

# **Building and Fire Research Laboratory Publications, 1990**

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**U.S. DEPARTMENT OF COMMERCE  
National Institute of Standards  
and Technology  
Building and Fire Research Laboratory  
Gaithersburg, MD 20899**

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Robert A. Mosbacher, Secretary  
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AND TECHNOLOGY  
John W. Lyons, Director**

**NIST**



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**April 1991**



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## ABSTRACT

**Building and Fire Research Laboratory Publications, 1990** is the first edition to reflect the combined publications of the Building and Fire Research Laboratory (BFRL) for calendar year 1990. In 1991 the Center for Building Technology (CBT) and the Center for Fire Research (CFR) were combined to form BFRL. This publication is a supplement to previous editions of **Fire Research Publications** and the **Building Technology Publications**. Contact the author if you would like information about the earlier editions. Only publications prepared by the members of the BFRL staff, by other National Institute of Standards and Technology (NIST) personnel for BFRL, or by external laboratories under contract or grant from the BFRL are cited.

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## Literature Citations Grouped by First Author

### Aaron, D. A.

Aaron, D. A.; Domanski, P. A.  
Experimentation, Analysis, and Correlation of Refrigerant-22 Flow Through Short Tube Restrictors.

National Institute of Standards and Technology,  
Gaithersburg, MD  
ASHRAE Transactions, Vol. 96, No. 1, 1990.  
AT-90-1-2;

refrigerants; short tube restrictors; tests; short tubes; flow dependency; flow model; mass flow; flow charts

Refrigerant-22 flow through short tube restrictors was investigated. The analysis pertained to initially sub-cooled refrigerant flowing through short tubes with  $5 < L/D < 20$ . The flow conditions studies were those typically found in heat pumps. Flow dependencies upon upstream subcooling, upstream pressure, downstream pressure, tube length, tube diameter, entrance chamfering, and exit chamfering were examined. A correlation and flow charts for mass flow rate prediction were developed from a large experimental data base. For a given inlet pressure and subcooling, the flow behaved differently depending upon the downstream pressure level. For downstream pressures greater than the approximate liquid saturation pressure of the entering refrigerant, the flow was strongly dependent upon the downstream pressure, as is typically found for single-phase fluid flow through a duct. However, for downstream pressures below the saturation pressure, as is typically found during heat pump operation, the flow demonstrated a very weak dependence upon the downstream pressure and could be termed as non-ideal choked flow. For the latter case, the mass flow rate was directly proportional to upstream subcooling, upstream pressure, and cross-sectional area, and was inversely proportional to the restrictor length. The mass flow rate was highly sensitive to inlet chamfering and insensitive to exit chamfering.

### Alarie, Y. C.

Alarie, Y. C.; Caldwell, D. J.  
Toxicity of Plastic Combustion Products.  
Quarterly Report. Pittsburgh Univ., PA  
Quarterly Report; 73 p. July 11, 1990.

combustion products; toxicity; plastics; computer programs; animals; mass loss; experiments; heat flux; air flow; smoke; polyurethane foams; large scale fire tests

A manuscript detailing the development of the UPitt II system and our results from experiments conducted using Douglas fir specimens without animal exposure was published in the January/February 1990 issue of the Journal of Fire Sciences. Our goals this quarter were: 1) to test the computer program written to collect both animal respiration data and instrument (gas concentration and mass loss) data, 2) to complete the series of animal experiments with Douglas

fir, using previously investigated irradiance (heat flux) levels (Q) and selected airflows (V) to determine how the burning conditions influenced the lethal potential of smoke from burning Douglas fir, and 3) to initiate work with the rigid polyurethane foam used at NIST in the full scale fire experiments.

Alarie, Y. C.; Caldwell, D. J.  
Toxicity of Plastic Combustion Products.  
Quarterly Report. Pittsburgh Univ., PA  
Quarterly Report; 52 p. October 12, 1990.

combustion products; toxicity; plastics; animals; smoke; polyurethane foams; experiments; irradiation; computer programs; statistical analysis; blood; carboxyhemoglobin

The manuscript presenting the results of animal experiments conducted with Douglas fir specimens that we previously submitted to the Journal of Fire Sciences has been accepted for publication. A copy of the revised manuscript is enclosed as Appendix I. Our goal during this quarter was to complete work with the rigid polyurethane foam (RPF) using the UPitt II flaming combustion/toxicity of smoke apparatus that we initiated during the previous quarter. We have met this goal and are presenting preliminary results from animal experiments conducted at Q of 35 kW/m<sup>2</sup>. A schematic diagram presents a brief description of the apparatus and its functions.

### Babrauskas, V.

Babrauskas, V.  
Cone Calorimeter--A New Tool for Fire Safety Engineering.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
ASTM Standardization News, Vol. 18, No. 1,  
32-35, January 1990.

cone calorimeters; fire safety engineering; test methods; flammability; heat release rate

ASTM is in the final stages of balloting on a new flammability test methods--the cone calorimeter, more formally known as Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter. The method was developed at the National Institute of Standards and Technology (NIST) and makes available in a single test apparatus the majority of measurements that are needed to do a bench-scale characterization of specimens for flammability.

Babrauskas, V.; Peacock, R. D.  
Heat Release Rate: The Single Most Important Variable in Fire Hazard.

National Institute of Standards and Technology,  
Gaithersburg, MD

Fire Retardant Chemicals Association (FRCA).  
Fire Safety Developments and Testing: Toxicity,  
Heat Release, Product Development, Combustion  
Corrosivity. Fall Meeting, 1990. October 20-25,  
1990, Ponte Vedra Beach, FL, FRCA, Lancaster,  
PA, 67-80 pp, 1990.

heat release rate; fire hazard; fire endurance; building fires;  
fire tests

Heat release rate measurements are sometimes seen by manufacturers and product users as just another piece of data to gather. It is the purpose of this paper to explain why heat release rate is in fact, the single most important variable in characterizing the 'flammability' of products and their consequent fire hazard. Examples of typical fire histories are given which illustrate that even though fire deaths are primarily caused by toxic gases, the heat release rate is the best predictor of fire hazard. Conversely, the relative toxicity of the combustion gases plays a smaller role. The delays in ignition time, as measured by various Bunsen burner type tests, also have only a minor effect on the development of fire hazard.

Babrauskas, V.  
Large-Scale Toxicity Correlations.

National Institute of Standards and Technology,  
Gaithersburg, MD

U. S./Japan Government Cooperative Program on  
Natural Resources (UJNR). Fire Research and  
Safety. 11th Joint Panel Meeting. October 19-24,  
1989, NISTIR 4449, Berkeley, CA, Jason, N. H.  
and Cramer, D. M., Editor(s), 80-85 pp, 1990.

toxicity test methods; chairs; room burns; carbon monoxide  
Some of the recent work done at NIST in the area of validating reduced-scale toxicity test methods against full-scale room fire data is reviewed. The agreements and disagreements obtained thus far are summarized. The current NIST research program for systematizing the validation process itself is also reviewed.

Babrauskas, V.; Harris, R. H., Jr.; Braun, E.; Levin,  
B. C.; Paabo, M.; Gann, R. G.

Large-Scale Validation of Bench-Scale Fire  
Toxicity Tests.

National Institute of Standards and Technology,  
Gaithersburg, MD

Interscience Communications Ltd.; National  
Institute of Standards and Technology; Building  
Research Establishment; and Society of Fire  
Protection Engineers. Interflam '90.

Fire Safety. International Fire Conference, 5th.  
September 3-6, 1990, Canterbury, England,  
Interscience Communications Ltd., London,  
England, Franks, C. A., Editor(s), 3-12 pp, 1990.

fire safety; toxicity test methods; validation; polyvinyl  
chloride; radiant heating; polyurethane foams; rigid foams;  
room fires; wood

A large number of bench-scale fire toxicity tests have been proposed over the last two decades. So far, none of them has reached acceptance by ISO, by ASTM, or by the majority of professionals in this area. The reasons are varied, but a major concern has been that none of the methods were seen to adequately predict the behavior of real, large-scale building fires. Such validation efforts have been held back both due to a shortage of good quality data, and because agreement had not been reached on the criteria for successful validation. NIST has now completed a pilot project to address both of these issues. In this study, systematic criteria for validation have been put forth. An initial data set has been compared against these criteria, comprising 2 bench-scale methods, 3 test materials, and a single real-scale fire scenario. The project results indicate that the course being pursued is appropriate, and provide illustrative performance data for the two bench-scale methods. The present project was a pilot study; further validation data will have to come from additional test materials and additional real-scale fire scenarios being examined. As a result of these studies, a factor-of-3 agreement between bench-scale and real-scale results was established as both useful and practical.

Babrauskas, V.

Modern Test Methods for Flammability.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4326; 24 p. June 1990.

Available from National Technical Information  
Services PB91-167676

Business Communications Co., Inc. (BCC). Recent  
Advances in Flame Retardancy of Polymeric  
Materials--Materials, Applications, Industry  
Developments, Markets. Special Conference. May  
15-17, 1990, Stamford, CT, 1-20 pp, 1990.

flame retardants; flammability; test methods; room fires;  
oxygen consumption; heat release; ignition; flame spread;  
smoke; toxic products

During the last decade, significant improvements have become available in flammability testing. Rationally-based new methods, derived from fundamental engineering principles are replacing the previously used empirical tests. The major emphasis in this development work has been to provide a basic set of bench-scale methods which can be used to predict full-scale product performance. Reference methods for conducting full-scale tests will continue to be needed to handle products or situations where the bench-scale methods are not applicable. The bulk of the testing needs, however, can now be fulfilled by use of

bench-scale tests which are not only simple to run, but are known to accurately predict the full-scale performance.

**Babrauskas, V.**

**New Test Methods for Assessing Smoke, Toxic Products, Corrosive Products, and Heat Release in Fires.**

National Institute of Standards and Technology, Gaithersburg, MD

Plastics and Rubber Institute AND British Plastics Federation. **Flame Retardants 1990. International Conference, 4th. January 17-18, 1990, London, England, Elsevier Applied Science, New York, 20-33 pp, 1990.**

flame retardants; smoke; toxic products; heat release; test methods; large scale fire tests; oxygen consumption

The existing inventory of various national tests for determining properties is gradually being supplanted by a new generation of test methods. These methods, unlike the earlier empirically designed ones, have been based on theoretically sound principles. The data from these new test methods are not arbitrary, but are suitable for quantitative fire engineering, and specifically as needed input data to fire models. Several such new methods are discussed in the areas of smoke, toxic products, corrosive products, and heat release.

**Barnett, J. R.**

**Barnett, J. R.; Beyler, C.**

**Development of an Instructional Program for Practicing Engineers HAZARD I Users. Final Report. July 12, 1990. Worcester Polytechnic Institute, MA**

Fire Science Technologies, Columbia, MD

NIST-GCR-90-580; 161 p. August 1990.

Available from National Technical Information Services PB90-265315

computer models; fire statistics; hazard assessment; manuals; safety factors; training

With the release of HAZARD I, a prototype hazard assessment method and software, the National Institute of Standards and Technology (NIST) has brought to the fire protection engineering community a new generation of hazard analysis capabilities. In order to help HAZARD I users benefit from the software, Worcester Polytechnic Institute (WPI) has developed a five day short course. The short course emphasizes correct use of the software, and how to recognize misuse. The course has been offered three times to a broad range of students. In general, only those students with an engineering background were able to learn enough about the HAZARD I software to feel that they could continue to learn how to use the software on their own and eventually use it in practice. Nonetheless, virtually all of the students benefited from the course and found it a worthwhile experience.

**Benner, B. A., Jr.**

**Benner, B. A., Jr.; Bryner, N. P.; Wise, S. A.; Mulholland, G. W.; Lao, R. C.; Fingas, M. F.**

**Polycyclic Aromatic Hydrocarbon Emissions From the Combustion of Crude Oil on Water.**

National Institute of Standards and Technology, Gaithersburg, MD

Environment Canada, Ottawa Environmental Science and Technology, Vol. 24, No. 9, 1418-1427, 1990.

crude oil; water; polycyclic aromatic hydrocarbons; emissions; combustion; pool fires; carbon

This work involved an investigation of some of the factors necessary to assess the environmental impact of an in situ burn: the fraction of an oil layer that can be burned, the quantity of smoke, and the concentrations of 18 polycyclic aromatic hydrocarbons (PAHs) in the smoke, crude oil, and burn residue. Alberta Sweet crude in 2-, 3-, 5-, 10-, and 30-mm layers on water was burned and smoke samples were collected at elevated and ambient temperatures, and analyzed by two independent laboratories. While burning the crude oil produced less total PAHs than were in the original crude oil, the concentrations of PAHs with five or more rings were 10-20 times greater in the smoke than in the oil. The organic carbon fraction of the smoke was in the range of 14-21%. As the fuel layer thickness was increased from 2 to 10 mm, the smoke yield increased from 0.035 to 0.080 g of smoke/g of fuel, and the percentage of oil residue decreased from 46 to 17%. By consuming much of the oil spill and reducing the amount of PAHs in the water, and by dispersing the combustion products over a larger area, in situ burning can mitigate the local environmental impact of an oil spill. There appears to be a range of conditions, such as in Arctic ice fields, where in situ burning might be the most viable cleanup method.

**Bentz, D. P.**

**Bentz, D. P.; Garboczi, E. J.**

**Digitized Direct Simulation Model of the Microstructural Development of Cement Paste.**

National Institute of Standards and Technology, Gaithersburg, MD

Materials Research Society Symposium Proceedings. Volume 195. 1990, 523-530 pp, 1990.

cement paste; simulation; diffusion-limited aggregate; hydration process; microstructural model; percolation properties; pore space; diffusivity

The complex microstructure of hardened cement paste is produced by hydration reactions between cement particles and the water in which they are suspended. In recent years, algorithms like the diffusion-limited aggregation (DLA) and Eden models have demonstrated that simple growth rules

can result in complex aggregated structures. The model described in this paper simulates, via simplified growth rules, the microstructural development of hydrating cement paste. This model has similarities to DLA, but with the additional novel features of dissolution of solid particles, and a free-space nucleation probability. The percolation aspects and transport properties of the model's pore space are computed and discussed.

**Bentz, D. P.; Nguyen, T.**  
**Simulation of Diffusion in Pigmented Coatings on Metals Using Monte-Carlo Methods.**  
National Institute of Standards and Technology,  
Gaithersburg, MD  
*Journal of Coatings*, Vol. 62, No. 783, 57-63, April 1990.

metals; coatings; simulation; algorithms; thickness; pigment volume concentration; pigment dispersion; pigment shape-orientation; surface defects (pinholes); cycle exposures  
The degradation of many organic coating systems is controlled by processes occurring at the coating-substrate interface. These degradation processes require that species, such as H<sub>2</sub>O, O<sub>2</sub>, or ions, diffuse from the atmosphere, through the coating, to the interfacial region. This paper presents a two-dimensional model for the diffusion of these species through a pigmented coating. The model is implemented via digitized Monte Carlo simulations of the random walk behavior of individual species within the coating layer. The model has been developed to include a variety of parameters such as coating thickness, pigmentation (pigment volume concentration, pigment particle geometry, pigment absorption characteristics, etc.), and pinholes at the coating-atmosphere interface. Results are presented for a number of cases which explore the effects of pigment volume concentration, pigment dispersion, pigment shape and orientation, the presence of surface defects, and constant vs cyclic environments. Key features of the digitized simulation model are its flexibility, the visualization it provides the researcher, and the possibility of executing the algorithms on digitized images of cross sections of real coating systems.

### **Blaisten-Barojas, E.**

**Blaisten-Barojas, E.; Nyden, M. R.**  
**Molecular Dynamics Study of the Depolymerization Reaction in Simple Polymers.**  
Johns Hopkins Univ., Baltimore, MD  
National Institute of Standards and Technology,  
Gaithersburg, MD  
*Chemical Physics Letters*, Vol. 171, No. 5-6, 499-505, August 17, 1990.  
depolymerization; combustion; equations; degradation; monomers; size distribution  
A molecular dynamics experiment was designed to follow the sequence of depolymerization reactions occurring when a

polymer degrades into its constituent monomers. This simulation addresses internal changes that certain materials undergo at the moment of burning. Polymer fragments were thermally generated from the random scission of longer polymer chains containing 50-950 units. Subsequently, these thermal fragments depolymerized and coiled dramatically, forming incipient "agglomerates". These agglomerates cooled while depolymerizing; the cooling mechanism remarkably inhibits the depolymerization reaction and eventually terminates the degradation process leading behind a sample of cold stable agglomerates. The size distribution of the polymer fragments is given as well as the IR spectrum of a typical sample at 2000 K.

### **Boynton, R. M.**

**Boynton, R. M.; Fargo, L.; Collins, B. L.**  
**Categorical Color Rendering of Four Common Light Sources.**  
California Univ., San Diego, La Jolla  
National Institute of Standards and Technology,  
Gaithersburg, MD  
*Color Research and Application*, Vol. 15, No. 4, 222-230, August 1990.  
color; light sources; tungsten-incandescent; illuminants; CIE color-rendering index  
Subjects were asked to sort samples from the Optical Society of America (OSA) Uniform Color Scales set into 33 color categories under four separate illuminates: tungsten-incandescent, metal halide, high-pressure sodium, and clear mercury. Sorting required that each color sample be designated as a "good," "acceptable," or "poor" example within one of the eleven basic color categories specified by Berlin and Kay. Three indices of the categorical color-rendering capacity of the sources were developed. Assuming tungsten-incandescent as the reference illuminant, all three measures rated the color-rendering quality of the tested illuminants from best to worst in the order listed above, in agreement with the CIE color-rendering index.

### **Braun, E.**

**Braun, E.; Davis, S.; Klote, J. H.; Levin, B. C.; Paabo, M.**  
**Assessment of the Fire Performance of School Bus Interior Components. Final Report.**  
National Institute of Standards and Technology,  
Gaithersburg, MD  
NISTIR 4347; 177 p. July 1990.  
Available from National Technical Information Services PB90-265307  
buses; cone calorimeters; seats; flame spread; furniture calorimeters; combustion products; smoke; tenability limits; toxicity; large scale fire tests; small scale fire tests

Since seat assemblies represent the single largest type of combustible fuel in a school bus interior, this study is limited to currently used and state-of-the-art material assemblies. Six different seat assemblies having a range of fire performance were examined. Small-scale tests (Cone Calorimeter, LIFT, and NBS Toxicity Protocol) were performed on these materials. Large-scale tests (Furniture Calorimeter) were conducted on single seat assemblies. Full-scale tests were performed using a simulated bus enclosure measuring 2.44 m wide by 2.13 m high by 8.23 m long and three seat assemblies. The impact of ignition source size was determined by computer simulation. It was found that a 500 kW ignition source could produce untenable thermal conditions in the simulated bus enclosure. Seat assemblies were exposed to 50 kw and 100 kw ignition sources in the large-scale tests and 100 kW ignition source in the full-scale tests. It was found that the small-scale tests were unable to provide a simple method for material selection that was consistent with the full-scale test results. At the present time, small-scale fire tests of materials cannot be depended upon to predict the fire behavior in the real world. Therefore, based on the full-scale test results, a generalized full-scale test protocol for seat assembly evaluation was developed that combines full-scale testing in an enclosure with an analysis protocol that determines the time-to-untenable conditions. The procedure defines the conditions under which toxicity testing would be necessary. Full-scale test instrumentation and material orientation are also described.

Braun, E.; Gann, R. G.; Levin, B. C.; Paabo, M.  
Combustion Product Toxic Potency Measurements:  
Comparison of a Small Scale Test and  
"Real-World" Fires.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
Journal of Fire Sciences, Vol. 8, No. 1, 63-79,  
January/February 1990.

small scale fire tests; large scale fire tests; combustion products; toxicity; fire science; decomposition products; animals; time; rats

A long range goal of fire science is to be able to predict "real-world" fire performance from a small set of laboratory scale fire measurements. One material property of primary concern is the toxicity of decomposition products. Several small scale toxicity protocols that measure toxic potency of the smoke from burning materials have been developed. While several attempts have been made to correlate individual protocols with large scale results, no systematic set of criteria for determining the extent of similarity has been defined and tested. In this paper, three criteria have been proposed and tested using one set of materials (cotton fabric and polyurethane foam) in two different large-scale enclosures and three different fire scenarios. Tests were conducted to determine the extent of similarity between the NBS Toxicity Test Protocol and large-scale "real-world" fire performance. The similarity criteria were: LC50 values,

time to death of the animals, and toxicant(s) causing the deaths (i.e., the ratios of yields of known toxicants and the contribution of the unknown toxicants). Comparison of test results showed that similar LC50 values were observed. However, toxicant yields varied and animal deaths occurred at different times, implying a difference in physiological syndrome(s).

## **Bukowski, R. W.**

Bukowski, R. W.

CFR's Office of Technology Transfer--What It Can Do For You, and Vice-Versa.

National Institute of Standards and Technology,  
Gaithersburg, MD

Fire Journal, Vol. 84, No. 4, 15, July/August 1990.  
technology transfer

The fire research community is often accused of being out of touch with the real issues facing those who deliver safety to the public. It is said we study only that which excites our scientific curiosity and then speak (or write) in Greek when describing what we have found. Conversely, researchers complain that practitioners are too busy "putting out fires" to devote any attention to learning or even understanding the new technology that comes from their research.

Bukowski, R. W.

Fire Hazard Prediction--HAZARD I and Its Role in Fire Codes and Standards.

National Institute of Standards and Technology,  
Gaithersburg, MD

ASTM Standardization News, Vol. 18, No. 1,  
40-43, January 1990.

fire hazards assessment; computer programs; standards

For at least two decades, fire researchers have pursued the goal of a capability to predict the outcome of an arbitrary fire in an arbitrary building. As the capabilities of both fire science and computing equipment have grown, we have seen the emergence of mathematical models for fires in single rooms, and then in multiple, connected rooms. Other, specialty models have also been produced that deal in detail with specific phenomena or application areas. The steady expansion of the understanding of the physics and chemistry of fire has meant increases in both the detail and accuracy with which these models function.

Bukowski, R. W.; Jones, W. W.; Hall, J. R., Jr.;  
Clarke, F. B., III

Fire Risk Assessment Method: Case Study 4,  
Interior Finish in Restaurants.

National Institute of Standards and Technology,  
Gaithersburg, MD

National Fire Protection Assoc., Quincy, MA  
Benjamin/Clarke Assoc., Kensington, MD

NISTIR 90-4246; 36 p. May 1990.  
Available from National Technical Information Services PB90-244450  
interior finishes; restaurants; computer models; fire statistics; hazard assessment; probability; risk assessment  
Traditional methods of assessing fire risk are based on probabilistic treatment of fire incident data. Recent advances in the ability to make deterministic predictions of the consequences of specific fire scenarios, presents an opportunity to reduce this dependency on incident data and greatly improve the ability to assess the risk associated with new products for which such data do not exist. This paper presents a trial application of a risk assessment method developed for such a purpose. A separate report provides the essential documentation for the methodology to be understood and applied by others. There are three other associated reports detailing trial applications of the methodology to other selected products and occupancies.

Bukowski, R. W.; Stiefel, S. W.; Hall, J. R., Jr.; Clarke, F. B., III  
Fire Risk Assessment Method: Description of Methodology.  
National Institute of Standards and Technology, Gaithersburg, MD  
National Fire Protection Assoc., Quincy, MA  
Benjamin/Clarke Assoc., Kensington, MD  
NISTIR 90-4242; 76 p. May 1990.  
Available from National Technical Information Services PB90-235052  
computer models; fire statistics; hazard assessment; probability; risk assessment  
Traditional methods of assessing fire risk are based on probabilistic treatment of fire incident data. Recent advances in the ability to make deterministic predictions of the consequences of specific fire scenarios, presents an opportunity to reduce this dependency on incident data and greatly improve the ability to assess the risk associated with new products for which such data do not exist. This paper presents a risk assessment method developed for such a purpose, and provides the essential documentation for the methodology to be understood and applied by others. There are also four associated reports detailing trial applications of the methodology to specific products in specified occupancies.

Bukowski, R. W.  
Modeling Techniques for Safety Management.  
National Institute of Standards and Technology, Gaithersburg, MD  
American Society of Safety Engineers (ASSE).  
Building Our Professional Heritage--Protecting Our Nation's Resources. Professional Development Conference and Exposition, 29th. June 24-27, 1990,

Washington, DC, Am. Soc. of Safety Engineers, Des Plaines, IL, 38-44 pp, 1990.  
computer programs; safety; hazard assessment  
HAZARD I is a method for predicting the hazards to the occupants of a building from a fire therein. Within prescribed limits, HAZARD I allows you to predict the outcome of a fire in a building populated by a representative set of occupants in terms of which persons successfully escape and which are killed, including the time, location, and likely cause of death for each.

### **Burch, D. M.**

Burch, D. M.; Licitra, B. A.; Zarr, R. R.  
Comparison of Two Test Methods for Determining Transfer Function Coefficients for a Wall Using a Calibrated Hot Box.  
National Institute of Standards and Technology, Gaithersburg, MD  
Journal of Heat Transfer, Vol. 112, 35-42, February 1990.  
walls; calibrated hot box; test methods; heat transfer; transfer function; transient thermal performance; air temperature; interior surface  
This paper experimentally verifies and compares two dynamic test methods for a calibrated hot box to characterize the transient thermal performance of complex walls. In these methods, a wall specimen is sandwiched between the two conditioning chambers of a calibrated hot box. The exterior surface of the wall specimen is subjected to a time-varying excitation function in air temperature. At the interior surface, the air temperature is maintained steady, and the heat transfer response is measured. Conduction transfer function coefficients that relate the measured heat transfer response to the excitation function are derived. The two dynamic test methods were applied to an insulated hollow concrete block wall that contained significant thermal bridges and lateral heat flows. Empirical transfer function coefficients derived by the test methods predicted with good agreement the heat transfer response of this wall specimen when its exterior surface was subjected to excitation functions that differed markedly from those used to derive the coefficients.

Burch, D. M.; Thomas, W. C.; Mathena, L. R.; Licitra, R. A.; Ward, D. B.  
Transient Moisture and Heat Transfer in Multi-Layer Non-Isothermal Walls--Comparison of Predicted and Measured Results.  
National Institute of Standards and Technology, Gaithersburg, MD  
Virginia Polytechnic Institute and State University, Blacksburg  
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Proceedings, Thermal Performance of the Exterior Envelopes of Buildings IV. December 4-7, 1990, Orlando, FL, 513-531 pp, 1990.

walls; transient moisture; heat transfer; mathematical models; transient heat; moisture transfer rate; paints; insulation

A distributed-capacity, finite-difference model is presented for predicting the transient heat and moisture diffusion through a multilayer plane wall. The model is one-dimensional and uses a single potential (i.e., water vapor pressure) to predict the moisture transfer rate. This model was used with independently measured moisture properties to predict the results of a simple experiment. Two plane walls, measuring 2 ft by 2 ft by 4.5-in. thick (0.61 by 0.61 by 0.11 m) were exposed to a step decrease in temperature and humidity at their exterior surfaces. The walls were comprised of gypsum board with interior latex paint, cavity insulation, and white pine with exterior oil-base paint. One of the walls was insulated with glass-fiber insulation, the other with cellulose insulation. Moisture was permitted to accumulate within the walls during a 34-day period. The model predicted with good agreement the accumulation of moisture in the wood. Laboratory methods to measure independently the moisture properties of the materials are also described. The effect of moisture accumulation on the overall thermal resistance of the two walls was investigated.

