed knowledge of them, and to establish priorities for action...to establish a baseline for measuring program effectiveness...to keep in-house staff and others aware of developments in the fire field.


Chemistry Program

Objectives: To upgrade understanding of the structure and chemical composition of flames and the effect of chemically evolved smoke and combustion gases on smoke and toxic gas formation.
Program for Chemistry

Clayton Huggett, Chief

Current Activities:

- The structure of typical flames, including flames containing chemical retardants, is being studied experimentally by mass spectrometric techniques and theoretically through thermodynamic calculations.

- Major components in combustion samples are quantitatively determined using gas chromatographic, infrared spectroscopic, and wet chemical techniques. Combustion gas analysis equipment will be improved to monitor components (e.g., hydrogen cyanide) continuously. Correlation of laboratory and full-scale smoke and gas measurements will be made.

- Liaison is maintained with other fire research programs to study flame retardants and other aspects of flame chemistry.

- Contracted research studies chemical kinetics and flame dynamics and develops models of flames and flame inhibition.

- A study of the fire safety aspects of polymeric materials is being jointly sponsored with the National Academy of Sciences.

- Under NBS grants, the University of Pittsburgh and the University of Utah are studying the toxicity of combustion products from plastics.

- Princeton University, under an NBS grant, is modeling the generation of toxic gases by smoldering combustion.

- Charring polymer flame retardant mechanisms are being studied for NBS by the University of California.

- The chemistry and methods of controlling cellulose fires is researched for NBS by the University of Montana.

- Clemson University is studying flame retardation mechanisms in fabrics for NBS.

- An investigation of hydroxyl radical reactions of fundamental importance to flame initiation and propagation is being carried out at the University of Maryland.

- Johns Hopkins University is conducting a fire fatalities study for NBS.

Program for Chemistry Publications:


Physics and Dynamics for Program
Program for Physics and Dynamics
John Rockett, Acting Chief

Current Activities:
- A model corridor test facility is being used to investigate the use of partial scaling relationships in simulating full-scale corridor fire spread over flooring materials.
- A mathematical model of ignition phenomena has been constructed which successfully predicts ignitable boundaries of various solid fuels under various environmental conditions.
- Preliminary measurements are being made of the aerosols and gaseous products given off in the early stages of a smoldering upholstery fire.
- Contractors are working to develop mathematical models of fire under a variety of conditions.
- Under an NBS grant, the Massachusetts Institute of Technology studies the physical and chemical kinetic models of flame propagation and inhibition.

Physics and Dynamics Publications:
Program for Fire Prevention

• Products

Objective: to develop and recommend standards or other regulations to control fire safety aspects of consumer products, particularly in support of the Consumer Product Safety Commission.
1. **Fire Prevention - Products Publications**

   - The effect of dry cleaning on flame retardant fabrics is being studied.
   - The Textile Research Institute, under NBS contract, studies the flamemittability and combustion behavior of textiles.
   - The University of Maryland is investigating the ease of laundering flamemittability to determine whether standards are being repeated.
   - Conclusions study the effects of seams, seam finish construction, and other variables on fabric.
   - Comparative testing conducted on weathered apparel.
   - NBS flame retardant fabric test method development and other work on new flamemittability test method development is being considered.

2. **Program for Fire Prevention - Products**

   - Abstracts of Papers on Testing and Analysis of flamemittability.

3. **Current Activities**

   - James Winter, Chief

   **Program for Fire Prevention - Products**
Program for Fire Control
• Furnishings

Objective: to characterize the fire hazards of interior furnishings and to develop test methods for their control.
Program for
• Fire Control
Construction

Objective: to study the flammability characteristics and fire performance of construction materials and assemblies... to develop test methods for various building components... to develop models to predict the course of fire in buildings.
Technical Approach for NBS:

Building Design and Urban Planning: A Social, Economic, and Environmental Study, "Fire Safety, in

Analytical Methods: Estimating the Thermal Performance of NBS.

The development of analytical methods is being proposed in

A literature review of the characteristics of smoke generated in

A versatile, flame spread test is being developed.

The smoke density chamber test is being used for research.

The fire load survey is to update basic data for codes.

Fire-resistant models are being developed to estimate the fire

Mathematical models are being developed for buildings.

The flame retardant characteristics of wood, plastic, and other com-

Fire retardant is being studied in interior listeners in residential

The performance of structural wall, floor/ceiling, and column

Current Activities:

Program for Fire Control - Construction

Dennis Gross, Acting Chief

Fire-Contol Publications:

Scale Heat Release Rate Calculator

and is also coordinating a study, "Characterization of the SH-32
Large American Society of Testing and Materials (ASTM) ET119 Fire Test

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Program for Fire Detection and Control Systems

Objective: to develop performance specifications for residential smoke detection devices and systems...to develop design requirements for automatic fire suppression systems...to develop methods to measure smoke movement in buildings.
Program for Fire Detection and Control Systems
Richard Bright, Acting Chief

Current Activities:

- Laboratory performance tests are being conducted on smoke detectors to outline requirements to be included in future standards.