#### **Buschmeier, M.**

Buschmeier, M.; Mulroy, W.; Didion, D. A.  
Initial Laboratory Evaluation of a Single Solution Circuit Cycle for Use With Nonazeotropic Refrigerants.  
Universitaet Hannover, West Germany  
National Institute of Standards and Technology,  
Gaithersburg, MD  
NISTIR 4406; 46 p. October 1990.  
Available from National Technical Information Services PB91-112862

air conditioning; capacity modulation; heat pumping; nonazeotropic refrigerants; refrigeration cycles; refrigerant mixtures; single solution circuit; vapor compression cycle  
Tests were conducted at the National Institute of Standards and Technology (formerly the National Bureau of Standards) to evaluate a single solution circuit cycle for use with nonazeotropic refrigerant mixtures. The single solution circuit cycle incorporates a liquid refrigerant pump in parallel with a compressor. This allows separate control of refrigerant composition to match load and of refrigerant temperature change (glide) in the two-phase region to match the heat source or sink temperature glide. Load matching by composition shifting to match light loads to the extent possible with the tested mixture (R22/R11) was found to be an inefficient air conditioning mode control strategy. Nonlinearity of enthalpy vs. temperature in the two-phase

region of the R22/R11 limited the efficiency gains possible by glide matching to a 19% improvement over pure R22. The cycle did function as intended, allowing glide matching over a wide composition change. It is felt that with a more linear refrigerant, substantial efficiency gains over the normal vapor compression cycle would be possible for applications in which the heat source and sink glides vary substantially with load.

#### **Bushby, S. T.**

Bushby, S. T.  
Testing Conformance to Energy Management and Control System Communication Protocols. Part 1. Test Architecture.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
ASHRAE Transactions, Vol. 96, No. 1, 1990.  
AT-90-14-3.

energy management; control systems; communication protocols; architecture; tests; test methods; conformance test  
ASHRAE has formed a committee to develop a standard communication protocol for energy management and control systems (EMCS). The goal of being able to connect control equipment from any vendor and make it work as part of an integrated system will not be achieved until tests to determine conformance to the standard are developed. This paper is the first in a two-part series addressing the question of testing conformance to an EMCS protocol. This paper reviews international efforts to develop procedures for testing conformance to computer communication protocol standards. A particular variation of the "coordinated abstract test method" (ISO 1987c) is proposed as the best architecture for testing conformance to the ASHRAE protocol. This approach will minimize the burden placed on implementors by the conformance test without sacrificing the ability to conduct thorough tests. No direct access to layer boundaries will be required, and integrity of the implementor's software can be maintained. The proposed structure of the ASHRAE protocol lends itself to this approach because only one additional protocol service and one standard object type will need to be added.

Bushby, S. T.  
Testing Conformance to Energy Management and Control System Communication Protocols. Part 2. Test Suite Generation.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
ASHRAE Transactions, Vol. 96, No. 1, 1990.  
AT-90-14-4.

energy management; control systems; communication protocols; test suite generation; tests; test methods; test suite design; sequence generation  
ASHRAE has formed a committee to develop a standard communication protocol for energy management and control systems (EMCS). The goal of being able to connect control

equipment from any vendor and make it work as part of an integrated system will not be achieved until tests to determine conformance to the standard are developed. This paper is the second in a two-part series addressing the question of testing conformance to an EMCS protocol. This paper reviews international efforts to develop procedures for generating test suites used to determine conformance to a communication protocol standard. Four criteria are defined for evaluating the alternatives, and recommendations for the ASHRAE standard are made. An outline for the ASHRAE test suite is presented along with comments about the future steps needed to completely define it.

### **Byrd, W. E.**

Byrd, W. E.; McKnight, M. E.

Potential Methods for Measuring and Detecting Lead in Existing Paint Films: A Literature Review.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 89-4205; 45 p. January 1990.

Available from National Technical Information Services PB90-263234

analysis; lead; literature review; paints; x-ray fluorescence; flame atomic absorption; spot test; inductively coupled plasma; neutron activation analysis; voltammetry; mass spectrometry; ion selective electrodes

Recent legislation required the U. S. Department of Housing and Urban Development (HUD) to establish procedures to eliminate, as far as practicable, the hazards of lead-based paint poisoning in any existing HUD-controlled housing. Thus, HUD promulgated a regulation which requires abatement to eliminate lead-base paint poisoning hazards in housing and in which the concentration of lead in paint equals or exceeds 1 mg/cm<sup>2</sup>. The legislation also required HUD to review test methods for measuring lead in paint. The National Institute of Standards and Technology (NIST) was given this task. That review is the subject of this report.

Test methods were evaluated based on the following criteria: 1) safety, 2) reliability, 3) accuracy, 4) precision, 5) detection limit, 6) ease of use, and 7) technical skill required to make a measurement, 8) nondestructive, and 9) cost of an analysis. Methods were separated into two categories: 1) field test methods and 2) laboratory test methods. The laboratory test methods were also separated by whether the sample needed to be in solution or could be analyzed as a solid. None of the potential test methods met all of the desired criteria.

### **Carino, N. J.**

Carino, N. J.; Clifton, J. R.

Outline of a National Plan on High-Performance Concrete: Report on the NIST/ACI Workshop, May 16-18, 1990.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 4465; 62 p. December 1990.

Available from National Technical Information Services PB91-143321

concrete; durability; high-performance concrete; high-strength concrete; institutional barriers; low-permeability concrete; mechanical properties; mixture proportioning; research; specifications; standard test methods; structural design; workshop A workshop on high-performance concrete (HPC) was held in Gaithersburg, MD on May 16, 17, and 18, 1990. The workshop was co-sponsored by the American Concrete Institute. High-performance concrete was defined as concrete having desired properties and uniformity which cannot be obtained routinely using only conventional constituents and normal mixing, placing, and curing practices. The workshop objectives were to: [1] Identify currently and planned research programs on HPC; [2] Identify potential applications where HPC could be used on a routine basis; [3] Identify the technical barriers to widespread use of HPC; [4] Identify institutional barriers and deficiencies in standards which hinder the use of HPC; [5] Develop a listing of critical research to overcome the technical barriers and provide a sound basis for the needed standards. To achieve these objectives, noted international experts in concrete technology were invited to participate in the workshop. Eight working groups were organized to address different topics. This report summarizes the discussions and conclusions of the working groups. Each chapter begins with a brief introduction providing background on the nature of the problems addressed by the working group. Specific research topics are identified, and discussions are provided to explain the rationale for the needed research. The recommended research is proposed as the basis for a national program to exploit the potential of high-performance concrete and ensure U. S. competitiveness in concrete technology. Recommendations for implementing the plan are provided.

Carino, N. J.

Performance of Buildings.

National Institute of Standards and Technology, Gaithersburg, MD

NIST SP 778; ICCSSC TR11; 201 p. January 1990.

Available from Government Printing Office

National Institute of Standards and Technology. Performance of Structures During the Loma Prieta Earthquake of October 17, 1990, Lew, H., Editor(s), 4/1-53 pp, 1990.

earthquakes; building codes; fire safety; damage; bridges (structures); highways; structural engineering; housing; geology; lifelines; seismic; specifications; viaducts

This chapter describes the performance of buildings within the Bay area and within the epicentral region. Because of the large area in which buildings were damaged, the

inspections concentrated on those regions which experience a large amount of severe damage. As discussed in Chapter 3 the most serious damage was concentrated in areas of deep soil deposits. Most structures designed according to modern codes and standards performed well without structural damage. The majority of the damaged structures were either wood-framed dwellings or unreinforced masonry buildings which had not been strengthened to increase their seismic resistance. It should be noted that the Loma Prieta earthquake was not a severe test of buildings designed according to modern seismic criteria. Except for the epicentral region, peak ground accelerations were less than implied by modern building codes. Also, the duration of strong ground shaking was only 10 to 15 seconds. Thus, the favorable performance of the majority of modern buildings can not be used as evidence that current seismic design criteria are adequate. There were isolated failures in modern structures to which the team did not gain access. Detailed investigations of the circumstances associated with these failures can provide opportunities to improve design standards if it is found that the failures occurred where standards were met. The Loma Prieta earthquake also provided opportunities to evaluate the performance of the various seismic strengthening methods used within the affected region. The team observed many instances of successful strengthening measures, but there were also examples of unsuccessful measures. This chapter provides examples of the type of damage observed in the more severely affected regions. Probable failure mechanisms are discussed where possible, but no attempt is made to provide in-depth explanations of the underlying factors leading to the observed damage.

**Carino, N. J.**  
**Potential Nondestructive Testing Methods for Evaluation of Stone. Letter Report to National Park Service.**  
**National Institute of Standards and Technology, Gaithersburg, MD**  
**Letter Report; 14 p. 1990.**  
concrete; impact-echo; nondestructive testing; pulse velocity; radar; rebound hammer; stone  
The National Park Service is planning condition assessments of the Lincoln and Jefferson Memorials. NIST was requested to recommend potential nondestructive testing methods that could be used to assess the condition of the stone. The four techniques which are discussed have been applied in the assessment of concrete structures, and it is believed they are equally applicable to the inspection of stone. The methods are: the rebound hammer, ultrasonic pulse velocity, impact-echo, and ground penetrating radar. The objective of this report is to explain the operating principles, advantages and disadvantages of these methods.

## **Cheok, G. S.**

**Cheok, G. S.; Stone, W. C.**  
**Behavior of 1/6-Scale Model Bridge Columns Subjected to Inelastic Cyclic Loading.**  
**National Institute of Standards and Technology, Gaithersburg, MD**  
**ACI Structural Journal, Vol. 87, No. 6, 630-638, November/December 1990.**  
bridges (structures); columns (supports); computer programs; cyclic loads; ductility; earthquake-resistant structures; energy; failure; hinges (structural); lateral pressure; microconcretes; models; reinforced concrete; tests  
Circular, spirally reinforced concrete bridge columns were subjected to cyclic inelastic lateral loading in the laboratory. The bridge columns were one-sixth scale models of prototype columns designed in accordance with recent California Department of Transportation specifications. A total of six models were tested. Three of the models were constructed with microconcrete, and three were constructed with ready-mixed concrete using pea gravel. Variables included the aspect ratio, magnitude of axial load, and the type of material. The models were subjected to slow reversed cyclic lateral displacement with the axial load held constant. Results from the tests are presented in the form of load displacement curves and energy absorption plots.

**Cheok, G. S.; Lew, H. S.**  
**Performance of 1/3-Scale Model Precast Concrete Beam-Column Connections Subjected to Cyclic Inelastic Loads.**  
**National Institute of Standards and Technology, Gaithersburg, MD**  
**NISTIR 4433; 104 p. October 1990.**  
**Available from National Technical Information Services PB91-107623**  
beam-column; buildings; connections; cyclic loading; interior joints; joints; moment resistant; precast concrete; post-tensioned; reinforced concretes  
An experimental study of the behavior of precast concrete beam-column connections subjected to cyclic inelastic loading was initiated at the National Institute of Standards and Technology. The study was initiated to provide data for the development of a rational design procedure for such connections in high seismic regions. The objective of the study is to develop a moment resistant precast concrete connection that is economical and easily constructed. Results of the experimental tests of both monolithic and precast beam-column connections are described. The monolithic concrete specimens were designed to 1985 UBC Seismic Zone 2 and 4 criteria. The design of the precast concrete specimens was similar to that for the monolithic specimen designed to UBC seismic zone 4. The results from the monolithic specimens provide a benchmark for comparison with the results from the precast tests. The experimental program is divided into three phases. This report presents the findings of the first phase of the test program.

Comparisons of the performance of the monolithic beam-column joints with that of the precast joints in which the beam-to-column connection is provided by post-tensioning bars are presented. The effects of fiber reinforced grout between the beam and column are described. Comparisons are made between the energy dissipation, ductility, and failure mode for the two types of beam-column joints.

**Cheok, G. S.; Lew, H. S.**  
Seismic Performance of 1/3 Scale Post-Tensioned Precast Beam-Column Connections.  
National Institute of Standards and Technology, Gaithersburg, MD  
Earthquake Engineering Research Institute.  
U. S. National Conference on Earthquake Engineering, 4th. Volume 2. May 20-24, 1990, Palm Springs, CA, Earthquake Engineering Res. Inst., El Cerrito, CA, 757-766 pp, 1990.  
beam-column; buildings; connections; cyclic loadings; interior joints; joints; moment resistant; precast concrete; post-tensioned; reinforced concrete

At present there is limited guidance regarding the design and detailing of precast structures for seismic resistance. The 1985 Uniform Building Code (UBC) currently permits the use of precast concrete elements to resist seismic forces provided the design and detailing used satisfy the code requirements for cast-in-place concrete structures. Technical data are needed to establish provisions for codes and standards, thereby promoting precast construction in seismically active regions. A study of the behavior of precast beam-column connections subjected to cyclic inelastic loading was initiated at the National Institute of Standards and Technology. The objective of the study is to develop a moment resistant precast connection that is economical and easily constructed. The experimental program consists of testing both monolithic and precast beam-column connections. The monolithic specimens were designed to 1985 UBC seismic zone 4 criteria. The results from the monolithic specimens provide a reference for comparison with the results from the post-tensioned beam-column tests. The moment resistance of the connection is provided by post-tensioning bars. The effects of fiber reinforced grout between the beam and column are studied. Energy dissipation, ductility, and failure mode will be used to determine the overall behavior of the connections.

**Cherry, S. M.**  
Cherry, S. M.  
Summaries of Center for Fire Research In-House Projects and Grants--1990.  
National Institute of Standards and Technology, Gaithersburg, MD  
NISTIR 4440; 270 p. October 1990.

Available from National Technical Information Services PB90-127101  
fire research; charring; combustion; fire models; flame spread; ignition; polymers; smoke; soot; toxicity  
This report describes the research projects performed in the Center for Fire Research and under its grants program during FY1990 (October 1, 1989-September 30, 1990).

### **Clarke, F. B., III**

Clarke, F. B., III; Bukowski, R. W.; Stiefel, S. W.; Hall, J. R., Jr.; Steele, S. A.  
National Fire Risk Assessment Research Project. Final Report.  
Benjamin/Clark Associates Inc., Kensington, MD  
National Institute of Standards and Technology, Gaithersburg, MD  
National Fire Protection Research Foundation, Quincy, MA  
77 p. July 1990.

risk assessment; risk analysis; life safety; residential buildings; office buildings; carpets; hotels; restaurants; wall coverings; ignition testing

This paper describes the work of the National Fire Protection Research Foundation's Project on Fire Risk. The objective of the project is to develop a quantitative method for predicting the expected life safety loss (or risk) associated with the use of new and existing products. "Product" is defined as an item capable of being evaluated by laboratory-scale fire performance tests and therefore generally does not include building design features. Fire death is the measure of risk.

### **Clifton, J. R.**

Clifton, J. R.; Rossiter, W. J., Jr.; Kaetzel, L. J.  
Expert Systems for Roofing Construction.  
National Institute of Standards and Technology, Gaithersburg, MD  
International Journal of Roofing Technology, Vol. 2, 57-60, 1990.

roofing (finishes); construction; expert systems  
This paper describes expert technology, including the principles, development and applications of expert systems. The paper also discusses the applications of expert systems in roofing and provides an example of their use to reduce slippage problems in built-up bituminous membranes.

**Clifton, J. R.**  
Frost-Resistance of Concrete.  
National Institute of Standards and Technology, Gaithersburg, MD  
NISTIR 90-4229; 21 p. January 1990.  
Available from National Technical Information Services PB90-162116

aggregate; concrete; durability; entrained-air; freezing; frost; models; service life; tests

Freezing of water in the pores of concrete is one of the major degradation processes of concrete. It results in cracking and reduced service life. Concrete exposed to frost conditions may rapidly degrade or be durable for decades. This report reviews the major factors affecting the frost resistance of concrete and test methods for evaluating the service life of concrete. Mathematical models which describe the mechanisms of frost damage and methodologies for predicting the durability of concrete exposed to frost conditions are reviewed to determine their relevance to service life predictions.

Clifton, J. R.

#### Methods for Predicting the Service Life of Concrete.

National Institute of Standards and Technology,  
Gaithersburg

5th International Conference on Durability of Building Mats and Components, November 7-9, 1990. Brighton, United Kingdom, 361-373 pp, 1990.

accelerated testing; concrete; mathematical modeling; reliability methods; service life predictions; simulation modeling; stochastic methods; degradation

At present the design of concrete is usually based on empirical relationships between materials and properties, and experience with its performance. Another approach for selecting concrete is based on predictions of service life. While this approach is not yet often used, it is likely to have an increasingly important role in designing concrete. There are several methods for predicting the service lives of construction materials. They include i) estimates based on experience, ii) deductions from performance of similar materials, iii) accelerated testing, iv) applications of reliability and stochastic concepts, and v) mathematical and simulation modeling based on the chemistry and physics of degradation processes. These methods are discussed in this paper, along with examples of their applications.

Clifton, J. R.; Knab, L. I.

#### Selection of Siliceous Aggregate for Concrete.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4327; 21 p. June 1990.

Available from National Technical Information Services PB90-235029

aggregate; alkalis; alkali-aggregate reaction; concrete; durability; siliceous aggregate; testing

Alkali-aggregate expansion reactions are one of the potentially serious degradation problems that could affect the structural stability of underground concrete structures for disposing of low-level radioactive waste (LLW). It appears

that all aggregates react to some degree with alkalis in cement. In the majority of cases the reactions are beneficial (e.g., increasing the bond between aggregate and hydrated cement paste) or innocuous. In some cases, however, the reactions result in the formation of expansive products which can cause serious cracking of the concrete. This report deals with the selection of siliceous aggregates to avoid deleterious alkali-aggregate expansions. Current practices used to prevent expansive alkali-silica reactions and the standard test methods used to identify reactive aggregates are first discussed. Then the results of a study on using a new alkali-silica reactivity test to select siliceous aggregates for use in the concrete of LLW storage structures are presented. It is recommended that siliceous aggregates, selected for constructing underground vaults for disposal of LLW, have an expansion of less than 0.10 percent using the new test.

#### Collins, B. L.

Collins, B. L.; Dahir, M. S.; Madrzykowski, D.

#### Evaluation of Exit Signs in Clear and Smoke Conditions.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4399; 80 p. August 1990.

Available from National Technical Information Services PB90-269523

smoke; color; exits; optical density; egress; lighting equipment; visibility

The present paper provides a short review of the research literature on the visibility of exit signs, directional markings, and emergency lighting. It also presents a study which assessed the visibility of several types of exit signs including conventional and electroluminescent (EL) in both clear and smoky conditions. A two-part evaluation was performed. In the first, signs were measured photometrically in clear conditions with two different photometers in a laboratory to determine their luminance under dark conditions and with an ambient room illuminance of 54 lx (5 fc). Analysis of these data indicated very wide variations in luminance (from about 0.9 to 1350 cd/m<sup>2</sup>) as a function of sign type. In the second part of the study, the visibility of the signs in both clear conditions and smoke was assessed psychophysically. A total of 21 observers participated in the assessment of visibility. Analysis of the data indicated that overall sign luminance was one of the primary determinants of visibility in smoke conditions, while uniformity was also an important contributor. The data indicated that some EL signs can be effective in clear conditions and in smoke (particularly if their luminance is above about 10 cd/m<sup>2</sup>). Consideration of the results indicated that somewhat different characteristics of the signs seemed to determine their visibility for clear conditions than smoke, with uniformity (or sign configuration) playing a larger role in clear conditions, and luminance being more critical in smoke. Finally, the data indicated the need for further research in which the effects of color, sign configuration, and luminance are varied parametrically.

Collins, B. L.  
Evaluation of the Role of Luminance Distributions in Occupant Response to Lighting.  
National Institute of Standards and Technology, Gaithersburg, MD  
CIBSE National Lighting Conference. April 1990, Cambridge, England, 1-10 pp, 1990.  
lighting equipment; luminance; occupant response; evaluation; office buildings; lighting characteristics; daylight Findings from a detailed analysis of post-occupancy evaluation data, which involved thirteen office buildings typical of current design practice, are discussed. Analysis of the data indicates that occupant satisfaction could be related to patterns of luminance, lighting characteristics, and presence of daylight in the office.

Collins, B. L.  
Papers Presentations Shine.  
National Institute of Standards and Technology, Gaithersburg  
Lighting Design and Application Magazine, Vol. 20, No. 10, 21-23, October 1990.  
lighting; lamps; conservation; fluorescent; incandescent; metal halide; high pressure sodium  
The 48 papers presented July 29-August 2 at the IESNA conference in Baltimore, MD, spanned the wide variety of areas of interest to the lighting professional. Topics included light sources and conservation issues for displays; efficiency standards for lamps; daylight measurement and modelling; lamp performance including fluorescent, incandescent, metal halide, high pressure sodium, and special sources; tunnel and used in photographing and videotaping cultural assets and objects of art. Damage may be caused by both ultraviolet and infrared radiation exposure during photography because illuminance levels are much higher than needed for display purposes. The authors identified characteristics of three lamps with dichroic filters that appear to reduce infrared radiation and water evaporation from objets d'art. The lamps are now in development.

Collins, B. L.; Fisher, W.; Gillette, G.; Marans, R. W.  
Second-Level Post-Occupancy Evaluation Analysis.  
National Institute of Standards and Technology, Gaithersburg, MD  
Lighting Research Institute Michigan Univ., East Lansing  
Journal of the Illuminating Engineering Society, Vol. 19, 21-44, Summer 1990.  
post-occupancy evaluation; illuminance; lighting; brightness; glare; office buildings  
Post-occupancy evaluation (POE) have been used by a number of researchers (Harris, 1987; Rubin and Collins, 1988; Markus, 1967) as a tool for documenting, evaluating, and improving environmental conditions in offices. In a project sponsored by the U. S. Department of Energy and

the New York State Energy Research and Development Authority during 1984-1986 POE data were collected on lighting power densities, photometric levels, and user attitudes for 912 workstations in 13 office buildings that contained lighting systems somewhat typical of current lighting practice. The purpose of the present evaluation is to examine the relationships between individual lighting system type and these data. Earlier analyses and documentation can be found in Gillette and Brown (1986), Gillette and Brown (1987), Marans (1987), Marans and Brown (1987), and Gillette (1988).

### Cook, G. R.

Cook, G. R.; Simiu, E.  
Chaotic Motions of Forced and Coupled Galloping Oscillators.  
National Institute of Standards and Technology, Gaithersburg, MD  
Journal of Wind Engineering and Industrial Aerodynamics, Vol. 36, 1083-1094, 1990.  
oscillators; numerical simulations; experiments; Farey construction; nonlinear dynamical systems  
Numerical simulations of the behavior of a periodically forced square galloping oscillator yielded results showing that the behavior of this system has similarities with the behavior of the circle map. Lock-in regions were found to be ordered as rational numbers obtained by the Farey construction. At the transition from quasiperiodic to chaotic motion corresponding to a winding number equal to the golden mean, the fractional dimension of the critical line was found to be 0.864, that is, to within 0.5% of the theoretical value for the circle map. Numerical studies were also performed on an autonomous system consisting of two elastically coupled galloping oscillators. Preliminary tests conducted in the 0.3 m diameter water tunnel of the David Taylor Research Center and in the CBT wind tunnel demonstrated the feasibility of the experimental study of both the forced oscillator and the autonomous coupled oscillators described in the paper. Research on these systems is being conducted in collaboration with the Center for Computational and Applied Mathematics, NIST, and the David Taylor Research Center, U. S. Department of the Army.

Cook, G. R.; Simiu, E.  
Periodic and Chaotic Motions of a Modified Stoker Column: Experimental and Numerical Results.  
National Institute of Standards and Technology, Gaithersburg, MD  
NIST BSS 168; 44 p. February 1990.  
Available from Government Printing Office  
buckling; chaotic motion; dynamical systems; nonlinearity; structural dynamics; structural engineering; vibrations  
Records are presented of typical measured motions of a modified forced Stoker column, including periodic motion

around a stable fixed point, periodic snap-through motion, and chaotic motion. Characterizations of the recorded chaotic motion include: the autocorrelation function; the spectral density plot; capacity dimensions; and the Lyapounov exponent. Two sets of numerical simulations were performed, in which the same spring stiffnesses (measured under static conditions) and the same dissipative forces (based on the viscous damping model) were used. The first set, in which the device was modeled as a multidegree of freedom system to account for the distributed mass and stiffness of the springs, yielded chaotic motions qualitatively similar to those recorded in the laboratory. No chaotic motions could be obtained from the second set, which did not reflect the fact that the spring properties are distributed and in which the device was therefore modeled as a one degree of freedom system. To the writers' knowledge this is the first reported instance of an experimental structural system with continuous members for which a qualitatively successful simulation of the chaotic motion appears to necessitate the inclusion in the model of additional degrees of freedom to account for the effects of continuity.

#### **Cooper, L. Y.**

Cooper, L. Y.

Algorithm and Associated Computer Subroutine for Calculating Flow Through a Horizontal Ceiling/Floor Vent in a Zone-Type Compartment Fire Model.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 4402; 53 p. October 1990.

Available from National Technical Information Services PB91-120170

building fires; compartment fires; computer models; fire models; mathematical models; vents; zone models

An algorithm and associated computer subroutine is presented for calculating the effects on two-layer compartment fire environments of the quasi-steady flow through a horizontal vent connecting two spaces. The two spaces can be either two inside rooms of a multi-room facility or one inside room and the outside ambient environment local to the vent. The description of the flow through the vent is determined by combining considerations of 1) the unidirectional-type of flow driven by a cross-vent pressure difference and, when appropriate, 2) the exchange-type of flow induced when the fluid configuration across the vent is unstable, i.e., when a relatively cool, dense gas in the upper space overlays a less dense gas in the lower space. In the algorithm, calculation of the rates of flow exchange between the two spaces is based on a previously reported theory. Characteristics of the geometry and the instantaneous environments of the two spaces are assumed to be known and specified as inputs. The outputs calculated by the algorithm/subroutine are the rates and the properties of the vent flow at the elevation of the vent as it enters the

top space from the bottom space and/or as it enters the bottom space from the top space. Rates of mass, enthalpy, and products of combustion extracted by the vent flows from upper and lower layers of inside room environments and from outside ambient spaces are determined explicitly. The algorithm/subroutine is called VENTCF. The computer subroutine is written in FORTRAN 77. The subroutine is completely modular, and it is suitable for general use in two-layer, multi-room, zone-type fire model computer codes. It has been tested over a wide range of input variables and these tests are described.

Cooper, L. Y.; Forney, G. P.

Consolidated Compartment Fire Model (CCFM) Computer Code Application CCFM.VENTS. Part 1. Physical Basis.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 4342; 96 p. July 1990.

Available from National Technical Information Services PB90-250192

computer models; building fires; compartment fires; fire models; mathematical models; vents; zone models

A project was carried out at the National Institute of Standards and Technology (NIST) to study the feasibility of developing a new-generation, multi-room, compartment fire model computer code, called the Consolidated Compartment Fire Model (CCFM) computer code. The idea was that such a code would consolidate past progress in zone-type compartment fire modeling, and allow readily for integration of future advances with the greatest possible flexibility. The project led to the development of a prototype multi-room CCFM product called CCFM.VENTS. This is Part 1 of a four-part report which documents the above effort. Introductory remarks discuss the generic features of the CCFM and the specific features of CCFM.VENTS. The main objective of this Part 1 document is to present a comprehensive description of the governing equations of CCFM.VENTS and their technical basis. The other three parts of this report are: Part 2: Software Reference Guide; Part 3: Catalog of Algorithms and Subroutines; and Part 4: User Reference Guide.

Cooper, L. Y.; Forney, G. P.

Consolidated Compartment Fire Model (CCFM) Computer Code Application CCFM.VENTS. Part 3. Catalog of Algorithms and Subroutines.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 4344; 126 p. July 1990.

Available from National Technical Information Services PB90-250218

computer models; building fires; compartment fires; fire models; mathematical models; vents; zone models

A project was carried out at the National Institute of Standards and Technology (NIST) to study the feasibility of

developing a new-generation, multi-room, compartment fire model computer code, called the Consolidated Compartment Fire Model (CCFM) computer code. The idea was that such a code would consolidate past progress in zone-type compartment fire modeling, and allow readily for integration of future advances with the greatest possible flexibility. The project led to the development of a prototype multi-room CCFM product called CCFM.VENTS. This is Part 3 of a four-part report which documents CCFM.VENTS. It is a catalog of all the modular algorithms and associated computer subroutines used to simulate the physical phenomena in CCFM.VENTS. Each physical algorithm entry includes a description of the phenomenon simulated, a concise presentation of the calculation procedure used, identification of all input and output parameters, and a listing of the subroutine. The catalog entries have been developed and are presented as modular, stand-alone products. The stand-alone design feature allows the catalog entries to be used both in CCFM and in any other modular, zone-type, compartment fire model computer code. The other three parts of this report are: Part 1: Physical Basis; Part 2: Software Reference Guide; and Part 4: User Reference Guide.

Cooper, L. Y.

**Estimating the Environment and the Response of Sprinkler Links in Compartment Fires With Draft Curtains and Fusible Link-Actuated Ceiling Vents--Theory.**

National Institute of Standards and Technology, Gaithersburg, MD

Fire Safety Journal, Vol. 16, No. 2, 137-163, 1990.  
sprinklers; building fires; compartment fires; computer models; algorithms; mathematical models; vents; sprinkler response; zone models

The physical basis and associated mathematical model for estimating the fire-generated environment and the response of sprinkler links in well-ventilated compartment fires with draft-curtains and fusible link-actuated ceiling vents is developed. Complete equations and assumptions are presented. Phenomena taken into account include: the flow dynamics of the upward-driven, buoyant fire plume; growth of the elevated-temperature smoke layer in the curtained compartment; the flow of smoke from the layer to the outside through open ceiling vents; the flow of smoke below curtain partitions to building spaces adjacent to the curtained space of fire origin; continuation of the fire plume in the upper layer; heat transfer to the ceiling surface and the thermal response of the ceiling as a function of radial distance from the point of plume-ceiling impingement; the velocity and temperature distribution of plume-driven near-ceiling flows and the response of near-ceiling-deployed fusible links as functions of distance below the ceiling and distance from plume-ceiling impingement. The theory presented here is the basis of a user-friendly computer

program, LAVENT, which is supported by a user guide and which can be used to study parametrically a wide range of relevant fire scenarios.

Cooper, L. Y.

**Model for Predicting the Generation Rate and Distribution of Products of Combustion in Two-Layer Fire Environments.**

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 4403; 53 p. September 1990.

Available from National Technical Information Services PB91-107151

combustion; building fires; compartment fires; computer models; fire models; mathematical models; zone models

A model is developed for predicting the generation rates of oxygen, fuel, and any other products of combustion in rooms containing fires. The model is called the generalized global equivalence ratio model. It extends the steady state global equivalence ratio model established from steady-state data of several previous experimental studies. After describing the model in detail, a concise algorithm is outlined for implementing it in two-layer zone-type compartment fire model computer codes. With the algorithm in place, such codes could be used to simulate the distribution of combustion products in single or multi-room fire environments. In an example application, the model simulates the time-dependent environment, including that of steady-state, in conditions and under the assumption of complete stoichiometric combustion, solutions for concentrations of products of combustion are obtained and presented. The solutions are used to predict the time-to-extinguishment of a burning methane fuel source embedded in an initially ambient-atmosphere upper layer.

Danner, W. F.

Danner, W. F.

**Proposed Integration Framework for STEP (Standard for the Exchange of Product Model Data).**

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 90-4295; 28 p. April 1990.

Available from National Technical Information Services PB90-207358

framework; information modeling; integration framework; IPO; PDES; product data; product data modeling; product modeling; STEP

This paper presents a proposed integration framework for product data modeling. The framework provides for the representation of functional, programmatic, and physical product data across all phases of a product's life cycle. It provides a single coherent approach to product data modeling for the specification of application views. Most importantly, it creates an open system that encourages the

innovative use of information. The framework has as its major feature an integrated product information model with four conceptual levels. These include generic product description, property description, representation and presentation, and mathematical resources. A generic product data model is the key element of the framework. It is composed of application-independent facts common to all products. The generic model is a distillation from the models currently under consideration by the STEP and PDES projects. The generic product data model meets the requirements of multiple application areas by providing for the interpretation of generic facts in specific contexts. It also provides a logical structure for the integrated product information model which is used by application models to fulfill user requirements.

### **Deal, S.**

Deal, S.; Beyler, C.

Correlating Preflashover Room Fire Temperatures. Worcester Polytechnic Institute, MA Journal of Fire Protection Engineers, Vol. 2, No. 2, 33-48, 1990.

room fires; flashover; temperature; equations; databases; vents; flow rate; ventilation; stoichiometric mixtures

In this investigation the existing correlational methods for predicting room fire temperatures are evaluated by comparison with a database of 559 data points derived from over 250 room fire experiments. In addition, several new methods based on a simple energy balance are proposed and evaluated.

### **Didion, D. A.**

Didion, D. A.; Bivens, D. B.

Role of Refrigerant Mixtures as Alternatives to CFCs.

National Institute of Standards and Technology, Gaithersburg, MD

International Journal of Refrigeration, Vol. 13, 163-175, May 1990.

refrigerants; alternative refrigerants; refrigerant mixtures; azeotropes; near-azeotropes; zeotropes

Refrigerant mixtures may provide some solutions to the problem of the very limited number of fluids which have suitable properties to provide alternatives to CFCs. Mixing of refrigerants allows the adjustment or tuning of the most desirable properties of the mixture by varying the molar fraction of the components. There are three categories of mixtures which can be used as working fluids: azeotropes, near-azeotropes and zeotropes. Azeotropes are usually binary and have long been used in the refrigeration industry; it is unlikely that new combinations will now be found. Near-azeotropes have a much greater potential for development, but under leakage conditions may alter their composition and properties. Near-azeotropes have the most potential as drop-in alternative to CFCs. Azeotropes have potential for improvements in energy efficiency and capacity

modulation, but, as they require hardware design changes can only be considered in new system designs. However, with the long-term concerns about global warming, energy efficiency, and therefore the use of zeotropes will probably have a great influence on the refrigeration industry.

Didion, D. A.; Cohen, R.; Tree, D. R.

Role of R22 in Refrigerating and Air Conditioning Equipment.

National Institute of Standards and Technology, Gaithersburg, MD

International Institute of Refrigeration. International Colloquium of Brussels, Refrigeration and CFCs. March 19-20, 1990, Paris, France, 1-18 pp, 1990.

alternatives; chlorofluorocarbons; hydrochlorofluorocarbons; hydrofluorocarbons; refrigerants; system design

The U. S. Environmental Protection Agency has recently performed an analysis that shows the need for nearly 100% worldwide-acceptance of total CFC phase out. The adoption of HFCs (for example R134a) and HCFCs (for example R123 and R22) alternatives, at least in the interim, is the only feasible means by which this schedule can be met. In the past four years, there has been more research for the adaptation of R134a and R123 to R12 and R11 systems than ever in the history of the refrigeration industry. Refrigerant properties measurements, materials compatibility studies, and hardware and system design changes have been conducted worldwide with information exchanged between countries on almost a daily basis. Even so, some previously unforeseen problems persist so that the system design for virtually any application is not yet final, and for some applications system design solutions are not even in sight. Tried and proven R22 systems are being extended to temperature and capacity ranges beyond their usual application to fill in these gaps; for example, for food refrigeration systems. Manufacturers in developed countries need alternatives and strategies that they can depend on before investing in the development of new products and equipment necessary for the CFC phase out. It is not likely that industry will make the large investments necessary to produce new equipment until new refrigerants are proven acceptable and are known to be available in adequate quantity for use. Developing countries need viable alternatives to combat a natural reluctance to participate in the CFC phase out in order to improve their standards of living. They cannot afford the risk or economic impact of a refrigeration systems that are unproven or not in adequate supply. Thus, the HCFC and HFC refrigerants represent the only interim solution known today.

### **Dijkers, R. D.**

Dijkers, R. D.

NIST Structural Research Publications, 1984-1989.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 90-4297; 54 p. May 1990.

Available from National Technical Information Services

bibliography; publications; structural research

This report contains a list of research reports and papers authored or co-authored by members of the Structures Division, Center for Building Technology, National Institute of Standards and Technology during the period, 1984-1989. Subject categories included are: Concrete, Construction Safety, Earthquake Engineering, Geotechnical Engineering, Masonry, Miscellaneous, Nondestructive Testing, Offshore Structures, Probability Theory, Steel, Structural Dynamics, Structural Investigations, and Wind Engineering.

### **Dols, W. S.**

Dols, W. S.

Ventilation Characterization of the Consumer Product Safety Commission Combustion Test Facility.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 4415; 22 p. September 1990.

Available from National Technical Information Services PB91-107490

air exchange rate; chambers; mixing; tracer gas techniques; ventilation

The Consumer Product Safety Commission (CPSC) is evaluating pollutant emissions from kerosene and methane heaters using a test chamber. Under an interagency agreement with CPSC, the Indoor Air Quality and Ventilation Group of the National Institute of Standards and Technology (NIST) measured the air exchange rate of the chamber under various ventilation system operating conditions, the extent of air mixing within the chamber, and the interior volume of the chamber. The air exchange rate of the chamber was determined using the tracer gas decay method with sulfur hexafluoride (SF<sub>6</sub>) as the tracer gas. Carbon dioxide (CO<sub>2</sub>) was also used as a tracer gas in order to verify the decay rates obtained with the SF<sub>6</sub> system; however CO<sub>2</sub> could not be used during combustion tests. The effect of pollutant monitoring systems and combustion devices on air exchange rates was also examined. Based on multi-point concentration measurements during decays, the extent of mixing within the chamber appeared to be adequate to employ the single-zone tracer gas decay method. The interior air volume of the chamber was determined using the constant injection tracer gas technique and yielded a volume very close to the volume based on the physical dimensions of the chamber. Recommendations for an air exchange rate measurement system for the chamber and modifications to be made in order to more effectively utilize the system are made.

### **Domanski, P. A.**

Domanski, P. A.

Rating Procedure for Mixed Air-Source Unitary Heat Pumps Operating in the Heating Mode.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 90-4298; 14 p. May 1990.

Available from National Technical Information Services PB90-221854

capacity; heat pump; mixed system; mixed-matched system; rating procedure; seasonal efficiency

A procedure is presented for determining the heating performance ratings of air-source unitary heat pumps consisting of an outdoor section and an indoor section which were not tested together as a system. The procedure allows calculation of capacity at the 47 deg F rating point and heating seasonal performance factor, HSPF, using as a reference point performance ratings of the outdoor unit tested under current DoE procedures in conjunction with a different indoor section. This procedure requires as input data the matched system rated performance, the ratio of condensing capacities of mixed and matched indoor coils, and the ratio of powers of mixed and matched indoor fans.

Domanski, P. A.; McLinden, M. O.

Simplified Cycle Simulation Model for the Performance Rating of Refrigerants and Refrigerant Mixtures.

National Institute of Standards and Technology, Gaithersburg, MD

American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE). CFC Purdue Conference. July 17-20, 1990, 1990.

refrigerants; simulation; vapor compression cycle; modeling; evaluation

A simulation program, CYCLE11, which is useful for the preliminary evaluation of the performance of refrigerants and refrigerant mixtures in the vapor compression cycle is described. The program simulates a theoretical vapor-compression cycle and departures from the theoretical cycle as occur in a heat pump and in a refrigerator. The cycles are prescribed in terms of the temperatures of the external heat transfer fluids with the heat exchangers generalized by an average effective temperature difference. The isenthalpic expansion process is assumed. The program includes a rudimentary model of a compressor and a representation of the suction line and liquid line heat exchange. Refrigerant thermodynamic properties are calculated using the Carnahan-Sterling-DeSantes equation of state. Refrigerant transport properties are not included in the simulations. The program can generate merit ratings of refrigerants for which limited measurement data are available. An example of simulation results stresses the need for careful application of simplified models and consideration for the involved assumptions.

## **Dougherty, B. P.**

Dougherty, B. P.  
Proposed Methodology for Rating Integrated  
Air-Source Heat Pumps.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
Research Project 2033-26; EPRI CU-6813; 107 p.  
April 1990.

heat pumps; rating methodology; integrated appliance; space heating; air conditioning; water heating; seasonal performance

At the National Institute of Standards and Technology (NIST), work is on-going to develop a proposed procedure for testing and rating air-source heat pumps that heat, cool, and provide domestic water heating. The family of appliances providing these three functions are referred to here as integrated (or combined) heat pump/water heating appliances. For these appliances, the heat pump contributes to heating the water in a storage-type water heater through the use of a refrigerant-to-potable water heat exchanger. The work at NIST has centered upon developing a proposed rating methodology for integrated appliances that heat water in a water heating only mode and while simultaneously air-conditioning or space heating. Despite the emphasis, the proposed methodology provides a framework for rating other types of integrated heat pump/water heating appliances. The laboratory testing, the calculation procedure, and the method for reporting performance are described. The testing is an adaption of the laboratory tests conducted when rating conventional heat pumps and water heaters. Seasonal estimates of energy consumption rates are calculated using a bin type approach. Combined performance factors and operating costs are used for reporting performance.

## **Emmons, H. W.**

Emmons, H. W.  
Ceiling Jet in Fires.  
Harvard Univ., Cambridge, MA  
NIST-GCR-90-582; Home Fire Proj. Tech. Rpt. 82;  
51 p. December 1990.

Available from National Technical Information Services

ceiling jets; corridors; room fires; smoke movement  
The steady ceiling jet is examined with a simplified "top hat" theory. Friction causes the jet to change downstream with flow, depth, and/or hydraulic jump adjustments to produce Richardson Number =1 at the corridor exit, just as in hydraulics. Entrainment has a qualitative effect identical to friction, although there are quantitative differences. Heat transfer has, however, the opposite effect; the Richardson Number moves away from 1 as the flow proceeds. When all effects are included, high friction cases are predictable, while low friction cases are not. New experimental studies are needed to locate the reasons.

## **Evans, D. D.**

Evans, D. D.; Walton, W. D.  
Burning of Oil Spills.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
U. S./Japan Government Cooperative Program on  
Natural Resources (UJNR). Fire Research and  
Safety. 11th Joint Panel Meeting. October 19-24,  
1989, Berkeley, CA, Jason, N. H. and Cramer, D.  
M., Editor(s), NISTIR 4449, 217-222 pp, 1990.  
oil spills; combustion; smoke generation; crude oil; tests;  
pool fires; energy transfer

This study is directed at understanding the oil spill combustion process and the smoke generated from the burning. Measurements of 1.2 m diameter Murban crude oil pool fires show an initial steady energy release rate of 840 kW/m<sup>2</sup> which increases to 1860 kW/m<sup>2</sup> during the vigorous burning associated with boiling of the water sublayer. During the burning of the crude oil pools approximately 10 percent of the crude oil was converted to smoke with a high elemental carbon content in excess of 90 percent. Measurements of polycyclic aromatic hydrocarbon (PAH) components found in the original oil, showed that soot produced in the burning process carried a different distribution of PAH compounds, but that the total concentration of these compounds was equal to that found in the original crude oil.

Evans, D. D.; Walton, W. D.; Baum, H. R.; Rehm,  
R. G.; Harris, R. H., Jr.; Ghoniem, A.; Holland, J.  
Measurement of Large Scale Oil Spill Burns.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
Massachusetts Institute of Technology, Cambridge  
Consultant, Wheaton, MD

Environment Canada. Arctic and Marine Oil Spill  
Program Technical Seminar, 13th. June 6-8, 1990,  
Edmonton, Alberta, Canada, Environment Canada,  
Ottawa, Ontario, 1-38 pp, 1990.

oil spills; measurement; crude oil; pool fires; smoke yield;  
plumes; sampling; burning rate

Research has shown that burning can be an effective means to remove oil from the surface of the water. The combustion characteristics of crude oil have been measured in large laboratory tests using a nominal one meter diameter pool fire. This work reports on progress mid-way through a 2 1/2 year research program. The objective of this research is to develop measurement equipment and calculations that can be used to characterize oil spill burning at operational scale during field trials of the technology. Field scale measurement techniques for fire radiation, smoke yield, particulate sampling, plume trajectory are described.

Progress in the calculation of particulate deposition downwind of the burn site is presented.

### **Fang, J. B.**

Fang, J. B.; Grot, R. A.

Evaluation of Thermal Bridges Using a Mobile Test Facility.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 90-4258; 34 p. March 1990.

Available from National Technical Information Services PB90-198912

building; exterior envelope; heat flux; in-situ measurements; portable calorimeter; temperature; thermal bridge; thermal resistance; walls

The construction details of a mobile test facility with removable walls and roof used for installation and performance evaluation of the test specimens are described. Descriptions of the overall performance of a newly developed portable calorimeter employed for quantification of the heat flow through exterior walls of a building corner are given. Laboratory tests were conducted using an in-situ thermal resistance measurement technique to evaluate the performance of thermal bridges occurring in a metal-frame, insulated wall construction. The local heat flow rates and thermal resistances under steady-state conditions were measured by means of portable calorimeters, heat flux transducers and thermistors at various locations of the test structure. The measured wall thermal resistance values were compared with the predicted values obtained by the zone and the series/parallel resistance methods. The calorimeter measurement generally gave lower thermal resistance values than the heat flux transducers due to enhanced heat conduction through highly conductive fasteners and framing members.

### **Fang, J. B.**

Thermal Analysis of Directly Buried Conduit Heat Distribution Systems.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 4365; 96 p. August 1990.

Available from National Technical Information Services PB90-269481

computer programs; direct burial; district heating and cooling; finite element method; heat loss; heat transfer;

The calculations of heat losses and temperature fields for directly buried conduit heat distribution systems were performed using finite element method. The finite element analysis solved two-dimensional, steady-state heat transfer problems involving two insulated parallel pipes which were encased in the same conduit casing and in separate casings, and the surrounding earth. Descriptions of the theoretical basis, computational scheme, and the data input and outputs of the developed computer programs are presented. Numerical calculations were carried out for predicting the

temperature distributions within the existing high temperature hot water distribution system with two insulated pipes covered in the same metallic conduit and the surrounding soil. The predicted results generally agree with the experimental data obtained at the test site. The deviations between the predicted and measured values are found to range from 0 to 17 percent with an average of 6 percent. The rates of heat loss from two insulated pipes encased in separate conduits were calculated for different pipe sizes, fluid temperatures and insulation thickness. The results were compared with the predictions from a steady-state, one-dimensional radiant heat conduction model. The discrepancies between finite element and radial conduction models in pipe heat loss values are discussed.

### **Fanney, A. H.**

Fanney, A. H.

Measured Performance of Residential Water Heaters Using Existing and Proposed Department of Energy Test Procedures.

National Institute of Standards and Technology, Gaithersburg, MD

ASHRAE Transactions, Vol. 96, No. Part 1, 288-295, January 1990.

ASHRAE. Winter Annual Meeting. February 10-14, 1990, Atlanta, GA, 1990.

heaters; residential buildings; test procedures; computers

A computer-based laboratory for testing residential water heaters has been fabricated at the National Institute of Standards and Technology (NIST). This paper describes the automated laboratory, summarizes existing and proposed Department of Energy test procedures for residential water heaters, and presents experimental results for six electric, five gas-fired, and two oil-fired storage-type water heaters obtained from local distributors.

### **Fernandez-Pello, A. C.**

Fernandez-Pello, A. C.

Fire Propagation in Concurrent Flows. Final Progress Report. August 1, 1989-July 31, 1990.

California Univ., Berkeley

NIST-GCR-90-586; 132 p. December 1990.

Available from National Technical Information Services PB91-157206

burning rate; flame spread; flame spread rate; ignition; turbulence; turbulent flow; turbulent heat transfer

A research program is being conducted to study the mechanisms controlling the spread of fire in a turbulent forced gas flows moving in the direction of flame propagation. The research tasks completed during this reporting period include an experimental studies of the effect of flow turbulence on the rate of concurrent flame spread, and of mass burning when the combustible material is in a floor configuration. The results of the experiments with

thick PMMA sheets show that flow turbulence affects significantly the flame spread and mass burning processes. As the turbulence intensity is increased, the flame spread rate decreases because the flame length sharply decreases, and the mass burning rate increases because the surface heat flux increases. Currently underway is a complementary study with the combustible material placed in a ceiling geometry to observe the effect of buoyancy on the flame spread and mass burning processes. An additional task also completed during this period is a review of the processes of ignition and flame spread of solid combustibles. The review presents a novel approach to the analysis and prediction of both processes based in their close interrelationship.

### **Forney, C. L.**

Forney, C. L.; Jones, W. W.  
Fire Risk Assessment Method: Guide to the Risk Methodology Software. Internal Report. Final Report.  
National Institute of Standards and Technology, Gaithersburg, MD  
NISTIR 4401; 55 p. September 1990.  
Available from National Technical Information Services PB91-107169  
risk assessment; compartment fires; fire growth; software development; fire hazards  
This guide provides the background on the computer programs used in the Risk Assessment Method. The program modules are tabulated and explained, together with the file requirements for each. Two examples are carried through the process to show the actual use of the programs in performing an assessment of the risk due to unwanted fires.

### **Forney, G. P.**

Forney, G. P.; Cooper, L. Y.  
Consolidated Compartment Fire Model (CCFM) Computer Code Application CCFM.VENTS. Part 2. Software Reference Guide.  
National Institute of Standards and Technology, Gaithersburg, MD  
NISTIR 4343; 92 p. July 1990.  
Available from National Technical Information Services PB90-250200  
computer models; building fires; compartment fires; fire models; mathematical models; vents; zone models  
A project was carried out at The National Institute of Standards and Technology (NIST) to study the feasibility of developing a new-generation, multi-room, compartment fire model computer code, called the Consolidated Compartment Fire Model (CCFM) computer code. The idea was that such a code would consolidate past progress in zone-type compartment fire modeling, and allow readily for integration

of future advances with the greatest possible flexibility. The project led to the development of a prototype multi-room CCFM product called CCFM.VENTS. This is Part 2 of a four-part report which documents the above effort. The main objective of this Part 2 document is to document the design and underlying structure of the CCFM.VENTS computer software. It serves as a guide for those persons interested in extending, modifying and if necessary correcting CCFM.VENTS at a later date. The other three parts of this report are: Part 1: Technical Basis; Part 3: Catalog of Algorithms and Subroutines; and Part 4: User Reference Guide.

Forney, G. P.; Cooper, L. Y.; Moss, W. F.  
Consolidated Compartment Fire Model (CCFM) Computer Code Application CCFM.VENTS. Part 4. User Reference Guide.  
National Institute of Standards and Technology, Gaithersburg, MD  
NISTIR 4345; 51 p. July 1990.  
Available from National Technical Information Services PB90-250226  
computer models; building fires; compartment fires; fire models; mathematical models; vents; zone models  
A project was carried out at The National Institute of Standards and Technology (NIST) to study the feasibility of developing a new-generation, multi-room, compartment fire model computer code, called the Consolidated Compartment Fire Model (CCFM) computer code. The idea was that such a code would consolidate past progress in zone-type compartment fire modeling, and allow readily for integration of future advances with the greatest possible flexibility. The project led to the development of a prototype multi-room CCFM product called CCFM.VENTS. This is Part 4 of a four-part report which documents the above effort. The main objective of this Part 4 document is to document the use of CCFM.VENTS. Its capabilities and limitations are described. A simple two room tutorial is presented to get the user quickly acquainted with the input requirements of CCFM.VENTS. Each CCFM.VENTS command is described. Finally, a program for plotting CCFM.VENTS data is presented. This program runs on an IBM-PC or compatible with a VGA graphics monitor. The other three parts of this report are: Part 1: Technical Basis; Part 2: Programmers Reference Guide; and Part 3: Catalog of Algorithms and Subroutines.

Forney, G. P.; Jones, W. W.  
Software Development Tools.  
National Institute of Standards and Technology, Gaithersburg, MD  
NISTIR 4363; 42 p. June 1990.  
Available from National Technical Information Services PB90-250051

computer programs; compartment fires; fire growth; mathematical models

This paper discusses the use of software tools in the development of models produced by the Center for Fire Research (CFR). There are two types of tools described in this paper. The first type consists of executable programs that characterize the subroutine and data structures of FORTRAN programs. A second class of software tools are subroutines that support various utility functions required by CFR models. We will discuss how each of these tools are used and why their development was necessary. In addition, we will indicate how these tools might be improved.

### **Gaddy, G. D.**

Gaddy, G. D.; Rossiter, W. J., Jr.; Eby, R. K.

Application of Thermal Analysis Techniques to the Characterization of EPDM Roofing Membrane Materials.

National Institute of Standards and Technology, Gaithersburg American Society for Testing and Materials. Roofing Research and Standards Development, 2nd Volume. ASTM STP 1088. Philadelphia, PA, American Society for Testing and Materials, Wallace, T. J.; Rossiter, W. J., Editor(s), 37-52 pp, 1990.

ASTM D 4637; characterization; environments; EPDM rubber; roofing; single-ply membranes; thermal analysis This study was conducted to provide data on the feasibility of using thermal analysis (TA) methods for the characterization of roofing membrane materials. TA methods have not been widely applied to such materials. The methods used were thermogravimetry (TG), differential scanning calorimetry (DSC), and dynamic mechanical analysis (DMA). Three black (carbon black filled), two white (titanium dioxide pigmented), and one white on black laminated ethylene propylene diene terpolymer (EPDM) membrane materials were analyzed before and after exposure to the heat, ozone and UV conditions given in ASTM D 4637, as well as to outdoor exposure. Load-elongation tests were conducted to compare the results with those of the TA methods. The results indicated that: (1) TA techniques can be used to characterize EPDM membrane materials; (2) both the black and white membrane materials showed only slight property changes under exposure, as determined using the TA methods; and (3) in contrast to the TA results, the load-elongation values displayed relatively large changes. The TA tests determined bulk properties of the rubber sheets, whereas the elongation measurements were, to a great extent, influenced by surface characteristics. Based on the study results, it is recommended the work continue to provide additional data necessary for use to TA methods in standards.

### **Gann, R. G.**

Gann, R. G.; Barnes, J. D.; Davis, S.; Harris, J. S.; Harris, R. H., Jr.; Herron, J. T.; Levin, B. C.; Mopsik, F. I.; Notarianni, K. A.; Nyden, M. R.; Paabo, M.; Ricker, R. E.