- Patterns of heat flow in corridors and water flow rates are being studied to determine the most effective types of sprinklers for various fires.

- A design model is being developed to allow a rational base for corridor sprinkler protection.

- Performance specifications are being prepared for smoke detection devices to assure consistent quality of detectors available to the consumer.

- A computer analysis for modeling smoke movement in buildings is being developed and will be used in conjunction with an NBS-developed gas tracer technique to depict smoke movement.

- Under NBS contract, Integrated Systems is carrying out simulation studies on air movement and smoke diffusion.

- Factory Mutual Research Corporation is conducting a study of residential sprinkler protection for NBS.

- The Illinois Institute of Technology Research Institute studies detector sensitivity and siting requirements for dwellings, under NBS contract.

- "Smoke as a Determinant of Human Behavior in Fire Situations," is studied at the University of Maryland for NBS.

Fire Detection and Control Systems Publications:


Program for Design Concepts
Program for Design Concepts
Harold Nelson, Chief

Current Activities:

- Studies, research, and tests are being conducted to develop a scientific base of knowledge of fire safety for rational approaches to life safety in institutional and similar occupancies.

- A decision analysis study is underway to qualify and quantify hazard-producing and hazard-controlling elements to establish a logic mechanism to achieve optimum safety effectiveness, cost effectiveness, and design flexibility.

- Tests, analyses, and studies are being conducted to improve the ability to predict probable growth rates and ultimate severities of fires in rooms and the impact of these on various types of materials, furnishings, finishes, and arrangements.

- Studies are underway to find recurrent patterns of behavior for individuals and groups which can be used in the development of regulations or which can provide guidance in building design.

- Studies are being undertaken involving human factor laboratory investigations and other studies to determine means and methods of emergency alarm and communication devices, systems, and methodologies.

- Studies are being made of fire and smoke detection systems to improve design data and engineering criteria for the placement and use of detectors and associated devices, particularly in institutional occupancies.

- Tests and evaluations are included to determine the most practical, reliable, and effective means to control smoke movement in both small and large structures.

- Tests and studies are being conducted to cover all aspects of design, usage, capabilities, and cost optimization of automatic sprinkler installations in low hazard occupancies such as hospital rooms, school rooms, or offices.
The technical output of the Center for Fire Research must be put into practice.

Standards, organizations and the public must cooperate between technical staff and the laboratory for moving from the laboratory to the general community to be effective. Standards are the principal mechanism for moving from the laboratory to the general public. This cooperation between technical staff and application of our research is essential to insure the wide application of our research. A list of technical committee appointments is given in Appendix B.
APPENDIX B

Staff Participation in Voluntary Standards Organizations

National Fire Protection Association Committee on:

- Fire Test (Floor Coverings Subcommittee)
- Fire Test (Furniture Flammability)
- Fire Hazards in Oxygen-Enriched Atmospheres
- Dwelling Fire Prevention and Protection
- High-Rise Committee
- Home Fire Warning Systems
- Sprinkler Committee
- Safety to Life
- Safety to Life (Means of Egress Subcommittee)
- Air Conditioning
- Sectional Committee on Detection Devices
- Electronic Computer System
- Committee on Fire Test Methods
- Committee on Static Electricity
- Committee on Aviation Fire Safety
- Committee on Records Protection

American Society For Testing and Materials

Committee E-5 Fire Tests of Materials and Construction General Committee

5.01 Construction Assemblies Subcommittee
5.02 Smoke and Toxicity Subcommittee
5.03 Protection of Openings Subcommittee
5.04 Surface Burning Subcommittee
5.10 Research Subcommittee
5.91 Editorial Subcommittee
5.92 International Standards Subcommittee
5.93 Guide Criteria for Fire Test Methods Subcommittee

Committee E-39 Fire Hazard Standards

39.1000 Planning and Research Subcommittee
39.3004 Recommended Practices Subcommittee

Clayton M. Huggett
Richard G. Bright
Irwin A. Benjamin
Richard L. P. Custer
Irwin A. Benjamin
Irwin A. Benjamin
Irwin A. Benjamin
Irwin A. Benjamin
Richard G. Bright
Richard G. Bright
Alex F. Robertson
Alex F. Robertson
Harold E. Nelson
Irwin A. Benjamin
Lionel A. Issen
Alex F. Robertson
Irwin A. Benjamin
Alex F. Robertson
Alex F. Robertson
Daniel Gross
Alex F. Robertson
Daniel Gross
Irwin A. Benjamin
Alex F. Robertson
Irwin A. Benjamin
John W. Lyons
John W. Lyons
Irwin A. Benjamin
American Chemical Society
Chemical Literature Division Programs
Cellulose, Wood and Fiber Chemistry Division