Preliminary Screening Procedures and Criteria for Replacements for Halons 1211 and 1301.

National Institute of Standards and Technology, Gaithersburg, MD

NIST TN 1278; 311 p. August 1990.

Available from Government Printing Office

halon 1211; halon 1301; electrical resistivity; corrosion; residues; compatibility; plastics; fire suppression; halons; ozone; toxicity

The current halogenated fire suppressants, halons 1301 and 1211, are among the compounds whose production is restricted by the Montreal Protocol of 1987. The objective of this project is to facilitate identification of alternative chemicals by developing quick, inexpensive screening procedures for characterizing nine critical properties: fire suppression efficiency, ozone depletion potential, global warming potential, residue level, toxicity, long-term storage stability, metals corrosion, electrical conductivity, and compatibility with plastics. We have constructed and exercised such a series of tests that can be used to make decisions to pursue particular chemicals further. The procedures are straightforward to conduct, require about 5 moles of chemical, and can be performed in about 8 days for less than \$15k. Lower costs would result for concurrent testing of many chemicals. The results are reported in classes that relate to the performance of halons 1211 and 1301. Examples of testing sequences are provided. Interpretation of the results requires expert judgment since weak performance in a test may not be the basis for rejecting a chemical. These methods and performance classes have been developed for screening purposes only and should not be used for final selection, procurement or regulation without more extensive evaluation.

### **Gann, R. G.**

Replacement for the Halogenated Fire Suppressants: A Research Strategy and Plan.

National Institute of Standards and Technology, Gaithersburg, MD

U. S./Japan Government Cooperative Program on Natural Resources (UJNR). Fire Research and Safety. 11th Joint Panel Meeting. October 19-24, 1989, Berkeley, CA, Jason, N. H. and Cramer, D. M., Editor(s), NISTIR 4449, 45-53 pp, 1990.

halons; halogenated compounds; halon 1201; halon 1301; fire suppression

A consortium of industrial firms and Federal Agencies has developed a plan to identify candidate fire suppressants to replace halons 1211 and 1301. The strategy is to conduct a program of closely-coordinated research, empirical testing, and analysis.

### **Garboczi, E. J.**

Garboczi, E. J.; Bentz, D. P.  
Analytical and Numerical Models of Transport in Porous Cementitious Materials.  
National Institute of Standards and Technology, Gaithersburg, MD  
Materials Research Society Symposium Proceedings. Volume 176. 1990, 675-661 pp, 1990.

porous cementitious materials; analytical models; numerical models; equations

Fluid flow under applied pressure gradients and ionic diffusion under applied concentration gradients are important transport mechanisms that take place in the pore space of cementitious materials. This paper describes: 1) a new analytical percolation-theory-based equation for calculating the permeability of porous materials, 2) new computational methods for computing effective diffusivities of microstructural models or digitized images of actual porous materials, and 3) a new digitized-image mercury intrusion simulation technique.

Garboczi, E. J.; Bentz, D. P.  
Cement in the Computer Age.  
National Institute of Standards and Technology, Gaithersburg, MD  
Cementing the Future, Vol. 2, No. 1, 1,3-4, Winter 1990.

cements; computers

As the old saying goes, beauty is in the eye of the beholder. That is true for scientific models of cement-based materials, as well as in the world of fashion models. Researchers from different disciplines look at models differently. Pure, practical engineers want models that will quantitatively predict the results of tests (expensive tests) based on 5.3 or fewer easily, cheaply measured parameters. Such a model will then enable them to eliminate 526 of the originally planned 1084 samples in their testing program, and thus come in under budget after all. In the model, a multitude of basic philosophical sins will be over looked as long as the results agree with test data.

### **Gore, J. P.**

Gore, J. P.; Skinner, S. M.; Ip, U. S.  
Investigation of Simulated Oil-Well Blowout Fires.  
Annual Report.  
Maryland Univ., College Park  
NIST-GCR-90-581; 81 p. November 1990.  
Available from National Technical Information Services PB91-144337

well fires; blowout fires; oils; fire investigations; water; flame structure; flame radiation; fire suppression; laminar flames; simulation; temperature measurements; heat flux

A study of simulated oil well blowout fires aimed at improving the predictive capabilities needed for the development of radiation and fire suppression technology is described. Measurements of temperature distributions and radiative heat flux to representative locations are used to evaluate the analysis. Methane/air flames with suppression and heptane+methane/air flames without suppression are considered. The analysis consists of (i) construction of state relationships for fuel with water addition and two phase fuel mixtures using species concentration data for single fuels with the help of mixing rules and (ii) application of an existing flow solver under the locally homogeneous flow approximation. The predictions and measurements are in reasonably good agreement. Direct verification of the mixing rule for state relationships and treatment of two phase flow effects is necessary for further improvement.

### **Gross, D.**

Gross, D.  
Estimating Air Leakage Through Doors for Smoke Control.  
National Institute of Standards and Technology, Gaithersburg, MD  
Fire Technology, Vol. 26, No. 1, 75-81, February 1990.

Lund University. Science of Building Fire Safety. Symposium to Honor Professor Ove Pettersson on His Retirement. May 2-4, 1989, Lund, Sweden, 1-3 pp, 1989.

fire safety; building safety; air leakage; doors; smoke control; seals; air flow

One of the most difficult design problems in maintaining the fire-safety integrity of separating elements deals with joint and penetration details. Doors within walls represent a major challenge, in terms of both flame penetration and the passage of smoke and gases. With the increased attention now being given to the design of buildings to control smoke movement and to maintain smoke-free areas of refuge, better information on the flow of air and smoke-air mixtures through closed door assemblies is needed.

### **Gross, J. G.**

Gross, J. G.; Kammer, R. G.  
Developing a Response to EC '92.  
National Institute of Standards and Technology, Gaithersburg, MD  
Construction Specifier, Vol. 43, No. 9, 92-101, September 1990.

construction materials; standards; certification; regulations  
A global market for construction products and services is becoming a reality. The unification of the European market by the end of 1992, the increased international trade in the Pacific Rim, the interest of the Eastern European countries in purchasing Western technology, and the growing Third

World market all provide opportunities. However, each has built-in constraints to U. S. participation. Standards are the primary means by which purchasers, vendors, and regulators communicate. National and regional standards typically favor countries or groups of countries that generate them.

Gross, J. G.; Wright, R. N.

Development and Enforcement of U. S. Building Regulations.

National Institute of Standards and Technology, Gaithersburg, MD

U.S./Japan Natural Resources Development Program (UJNR). Wind and Seismic Effects. Joint Meeting of the U. S./Japan Cooperative Program in Natural Resources Panel on Wind and Seismic Effects, 21st. May 16-19, 1989, Tsukuba, Japan, Raufaste, N. J., Editor(s), NIST SP 776, 348-364 pp, 1990.

accelerograph; Armenia; bridges; codes; concrete; design criteria; disasters; earthquakes; geotechnical engineering; ground failures; inelastic; lifelines; liquefaction; masonry; repair and retrofit; risk assessment; seismicity; soils; standards; storm surge

U. S. practices for development and enforcement of building standards and codes are described for the guidance of those who seek to develop or apply improved building products or practices. Trends, such as mitigation of effects of natural hazards, conservation of energy, water and environment, and efforts to reduce barriers to beneficial innovations or trade, lead to demands for changes in building products and practices. Understanding of the U. S. building regulatory system and the roles of participating organizations is essential to introduction of new products or practices and to improvement of the building regulatory system.

Gross, J. G.

Harmonization of Standards and Regulations: Problems and Opportunities for the United States.

National Institute of Standards and Technology, Gaithersburg, MD

Building Standards, 32-35, March/April 1990.

standards; regulations; construction materials; certification  
A global market for construction products and services is becoming a reality. The unification of the European market by 1992, the increased international trade in the Pacific Rim, the interest in purchasing Western technology by the eastern European countries and the growing Third World market provide opportunities, but each has built-in constraints to United States participation. Standards are the primary means by which purchasers, vendors and regulators communicate. National and regional engineering standards typically favor the countries or groups of countries that generate them. The International Organization for Standardization (ISO) is widely recognized for international standards leadership. Compliance with its standards is a

strong argument for product acceptance in international trade. However, current participation international standards activities by the United States construction community is limited and often ineffective. This problem must be addressed to open international markets to the United States construction community and broaden that market's receptivity to current and future United States technology, construction products and professional services. The United States cannot afford to stay out of the world market. International trade agreements require that the United States be open to foreign products and services. The issue is whether the United States will influence the international standards which are becoming the basis for acceptance of products and services for much of the world's trade.

Gross, J. G.

International Harmonization of Standards.

National Institute of Standards and Technology, Gaithersburg, MD

American Society of Civil Engineers. Prospects for International Engineering Practice. May 1, 1990, Baltimore, MD, American Society of Civil Engineers, New York, 11-34 pp, 1990.

standards; evaluation; test methods; regulations

This paper focuses on the current and near future expected changes in the international construction market for products and services. The importance of standards as a basis for regulations, contracts, and quality assurance systems is discussed. A review of building and construction standards and their development and use in the United States is covered, including product approval systems which are supported by laboratory accreditation and certification. The European EC 92 programs, the development and use of international standards, and the related certification and testing programs are reviewed. The European effort directed to the harmonization of building regulations for all of Europe is also outlined. In the summary, eight action recommendations are provided for consideration by the U. S. construction community.

Jason, N. H.

Jason, N. H.

Fire Protection.

National Institute of Standards and Technology, Gaithersburg, MD

International City Management Association (ICMA). Municipal Year Book, 1990. The Authoritative Source Book of Urban Data and Developments, Intl. City Management Assoc., Washington, DC, 385-386 pp, 1990.

fire protection; bibliographies

Jason, N. H.  
Fire Research Publications, 1989.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
NISTIR 4311; 35 p. April 1990.  
Available from National Technical Information  
Services PB90-219809  
cigarettes; composite materials; cone calorimeters; fire  
models; fire research; flame research; oil spills; plastics;  
smoke control; sprinklers; toxicity  
"Fire Research Publications, 1989" is a supplement to  
previous editions. Earlier edition information is available  
upon request.

Jason, N. H.  
FIREDOC Vocabulary List, 3rd Edition.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
NIST SP 779; 104 p. February 1990.  
Available from Government Printing Office  
003-003-02997-1  
fire research; indexes (documentation); retrieval terms  
The third edition of the FIREDOC Vocabulary List contains  
over 4000 keywords and reflects the subject matter of  
published documents in the Fire Research Information  
Services (FRIS) collection. The keywords are used to locate  
documents in FIREDOC, the online bibliographic database  
to the FRIS collection.

Jason, N. H., Editor; Cramer, D. M., Editor  
U.S./Japan Government Cooperative Program on  
Natural Resources (UJNR). Fire Research and  
Safety. 11th Joint Panel Meeting. October 19-24,  
1989, Berkeley, CA,  
NISTIR 4449, 366 pp, 1990.  
Available Government Printing Office  
fire safety; fire research; building fires; building materials;  
combustion toxicology; compartment fires; computers;  
halons; hazard assessment; oil spills; pool fires; risk analysis;  
smoke  
The 11th Joint Meeting of the United States-Japan Panel on  
Fire Research and Safety was held on the campus of the  
University of California, Berkeley, October 19-24, 1989.  
Some disruption of the meeting resulted from the October  
17 earthquake. The epicenter was about 60 miles southeast  
of San Francisco, in the Loma Prieta mountains near Santa  
Cruz. Thus, some of the papers were not presented, but are  
included in this volume. This volume comprises a total of six  
progress reports and 30 supporting papers in three areas:  
Risk, Hazard and Evacuation; Fire and Toxicity Chemistry;  
and  
Fire and Smoke Physics. The next Panel Meeting will be  
held in Japan in the autumn of 1992.

Johnson, M. K.  
Johnson, M. K.; Lew, H. S.  
Experimental Study of Post-Installed Anchors  
Under Combined Shear and Tension Loading.  
National Institute of Standards and Technology,  
Gaithersburg  
NISTIR 90-4274; 81 p. 1990.  
Available from National Technical Information  
Services PB90-198425  
anchors; combined loading; concrete; embedment depth;  
expansion anchors; post-installed anchors; shear; tension  
The behavior of post-installed anchors subjected to static  
combined shear and tension loads was studied experimentally.  
Twenty-four 1 in. diameter wedge-type expansion anchors  
were tested in uncracked concrete. Anchors were not  
preloaded and were located sufficiently far from the edge of  
the concrete specimens. Test variables included the angle of  
inclination of applied load (measured with respect to a  
horizontal plane), anchor embedment depth, and concrete  
compressive strength. Shear failures occurred for specimens  
tested at load angles between 0 and 60 degrees and tension  
failures were observed for specimens tested at load angles  
between 60 and 90 degrees. There were two types of shear  
failures: Steel fracture near the bottom of the anchor at the  
tapered section for anchors with shallow embedment depths  
and steel fracture along the shank for more  
deeply-embedded anchors. Two types of tension failures  
occurred: Steel tensile failure at the threads and  
cone-shaped tensile failure of the concrete. For specimens  
failing in shear, anchor capacity depended mainly on  
embedment depth. A limiting capacity was reached at an  
embedment depth of approximately 6 in. when steel failure  
controlled. Anchor deformation was influenced by both load  
angle and embedment depth.

Jones, W. W.  
Jones, W. W.; Forney, G. P.  
Programmer's Reference Manual for CFAST, the  
Unified Model of Fire Growth and Smoke  
Transport.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
NIST TN 1283; 104 p. November 1990.  
Available from Government Printing Office  
compartment fires; fire growth; mathematical models;  
numerical models  
This document describes the unified model of fire growth  
and smoke spread, CFAST. This paper documents the  
internal structure of the model and details the method of  
modifying the model, together with examples. The intent is  
to provide a framework and methodology for maintenance  
of the model, together with a method of updating it. The  
reader is assumed to have a working knowledge of  
programming, software maintenance and modeling of  
physical phenomena.

Jones, W. W.

Refinement of a Model for Fire Growth and Smoke Transport.

National Institute of Standards and Technology, Gaithersburg, MD

NIST TN 1282; 50 p. November 1990.

Available from Government Printing Office

fire growth; smoke; compartment fires; mathematical models; numerical models; roof fires; toxicity

This document describes the changes which have occurred in FAST, FASTPLOT, FAST IN and the distribution disks in the change from 18.3, the release for Hazard I, and the current release 18.5. Included are an errata section for the Technical Note 1262, a revision history that is distributed with the release disks, the addendum to the Technical Note for the new key words, and the description of the implementation of the physical routines.

Joshi, A.

Joshi, A.; Pagni, P. J.

Thermal Analysis of Effect of a Compartment Fire on Window Glass.

September 1, 1988-August 31, 1989.

California Univ., Berkeley

NIST-GCR-90-579; 23 p. June 1990.

Available from National Technical Information Service PB90-244468

U. S./Japan Government Cooperative Program on Natural Resources (UJNR). Fire Research and Safety. 11th Joint Panel Meeting. October 19-24, 1989, Berkeley, CA, Jason, N. H. and Cramer, D. M., Editor(s), NISTIR 4449; 233-252 pp, 1990.

glass; windows; mathematical models; radiation; thermal stresses; vents

Glass breaking in fires is an important practical problem since a window acts as a wall prior to breaking and as a vent after breaking. As Emmons explained, windows break in fires due to thermal stress from the differential heating of the central portion and the shaded edge. If the depth of shading around the edge is much greater than the glass thickness, one can assume that the edge remains at its initial temperature. This paper determines the surface temperature history, [equation] of the glass. The temperature at breaking is when [equation] where [equation] and [equation] both give the strain at breaking in tension. The glass coefficient of linear thermal expansion is  $\alpha$ , the glass modulus is  $\epsilon$  and  $\sigma_b$  is its tensile strength. Typical property values suggest the range of 50 deg C-100 deg C for the breaking  $T$ . Here the transient, one-dimensional (into the glass normal to the pane), inhomogenous (in-depth radiation absorption) energy equation is solved using an innovative Laplace Transform technique suggested by Baum. Time varying equations are

solved numerically by using the trapezoidal rule for numerical integration and Newton-Raphson's method for determining the roots on non-linear equations. Results are presented for typical values of the governing dimensionless parameters.

Jung, D. S.

Jung, D. S.; Didion, D. A.

Mixing Rule for Liquid Viscosities of Refrigerant Mixtures.

National Institute of Standards and Technology, Gaithersburg, MD

Rev. Int. Froid, Vol. 13, 243-248, 1990.

refrigerants; mixing rule; liquid viscosities; refrigerant mixtures; mixing; azeotropes

An investigation of mixing rules for liquid viscosities of refrigerant mixtures is reported. Measured liquid viscosities of seven azeotropes and their corresponding pure components are compared with available mixing rules and Hildebrand's correlation. The results indicate that the viscosities of pure refrigerants are a strong function of volume, supporting Hildebrand's theory. The mixing rules popular in the refrigeration industry are not universally valid for all the mixtures considered. The volume change due to mixing is responsible for almost all of the deviations of the liquid viscosities of mixtures from ideal values. A simple relationship between excess viscosity and excess volume is developed, which results in deviations of less than 2% when used with Grunberg and Nissan's correlation. Based on this study, it is recommended that density measurements are accompanied by viscosity measurements for refrigerant mixtures.

Kaetzel, L. J.

Kaetzel, L. J.; Martin, J. W.; Hocker, M. M.

Automated Maintenance Management Program. Part 2. The Integration of Databases and Image Processing Results for the Quantitative Assessment of the Exterior Condition of Metal Buildings.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 89-4179; 38 p. January 1990.

Available from National Technical Information Services PB90-1620990

computer image processing; condition assessment; databases; decision support system; integrated knowledge system

The establishment of an automated system for assessing the exterior condition of structures can provide facility managers with an important tool for making decisions. The integration of different forms of knowledge into a coherent system provides the fundamental basis for an expert system. This system can reduce the time required to analyze and interpret information, and provides a historical record of the rate of

failure for building structures. This report discusses the feasibility of establishing an automated maintenance management program for making maintenance decisions using computer image processing to obtain quantitative results from field sites and information describing the characteristics of the structure. Relevant database technologies and the design and structure of the database for condition assessment are discussed. Image acquisition, processing, storage, and retrieval of images of a water tower are presented as a case study.

**Kaetzel, L. J.; Clifton, J. R.**

**Guide to the Use of the Cement and Concrete Research Remote Bulletin Board System (RBBS) Computer.**

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 4473; 48 p. December 1990.

Available from National Technical Information Services PB91-148528

cement and concrete research; information exchange; remote bulletin board computer

A computer system has been installed at the National Institute of Standards and Technology, Building Materials Division, for exchanging and disseminating information related to cement and concrete research. The computer is accessible, remotely, through telephone lines. Messages, and computer stored files in many formats can be exchanged among cement researchers. Also, information can be retrieved and/or viewed that describes: scheduled symposia, archived computer based models, project summaries, and published papers. This document describes how to use the computer system.

## **Kashiwagi, T.**

**Kashiwagi, T.; Omori, A.; Nanbu, H.**

**Effects of Melt Viscosity and Thermal Stability on Polymer Gasification.**

National Institute of Standards and Technology, Gaithersburg, MD

**Combustion and Flame, Vol. 81, No. 2, 188-201, 1990.**

gasification; viscosity; thermal stability; melting; surface temperature; polymethylmethacrylate

The effects of melt viscosity and thermal stability of a polymeric material on gasification rate under external radiant fluxes from 1.7 to 3.9 W/cm<sup>2</sup> are studied. The effects of melt viscosity are determined by using two different initial molecular weight polystyrene (PS) samples (about a factor of 2 difference in molecular weight); the combined effects of thermal stability with melt viscosity are determined by using two different initial molecular weight poly(methylmethacrylate) (PMMA) samples (about a factor of 4 difference in molecular weight). The results show that

thermal stability affects gasification rate but that the transport process of the in-depth degradation products through the molten polymer to the sample surface does not significantly affect gasification rate except at low external radiant flux. The global heat of gasification is sensitive enough to differentiate the effects of thermal stability of the sample, but its value also depends on external radiant flux; in addition, it decreases with an increase in exposure time. This indicates that the global heat of gasification is not a unique quantity for a polymeric material.

**Kashiwagi, T.; Omori, A.**

**Effects of Polymer Characteristics on Flammability Properties.**

National Institute of Standards and Technology, Gaithersburg, MD

U. S./Japan Government Cooperative Program on Natural Resources (UJNR). Fire Research and Safety. 11th Joint Panel Meeting. October 19-24, 1989, Berkeley, CA, Jason, N. H. and Cramer, D. M., Editor(s), NISTIR 4449, 54-62 pp, 1990.

flammability; pilot ignition; flame spread; heat release rate; thermal stability; surface temperature

The effects of material characteristics on piloted ignition, horizontal flame spreading, and heat release rate were studied by using two different polystyrene, PS, samples and two different poly(methyl methacrylate), PMMA, samples. The difference between the two PS samples was melt viscosity due to two different initial molecular weights and that between the two PMMA samples was thermal stability and melt viscosity also due to two different initial molecular weights. The results indicate that thermal stability of the material has significant effects on piloted ignition delay time, flame spread rate and heat release rate. The effects of melt viscosity, the transport of in-depth degradation products through the molten polymer layer inside the sample, are negligible on piloted ignition. However, they are significant on horizontal flame spreading behavior and reduce its rate by forming opposed slow fluid motion of molten polymer along the inclined vaporizing surface against the traveling flame front.

## **Kauffeld, M.**

**Kauffeld, M.; Mulroy, W.; McLinden, M.; Didion, D. A.**

**Experimental Evaluation of Two Nonazeotropic Refrigerant Mixtures in a Water-to-Water, Breadboard Heat Pump.**

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 90-4290; 62 p. June 1990.

Available from National Technical Information Services PB90-235003

air conditioning; heat pump; intracycle heat exchange; nonazeotropic refrigerants; refrigerant mixtures; refrigerants; refrigeration

An experimental, water-to-water, breadboard heat pump (that is one designed to be easily reconfigured) was constructed for comparison of pure R22 to the refrigerant mixtures R22/R114 and R13/R12. Three evaporator configurations were extensively studied. In all cases the best mixture outperformed R22. The best efficiency with R22/R114 was 32% higher and with R13/R12 was 16% higher than the best efficiency measured with R22. Other observations were, first, mixtures can take advantage of heat exchanger efficiency that, in a gliding temperature application, a pure refrigerant is incapable of utilizing. Secondly, heat exchange between the condensed and evaporating refrigerant is beneficial to some mixed refrigerants. Finally, mixtures exhibit nonlinearity of enthalpy versus temperature in the two phase region which has significant impact on both heat exchanger and cycle design.

### **Kedzierski, M. A.**

Kedzierski, M. A.; Webb, R. L.

Practical Fin Shapes for Surface-Tension-Drained Condensation.

National Institute of Standards and Technology,  
Gaithersburg, MD

Pennsylvania State Univ., University Park

Journal of Heat Transfer, Vol. 112, 479-485, May 1990.

condensation; fin shapes; fin profiles; profile definition; Adamek profiles; Gregorig profiles

This paper introduces a new family of high-performance fin profiles for surface-tension-drained condensation. Previously described profiles for this situation have been defined in terms of the fin curvature and arc length. The existing profiles are generally not suitable for commercial manufacture. The fin profiles presented in this paper are conveniently defined by the fin tip radius, the fin height, and the fin base thickness. Consequently, the designer may easily specify a fin shape with parameters that are compatible with those used by the manufacturing industry. The heat transfer performance of the new profiles provides an improvement over existing, commercial fin shapes. An analysis is presented to show the R-11 condensation performance of the new profiles as a function of the geometric variables. A recommended design practice for fins for surface-tension-drained condensation also is given.

Kedzierski, M. A.; Didion, D. A.

Visualization of Nucleate Flow Boiling for an R22/R114 Mixture and Its Components.

National Institute of Standards and Technology,  
Gaithersburg, MD

Experimental Heat Transfer, Vol. 3, 447-463, 1990.

nucleation; convective flow; quartz tube; refrigerants; mass flow; test apparatus; mass quality

Visualization of bubble nucleation during forced-convective flow inside a horizontal, electrically heated quartz tube was done in order to establish a comparison of this phenomenon between refrigerant mixtures and their pure components. The specific phenomena investigated were the suppression of nucleation due to increased mass flow quality while holding all other conditions fixed, and the comparison of the nucleate activity of the binary mixture to the nucleate activity of the pure components. The fluids investigated were a 37.7 mol% R22/62.3 mol% R114 binary mixture and the individual components R22 and R114. These fluids were pumped through an abraded, electrically heated quartz tube. A 16-mm high-speed camera was used, at 7000 frames/s, to film the boiling process. Detailed measurements of bubble frequency and bubble size were possible at low pressures, allowing direct calculation of the latent heat load required to nucleate a single bubble. Further work is required to develop a method that ensures statistically sound bubble frequency measurements. However, the standard deviations of the bubble diameter measurements were acceptable. The films were used to visually demonstrate the suppression of nucleation with increase in quality for R114, R22, and an R22/R114 mixture. The films suggest that, for a given quality, R114 exhibits much more nucleation than either R22 or the mixture, while the amount of nucleation demonstrated by R22 and the mixture was comparable even though the mixture was mostly R114 by mole. Arguments using the latent heat of vaporization, the vapor density, and the liquid thermal conductivity have been made to explain the visual trends.

### **Kelly, G. E.**

Kelly, G. E.; May, W. B., Jr.

Concept of an Emulator/Tester for Building Energy Management System Performance Evaluation.

National Institute of Standards and Technology,  
Gaithersburg, MD

ASHRAE Transactions, Vol. 96, No. 1, 1117-1126, 1990. AT-90-14-2.

emulator tester; building energy management; systems performance evaluation; building automation system hardware; BEMS software; algorithms; tests

The performance of a building energy management system (BEMS) can be evaluated by an emulator/tester consisting of a computer-based simulation of a building and its mechanical system connected to the BEMS in place of its sensors and actuator. The BEMS, through its software, then controls the simulated building/HVAC system as if it were an actual building, while the emulator/tester evaluates the BEMS' performance in terms of the energy consumed, the

degree of comfort maintained in the simulated space, system response time, accuracy of control, etc. The BEMS may be tested with any type of building/HVAC system for which a simulation model is available, and tests can be repeated on different BEMS under identical conditions. In order to understand the requirements associated with the design of an emulator/tester, an overview is presented of the different kinds of BEMS software that an emulator/tester could be used to evaluate. This is followed by a discussion of the expected behavior of typical BEMS supervisory software for controlling air-handling units, a description of possible performance rating criteria and test conditions, and a brief summary of possible test results.

### **Klassen, M.**

Klassen, M.; diMarzo, M.

Transient Cooling of a Hot Surface by Droplets Evaporation. Final Report. July 1988-July 1989.

Maryland Univ., College Park

NIST-GCR-90-575; Report 89-3; 108p. May 1990.

Available from National Technical Information Services PB90-227968

droplets; evaporation; solid fuels; thermal conductivity; water; vaporization

An infrared thermographic technique is developed to obtain the transient solid surface temperatures surrounding the droplet during vaporization. This technique is appealing because it is non-intrusive, detailing the surface response to the droplet without affecting the evaporation process. Surface recovery can also be monitored using this thermographic method. The transient temperature distribution of a Macor solid is detailed. It is found that contact temperature is held in the vicinity of the droplet during the majority of the droplet's evaporation until the droplet thickness diminishes greatly, where upon the temperature of the solid surrounding the droplet begins to rise. The non-dimensional radius of influence of droplet cooling is also detailed. The data obtained on the cooling effect induced on aluminum and on Macor from previous studies is used in concert with new data obtained on a quartz surface to characterize the induced cooling of a hot surface by an evaporating droplet. The role of the droplet size and shape is investigated for various high and low thermal conductivity surfaces. Droplet evaporation time, surface heat transfer coefficient and droplet shape parameter are also examined.

### **Klote, J. H.**

Klote, J. H.

Fire Experiments of Zoned Smoke Control at the Plaza Hotel in Washington, DC.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 90-4253; 75 p. April 1990.

Available from National Technical Information Services PB90-207259

smoke control; hotels; sprinklers; fire tests; smoke transport; stack effects; stairwells

A series of full-scale tests were conducted to evaluate the current approach to zoned smoke control systems with and without stairwell pressurization. Smoke movement and the performance of smoke control systems were studied with smoke generated from unsprinklered wood fires, sprinklered wood fires, and smoke bombs. As expected, the zoned smoke control system prevented smoke migration beyond the fire floor. The minimum pressure difference approach to achieve smoke control for zoned smoke control systems was evaluated. This minimum pressure difference approach is based on a tacit assumption of a constant mass flow rate into the zone where the fire is located. To evaluate this assumption, a model was developed for mass flow in the smoke zone. Agreement between experimental results and calculations based on the model was good. Concerns about expansion of combustion gases and fan temperatures were identified. Approaches to deal with these problems were developed. The experiments showed that chemical smoke from smoke bombs is very different from hot smoke from flaming fires. With few exceptions, smoke bombs should not be used for acceptance tests. Additional research is needed concerning smoke generation of sprinklered fires and concerning the interaction of fires and smoke control.

Klote, J. H.

Plaza Hotel Fire Experiments.

National Institute of Standards and Technology, Gaithersburg, MD

ASHRAE Journal, Vol. 32, No. 10, 25-26,28-29, October 1990.

hotels; experiments; smoke control; smoke movement  
Smoke is recognized as the major killer in building fires. Smoke often migrates to building locations remote from the fire space, threatening life and property. Stairwells and elevator shafts frequently become smoke-clogged, thereby blocking evacuation and fire fighting.

Klote, J. H.

Smoke Control Tests at the Plaza Hotel in Washington, DC.

National Institute of Standards and Technology, Gaithersburg, MD

U. S./Japan Government Cooperative Program on Natural Resources (UJNR). Fire Research and Safety. 11th Joint Panel Meeting. October 19-24, 1989, Berkeley, CA, Jason, N. H. and Cramer, D. M., Editor(s), NISTIR 4449, 173-180 pp, 1990.

hotels; smoke control; tests; high rise buildings; wood; pressurization; fans; experiments

In the spring of 1989, a series of full scale fire experiments of zoned smoke control were conducted at the seven story Plaza Hotel in Washington, DC. A zoned smoke control system is a system that uses pressurization produced by fans to restrict smoke flow to the zone of fire origin. The benefit of these systems is that other zones in the building remain essentially "smoke free" reducing property loss and hazard to life. No zoned smoke control system has been tested under real fire conditions either by a research effort or an accidental fire. However, fire experiments of smoke control systems for stairwells and elevators have been conducted.

### **Knab, L. I.**

Knab, L. I.; Clifton, J. R.; Waters, N.  
Evaluation of a Surface Treatment to Improve the Ero Resistance of Coquina Stone at Castillo de San Marcos.  
National Institute of Standards and Technology, Gaithersburg, MD  
NISTIR 90-4277; 40 p. March 1990.  
Available from National Technical Information Services PB90-198938

abrasion resistance; Castillo de San Marcos; consolidant; coquina stone; erosion resistance; moisture; preservation; stone surface treatment; temperature; water repellent

A surface treatment, which was intended to improve the erosion resistance of coquina stone at the Castillo de San Marcos, was evaluated. The commercially-available stone surface treatment was claimed to contain both consolidating and water-repellent agents. Limited, short-term tests intended to simulate two types of erosion and to identify any severe degradation problems were conducted. Erosion of sawn surfaces caused by (i) mechanical abrasion from strokes with a steel brush, and (ii) a thin stream of water flow were investigated in the laboratory in different stone orientations. The erosion resistance, based on mass loss, of the treated stone was compared with that of the untreated stone. The results showed that, for some test conditions, the erosion resistance of the stone was significantly improved by the treatment. For the other test conditions, however, the erosion resistance of the treated and untreated specimens was not significantly different. Hot-cold cycling, freeze-thaw cycling, and ultraviolet light-intermittent moisture exposure tests were conducted and no degradation was observed. In some cases, a slight darkening was discernible on the surface of treatedone with sawn surface. It was recommended that the surface treatment be applied to several trial areas at the Castillo de San Marcos, where erosion due to water flow or mechanical abrasion or both are occurring. The areas should be periodically observed and the erosion documented quantitatively, if possible, over an extended time period.

### **Koseki, H.**

Koseki, H.; Mulholland, G. W.; Jin, T.  
Study on Combustion Property of Crude Oil--A Joint Study Between NIST/CFR and FRI.  
Fire Research Institute, Tokyo, Japan  
National Institute of Standards and Technology, Gaithersburg, MD  
U. S./Japan Government Cooperative Program on Natural Resources (UJNR). Fire Research and Safety. 11th Joint Panel Meeting. October 19-24, 1989, Berkeley, CA, Jason, N. H. and Cramer, D. M., Editor(s), NISTIR 4449, 96-104 pp, 1990.

crude oil; combustion; burning rate; smoke emissions; carbon monoxide; temperature; pool fires; carbon dioxide; boiling point

In order to understand the combustion properties of crude oil pool fires, an experimental study was done in Fire Research Institute (FRI) large scale test facility. The radiative output, burning rate, and the concentrations of CO, CO<sub>2</sub>, and smoke (above the flame tip) were measured during the burning of Arabian light crude oil. Several different size tanks were used to study the scale effect. Crude oil burned less rapidly and gave off less thermal radiation compared with heptane, but when water boiling occurred the burning rate and thermal radiation increased by a factor of two or more. Water boiling is a kind of boilover phenomenon and which intensity is most related with tank size and fuel layer thickness.

### **Kulkarni, A. K.**

Kulkarni, A. K.; Kim, C. I.; Kuo, C. H.  
Heat Flux, Mass Loss Rate and Upward Flame Spread for Burning Vertical Walls. Annual Report.  
Pennsylvania State Univ., University Park  
NIST-GCR-90-584; 64 p. November 1990.  
Available from National Technical Information Services PB91-143297

heat flux; flame spread; interior finishes; mathematical models; measuring instruments; walls  
Progress made during the first year of NIST Grant 60NANB8D0849 for the period ending August 14, 1989 is reported here. The overall objective of the grant is to understand basic mechanisms of upward flame spread and to develop a methodology to predict the flame spread on practical wall materials, appropriately verified by experiments. In this report, progress made on the following tasks is deibed in individual sections, upward flame spread experiments, mathematical model, local mass loss rate apparatus, heat conduction in the interior of burning walls, and Gardon heat flux gage calibration.

## **Kurabuchi, T.**

Kurabuchi, T.; Fang, J. B.; Grot, R. A.  
Numerical Method for Calculating Indoor Air  
Flows Using a Turbulence Model.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 89-4211; 122 p. January 1990.

Available from National Technical Information  
Services PB90-162009

room air movement; contaminant dispersal; turbulent flow;  
numerical simulation; indoor air quality; buoyancy driven  
flows

This report describes a numerical method based on a finite difference technique for simulating indoor airflows in a building using a kappa-epsilon turbulence method. The model treats three dimensional non-isothermal turbulent flows using the Boussinesq approximation for buoyancy. It solves the resulting nonlinear system of momentum, energy and turbulence equations by an explicit time marching technique to obtain a solution for either a steady state or transient flow. An upwind/central combination scheme with arbitrary specification for the switching parameter is used to approximate the convective terms. This switching parameter can be specified at each point in the flow regime allowing for different strategies in different flow regions. The switching technique includes both the central and hybrid schemes found in the literature. A pressure relaxation method is used to satisfy the Poisson equation for continuity. The model handles a variety of flow, pressure, temperature and heat flux boundary conditions including prescribed inflows, outflows by either prescribing the flow or pressure, wall boundary conditions together with heat flux and temperature and/or heat transfer coefficients specified on the boundary. Volumetric heat sources are also included. The model has the ability of handling an arbitrary number of obstacles in the flow region. This permits the modeling of the effect of furniture and partitions on the flow field and also provides a means for modeling multi-room airflows. The predicted airflows can be used in a companion computer model for predicting the three-dimensional dispersion of contaminants in a building. The computer code for this model exists both in a vectorized version for the Cyber 205 supercomputer and in a non-vectorized version which has been successfully run on a Sun 3/260 workstation with a floating point processor board (based on a Weitek 1167) under a UNIX operating system on a Compaq 386/25 computer equipped with either an Intel 80387 or a Weitek 3167 coprocessor under an extended DOS operating system. The relative performance of these systems for the examples considered in this report are 1 second per iteration for the Cyber 205, 9 seconds for the Compaq 386/25 with a Weitek 3167 coprocessor, 30 seconds for the Compaq 386 with a 387 coprocessor and 90 seconds for the Sun 3/260 under UNIX. Isothermal simulations seem to converge in approximately 10,000 iterations and non-isothermal simulations in approximately 30,000 iterations. Several ideal and practical applications of the model are presented and the results of the simulations

are compared with existing experimental data contained in the literature.

## **Levin, B. C.**

Levin, B. C.; Rechani, P. R.; Landron, F.;  
Rodriguez, J. R.; Droz, L.; deCabrera, F. M.; Kaye,  
S.; Gurman, J. L.; Clark, H. M.; Yoch, M. F.

Analysis of Carboxyhemoglobin and Cyanide in  
Blood From Victims of the Dupont Plaza Hotel  
Fire in Puerto Rico.

National Institute of Standards and Technology,  
Gaithersburg, MD

Institute of Forensic Sciences, Caparra Heights, PR  
Pittsburgh Univ., PA

Journal of Forensic Sciences, Vol. 35, No. 1,  
151-168, January 1990.

blood; cyanide; hotels; carboxyhemoglobin; toxicology;  
carbon monoxide; hydrogen cyanide; death

A fire that occurred during the afternoon of December 31, 1986 in the Dupont Plaza Hotel in San Juan, Puerto Rico claimed 97 lives and injured more than 140 individuals. This fire has been considered one of the worst hotel fires that has occurred in this century and has been compared to the MGM Grand Hotel fire in Las Vegas, NV which claimed 85 lives in 1980 and the Winecoff Hotel Fire in 1946 which took 119 lives. Most of the articles and reports that have been written about the Dupont Plaza Hotel fire have described the findings of the investigation by the National Fire Protection Association who worked in cooperation with the U.S. Bureau of Alcohol, Tobacco and Firearms, the National Bureau of Standards and Puerto Rican authorities. They found that the fire was incendiary origin and was started in a stack of new furniture that was stored in corrugated boxes in a ballroom. This furniture, which consisted of dressers (constructed of wood and particle board) and soft beds containing foam mattresses, occupied an area of approximately 5.5 x 9.4 x 1.8 meters (18 x 31 x 6 feet). This initial fuel load plus other materials which may have become involved in the fire were sufficient to cause the ballroom to undergo flashover and produce a flame front that rapidly spread throughout the lobby and casino area. An engineering analysis of the early stages of this fire estimated that the flame front spread through the 437 m<sup>2</sup> (4700 ft<sup>2</sup>) casino (where most of the casualties were found) in 20 to 30 seconds. Both exits from the casino became blocked when the lobby area also filled with smoke.

## **Levin, B. C.**

Progress Report on Fire Toxicity and Chemistry  
Research in the United States.

National Institute of Standards and Technology,  
Gaithersburg, MD

U. S./Japan Government Cooperative Program on  
Natural Resources (UJNR). Fire Research and

Safety. 11th Joint Panel Meeting. October 19-24, 1989, Berkeley, CA, Jason, N. H. and Cramer, D. M., Editor(s), NISTIR 4449, 64-69 pp, 1990.

toxicity; chemistry; soot formation

Deaths, injuries, and losses due to fires continue to be major problems in the United States which still holds the dubious distinction of having the highest death rate per capita in the industrialized world. Interest in the fire problem was indicated by a major week-long symposium entitled "Fire and Polymers" which was sponsored by the American Chemical Society in Dallas, Texas in April, 1989. One day of that symposium was devoted to combustion product toxicity and the rest of the sessions were devoted to the chemistry. The proceedings of that meeting are in the process of being published.

Levin, B. C.; Braun, E.; Shields, J. R.; Lowe, D. L. Reduction of Hydrogen Cyanide Concentrations and Acute Inhalation Toxicity From Flexible Polyurethane Foam Combustion Products by the Addition of Copper Compounds. Part 3. The Effect of Copper Additives on the Flammability Characteristics of Flexible Polyurethane Foam.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 4441; 38 p. October 1990.

Available from National Technical Information Services PB91-132167

hydrogen cyanide; acute toxicity; polyurethane foams; flexible foams; combustion products; copper; flammability; inhalation; heat release rate; flame spread rate; smoke opacity

Previous reports from this laboratory have shown that flexible polyurethane foams (FPU) treated with copper dust, cupric oxide, cuprous oxide or copper sulfate produced significantly less hydrogen cyanide (HCN) when thermally decomposed than the identical but untreated control foams. The decreased atmospheric concentrations of HCN resulted in the reduction of the acute inhalation toxicity (as measured by lethality in Fischer 344 rats) produced from exposure to this smoke. This reduction of HCN and toxicity occurred regardless of whether the copper or copper compound was added to the foam during its formulation (prior to the foaming process) or as a post-treatment (after formulation). In all these reported experiments, the foams were thermally decomposed in the NBS Toxicity Test Method apparatus via a two phase procedure previously shown to produce high concentrations of HCN. This report addresses the issue of whether the addition of a copper cod to a flexible polyurethane foam would affect the flammability characteristics of the foam. The following properties were examined: 1: ignitability in three systems [the NBS Toxicity Test Method, the Cone Calorimeter, and Lateral Ignition and Flame Spread Test (LIFT)], 2: heat release rate under small-scale (Cone Calorimeter) and medium-scale (furniture calorimeter), 3: smoke obscuration (Cone Calorimeter, and

4: rate of flame spread (LIFT). In all cases, no differences in flammability characteristics between the treated and untreated foam were observed.

Levin, B. C.; Gann, R. G.

Toxic Potency of Fire Smoke: Measurement and Use.

National Institute of Standards and Technology, Gaithersburg, MD

Chapter 1; ACS Symposium Series 425.

American Chemical Society (ACS). Fire and Polymers--Hazards Identification and Prevention. National Meeting, 197th. April 9-14, 1989. Dallas, TX, American Chemical Society, Washington, DC, Nelson, G. L., Editor(s), 3-11 pp, 1990.

toxicity; smoke; fire hazard assessment; smoke measurement  
Accurate measurement of the toxic potency of smoke is a key to reducing human life loss in fires. This paper summarizes the approaches taken in measuring toxic potency and highlights four needed issues still to be researched. Direct comparison of only toxic potency values is not a valid means of determining the fire safety of materials and is not sufficient for evaluating fire hazard. The paper describes the N-Gas Model (a new method of assessing toxic potency) and two approaches (in which toxic potency is one of the factors) for assessing fire hazard: (a) HAZARD I, a comprehensive tool for calculating the outcome of a fire, and (b) a fire hazard index for comparing the contributions of alternative materials to the toxicity component of fire hazard.

Levin, B. C.; Paabo, M.; Highbarger, L.; Eller, N. Toxicity of Complex Mixtures of Fire Gases.

National Institute of Standards and Technology, Gaithersburg, MD

Toxicologist, Vol. 10, No. 1, 84, February 1990.

fire gases; toxicity; mixtures; tests; combustion products; animals; computer models

A model to predict the toxic interactions of the major gases produced in fires is being developed. The objectives are 1) To determine if the toxic effects of a material's combustion products can be explained by the toxicological interactions (as indicated by lethality) of the primary fire gases; 2) To develop a bioanalytical screening test which minimizes the use of animals and which examines whether a material produces extremely toxic (based on mass) or unusually toxic (based on the combination of gases deemed responsible) combustion products; and 3) To provide data for use in computer models to predict the hazard that people will experience under various fire scenarios. The toxicity of individual gases, CO, CO<sub>2</sub>, reduced O<sub>2</sub>, HCN, and NO<sub>2</sub> as well as various two, three and four gas combinations of these gases have been examined in Fischer 344 rats exposed for 30 min and observed for at least 14 days. The toxicity of CO, O<sub>2</sub>, and HCN was also examined as individual and combined gases in air for other exposure times (ranging from 1 to 60

min) and found to be additive. Carbon dioxide has synergistic toxicological effects when combined with any of the other tested gases. The current model also includes HCl and HBr using literature data. A physiologically-based pharmacokinetic approach to predict the rate of COHb formation is being used to examine the correlation between rats and humans.

### **Levine, R. S.**

Levine, R. S.; Greenaugh, K.  
Exhaust Gas Analysis for Harmful Species:  
191F1A Fire Fighting Trainer at Mayport, Florida.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
NISTIR 4318; 24 p. May 1990.  
Available from National Technical Information  
Services PB90-219577

toxic products; smoke; training devices; smoke production;  
chemical analysis; gas analysis

Gas sampling and subsequent analysis was carried out in a prototype Navy Firefighter Trainer to determine whether toxic species would be released to the environment by the Trainer. The Trainer uses propane gas for fires, and makes artificial smoke by vaporizing the smoke agent, butylated triphenyl phosphate, in hot air. There was concern that the smoke agent would react with the propane flame to form toxic products. No evidence of reaction or toxic species beyond those to be expected from a clean propane flame was found.

Levine, R. S.; Nelson, H. E.  
Full Scale Simulation of a Fatal Fire and  
Comparison of Results With Two Multiroom  
Models.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
NISTIR 90-4268; 105 p. August 1990.  
Available from National Technical Information  
Services PB91-107482

kitchen fires; model studies; carbon monoxide; home fires;  
death; large scale fire tests; simulation; smoke transport;  
toxic products

In 1987, a fire in a kitchen in Sharon, PA resulted in the deaths of three persons in upstairs bedrooms, one with a reported blood carboxyhemoglobin content of 91%. Considerable physical evidence remained. The fire was successfully simulated at full scale in a fully instrumented seven room test called SHARON 2. The data collected during SHARON 2 have been used to evaluate the precision of two multiroom computer fire codes: FAST 18 and HARVARD 6.3. A coherent ceiling layer flow occurred during the SHARON 2 simulation and quickly carried high concentrations of carbon monoxide (CO) to remote compartments. Such flow is not directly accounted for in

either computer code. However, both codes predict well the carbon monoxide buildup in the sixth room (i.e., the room most remote from the fire). Prediction of the pre-flashover temperature rise was good. Prediction of temperatures after flashover of the room of origin was less successful. Other predictions of conditions throughout the seven test rooms varied from good approximations to significant deviation from test data. Hypotheses are presented as to the reasons for the differences. At least some are believed due to phenomena not considered in the computer codes.

Levine, R. S.; Nelson, H. E.  
Full Scale Simulation of a Fatal Fire and  
Comparison of Results With Two Multiroom  
Models.

National Institute of Standards and Technology,  
Gaithersburg, MD

U. S./Japan Government Cooperative Program on  
Natural Resources (UJNR). Fire Research and  
Safety. 11th Joint Panel Meeting. October 19-24,  
1989, Berkeley, CA, Jason, N. H. and Cramer, D.  
M., Editor(s), NISTIR 4449, 209-216 pp, 1990.

kitchen fires; model studies; carbon monoxide; large scale  
fire tests; simulation; smoke transport; toxic products;  
bedrooms; home fires; death

A fire in a kitchen in Sharon, Pennsylvania killed three persons in upstairs bedrooms, one with a blood carboxyhemoglobin content of 91%. Considerable physical evidence remained. The fire was successfully simulated at full scale in a fully instrumented seven room test called Sharon 2. The data are used to evaluate the precision of two multiroom fire codes: FAST 18 and HARVARD 6.3. During the simulation, a coherent ceiling layer flow was observed that quickly carried high CO concentrations to remote compartments. Such flow is not directly accounted for in either fire code. However, both codes well predict the CO buildup. Prediction of temperatures was less successful. Hypotheses are presented as to the reasons for the differences. At least some are believed due to phenomena not in the codes.

### **Lew, H. S.**

Lew, H. S.  
Guidelines for Identification and Mitigation of  
Seismically Hazardous Existing Federal Buildings.  
National Institute of Standards and Technology,  
Gaithersburg, MD

U.S./Japan Natural Resources Development  
Program (UJNR). Wind and Seismic Effects. Joint  
Meeting of the U. S./Japan Cooperative Program  
in Natural Resources Panel on Wind and Seismic  
Effects, 21st. May 16-19, 1989, Tsukuba, Japan,

Raufaste, N. J., Editor(s), NIST SP 776, 155-162 pp, 1990.

accelerograph; Armenia; bridges; codes; concrete; design criteria; disasters; earthquakes; geotechnical engineering; ground failures; inelastic; lifelines; liquefaction; masonry; repair and retrofit; risk assessment; seismicity; soils; standards; storm surge

This report, Guidelines for Identification and Mitigation of Seismically Hazardous Existing Federal Buildings, was prepared by the Interagency Committee on Seismic Safety in Construction in support of the National Earthquake Hazards Reduction program, the President's plan to implement the Earthquake Hazards Reduction Act of 1977 (Public Law 95-124). The Guidelines are intended for consideration and use, as appropriate, by Federal agencies in their plans for mitigation seismic hazards in existing buildings. Some Federal agencies have their mitigation plan in operation. It is not the intent of these Guidelines to supersede the existing plans.

Lew, H. S.

Introduction.

National Institute of Standards and Technology,  
Gaithersburg, MD

National Institute of Standards and Technology.  
Performance of Structures During the Loma Prieta  
Earthquake of October 17, 1990, NIST SP 778,  
Lew, H., Editor(s), NIST SP 778, 1/1-2 pp, 1990.

earthquakes; building codes; fire safety; damage; bridges (structures); highways; structural engineering; housing; geology; lifelines; seismic; specifications; viaducts

At 5:04 p.m., Pacific Daylight Time, on October 17, 1989, an earthquake with a surface-wave magnitude of 7.1 occurred with its epicenter located about 10 miles (15 km) northeast of Santa Cruz and 60 miles (95 km) south-southeast of San Francisco, California. According to the U. S. Geological Survey, the earthquake ruptured a segment of the San Francisco, California. According to the U. S. Geological Survey, the earthquake ruptured a segment of the San Andreas fault below the Santa Cruz Mountains. The hypocenter was about 11 miles (18 km) beneath the Earth's surface, and the rupture propagated about 25 miles (40 km) both northwest and southeast within a 10-second period. The earthquake was felt over an area of 400,000 square miles (1,000,000 sq km), from Los Angeles to the south, Oregon to the north, and western Nevada to the east. This earthquake, named the Loma Prieta earthquake, was the largest on the San Andreas fault since the great San Francisco earthquake of 1906 ( $M = 8.3$ ) when a 275-mile (440-km) stretch of the fault ruptured.

Lew, H. S., Editor

National Institute of Standards and Technology.  
Performance of Structures During the Loma Prieta  
Earthquake of October 17, 1990, NIST SP 778,  
1990.

Available from Government Printing Office

earthquakes; building codes; fire safety; damage; bridges (structures); highways; structural engineering; geology; housing; lifelines; seismic; specifications; viaducts

Immediately following the magnitude 7.1 Loma Prieta earthquake of October 17, 1989, a team representing the Interagency Committee on Seismic Safety in Construction surveyed the damage to buildings, utilities and transportation structures. This report is based primarily on the data gathered during the site survey and the results of preliminary analyses of structural failures. Most structures designed in accordance with modern codes and standards performed well without serious structural damage. However, there were many concrete and masonry buildings and highway structures in the San Francisco Bay area which were not designed according to modern seismic design codes and which did not perform well. The majority of damaged structures had not been strengthened to increase earthquake resistance. Except for two deaths from landslides and one from fire, the remainder of the 62 deaths from the earthquake was due to partial or total collapse of older structures. This investigation provided the basis for recommendations to improve design and construction practices for buildings and lifeline structures and to mitigate damage to existing structures in future earthquakes.

Liu, S. T.

Liu, S. T.; Kelly, G. E.; Terlizzi, C. P.

Experimental Study on the Performance of a  
Combination Appliance for Domestic Hot Water  
and Space Heating.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4356; 32 p. August 1990.

Available from National Technical Information  
Services PB90-269515

ASHRAE SPC-124P; ANSI/ASHRAE 103-1988; boiler; combination appliance; DOE water heater test procedure; fan coil air handling unit; gas-fired heater; laboratory tests; methods of calculation; space heating; water heating

A Type II combination appliance consisting of a 50-gallon gas-fired water heater and a fan-coil air handling unit was tested in the laboratory to evaluate different methods for the determination of the combined heating seasonal, non-heating seasonal efficiencies and combined annual efficiency. Laboratory tests were conducted in accordance with the ANSI/ASHRAE 103-1988 for boilers and the DOE 10 CFR Part 430 for domestic water heaters to obtain the steady state and heating seasonal efficiencies of the water heater functioning as a space heating boiler and the energy factor of the heater functioning as a domestic water heater. These efficiency values were used to compute the combined heating seasonal and non-heating seasonal efficiency two different calculation methods. A series of tests with part load space heating cycling combined with domestic hot water draws were also conducted to measure the combined efficiencies

directly. Comparison of the measured seasonal efficiency with those obtained from the two proposed calculation methods showed very good agreement. Recommendation was made to adopt the NIST developed calculation method for the rating of the combination appliance.

#### **Lowe, D. L.**

Lowe, D. L.  
Calibration of Accufleet's Heat Flux Gauge (s/n 4615)--Report of Calibration.  
National Institute of Standards and Technology, Gaithersburg, MD  
Letter Report; 3 p. November 23, 1990.  
heat flux; measuring instruments; calibrating  
Per your request I have calibrated your 1" circular foil type heat flux gauge, Thermogage model 1000-1 with serial number 4615. A substitution technique was used to calibrate the gauge in an infrared radiant field at flux levels to nominally 4 W/cm<sup>2</sup>. A schematic of the test arrangement is shown in Figure 1.

Lowe, D. L.  
Calibration of Accufleet's Heat Flux Gauge (s/n 4616)--Report of Calibration.  
National Institute of Standards and Technology, Gaithersburg, MD  
Letter Report; 3 p. November 23, 1990.  
heat flux; measuring instruments; calibrating  
Per your request I have calibrated your 1" circular foil type heat flux gauge, Thermogage model 1000-1 with serial number 4616. A substitution technique was used to calibrate the gauge in an infrared radiant field at flux levels to nominally 4 W/cm<sup>2</sup>. A schematic of the test arrangement is shown in Figure 1.