Henry Tovey

American Association of Textile Chemists and Colorists
 Flammability and Fire Resistance Committee
 Correlation of Laboratory Tests with End Use Performance Committee
 Laundering Technology Committee

Information Council on Fabric Flammability
 Injury Statistics Committee
 Research Committee

American Apparel Manufacturers Association
 Apparel Products Flammability Committee

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 Injury Statistics Committee
 Research Committee

American Apparel Manufacturers Association
 Apparel Products Flammability Committee

Society of Fire Protection Engineers
 Committee on the Measurement of Fire Phenomena

International Committee on Planning and Design of Tall Buildings
 Task Group on Fire and Blast

Harold E. Nelson
APPENDIX C
Measures of Success – Accomplishments in FY 1974

Information and Hazard Analysis:

- Completed design concept for National Fire Data System to give first national fire loss picture.
- Began implementation of pilot system for National Fire Incident System, drawing on fire department data sources.

Chemistry:

- Built and used apparatus to continuously monitor HCN in combustion gases.
- Designed and built device to measure rate of heat release from fabrics.
- Developed techniques to study new flame species which may be active in flame retardancy of polymers which should enable design of safer polymers.
- Built prototype system measuring flash fire potential of aircraft interior materials.

Fire Prevention -- Products:

- Standard for the Flammability of Mattresses in effect.
- Proposed sampling plan for Standard for the Surface Flammability of Carpets and Rugs published.
- Sampling plan for Standard for the Surface Flammability of Small Carpets and Rugs published.

Fire Control -- Furnishings:

- Developed model predicting flame spread over the surface of floor coverings.
- Developed test method, now being adopted by industry, for flame spread over carpet surfaces for use in high risk occupancies.

Fire Control -- Construction:

- Completed construction of large-scale fire testing facility, Building 205.
- Measured flame spread, ease of ignition, and heat release for a variety of interior finish materials.
- Developed computer program predicting fire resistance of prestressed concrete.
- Completed test series on plastic pipe used in plumbing, showing how to reduce hazards by proper installation.

Fire Detection and Control Systems:

- Smoke detector designs of a number of manufacturers modified as a result of NBS recommendations.
- Conducted computer simulations on effect of stairwell door openings and windows on smoke movement.
- Prepared section of NFPA Life Safety Code on design criteria for smokeproof towers.
- Determined technical feasibility of coupling fast-acting detectors and sprinklers to protect nursing home patients from bedding fires.
- Studied smoke movement in VA hospitals.
- Completed first definitive state-of-the-art evaluation of detection systems.
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DIMENSIONS/NBS (formerly Technical News Bulletin)—This monthly magazine is published to inform scientists, engineers, businessmen, industry, teachers, students, and consumers of the latest advances in science and technology, with primary emphasis on the work at NBS. The magazine highlights and reviews such issues as energy research, fire protection, building technology, metric conversion, pollution abatement, health and safety, and consumer product performance. In addition, it reports the results of Bureau programs in measurement standards and techniques, properties of matter and materials, engineering standards and services, instrumentation, and automatic data processing.

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Handbooks—Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

Special Publications—Include proceedings of conferences sponsored by NBS, NBS annual reports, and other special publications appropriate to this grouping such as wall charts, pocket cards, and bibliographies.

Applied Mathematics Series—Mathematical tables, manuals, and studies of special interest to physicists, engineers, chemists, biologists, mathematicians, computer programmers, and others engaged in scientific and technical work.

National Standard Reference Data Series—Provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Developed under a world-wide program coordinated by NBS. Program under authority of National Standard Data Act (Public Law 90-396).

NOTE: At present the principal publication outlet for these data is the Journal of Physical and Chemical Reference Data (JPCRD) published quarterly for NBS by the American Chemical Society (ACS) and the American Institute of Physics (AIP). Subscriptions, reprints, and supplements available from ACS, 1155 Sixteenth St. N.W., Wash. D.C. 20036.

Building Science Series—Disseminates technical information developed at the Bureau on building materials, components, systems, and whole structures. The series presents research results, test methods, and performance criteria related to the structural and environmental functions and the durability and safety characteristics of building elements and systems.

Technical Notes—Studies or reports which are complete in themselves but restrictive in their treatment of a subject. Analogous to monographs but not so comprehensive in scope or definitive in treatment of the subject area. Often serve as a vehicle for final reports of work performed at NBS under the sponsorship of other government agencies.

Voluntary Product Standards—Developed under procedures published by the Department of Commerce in Part 10, Title 15, of the Code of Federal Regulations. The purpose of the standards is to establish nationally recognized requirements for products, and to provide all concerned interests with a basis for common understanding of the characteristics of the products. NBS administers this program as a supplement to the activities of the private sector standardizing organizations.


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