Lowe, D. L.  
Calibration of BASF's Heat Flux Gauge--Report of Calibration.  
National Institute of Standards and Technology, Gaithersburg, MD  
Letter Report; 3 p. November 23, 1990.  
heat flux; measuring instruments; calibrating  
Per your request I have calibrated your Pyrheliometer type heat flux gauge, HY-CAL model P-8400-J-100-120 with serial number Unknown. A substitution technique was used to calibrate the gauge in an infrared radiant field at flux levels to nominally 4 W/cm<sup>2</sup>. A schematic of the test arrangement is shown in Figure 1.

#### **Markstein, G. H.**

Markstein, G. H.; deRis, J.  
Wall-Fire Radiant Emission. Part 1. Slot-Burner Flames, Comparison With Jet Flames. Technical Report.  
Factory Mutual Research Corp., Norwood, MA  
FMRC J.I. 0Q0N5.BU; RC90-BT-2; 50 p. August 1990.

turbulent jet flames; thermal radiation; radiative heat transfer; heat release rate; radiometers  
Wide-angle radiometer measurements of total radiant emission and scanning-slit-radiometer measurements of the vertical distribution of radiant emission, were performed on 0.38-m-wide slot-burner flames adjacent to a 2.2-m-high water-cooled wall. Comparison measurements were performed on free-burning slot-burner flames and on jet flames. Methane, ethane, ethylene and propylene were used as fuels, with total heat-release rates, ranging from about 10 to 60 kW.

#### **Marshall, R. D.**

Marshall, R. D.  
Performance of Structures in Hurricane Hugo.  
National Institute of Standards and Technology, Gaithersburg, MD  
U.S./Japan Natural Resources Development Program (UJNR).  
Wind and Seismic Effects. Joint Meeting of the U.S./Japan Cooperative Program in Natural Resources Panel on Wind and Seismic Effects, 22nd. May 15-18, 1990, Gaithersburg, MD, Raufaste, N. J., Editor(s), NIST SP 796, 434-444 pp, 1990.  
buildings; building codes; damage; hurricanes; tropical cyclone; wind; wind speed  
Surface wind speeds and damage to structures during the passage of Hurricane Hugo through the Virgin Islands and Puerto Rico are described. Because of the scarcity of actual wind speed records and observations, it was necessary to resort to other indicators of surface wind speed such as reconnaissance aircraft data and intensity of damage. Maximum wind speeds on St. Croix corresponded to a mean recurrence interval of approximately 300 years, making Hugo one of the more intense hurricanes of the century. On St. Thomas and over northeastern Puerto Rico the wind speeds were equal to or less than the 50-year wind speed for this region of the Caribbean. Damage in the affected areas was extensive, in particular those areas exposed to the northeastern quadrant of the storm. The structural behavior of certain highrise and single-story buildings under overall wind loading was good. However, more attention needs to be given to the attachment of nonstructural elements such as doors, windows, and cladding. Seismic Effects was held at the National Institute of Standards and Technology from May

15-18, 1990. This publication, the proceedings of the Joint Meeting, includes the program, list of members, panel resolutions, task committee reports, and 33 technical papers. The papers were presented under six themes: (I) Wind Engineering, (II) Storm Surge and Tsunami, (III) Joint Cooperative Research Program, (IV) Earthquake Engineering, (V) Loma Prieta Earthquake, and (VI) Summaries of Task Committee Workshop Reports.

### **Martin, J. M.**

Martin, J. M.; Embree, E.; Tsao, W.  
Non-Osmotic, Defect-Controlled Cathodic Disbondment of a Coating From a Steel Substrate. National Institute of Standards and Technology, Gaithersburg, MD  
Journal of Coatings Technology, Vol. 62, No. 790, 25-33, 1990.

coatings; steel substrate; blister initiation; blister growth; temporal variability

A non-osmotic, defect-controlled cathodic disbondment model for coating failure is proposed for explaining experimental results which were inconsistent with an osmotically-controlled disbondment process. The proposed model attempts to integrate the physics of blister initiation and growth (that is, the development of internal stresses and the fracture of the coating from the substrate) with the better elucidated chemistry of blister growth. The proposed model has many features which are analogous to the linear and stress corrosion cracking models proposed for other materials. It also provides an alternative explanation for the well-known barrier effect in coatings.

Martin, J. M.; Embree, E.; Stutzman, P. Lechner, J. A.

Strength and Creep-Rupture Properties of Adhesive-Bonded EPDM Joints Stressed in Peel. National Institute of Standards and Technology, Gaithersburg, MD  
NIST BSS 169; 59 p. May 1990.

Available from Government Printing Office

butyl adhesive; creep-rupture life; EPDM; neoprene; peel performance criteria; seam; single-ply roofing; strain rate; stress-ratio; time-to-failure

The most frequently reported defect in ethylene-propylene-diene terpolymer (EPDM) single-ply roofing systems is in field-formed joints. The causes of these joint defects are largely unknown, but they tend to occur a short time after a roof is installed. The objectives of this research were 1) to determine the importance of the following material and fabrication variables in causing joint failures: adhesive thickness, cure time, mechanical load, adhesive type and surface cleanliness, 2) to rank these variables as they affect the creep-rupture life and strength of butyl-adhered EPDM joints, and 3) to determine the maximum peel stress which EPDM joints can sustain over

their design life. From our results, cure time and level of cleanliness of the EPDM membrane have the greatest effect on joint strength; while the thickness of the adhesive and the magnitude of the mechanical load have the greatest effect on a joint's creep-rupture time-to-failure. Thus, the rankings of variables in creep-rupture and short-time strength experiments were different and this difference should have important implications in standards writing and in establishing performance requirements for EPDM roofing joints. Creep-rupture results were used in determining the maximum design stress that butyl and neoprene-adhered EPDM joints can sustain when loaded in peel. The maximum sustainable stress is only a small fraction (less than 5%) of the short-time yield strength of a joint. Thus, efforts should be made to insure that the field-formed joints are only subjected to small peel loads.

### **McKnight, M. E.**

McKnight, M. E.; Bentz, D. P.; Roberts, W.  
Measuring the Extent of Rust on Steel After Abrasive Blasting: A Feasibility Study. National Institute of Standards and Technology, Gaithersburg, MD  
NISTIR 90-4257; 20 p. March 1990.

Available from National Technical Information Services PB90-195033

abrasive blasting; cleanliness; coatings; emissivity; imaging; infrared thermography; roughness; rust; steel; surface The service life of a coating on steel is known to depend upon the condition of the surface prior to painting. Factors used to assess surface preparation include extent of rust remaining on the surface, roughness, and concentration of inorganic contaminants. This report is only concerned with assessing the extent of rust. Presently, the extent of rust is determined using standard definitions and visual standards, a subjective procedure. Since a more objective procedure is desirable, video imaging and infrared thermographic techniques were assessed. It was concluded that infrared thermography does not provide the basis for a simple, sensitive method for assessing the extent of rust but that video imaging shows promise to meet this need.

### **McKnight, M. E.**

Review of Current Research and Activities Involving Characterization, Abatement and Disposal of Lead-Containing Paint Films.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 90-4285; 13 p. May 1990.

Available from National Technical Information Services PB90-225954

paints; lead; abatement; coatings; containment; disposal; films; measurement; removal

In response to a recent regulation for abating lead-based paint in housing and other environmental regulations, research projects and other activities are being conducted to provide information on procedures for carrying out abatement and maintenance of lead-containing paint films in a safe and cost-effective manner. Relevant Federal regulations, and current research projects and other activities addressing these issues are reviewed.

### **McLean, D. I.**

McLean, D. I.; Phan, L. T.; Lew, H. S.; White, R. N.

Punching Shear Behavior of Lightweight Concrete Slabs and Shells.

National Institute of Standards and Technology, Gaithersburg, MD

ACI Structural Journal, Vol. 87, No. 4, 386-392, July/August 1990.

concrete slabs; lightweight concretes; offshore structures; one-way slabs; prestressed concrete; punching shear; reinforced concrete; reinforcing steels; shear strength; shells (structural forms); walls

Results of an experimental investigation of the punching shear strength of reinforced and prestressed lightweight concrete slabs and shells representative of the exterior walls of offshore structures are summarized. Eight continuous slabs, one single-span slab, and six single-span shells were tested. The main variables investigated were amount of shear reinforcement, shell curvature, prestressing, span continuity condition, and size of loaded area. The punching shear strengths observed were much higher than those predicted by the 1983 ACI Building Code (ACI 318-83), particularly in the specimens with shear reinforcement and curvature. The higher strengths were primarily a result of the following: the relatively small span-to-thickness ratios of the specimens; superior performance of the headed shear reinforcing bars used in the study when compared to conventional stirrups; and the presence of arch action produced by shell curvature.

### **Megaridis, C. M.**

Megaridis, C. M.; Dobbins, R. A.

Bimodal Integral Solution of the Dynamic Equation for an Aerosol Undergoing Simultaneous Particle Inception and Coagulation.

Brown Univ., Providence, RI

Aerosol Science and Technology, Vol. 12, 240-255, 1990.

aerosols; equations; coagulation

A model is developed from the general aerosol dynamic equation, using a bimodal integral formulation that includes particle formation and growth by coagulation in the free molecular regime. The particle inception mode accounts for the introduction of newly formed particles which, through

coagulative collisions with one another, constitute the source of the particles in the growth mode. A numerical solution for the system of the first three moments of the particle volume distribution function is discussed, under the assumption of a logarithmic-normal behavior of the two modes of the size distribution function. The bimodal integral solution is subject to a detailed comparison with the MAEROS sectional model for the case of an aerosol that undergoes free molecular coagulation occurring simultaneously with particle formation by a Gaussian source pulse, under flamelike conditions.

### **Morehart, J. H.**

Morehart, J. H.; Zukowski, E. E.; Kubota, T.  
Species Produced in Fires Burning in Two-Layered and Homogeneous Vitiating Environments.  
California Institute of Technology, Pasadena  
NIST-GCR-90-585; 274 p. December 1990.

Available from National Technical Information Services PB91-157180

air; combustion products; diffusion flames; fire plumes; vitiation

The chemical species produced in a buoyant, turbulent diffusion flame exposed initially to a supply of fresh air and extending into a reduced-oxygen environment containing products of combustion are investigated. The stably stratified, vitiated region is formed by placing a hood above a burner so that it accumulates the gases of the fire plume, while the direct injection of air into the upper portion of the hood allows conditions to be studied where the stoichiometry of the collected gases is different than that of the plume flow crossing the interface between these two regions. Measurements of the composition show that the species produced in the flame depend primarily on the stoichiometry of the gases in the vitiated region, but are independent of the fuel-air ratio of the mass transported across the interface by the plume. Experiments were conducted with natural gas, ethylene, and propylene fuels. For natural gas fires, a weak dependence of species concentrations on the temperature of the product gas layer was observed over the range 500 to 900K.

### **Motevalli, V.**

Motevalli, V.; Marks, C. H.

Transient Characteristics of Unconfined Fire-Plume-Driven Ceiling Jets. Final Report. 1986-1989.

Worcester Polytechnic Institute, MA

Maryland Univ. College Park

NIST-GCR-90-574; 328 p. May 1990.

Available from National Technical Information Services PB90-227976

ceiling jets; fire plumes; fire tests; velocity measurements

An extensive study of small-scale, unconfined, fire-induced ceiling jets was conducted under ceiling transient and steady state conditions. Constant, steady fire strengths of between

0.5 to 2.0 kW and fire-to-ceiling heights of 1.0 m and 0.5 m were used producing non-dimensional convective heat input to the ceiling, in the range of  $4.5 \times 10^{-4}$  to  $1.0 \times 10^{-2}$ . The ceiling jet transient characteristics caused by the ceiling heating, as well as its steady state characteristics studied using velocity and temperature measurements. Detailed velocity and temperature measurements of the ceiling jet were made simultaneously using the cross-correlation velocimetry technique from the start of the fire until the ceiling reached steady state. Velocity and temperature profiles were obtained at several radial locations away from the plume impingement point. These measurements were made for transient and steady ceiling jet conditions in the case of the  $H=1.0$  m. All the transient measurements in the  $H=0.5$  m case were limited to temperature measurements. At steady state, however, both temperature and velocity measurements were obtained.

### **Nelson, H. E.**

Nelson, H. E.  
FPETOOL User's Guide.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
General Services Administration, Washington, DC  
NISTIR 4439; 37 p. October 1990.  
Available from National Technical Information  
Services  
computer programs; building fires; fire protection  
engineering; fire hazards; fire protection; fire safety  
FPETOOL is a computerized package of relatively simple  
engineering equations and models. FPETOOL consists of a  
package of engineering tools useful in estimating potential  
fire hazard and the response of the space and fire protection  
systems to the developing hazard is presented. To a large  
extent, user instructions are included as screen messages  
presented at the time of need by FPETOOL. This document  
covers information useful to the user, but not included as  
screen messages. A separate report, FPETOOL, Fire  
Protection Engineering Tools for Hazard Estimation  
(NISTIR 4380), also is available.

Nelson, H. E.  
FPETOOL--Fire Protection Tools for Hazard  
Estimation: An Overview of Features.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
Interscience Communications Ltd.; National  
Institute of Standards Technology; Building  
Research Establishment; and Society of Fire  
Protection Engineers. Interflam '90.  
Fire Safety. International Fire Conference, 5th.  
September 3-6, 1990, Canterbury, England,  
Interscience Communications Ltd., London,  
England, Franks, C. A., Editor(s), 85-92 pp, 1990.

fire safety; computer programs; fire protection; hazard  
assessment; equations; fire hazards  
FPETOOL is a computerized package of relatively simple  
engineering equations and models. It contains engineering  
tools useful in estimating potential fire hazard and the  
response of the space and fire protection systems to the  
developing hazard. The computations use established  
engineering relationships, which are discussed in this paper  
for the benefit of engineers and others interested in using  
the tools in the package.

### **Nelson, H. E.**

FPETOOL: Fire Protection Engineering Tools for  
Hazard Estimation.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
General Services Administration, Washington, DC  
NISTIR 4380; 120 p. October 1990.  
Available from National Technical Information  
Services PB90-269549

computer programs; building fires; fire protection enging;  
fire hazards; fire protection; fire safety  
FPETOOL is a computerized package of relatively simple  
engineering equations and models. A package of engineering  
tools useful in estimating potential fire hazard and the  
response of the space and fire protection systems to the  
developing hazard is presented. The computations use  
established engineering relationships. This paper outlines  
those relationships for the benefit of engineers and others  
interested in using the tools in the package. A separate  
report, FPETOOL User's Guide (NISTIR 4439), also is  
available.

### **Nelson, H. E.**

Performance of Fire Protection Systems.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
National Institute of Standards and Technology.  
Performance of Structures During the Loma Prieta  
Earthquake of October 17, 1990, Lew, H.,  
Editor(s), NIST SP 778, 6/1-3 pp, 1990.  
earthquakes; building codes; fire safety; damage; bridge  
(structures); highways; structural engineering; housing;  
geology; lifelines; seismic; specifications; viaducts  
In general, private fire protection facilities survived the  
earthquake without interruption while public fire protection  
systems were severely interrupted. Private fire protection  
systems are limited to a single facility and mostly within  
buildings while public fire protection systems are external,  
community wide, and often underground. Several affected  
communities, including San Francisco, were left in a  
condition where it is doubtful that they could have halted a  
serious spreading fire. The absence of a serious spreading  
fire (other than the one in the Marina District of San

Francisco) is believed to be a combination of factors including: [1] Prompt shut down of electric power (by the utilities); [2] Modern safeguards on burners and pilots on water heaters and other gas fired appliances in service at the time; [3] Warm weather (i.e., lack of use of heating equipment); [4] Absence of wind (a major fire spread factor if present); [5] High moisture content in ground and wild lands (relates to lack of significant wild fire problems); [6] The occurrence of modern earthquake with a short duration of strong ground shaking which caused limited damage on buildings and utility structures in the affected communities; [7] Good fortune.

Nelson, H. E.

Room Fires as a Design Determinate--Revisited.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
Fire Technology, Vol. 26, No. 2, 99-105, May 1990.

room fires; ventilation; geometry; fire plumes; conservation; air; oxygen; flashover

In 1965, I presented a paper entitled, "Room Fires as a Design Determinate," at the annual meeting of the Society of Fire Protection Engineers. This paper involved a number of firsts. It was my first published paper; it was part of the first technical seminar presented by the Society of Fire Protection Engineers; and it was published in the first volume of Fire Technology (pp. 197-204). After twenty-five years, a second look is in order. In 1965 I proposed two basic elements in determining the impact of a fire in a room, the first of these being the intensity of the fire. The intensity of the fire was divided into three categories as a function of the fuel, geometry, ventilation, and fire-resisting strength of the room construction. The purpose of this article is to point out a few of the elements overlooked in 1965 but now recognized as important, and to bring several new concepts to bear.

**Notarianni, K. A.**

Notarianni, K. A.

Five Small Flaming Fire Tests in a Simulated Hospital Patient Room Protected by Automatic Fire Sprinklers.

National Institute of Standards and Technology,  
Gaithersburg, MD

FR 3982; 191 p. October 31, 1990.

hospitals; fire tests; sprinklers; room burns; simulation; smoke detectors; sprinkler response; instruments; crib fires; fire spread; quick response sprinklers

A series of five tests was conducted to measure temperatures, radiation, and carbon dioxide, carbon monoxide, and oxygen concentrations resulting from small flaming wood crib fires within a simulated NIH hospital patient room protected with automatic fire sprinklers. Time to activation of quick and standard response sprinklers and ionization and photoelectric smoke detectors at several

locations in the room simulating multiple options for protection of the space were measured. The test series addressed the location of sprinkler heads in the hospital patient room, demonstrated the effect of privacy curtains around the beds, the effect of a shielded fire, and the effect of the wall sprinklers.

**Ohlemiller, T. J.**

Ohlemiller, T. J.; Corley, D. M.

Estimation of the Rate of Heat Release and Induced Wind Field in a Large Scale Fire.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4430; 57 p. October 1990.

Available from National Technical Information Services PB91-120154

large scale fire tests; forest fires; heat release rate; wind effects

Logging slash on a 486 hectare site in Ontario was burned as part of a Forestry Canada forest management program. A 100 hectare portion of this site was instrumented by several groups interested in large scale fires. The NIST Center for Fire Research utilized Forestry Canada data on mass loading before and after the fire, total burning area as a function of time and burning duration to estimate the spatial and temporal pattern of heat release during the burning of the instrumented section of the fire. Complete information necessary for making this estimate is lacking; the necessary assumptions and their accuracy (when known) are discussed. Heat release rate is reported for three different assumptions regarding the temporal behavior of flaming and smoldering phases of the combustion. This information is utilized in the context of a flow model due to Baum and McCaffrey to calculate the near-ground flow field induced by this heat release pattern and the results are compared to the point measurements made in the field.

Ohlemiller, T. J.

Forced Smolder Propagation and the Transition to Flaming in Cellulosic Insulation.

National Institute of Standards and Technology,  
Gaithersburg, MD

Combustion and Flame, Vol. 81, Nos. 3&4, 354-365, September 1990.

air flow; cellulosic materials; insulation; smoldering

It is well known that a smoldering fuel responds to an increased oxygen supply by becoming faster and hotter until, eventually, flames erupt. This sequence is examined quantitatively for thick horizontal layers of a permeable fuel, i.e., cellulosic insulation. Two configurations are possible, forward and reverse smolder; both were investigated experimentally. Reverse smolder was shown to respond only weakly to an increased air flow and it exhibited no transition to flaming at flow velocities up to 5 m/s. Forward smolder responded strongly to increased air flow and yielded transition to flaming at about 2 m/s for untreated material.

The influence of combustion retardants was also examined; these include boric acid, a smolder retardant, and borax, a flaming retardant. Both prevented the transition to flaming in the absence of adjacent flammable material but are less effective in its presence. The overall response of these various fuel mixtures and configurations suggests that both kinetics (via leading edge heat transfer effects) and oxygen supply rate (not the latter alone) play substantial roles in dictating smolder response to an air flow.

**Ohlemiller, T. J.; Villa, K. M.**

**Furniture Flammability: An Investigation of the California Bulletin 133 Test. Part 2. Characterization of the Ignition Source and a Comparable Gas Burner.**

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 4348; 42 p. June 1990.

Available from National Technical Information Services PB90-257692

furniture; flaming combustion; flammability; ignition; test methods; chairs; ignition source

The California Bulletin 133 upholstery ignition source is based on the use of crumpled newsprint. The present work examined the reproducibility of several aspects of this source when placed on an inert chair mock-up. The tendency of this source to heat the side arms of a chair, the area of the seat back subjected to high heat fluxes, the peak flux there and the flux duration all showed substantial variability. For inherently lesser variability a gas burner is preferred. A gas burner, derived from that developed at the British Fire Research Station, was shaped so as to deposit a similar pattern of heat to that of the CB 133 source. The two sources were tested for comparability both on chair mock-ups and on full-scale chairs made a wide variety of materials. The results indicate that the gas burner, as used here, is a somewhat less severe ignition source than is the CB 133 igniter.

**Ohlemiller, T. J.**

**Smoldering Combustion Propagation Through a Permeable Horizontal Fuel Layer.**

National Institute of Standards and Technology, Gaithersburg, MD

**Combustion and Flame, Vol. 81, No. 3&4, 341-353, September 1990.**

smoldering combustion; cellulose; insulation; char formation; wave structure; temperature profiles; oxidation

Although the propagation rate of smoldering through porous horizontal fuel layers has been measured for a variety of materials, there has been little work on the structure of the smolder reaction zone and the factors controlling it. These latter aspects are the focus here for the case of thick (18 cm) layers of wood-based fibers in the form of cellulosic insulation smoldering under natural convection air supply

conditions. Two-dimensional profiles of temperature, oxygen mole fraction, and residual organic material have been measured both for untreated insulation and for insulation having 25 wt% of the smolder retardant, boric acid, added on. It is inferred that the overall wave structure is dominated by oxygen diffusion from above. The heat release chemistry appears to involve both oxidative pyrolysis and char oxidation in a shifting balance depending on depth in the layer. Boric acid is unable to halt the smolder process in these thick fuel layers but it slows its spread by about a factor of 2 by a combination of endothermic and kinetic effects.

**Palmer, M. E.**

**Palmer, M. E.; Reed, K. A**

**3D Piping IGES Application Protocol, Version 1.0.**

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 4420; 257 p. October 1990.

Available from National Technical Information Services PB90-120196

application protocols; application validation; CAD data exchange; computer-aided design; data exchange standards; data translation quality assurance; data translators; IGES application protocols; information management; piping design; piping systems

The 3D Piping IGES Application Protocol (AP) specifies the mechanisms for defining and exchanging 3D piping system models in IGES format. The AP defines three-dimensional arrangement data of piping systems which includes definition data types of geometry (shape and location), connectivity, and material characteristics. The scope of this AP includes only piping system data and not drawings or internal details of equipment. The specified piping model is sufficiently detailed to support the fabrication and final assembly of a piping system. IGES is designed to support a broad range of applications and information, and it is recognized that few implementations will support all of the specification. An application protocol defines a logical subschema of the IGES specification, the usage of the subschema, and the necessary benchmarks for testing implementations. The 3D Piping IGES Application Protocol is the first IGES AP to be delivered to industry and is an important example for the development of STEP (Standard for the Exchange of Product Model Data) application protocols.

**Parker, W. J.**

**Parker, W. J.; Tu, K. M.; Nurbakhsh, S.; Damant, G. H.**

**Furniture Flammability: An Investigation of the California Technical Bulletin 133 Test. Part 3. Full Scale Chair Burns.**

National Institute of Standards and Technology, Gaithersburg, MD

Bureau of Home Furnishings and Thermal Insulation, North Highlands, CA  
NISTIR 4375; 43 p. July 1990.

Available from National Technical Information Services PB90-257700

furniture; flammability; test methods; carbon monoxide; cone calorimeters; furniture calorimeters; heat release; large scale fire tests; room fires; chairs

Ten sets of upholstered chairs were obtained. One chair out of each set was tested in the ASTM room, two chairs out of each set were tested in the furniture calorimeter, and four chairs from each of six sets in the California Technical Bulletin 133 (TB133) room. The chairs in the different sets varied only in the type of fabric, type of foam, and whether or not there was a fiberglass interliner present. The size, frame and style remained constant. Some of the chairs were ignited with the standard TB133 newspaper ignition source. The others were ignited by a gas burner designed to simulate the newspaper ignition source. The rooms were instrumented to measure the total heat release rate of the chairs by oxygen consumption. It was found that (1) similar results were obtained in the TB133 and ASTM rooms, (2) a total heat release rate of 65 kW in either of the rooms or in the furniture calorimeter was equivalent to the failure criterion of a 111 deg C (200 deg F) temperature rise 25 mm below the ceiling and directly above the burning chair in the TB133 test and (3) below 600 kW the heat release rates of the chairs measured in the rooms were the same as those in the furniture calorimeter. The combinations of fabric, fiberglass interliner and foam were also tested in the cone calorimeter. Correlations are presented between the full scale and bench scale results. Calculations of the room temperatures, using Hazard I and the measured heat release rates, are also shown.

#### **Peacock, R. D.**

Peacock, R. D.; Krasny, J. F.; Rockett, J. A.; Huang, D.

Protecting Fire Fighters Exposed in Room Fires. Part 2. Performance of Turnout Coat Materials Under Actual Fire Conditions.

National Institute of Standards and Technology, Gaithersburg, MD

Fire Technology, Vol. 26, No. 3, 202-222, August 1990.

fire fighters; protective clothing; turnout coats; safety; fire tests; room fires; full scale fire tests

Seven experimental fires varying in fire load were conducted in a simulated townhouse. Specimens of various current fire fighters turnout coat materials were exposed in the room of fire origin. The time at which conditions would become untenable for the fire fighter due to pain, as well as the time to second degree burn, were calculated. These times ranked the coat specimens in roughly the same order as the "Thermal Protection Performance" measured according to

NFPA 1971-1986, especially if the heat in the room developed rapidly.

Peacock, R. D.; Bukowski, R. W.

Prototype Methodology for Fire Hazard Analysis. National Institute of Standards and Technology, Gaithersburg, MD

Fire Technology, Vol. 26, No. 1, 15-40, February 1990.

American Society of Safety Engineers (ASSE). Building Our Professional Heritage--Protecting Our Nation's Resources. Professional Development Conference and Exposition, 29th. June 24-27, 1990, Washington, DC, Am. Soc. of Safety Engineers, Des Plaines, IL, 20-37 pp, 1990.

hazard analysis; methodology; fire models; expert systems; evacuation; fire safety; computer programs

The first version of a method for predicting the hazards to occupants involved in a building fire is described. The method and available computer software, called HAZARD I, can predict the time varying environment in a building resulting from a specified fire; the locations and actions of occupants; and the impact of the exposure of each of the occupants to the fire products in terms of whether the occupants successfully escape, are incapacitated, or are killed.

#### **Persily, A. K.**

Persily, A. K.

Development of Thermal Envelope Design Guidelines for Federal Office Buildings.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 4416; 85 p. October 1990.

Available from National Technical Information Services PB91-112839

airtightness; building envelopes; building performance; design; office buildings; thermal bridges; thermal envelope  
Office building envelopes are generally successful in meeting a range of structural, aesthetic and thermal requirements. However, poor thermal envelope performance will occur when there are discontinuities in the envelop insulation and air barrier systems, such as thermal bridges and air leakage sites. These discontinuities result from designs that do not adequately account for heat, air and moisture transmission, with many thermal defects being associated with inappropriate or inadequate detailing of the connections of envelope components. Despite the existence of these thermal envelope performance problems, information is available to design and construct envelopes that do perform well. In order to close the gap between available knowledge and current practice, the Public Buildings Service of the General Services Administration has entered into an

interagency agreement with the Center for Building Technology of the National Institute of Standards and Technology to develop thermal envelope design guidelines for federal office buildings. The goal of this project is to transfer the knowledge on thermal envelop design and performance from the building research, design and construction communities into a form that will be used by building design professionals. This report describes the NIST/GSA envelop design guidelines development at the end of the first year of effort on the project. The effort to this point has consisted of a literature review of research results and technical information on the thermal envelope performance and design, an assessment of existing design guidelines as they relate to the thermal envelope, and the development of a format and outline for the design guidelines.

Persily, A. K.; Axley, J.  
Measuring Airflow Rates With Pulse Tracer Techniques.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
Massachusetts Institute of Technology, Cambridge  
American Society for Testing and Materials (ASTM). Air Change Rate and Airtightness in Buildings. Sherman, M. H., Editor(s), ASTM STP 1067. 1990, ASTM, Philadelphia, PA, 31-51 p., 1990.

air exchange; airflow; infiltration; measurement; multi-zone; tracer gas; ventilation

New tracer gas techniques for measuring airflow rates in HVAC ducts and buildings airflow systems are described. These pulse tracer techniques are based upon the application of integral mass balance equations to the tracer gas concentration response of an airflow system to pulse injection of tracer. For building airflow systems, or portions of them, the airflow system is first idealized by appropriate multi-zone model, pulse injection of tracer are applied to each zone independently, and the concentration response of each of the zones is measured. The multi-zone integral mass balance equations are formed and solved to determine the airflow rates between the zones. The airflows that are determined and the accuracy of these determinations are dependent not only upon the air exchange characteristics of the building, but also on the appropriateness of the system idealization employed. This paper presents the theoretical basis of the pulse techniques for measuring airflows in ducts, and for studying single-zone and multi-zone building airflow systems. Procedures for formulating appropriate multi-zone idealizations of building airflow systems are described and practical details of pulse testing outlined. A series of field studies are reviewed, providing examples of procedures used for formulate system idealizations, experimental techniques employed to conduct the tests, and airflow rate measurement results.

Persily, A. K.; Dols, W. S.  
Relation of CO<sub>2</sub> Concentration to Office Building Ventilation.

National Institute of Standards and Technology,  
Gaithersburg, MD

American Society for Testing and Materials (ASTM). Air Change Rate and Airtightness in Buildings. ASTM, Philadelphia, PA, Sherman, M. H., Editor(s), ASTM STP 1067, 77-92 pp, 1990.

building performance; indoor air quality; infiltration; measurement; mechanical ventilation; office buildings; tracer gas; ventilation

Tracer gas techniques have been used to study air exchange in mechanically ventilated office buildings for many years. The analysis of the concentration of carbon dioxide (CO<sub>2</sub>) generated by building occupants has been suggested as an alternate means of evaluating building air exchange and ventilation system performance. Various techniques for CO<sub>2</sub> analysis have been proposed. These include measuring the decay rate of CO<sub>2</sub>, concentration after the occupants leave the building, analyzing real-time CO<sub>2</sub> concentration data in conjunction with a CO<sub>2</sub> mass balance equation, and using instantaneous CO<sub>2</sub> concentration readings to directly determine air exchange rates. Local CO<sub>2</sub> concentrations have also been suggested as a means of evaluating ventilation effectiveness. These techniques require specific assumptions and unique conditions in order to yield reliable information on building air exchange characteristics, and these requirements may not always be met in office buildings. This paper examines the relationship between CO<sub>2</sub> concentration and building air exchange. A dataset of simultaneously measured air exchange rates, based on sulfur hexafluoride (SF<sub>6</sub>) decay, and CO<sub>2</sub> concentration obtained in three office buildings is employed to examine this relationship. The results indicate that CO<sub>2</sub> decay rates can provide reliable estimates of building air exchange rates, but that there may be significant error associated with the use of instantaneous concentrations to determine air exchange rates.

**Phan, L. T.**

Phan, L. T.

Seismic Instrumentation of Existing Buildings.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4419; 62 p. October 1990.

Available from National Technical Information Services

analytical model; buildings; dynamic; earthquakes; frequency; ground acceleration; instrumentation; model; mode shape; seismometers; spectral density; vibration

Two existing GSA buildings, one in Long Beach, California and one in Portland, Oregon, were subjected to low-level vibration tests to determine their dynamic properties and response frequencies. The measured dynamic properties of the buildings were incorporated into the computer models of the buildings and time-history analyses using these models

were performed. Reasonable agreement between the measured and calculated response frequencies and deflected shapes were observed. The differences in calculated and measured response frequencies range from 3% to 31%. The larger difference is in the torsional response of the Portland building. This is probably due to the irregular geometry of this building. The models were then analyzed with past earthquake acceleration records used as source of excitations. The Portland building was subjected to three components of acceleration obtained from the November 1962 Portland earthquake. The Long Beach building was subjected to three components of acceleration obtained from the 1987-Whittier Narrows earthquake. The purpose of the analyses is to reveal building response under these realistic earthquake excitations, so that logical seismic instrumentation schemes can be developed for these buildings. The results of the analyses suggest that the response of the Portland building is influenced more by torsional and rocking motions, while the response of the Long Beach building is influenced mainly by translational modes. From the observed behavior of the buildings, a seismic instrumentation scheme is developed for each building, and a general guideline for seismic instrumentation in existing building is recommended.

#### **Pielert, J. H.**

Pielert, J. H.

Proficiency Testing as a Component of Quality Assurance in Construction Materials Laboratories. National Institute of Standards and Technology, Gaithersburg, MD

RILEM/ILAC. Test Quality for Construction Materials and Structures. October 15-17, 1990, St. Remy Les Chavreuse, France, Chapman and Hall, New York, Fickelson, M., Editor(s), 60-70 pp, 1990.

cement; concrete; construction; interlaboratory; laboratory; preon; proficiency; tests

Proficiency testing is a procedure for using results generated in interlaboratory test comparisons for the purpose of assessing the technical competence of participating testing laboratories. This gives users of laboratory service confidence that a testing laboratory is capable of obtaining reliable results. Interlaboratory testing involves the organization, performance and evaluation of tests on the same or similar materials by two or more different laboratories in accordance with predetermined conditions. Interlaboratory testing may also be used for checking the individual performance of laboratory staff, evaluating the effectiveness of a test method, and determining characteristics of a material or product. Programs in the United States which use proficiency testing to evaluate laboratory performance are discussed along with international programs which have been identified by RILEM Technical Committee 91-Cement Reference Laboratories. The U. S. Construction Materials Reference Laboratories which distributes over 6000 samples of 13

different construction materials is highlighted, along with ASTM standardization activities related to proficiency and interlaboratory testing.

Pielert, J. H., Editor

RILEM TC91-CRL on Testing and Control Procedures for Cement and Concrete Reference Laboratories. Evaluation of Cement and Concrete Laboratory Performance, Proceedings of the Workshop. September 6-7, 1989, Tel Aviv, Israel, NIST SP 788, 144 pp, 1990.

Available from Government Printing Office

accreditation; cement; concrete; laboratory; quality assurance; testing

A workshop sponsored by RILEM Technical Committee 91-CRL was held in Tel Aviv, Israel on September 6-7, 1989 to consider the evaluation of cement and concrete testing laboratory performance. The workshop attracted 30 participants from the United Kingdom, France, Israel, Sweden, United States, Austria, Switzerland, Germany F. R., Finland and Spain. Papers were presented on the following subjects: (1) quality assurance programs for testing laboratories, (2) assessment of the technical performance of laboratories, and (3) role of reference laboratories. The workshop resulted in an excellent exchange of information and showed a high degree of interest in the quality of testing of cement and concrete on the international level.

#### **Pitts, W. M.**

Pitts, W. M.

Carbon Monoxide Production and Prediction.

National Institute of Standards and Technology, Gaithersburg, MD

U. S./Japan Government Cooperative Program on Natural Resources (UJNR). Fire Research and Safety. 11th Joint Panel Meeting. October 19-24, 1989, Berkeley, CA, Jason, N. H. and Cramer, D. M., Editor(s), NISTIR 4449, 33-39 pp, 1990.

carbon monoxide; enclosures; fire models

A long-term research plan has been formulated which is designed to improve the understanding of and predictive capability for the formation of carbon monoxide in enclosure fires. The current understanding of the problem is briefly discussed. Goals (milestones) for the project are listed and the research plan is discussed in terms of eighteen individual research components.

Pitts, W. M.; Nyden, M. R.; Gann, R. G.; Mallard, W. G.; Tsang, W.

Construction of an Exploratory List of Chemicals to Initiate the Search for Halon Alternatives.

National Institute of Standards and Technology, Gaithersburg, MD

NIST TN 1279; 206 p. August 1990.

Available from Government Printing Office  
halons; fire suppression; ozone; chemical properties; physical properties; combustion

Production of the currently-used halogenated fire suppressants (halons) will be curtailed because of their contribution to stratospheric ozone depletion. This report, one of the first efforts toward identifying alternatives, documents the rationale for and selection of a set of approximately one hundred gases and/or liquids, covering a range of chemical and physical principles thought to affect flame suppression capability and stratospheric ozone depletion. An Appendix provides extensive information on each of the selected chemicals. Also included in the report are an introduction to combustion concepts, fire suppression mechanisms, test approaches for flame suppression effectiveness, and the mechanisms by which the current commercial halons can decrease stratospheric ozone.

### **Pommersheim, J. M.**

Pommersheim, J. M.; Clifton, J. R.  
Models of Transport Processes in Concrete.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
Bucknell Univ., Lewisburg, PA  
NISTIR 4405; 101 p. September 1990.

Available from National Technical Information Services PB91-107219

acid attack; chloride; concrete; convection; corrosion; degradation; diffusion; leaching; mathematical models; service life; sulfate attack; transport processes

An approach being considered by the U. S. Nuclear Regulatory Commission for disposal of low-level radioactive waste is to place the waste forms in concrete vaults buried underground. The vaults would need a service life of 500 years. Approaches for predicting the service life of concrete of such vaults include the use of mathematical models. Mathematical models are presented in this report for the major degradation processes anticipated for the concrete vaults, which are corrosion of steel reinforcement, sulfate attack, acid attack and leaching. The models mathematically represent rate controlling processes including diffusion, convection, and reaction and sorption of chemical species. These models can form the basis for predicting the life of concrete under in-service conditions.

### **Puri, R.**

Puri, R.; Santoro, R. J.  
Influence of Soot Particles on CO Production in Diffusion Flames.  
Pennsylvania State Univ., University Park 4 p.  
soot; carbon monoxide; diffusion flames; quenching; oxidation; hydroxyl radicals  
In recent years, numerous investigations have focussed on CO production and emission from fires and diffusion flames since CO is widely recognized as the most serious

combustion product resulting from fires. High concentrations of CO as well as soot characterize typical fire situations and it has been recognized that there may be a relationship between the CO and soot concentrations observed in fires. In order to avoid the need for detailed kinetic modeling in these complex reacting flows, several workers have pursued approaches emphasizing correlations. While some workers have tried to directly correlate observed CO and soot concentrations, others have used the conserved scalar approach to relate CO as well as soot concentrations with the local equivalence ratio. In the present study, a more fundamental understanding of the nature of the interaction between CO and soot is sought. Two possible mechanisms, radiative quenching and oxidation competition by soot for hydroxyl radicals, are examined with respect to their effect on CO concentration.

### **Puri, R.; Santoro, R. J.**

Role of Soot Particle Formation on the Production of Carbon Monoxide in Fires.  
Pennsylvania State Univ., University Park  
Edinburgh Univ. Fire Safety Science, 3rd International Symposium. July 8-12, 1991, Scotland, UK, 1-28 pp, 1990.

carbon monoxide; soot formation; diffusion flames; laminar flames; soot; burners; temperature measurements; reaction rate; oxidation

A systematic study of the effects of soot formation on the production of carbon monoxide (CO) in laminar diffusion flames has been conducted. Increased amounts of soot have been observed to result in larger concentrations of CO in the higher regions of the flames. Comparisons of CO state relationships as a function of local equivalence ratio show distinct effects as the local soot volume fraction is varied. Fuel rich regions exhibit lower CO mole fractions as soot concentration increases, whereas higher CO mole fractions are observed under fuel lean conditions. An analysis of the likely mechanisms responsible for these effects has been conducted to explain the observations as well as to identify future research directions.

### **Puri, R.; Santoro, R. J.**

Sonic Probe Sampling in Particle Laden Comion Flows.

Pennsylvania State Univ., University Park 3 p.

combustion; probes; sampling; validation; tests  
Today particle formation and growth from gas phase species command a considerable amount of attention in the areas of combustion science and material processing. In order to further the understanding of these formation and growth processes, measurements of gas phase species which are precursors to particles and are critical to their subsequent growth are essential.

## Quintiere, J. G.

Quintiere, J. G., Editor; Cooper, L. Y., Editor  
American Institute of Aeronautics and  
Astronautics/American Society of Mechanical  
Engineers (AIAA)/ASME).

Heat and Mass Transfer in Fires. AIAA/ASME  
Thermophysics and Heat Transfer Conference.  
June 18-20, 1990, Seattle, WA, Am. Soc. Mech.  
Engrs., New York, HTD-Vol. 141, 142 pp, 1990.

heat transfer; mass transfer; temperature fields; composite  
materials; LP gas; enclosures; diffusion flames;  
ceiling jets; heat flux; scale models; smoke; water sprays;  
evaporation cooling; flame spread rate; cone calorimeters  
Fire research has developed to a stage where it is now  
possible to recognize an established body of accrued  
knowledge constituting a science of fire. The papers in this  
volume are indicative of the state-of-the-art. They  
emphasize the thermal aspects of fire and represent only one  
component of the science of fire. In addition, fire safety  
science includes the effects of fire on people as well as on  
structures and materials. The challenge to the engineer is  
the translation and further development of fire science into  
a rational practice of public safety. The complex nature of  
fire safety has required empirical tests and prescriptions built  
on judgment and experience to form the practice of fire  
safety. In the USA, more than \$50 billion are spent annually  
on fire safety and its impact. The USA also has the highest  
annual fire death rate among other countries; a fact that is  
still not clearly understood today. Only through the  
development and translation of the science of fire will society  
have the tools to effectively reduce these costs and losses.  
Fire research is a small fledgling field, but its contributions  
can have a significant impact on the cost reliability of safety  
measures we take for granted. These papers represent a  
valuable contribution to that process.

## Quintiere, J. G.

Canadian Mass Fire Experiment, 1989.  
National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4444; 63 p. November 1990.  
Available from National Technical Information  
Services PB91-143305

mass fires; energy transfer; forest fires; smoke emissions  
Working with Forestry Canada and the Ontario Ministry of  
Natural Resources, the Defense Nuclear Agency carried out  
an extensively instrumented experiment of a prescribed burn  
in forest debris to simulate conditions of a mass fire. In  
addition to the Canadian team, a multi-institutional US team  
made both ground and airborne measurements of the fire  
and smoke conditions. The fire reported on was in Hill  
Township, Ontario and covered nearly 480 in its overall  
burning area. Both flaming and smoldering modes  
contributed to the energy and combustion products of this  
fire. Significant quantities measured and determined included

estimations of energy release rate, emission factors for smoke  
particulates and species, ground level wind and temperatures,  
and aspects of cloud dynamics and cloud particles. The fire  
caused a capping cloud to form and reach a level of 6.5 km.  
Rain, snow, hail and lightning were reported along with  
ground level fire whirls and water spouts on the adjoining  
lakes. Fire spread rates reached 1 m/s and fire induced  
winds reached 12 m/s.

## Quintiere, J. G.

Furniture Flammability: An Investigation of the  
California Technical Bulletin 133 Test. Part 1.  
Measuring the Hazards of Furniture Fires.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4360; 29 p. July 1990.

Available from National Technical Information  
Services PB90-256850

furniture; flammability; test methods; fire hazards; carbon  
monoxide; flashover; ignition; smoke

The hazards due to furniture fires are examined. These  
include ignition of an adjoining item, flashover, CO toxicity,  
and reduced visibility as a result of smoke. Theoretical  
analyses are given to quantify the hazards, and typical  
parametric values are given for several materials  
representative of a range of fire performance. Results are  
presented in terms of conditions at the flame tip, at the  
onset of flashover, and for a ventilation-limited fire. Critical  
hazard measurements are identified, and an illustration is  
given on how to characterize the hazards. Finally, a critical  
review of the measurements used in the California Technical  
Bulletin 133 is made, and recommendations for  
improvements are offered.

## Quintiere, J. G.

Report of the Fourth CIB W14 Workshop on Fire  
Modeling; Conseil International Du Batiment  
(CIB) Commission W14 on Fire. February 12-14,  
1990.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4338; 82 p. June 1990.

Available from National Technical Information  
Services PB90-247420

flammability; fire models; interior finishes; zone models

A summary of presentations are presented for the 4th  
Conseil International du Batiment (CIB) Workshop on Fire  
Modeling. The scope of the presentations, 47 in number,  
include reports of recent developments and applications of  
zone and field models, presentations on specific phenomena  
needed by computer algorithms, and presentations on the  
subject of interior finish flammability. The workshop showed  
that a variety of models are in international use, that data is  
lacking to confirm the accuracy of the models for  
applications beyond their base of development, and that it is

becoming evident that the fire growth hazard of interior finish materials can be predicted from small scale test data.

### **Raufaste, N. J.**

Raufaste, N. J.

Building Technology Project Summaries 1990.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 90-4288; 107 p. April 1990.

building research; building technology; criteria; measurement methods; performance criteria; project summaries; standards; technical bases; test methods

The Center for Building Technology (CBT) of the National Institute of Standards and Technology (NIST) is the national building research laboratory. CBT works cooperatively with other organizations, private and public, to improve building practices. It conducts laboratory, field, and analytical research to predict, measure, and test the performance of building materials, components, systems, and practices. CBT's technologies are widely used in the building industry and adopted by governmental and private organizations that have standards and codes responsibilities. This report summarizes the research underway in the Center during 1990.

Raufaste, N. J., Editor

U.S./Japan Natural Resources Development  
Program (UJNR).

Wind and Seismic Effects. Joint Meeting of the U.S./Japan Cooperative Program in Natural Resources. Panel on Wind and Seismic Effects, 21st. May 16-19, 1989, Tsukuba, Japan, NIST SP 776, 413 pp, 1990.

Available from Government Printing Office

accelerograph; Armenia; bridges; codes; concrete; design criteria; disasters; earthquakes; geotechnical engineering; ground failures; inelastic; lifelines; liquefaction; masonry; repair and retrofit; risk assessment; seismicity; soils; standards; storm surge

The 21st Joint Meeting of the U.S.-Japan Panel on Wind and Seismic Effects was held at the Public Works Research Institute, Tsukuba, Japan, from May 16-19, 1989. This publication, the proceedings of the Joint Meeting, includes the program, list of members, panel resolutions, task committee reports, and 33 technical papers. The papers were presented under six themes; (I) Wind Engineering, (II) Earthquake Engineering, (III) Storm Surge and Tsunami, (IV) U.S.-Japan Cooperative Research Program, (V) Code Development Process and Code Enforcement Responsibility, and (VI) Armenia Earthquake (oral presentation).

Raufaste, N. J., Editor

U.S./Japan Natural Resources Development  
Program (UJNR).

Wind and Seismic Effects. Joint Meeting of the U.S./Japan Cooperative Program in Natural Resources. Panel on Wind and Seismic Effects, 22nd. May 15-18, 1990, Gaithersburg, MD, NIST SP 796, 524 pp, 1990.

Available from Government Printing Office

accelerograph; bridges; codes; concrete; design criteria; disasters; earthquakes; geotechnical engineering; ground failures; inelastic; lifelines; liquefaction; Loma Prieta; masonry; repair and retrofit; risk assessment; seismicity; soils; standards; storm surge; structural engineering; tsunami; wind loads

The 22nd Joint Meeting of the U.S.-Japan Panel on Wind and Seismic Effects was held at the National Institute of Standards and Technology from May 15-18, 1990. This publication, the proceedings of the Joint Meeting, includes the program, list of members, panel resolutions, task committee reports, and 33 technical papers. The papers were presented under six themes: (I) Wind Engineering, (II) Storm Surge and Tsunami, (III) Joint Cooperative Research Program, (IV) Earthquake Engineering, (V) Loma Prieta Earthquake, and (VI) Summaries of Task Committee Workshop Reports.

### **Reed, K. A.**

Reed, K. A.; Harrod, D., Jr.; Conroy, W.

Initial Graphics Exchange Specification (IGES)  
Version 5.0.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4412; 600 p. September 1990.

Available from National Technical Information  
Services

digital data interchange; product definition data; computer aided design; computer aided drafting

This document contains Version 5.0 of the Initial Graphics Exchange Specification (IGES). The Initial Graphics Exchange Specification defines a file structure format, a language format, and the representation in these formats of geometric, topological, and non-geometric product definition data that occur in computer-aided design and drafting systems. Product definition data represented in these formats will be exchanged through a variety of physical media. The specific features and protocols for the communications media are the subject of other standards. The methodology for representing product definition data in this Specification is extensible and independent of the modeling methods used. Version 5.0 includes more than eighty Editorial Change Orders that have been approved by the IGES/PDES Organization since the issuance of Version 4.0. Besides corrections and clarifications, these changes introduce the Version 5.0 new area fill patterns and line font patterns to support AEC drafting, new properties and attributes to support electrical and printed wire assembly

manufacturing, a perspective view capability, and a bounded surface entity for communicating trimmed surfaces.

### **Rockett, J. A.**

Rockett, J. A.

Using the Harvard/NIST Mark VI Fire Simulation.  
National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4464; 44 p. November 1990.

Available from National Technical Information  
Services PB91-144394

fire simulation; computer programs; manuals

Installation and use of the Harvard/NIST VI multi-room fire simulation (computer code on the IBM PC and compatibles) is described. Two separate auxiliary programs, MASBANK and PREPLOT are also described and their use illustrated. Use of the input menus is described and illustrated. Comments are made on the effect of the choice of alternative sub-models on predicted results. Some suggestions for use on other computers are made. The HO6.3 disks for use with this report include: Disk #1: All files (in packed form) needed to run HO6.3 and the two auxiliary programs: MASBANK and PREPLOT. A group of (packed) files including a short data base file and a sample output of HO6.3. Disk #2: Section 1 including 17 out of 25 source code files for HO6.3. Disk #3: Section 2 including the final 8 source code files of HO6.3 and source code for MASBANK, PREPLOT and the auxiliary source code file DTIME.

### **Rossiter, W. J., Jr.**

Rossiter, W. J., Jr.; Gaddy, G. D.

Summary of the Workshop on the Applicability of  
Thermal Analysis to Characterization of Roof  
Membrane Materials.

National Institute of Standards and Technology,  
Gaithersburg, MD

Johns Hopkins Univ., Baltimore, MD

NISTIR 4458; 40 p. November 1990.

Available from National Technical Information  
Services

characterization; low-sloped roofing; membranes; performance; properties; roofs; thermal analysis; workshop  
Thermal analysis methods have not yet been widely used for the characterization of roof membrane materials, although they have been employed for more than three decades in the characterization of synthetic polymeric products. In 1988, a proposal was made by a Joint International Committee under the auspices of CIB/RILEM that thermal analysis methods be added to the inventory of test methods currently used to characterize roof membrane materials. The U. S. Army Construction Engineering Research Laboratory (CERL) has underway a program for evaluating the

performance of roof membrane materials including the development of new or improved methods for determining their important properties. Thermal lysis methods offered a means for such characterization. However, an important question was whether they could be meaningfully incorporated in voluntary consensus standards pertaining to membrane materials. Thus, a Workshop was convened to address this issue. This report presents the results of the Workshop. Thirteen presentations were made by participants who had experience in the application of thermal analysis to roofing products. The participants discussed the key issue in relation to the information provided during the presentations. Based on the results of the discussions, the following conclusions were made. First, thermal analysis methods are valuable tools for use in the research laboratory, for tracking manufacturing processes to check that they remain in control, and for troubleshooting. Second, thermal analysis methods do not have immediate use in consensus standards for roofing. The main reason is that they are not considered to be predictive, in themselves, of the performance that a product may provide in service. Another reason is the cost of the equipment, which may prohibit general use of the methods, and make their incorporation in standards unattractive at the present time.

### **Rubin, A.**

Rubin, A.

High Technology Office Evaluation Survey--A  
Pilot Study.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4354; 68 p. June 1990.

Available National Technical Information Services  
PB90-244427

acoustics; air quality; design process; ergonomics; furniture systems; lighting; open-office design; post-occupancy-evaluation; space requirements; thermal comfort

This report is intended to provide insights about how offices and workstations are planned and designed in the private and public sectors. Among the issues explored are the quality workplace, the effects of technology on design, space allocations, and systems furnishings. The data were collected by a detailed questionnaire survey, administered with the cooperation of the Corporate Architects Committee of the American Institute of Architect (AIA). The respondents were designers and facility managers of major corporations and governmental agencies with broad planning experience and major design responsibilities. The sample is a limited one, including only twenty-two respondents, and therefore the findings are indicative of current design practices and experiences. The survey was designed to cover a broad range of topics and provide the opportunity to comment freely about them. As a result, much of the data is in narrative form.

**Rubin, A.**  
Post-Occupancy Evaluation of Federal Buildings--The Portland Federal Building and Others.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4307; 178 p. April 1990.

Available from National Technical Information  
Services PB90-219833

acoustics; air quality; design process; ergonomics; furniture systems; lighting; post-occupancy evaluation; thermal comfort; wiring

The introduction of new technologies in office buildings has changed the working environment for government employees. The effects of these new conditions are not yet well understood. This report presents an evaluation of the working conditions at the "old" and new Portland Federal Building, occupied by the Bonneville Power Administration (BPA). Assessments were made by questionnaires filled out by employees, and interviews with operational and facility management personnel. Other federal buildings were examined to obtain supplementary information. Interviews were conducted with facility management personnel at the Department of Labor, the Treasury Department, the General Services Administration (GSA) and the Office of Personnel Management (OPM). A limited questionnaire survey was conducted at OPM. Some of the buildings examined were new ones, while others were being retrofitted. A summary of the "lessons learned" is included, in addition to evaluations of the buildings examined.

#### **Ryan, J. D.**

Ryan, J. D.; Babrauskas, V.; O'Neill, T. J.; Hirschler, M. M.

Performance Testing for the Corrosivity of Smoke.  
E. I. DuPont de Nemours and Co., Wilmington,  
DE

National Institute of Standards and Technology,  
Gaithersburg, MD

Goodrich (B. F.) Co., Avon Lake, OH

American Society for Testing and Materials  
(ASTM). ASTM International Symposium on  
Characterization and Toxicity of Smoke. Abstract  
Booklet. ASTM Committee E-5 on Fire  
Standards. December 5, 1988, Phoenix, AZ,  
ASTM, Philadelphia, PA, ASTM STP 1082, 75-88  
pp, 1990.

smoke; tests; corrosion; combustion products

The corrosivity of combustion products has arisen as an issue for both product manufacturers and standards bodies. While many industries can have concerns in this area, electronic communications and control equipment are especially vulnerable to the problem. The best way to manage the smoke corrosivity issues is to avoid a fire. In the event a fire

does occur, a number of actions must be taken. An important consideration is that the materials and products used should have been chosen with due consideration of their corrosion-causing potential. To do this requires a suitable corrosivity test. It has traditionally been assumed that smoke corrosivity is directly correlated to the mission of acid gases. The results of recent experiments have shown that materials which do not release acid gases can, nevertheless, cause corrosion of metal surfaces, as determined by metal loss. In addition, for electrical equipment there are two other types of related nonthermal damage from combustion products which must be considered, viz, ohmic bridging and degradation of contacts. Laboratory tests proposed to date to measure the corrosive effects of combustion products all have significant deficiencies; some methods are not performance-based at all and are merely tests for pH. In others, unrealistic specimen heating or unrealistic exposure targets are used. To facilitate the development of a better test, a series of criteria have been developed. A specific test method was evolved from these criteria. The method is performance-based and incorporates realistic fire heating conditions.

#### **Sansalone, M.**

Sansalone, M.; Lin, Y.; Carino, N. J.

Impact-Echo Response of Plates Containing Thin Layers and Voids.

National Institute of Standards and Technology,  
Gaithersburg, MD

Review of Progress in Quantitative Nondestructive  
Evaluation. Volume 9B, Plenum Press, New York,  
Thompson, D. O.; Chimenti, D. E., Editor(s),  
1935-1942 pp, 1990.

reinforced concretes; structures; plates; thin layers; voids;  
impact-echo method; finite element studies; ducts

An ongoing research program initiated in 1983 by Carino and Sansalone has been aimed at developing the theoretical basis and practical applications for a new nondestructive technique for detecting flaws in reinforced concrete structures. The technique, known as impact-echo, is well documented and only a brief overview of the principle of the method, signal processing techniques, and instrumentation is presented. This paper highlights the results of a recent investigation into the feasibility of using the impact-echo technique to detect voids in plates containing thin layers of materials having different acoustic impedances.

#### **Santoro, R. J.**

Santoro, R. J.

Fundamental Mechanisms for CO and Soot  
Formation in Diffusion Flames. Quarterly  
Progress Report. May 1, 1990-July 21, 1991.  
Pennsylvania State Univ., University Park, PA  
Quarterly Progress Report; 4 p. 1990.

diffusion flames; carbon monoxide; soot formation; sampling;  
probes

The following report and attachments describe the progress made during the period May 1 through July 31, 1990 for grant 60NANB0D1035 entitled "Fundamental Mechanisms for CO and Soot Formation in Diffusion Flames". During this period our activities have focused in two general areas. The first area involves our continued examination of the relationship between soot particle and CO formation, while the second area deals with the application of a new sampling probe technique which Rahul Puri, the graduate student associated with the program, has recently developed.

### **Saunders, S. C.**

Saunders, S. C.; Jensen, M. A.; Martin, J. W.  
Study of Meteorological Processes Important in the Degradation of Materials Through Surface Temperature.

National Institute of Standards and Technology,  
Gaithersburg, MD

NIST TN 1275; 45 p. April 1990.

Available from Government Printing Office  
diurnal cycle; energy-balance equation; environmental factor;  
Fourier analysis; meteorological data; panel temperature;  
time series analysis

One of the greatest impediments in forecasting the service life of a material exposed outdoors is the uncontrolled and non-predictable nature of the ambient factors comprising its environment. This contributes to the difficulty of establishing the cause-and-effect relationship between these factors and the rate of material degradation. To surmount these difficulties it is necessary to characterize quantitatively each of the factors comprising the exposure environment which are thought to be important in the material's degradation. The selection and quantification of these factors must accommodate not only the periodicity of the diurnal cycle but its statistical fluctuation. The objective of this research is to develop a general mathematical model through Fourier analysis, characterizing the diurnal variation in the primary factor, material temperature. This factor is felt to be important in the degradation of a wide range of materials and protective systems, including coated steel panels. The steps taken and problems encountered in developing such a model are outlined. It is concluded that the simulated data generated from this model display virtually the same stochastic behavior as does the real data and that, if appropriate meteorological records are available, it will be possible to characterize and reproduce the statistical behavior for any locality, season and panel orientation.

### **Sivathanu, Y. R.**

Sivathanu, Y. R.; Kounalakis, M. E.; Faeth, G. M.  
Structure and Radiation Properties of Turbulent  
Diffusion Flames. Annual Report.

Michigan Univ., Ann Arbor

NIST-GCR-90-570; 104 p. February 1990

Available from National Technical Information  
Services PB90-218777

diffusion flames; turbulent flames; flame structure; flame  
radiation; luminous flames; temperature; soot

A theoretical and experimental study of the structure and radiation properties of turbulent diffusion flames is described. Generalized state-relationship correlations, giving the mass fractions of major gas species (N<sub>2</sub>, O<sub>2</sub>, fuel, CO<sub>2</sub>, H<sub>2</sub>O, CO and H<sub>2</sub>) as functions of local fuel-equivalence ratios, were developed for hydrocarbon/air diffusion flames. Instantaneous soot volume fractions and temperatures were measured in the fuel-rich (underfire) region of turbulent nonpremixed acetylene, propylene, ethylene and propane flames burning in still air.

### **Skelly, M. J.**

Skelly, M. J.

Experimental Investigation of Glass Breakage in  
Compartment Fires.

Virginia Polytechnic Institute and State Univ.,  
Blacksburg

NIST-GCR-90-578; 91 p. June 1990.

Available from National Technical Information  
Services PB90-244443

glass; compartment fires; windows; building fires; fire tests;  
radiant heating

An experimental investigation has been completed which studied the breaking of window glass by fire. The experiments were carried out in a specially designed compartment to achieve two-layer flows characteristic of normal building fires. The experimental data was collected from two test groups: the first for windows with their edges insulated from the fire (edge-protected) and the second for windows uniformly heated by the fire (edge-unprotected). The results of the edge-protected window tests indicated that the glass breakage was caused by a critical temperature difference between the central heated portion of the pane and the glass edge. The experimental work showed the critical value to be approximately 90°C. After the material properties of the glass were determined, the theoretical findings of Keski-Rahkonen were used to obtain a value of 70°C; the difference attributed to radiative heating. The test results also demonstrated a distinctive loss of integrity by the windows. When breakage occurred, the cracks spread throughout the glass, joined together and caused at least partial collapse of the pane. The results from the edge-unprotected window tests were quite different. There were relatively few cracks developed and almost no propagation across the glass. Consequently, there was no window collapse in any of these cases. The breakage did initiate at a consistent glass temperature value, however, the mechanism for these tests is not known.

**Smith, R. L.**

Smith, R. L.  
Concept of the Calculus of Fire Safety.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
NISTIR 4459; 22 p. November 1990.  
Available from National Technical Information  
Services PB91-132134

fire safety; artificial intelligence; expert systems; computer  
programs; fire risk

Many people (builders, owners, designers, occupants, etc.)  
have an interest in appraising the fire safety of existing or  
proposed buildings. Computers are playing an ever  
increasing role in fire safety analysis and in the technology  
transfer of fire science. In this report the concept of the  
Calculus of Fire Safety is developed as a declarative  
programming language. This calculus will enable users to  
specify what fire safety question is to be answered without  
specifying how the answer is to be obtained. Advances in  
Artificial Intelligence programming techniques will enable the  
implementaion of the Calculus of Fire Safety on widely  
available workstations. This will provide a very powerful tool  
to anyone interested in determining the fire safety of  
buildings.

**Smith, R. L.**

EXPOSURE: An Expert System Fire Code.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
NISTIR 4373; 41 p. July 1990.  
Available from National Technical Information  
Services PB90-257601

expert systems; fire codes; artificial intelligence; building  
codes; computer programs; exposure

This report address the issue of developing an expert or  
knowledge-based system that deals with the problem of  
preventing the spread of fire between buildings. A  
knowledge-based program, EXPOSURE, has been  
developed that facilities using more appropriate technology,  
expanding the problem domain, and providing cost-effective  
solutions. EXPOSURE can solve the problem of the  
prevention of the spread of fire between buildings for the  
case when the exposed building has combustible walls. The  
use of the expert system EXPOSURE and NFPA 80A  
produce significantly different recommended minimum  
separation between buildings. In some cases EXPOSURE  
calls for significantly greater separation and in others  
significantly less. In one case the separation required by  
NFPA 80A was more than five times greater than what  
EXPOSURE recommended. This program demonstrates  
that significant cost savings in achieving the desired level of  
fire safety and in assuring the levels of safety can be obtained  
by use of expert system fire codes.

**Smith, R. L.**

EXPOSURE80A: A Computer Program Version  
of NFPA 80A.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4372; 48 p. July 1990.

Available from National Technical Information  
Services PB90-257726

fire codes; building codes; computer programs; exposure  
This report describes a computer program,  
EXPOSURE80A, written in Symbolics Common Lisp, that  
leads the user through NFPA 80A: Recommended Practice  
for Protection of Buildings From Exterior Fire Exposures.  
EXPOSURE80A is designed for use by fire protection  
professionals. It tells the user whether two buildings comply  
with the recommendations of NFPA 80A and if they do not,  
it suggests changes that will bring the buildings into  
compliance. EXPOSURE80A is easier to use than the  
written version of NFPA 80A since an understanding of  
NFPA 80A is not required. The approach used in  
EXPOSURE80A provides valuable information about the  
knowledge required of the user and the appropriate interface  
for the targeted class of users of an expert system,  
EXPOSURE, which is described in National Institute of  
Standards and Technology report NISTIR 4373.

**Smith, R. L.**

Program for Calculating the Maximum Radiation  
on a Wall.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4437; 33 p. November 1990.

Available from National Technical Information  
Services PB91-120139

walls; exposure; radiative heat transfer; computer programs  
This report describes a program module of the expert system  
EXPOSURE. This module, written in Common Lisp, is for  
calculating the maximum electromagnetic radiation incident  
upon a building's wall due to the burning of a neighboring  
building. It is assumed that the burning building has an  
arbitrary number of rectangular openings emitting radiation.  
The exposed wall can be considered as being composed of a  
number of rectangular regions. These regions may be  
openings on regions of different materials. This program can  
determine the maximum radiation for each of these regions  
and for the wall less these regions.

**Smyth, K. C.**

Smyth, K. C.; Tjossem, P. J. H.; Hamins, A.;  
Miller, J. H.

Concentration Measurements of OH and  
Equilibrium Analysis in a Laminar Methane-Air  
Diffusion Flame.

National Bureau of Standards, Gaithersburg, MD  
George Washington Univ., Washington, DC  
Combustion and Flame, Vol. 79, 366-380, 1990.

diffusion flames; methane; concentration measurement;  
laminar flames; equilibrium; lasers

Absolute concentration measurements of hydroxyl radical have been made in a laminar, co-flowing methane-air diffusion flame using laser absorption and laser-induced fluorescence methods to probe the transition. The maximum OH concentration is found to be [equation] at a temperature of 280 K, which is twice the value calculated assuming local total equilibrium but less than half that predicted from partial equilibrium [equation]. Evidence is presented that in general partial equilibrium does not exist for the fast, bimolecular chain branching and radical shuffle reactions in this flame. The overall chemical production-destruction rate profile of OH has been determined, as well as the rates of hydrogen abstraction reactions by hydroxyl radical to form the vinyl and ethynyl radicals. These results are used to identify the most rapid routes for the production of radical species important in chemical growth processes.

Smyth, K. C.; Tjossem, P. J. H.  
Radical Concentration Measurements in  
Hydrocarbon Diffusion Flames.

National Institute of Standards and Technology,  
Gaithersburg, MD

Applied Physics B, Vol. 50, 499-511, 1990.

diffusion flames; lasers; radical concentrations; absorptivity  
Absolute OH concentrations and relative H-atom and O-atom profiles have been measured in a laminar, co-flowing methane/air diffusion flame burning at atmospheric pressure. Laser absorption and laser-induced fluorescence methods were used to probe the [equation] transition in OH. The maximum OH concentration is found to be  $1.8 \pm 0.2 \times 10^{16} \text{ cm}^{-3}$  (mole fraction  $= 5.0 \times 10^{-3}$ ) at a temperature of 2080 K, which is twice the value calculated assuming local total equilibrium but less than half that predicted from partial equilibrium [equation]. Multiphoton ionization has been used to detect H atoms, while laser-induced fluorescence 845 nm excited two photon absorption at 226 nm was employed to observe O atoms. In both cases it was found that low photon intensities and a retroreflected beam, Doppler-free geometry was required in order to avoid the photolytic production of the species of interest. For all of the concentration profile data it is necessary to correct the raw signals for variations in collisional quenching. In the case of the multiphoton ionization measurements the variation in electron detection sensitivity as a function of flame position must be accounted for as well. Establishing absolute H-atom and O-atom concentrations is discussed in terms of partial equilibrium considerations and detailed flame structure calculations.

Smyth, K. C.; Bryner, N. P.  
Short-Duration Autoignition Temperature  
Measurements for Hydrocarbon Fuels.

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 4469; 47 p. December 1990.

Available from National Technical Information  
Services

ASTM E659; autoignition temperature; engine knock;  
hydrocarbon fuels; ignition; ignition temperature; ignition  
testing; stoichiometry; surface ignition

A new apparatus has been designed, built, and extensively tested for making short-duration autoignition temperature measurements of hydrocarbon fuels under conditions where the fuel/air stoichiometry, the nature of the hot metal surface, and the contact time are well controlled. This approach provides a much more reliable database to establish the importance of fuel structure effects than the current ASTM E659 procedure. Over 1100 individual autoignition temperature determinations have been made for the ignition of 15 hydrocarbon fuels on heated nickel, stainless steel, and titanium surfaces for three different fuel/air mixtures. Excellent reproducibility has been achieved with the new apparatus. The measured autoignition temperatures generally decrease for the larger hydrocarbons and for richer mixtures, with the C2 hydrocarbons (ethane, ethylene, and acetylene) having particularly low values. The highest autoignition temperatures are observed for nickel surfaces and the lowest for stainless steel, with titanium being an intermediate case. A review of the autoignition literature suggests that the branched alkanes should be more resistant to autoignition than the linear isomers, and thus present a reduced hazard. Limited data obtained in this study are consistent with this prediction. Promising directions for substantiating these observations and additional areas for future research are outlined.

Smyth, K. C.; Tjossem, P. J. H.  
Signal Detection Efficiency in Multiphotonization  
Flame Measurements.

National Institute of Standards and Technology,  
Gaithersburg, MD

Applied Optics, Vol. 29, No. 33, 4891-4898,  
November 20, 1990.

signal detection; ionization; laminar flames; diffusion flames;  
atmospheric pressure; carbon monoxide; argon

Multiphoton ionization is often the most sensitive method available for detecting radical species in flame environments. To make accurate relative concentration measurements, however, the electron (or ion) detection efficiency as a function of flame position must be known. Two methods are presented for determining this quantity in a laminar CH<sub>4</sub>/air diffusion flame burning at atmospheric pressure: (1) simultaneous detection of ionization and fluorescence in CO, following two-photon excitation of the [equation] state at 230.0 nm; (2) comparison of 3 + 1 multiphoton ionization of the 4s' state of argon at 314.4 nm with mass spectrometric measurements. The results show significant variation of the electron detection efficiency in the lean, stoichiometric, and rich flame regions, with the greatest detection sensitivity

observed in the high-temperature, primary reaction zones (i.e., near stoichiometric conditions). Corrections to multiphoton ionization data obtained for H atoms are discussed in terms of determining relative concentration profiles across the methane/air diffusion flame.

### **Snell, J. E.**

Snell, J. E.

**Fire Hazard and Risk: Evaluating Alternative Technologies.**

National Institute of Standards and Technology, Gaithersburg, MD

National Conference of States on Building Codes and Standards; Council of American Building Officials; Department of Housing and Urban Development; National Association of Home Builders; National Fire Protection Association; National Fire Sprinkler Association and National Institute of Standards and Technology. **Sprinklers in Residential and Commercial Building August 19-20, 1990, Charleston, SC, Natl. Conf. States on Bldg. Codes and Standards, McIntyre, M., Editor(s), 1 pp, 1990.**

sprinklers; sprinkler systems; residential buildings; commercial buildings; fire hazard; fire risk; fire safety; risk analysis; fire protection; smoke detectors; smoke control; sprinklers

Fire safety decisions typically involve difficult choices between safety, cost and functionality. Obviously, buildings could be completely fire safe by making sure they, and their contents simply do not burn, or by providing technologies that would clearly overpower any possible fire threat. Unfortunately, few would like, could afford or would be comfortable in such surroundings. Typically, the cost and functionality aspects of designs and products are well understood and effectively communicated. However, until recently means have not been available to quantify the fire hazard or risk people face, or to measure the effectiveness of fire protection technologies in specific real world situations. This paper reviews the status and potential of new tools for evaluating fire hazard and risk, cites examples of recent applications, and offers observations relevant to the current debate on the best means to provide fire safety in residential and commercial buildings.

Snell, J. E.

**Fresh Look at Strategies for Fire Safety.**

National Institute of Standards and Technology, Gaithersburg, MD

Interscience Communications Ltd.; National Institute of Standards and Technology; Building Research Establishment; and Society of Fire Protection Engineers. **Interflam '90. Fire Safety.**

**International Fire Conference, 5th. September 3-6, 1990, Canterbury, England, Interscience Communications Ltd., London, England, Franks, C. A., Editor(s), 305-314 pp, 1990.**

fire safety; fire statistics; fire research; costs

Society depends primarily on some combination of public education, codes and fire brigades for fire safety. Clearly, this combination has worked, at least to the extent that cities no longer burn to the ground, and that numbers of fires and in most cases fire deaths have been steadily decreasing. Recently, however, in the U.S.A., fire deaths and injuries have plateaued (and may even be increasing) and the costs of fire safety to society have been increasing and in most cases well ahead of inflation. The question then is what is needed, more of the same or something new and if so what? This paper presents a preliminary analysis of this situation from the perspective of the potential contribution of fire research. It points to the need for major technical innovations in fire areas to provide the basis for legitimizing fire prevention technology, or what we have termed the technologies for "assured fire safety." These technologies may complement and strengthen the traditional fire safety strategies, further reducing the losses to fire and the economic burdens of fire on society. The potential benefits of international cooperation in this area are significant.

### **Steckler, K. D.**

Steckler, K. D.; Quintiere, J. G.; Klote, H.

**Johnson City Fire---Key Factors.**

National Institute of Standards and Technology, Gaithersburg, MD; 9 p. 1990.

building fires; apartments; high rise buildings; elderly persons; living rooms; fire departments; evacuation; ceilings; combustibles; smoke movement; fire investigations

The fire occurred in the John Sevier Retirement Center, Johnson City, Tennessee on December 24, 1989. The facility is an eleven-story building with a one-story section on its east side and a three-story section on its south side. These sections are integral and form a single connected building. The fire was reported to have started in the living room of apt. 102, which is located in the one-story section on the east side of the building. According to the Johnson City fire department, the building evacuation alarm sounded at 5:11 pm upon activation of a corridor smoke detector. A local alarm sounding only in apartment 102 and causing an "assistance needed" call to the main desk was triggered by a single station smoke detector in the bedroom of apt. 102. Shortly after the activation of the building evacuation alarm (corridor detector), Mr. Donnelly reported to us that the occupant of apt. 102 fled the apartment, leaving the door to the corridor open. The door between the living room and bedroom was reported to have been closed.

## **Stiefel, S. W.**

Stiefel, S. W.; Bukowski, R. W.; Hall, J. R., Jr.;  
Clarke, F. B., III  
Fire Risk Assessment Method: Case Study 1,  
Upholstered Furniture in Residences.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
National Fire Protection Assoc., Quincy, MA  
Benjamin/Clarke Assoc., Kensington, MD  
NISTIR 90-4243; 64 p. June 1990.  
Available from National Technical Information  
Services PB90-234998

upholstered furniture; computer models; fire statistics;  
hazard assessment; probability; risk assessment  
Traditional methods of assessing fire risk are based on  
probabilistic treatment of fire incident data. Recent  
advances in the ability to make deterministic predictions of  
the consequences of specific fire scenarios, presents an  
opportunity to reduce this dependency on incident data and  
greatly improve the ability to assess the risk associated with  
new products for which such data do not exist. This paper  
presents a trial application of a risk assessment method  
developed for such a purpose. A separate report provides  
the essential documentation for the methodology to be  
understood and applied by others. There are three other  
associated reports detailing trial applications of the  
methodology to other selected products and occupancies.

Stiefel, S. W.; Bukowski, R. W.; Hall, J. R., Jr.;  
Clarke, F. B., III  
Fire Risk Assessment Method: Case Study 2,  
Carpet in Offices.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
National Fire Protection Assoc., Quincy, MA  
Benjamin/Clarke Assoc., Kensington, MD  
NISTIR 90-4244; 43 p. June 1990.  
Available from National Technical Information  
Services PB90-235037

carpets; office buildings; computer models; fire statistics;  
hazard assessment; probability; risk assessment  
Traditional methods of assessing fire risk are based on  
probabilistic treatment of fire incident data. Recent  
advances in the ability to make deterministic predictions of  
the consequences of specific fire scenarios, presents an  
opportunity to reduce this dependency on incident data and  
greatly improve the ability to assess the risk associated with  
new products for which such data do not exist. This paper  
presents a trial application of a risk assessment method  
developed for such a purpose. A separate report provides  
the essential documentation for the methodology to be  
understood and applied by others. There are three other  
associated reports detailing trial applications of the  
methodology to other selected products and occupancies.

Stiefel, S. W.; Bukowski, R. W.; Hall, J. R., Jr.;  
Clarke, F. B., III  
Fire Risk Assessment Method: Case Study 3,  
Concealed Combustibles in Hotels.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
National Fire Protection Assoc., Quincy, MA  
Benjamin/Clarke Assoc., Kensington, MD  
NISTIR 90-4245; 48 p. June 1990.  
Available from National Technical Information  
Services PB90-235045

hotels; combustibles; computer models; fire statistics; hazard  
assessment; probability; risk assessment  
Traditional methods of assessing fire risk are based on  
probabilistic treatment of fire incident data. Recent  
advances in the ability to make deterministic predictions of  
the consequences of specific fire scenarios, presents an  
opportunity to reduce this dependency on incident data and  
greatly improve the ability to assess the risk associated with  
new products for which such data do not exist. This paper  
presents a trial application of a risk assessment method  
developed for such a purpose. A separate report provides  
the essential documentation for the methodology to be  
understood and applied by others. There are three other  
associated reports detailing trial applications of the  
methodology to other selected products and occupancies.

## **Stone, W. C.**

Stone, W. C.; Cooper, J. D.; Carino, N. J.  
Performance of Bridge and Highway Structures.  
National Institute of Standards and Technology,  
Gaithersburg, MD  
National Institute of Standards and Technology.  
Performance of Structures During the Loma Prieta  
Earthquake of October 17, 1990, Lew, H.,  
Editor(s), NIST SP 778, 5/1-92 pp, 1990.  
earthquakes; building codes; fire safety; damage; bridges  
(structures); highways; structural engineering; housing;  
geology; lifelines; seismic; specifications; viaducts  
The main highway network in the San Francisco Bay region  
sustained serious damage at several locations. The most  
notable is the damage to and collapse of the long, double  
decked viaduct sections of freeway in the San Francisco and  
Oakland areas. Except for the collapse of a single link span  
of the double-deck section of the San Francisco-Oakland Bay  
Bridge, most bridges in the area of the San Francisco Bay  
survived the earthquake with relatively minor damage. Most  
bridges and viaducts had been strengthened in the California  
Department of Transportation (Caltrans) Phase 1 seismic  
retrofit program which included identification of structures  
that are vulnerable to excessive displacements in the  
longitudinal direction and have the potential to have spans  
collapse. Typically, these structures have narrow hinge seats

or discontinuities in the superstructure across piers or abutments and were constructed prior to 1971. Cables or bars were placed across these joints, tying the elements of the superstructure together. This chapter describes damage to the Bay Bridge, and to I-880 (Nimitz Freeway) and other double-deck elevated highway structures. The results of preliminary analyses to determine the most likely causes of the collapse of I-880 are presented below.

**Stone, W. C.; Cheok, G. S.**

Post-MECO Propulsion System Requirements for Placement of an STS External Tank in Low Earth Orbit.

National Institute of Standards and Technology, Gaithersburg, MD

American Society of Civil Engineers. Engineering Construction, and Operations in Space II: Volume 2.

Proceedings of Space 90. 22-26 pp., 1990, Albuquerque, NM, American Society of Civil Engineers, New York, Johnson,

S. W.; Wetzel, J. P., Editor(s), 917-926 pp, 1990.

atmospheric drag; external tanks; orbital lifetime; orbital mechanics; propulsion requents; space shuttle

This paper discusses the findings of a series of computer simulations carried out at the National Institute of Standards and Technology to investigate the requirements for powered flight of the external tank following separation from the Shuttle orbiter at main engine cutoff (MECO). The object of the investigation was to determine the minimum thrust and fuel requirements for an autonomous exterior propulsion package attached to the external tank to avoid re-entry on the critical first orbit, and to place the tank in a short term stable orbit from which customary orbit maintenance procedures may be carried out. It is shown that a 1000 lbf (4450 N) hydrogen/oxygen thruster is capable of boosting the tank to a transfer orbit with an apogee of 206 km and a perigee of 159 km by means of expending a 1100 lbf (500 kg) propellant at the initial orbit apogee following MECO. The subsequent orbit will have a decay time of 46 hours (32 orbits) to re-entry under solar maximum conditions. Estimates for propellant mass required for subsequent boost to a 500 km altitude storage orbit are presented.

**Stutzman, P. E.**

Stutzman, P. E.

Serial Sectioning of Hardened Cement Paste for Scanning Electron Microscopy.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 90-4235; 23 p. March 1990.

Available from National Technical Information Services PB90-195009

backscattered electron imaging; cement paste; Knoop identification; microstructure; polishing; serial sectioning; scanning electron microscopy

Serial sectioning is a technique of making and examining thin sections of material to obtain information on three-dimensional structures from a series of two-dimensional images. Procedures were developed to make serial sections of hardened cement paste by the removal of thin layers by polishing. Backscattered electron imaging of the remaining paste block was used to record the paste microstructure after each section was removed. Procedures developed cover the polishing practice, the removal of thin layers by polishing, the estimation of layer thickness, and the location and alignment of specific regions for imaging.

**Tamura, G. T.**

Tamura, G. T.; Klote, J. H.

Experimental Fire Tower Studies on Controlling Smoke Movement Caused by Stack and Wind Action.

National Research Council of Canada, Ottawa, Ontario;

National Institute of Standards and Technology, Gaithersburg, MD;

American Society for Testing and Materials (ASTM).

Characterion and Toxicity of Smoke. International Symposium. ASTM Committee E-5 on Fire Standards. December 5, 1988, Phoenix, AZ. ASTM, Philadelphia, PA,

Hasegawa, H. K., Editor(s), ASTM STP 1082, 165-177 pp, 1990.

smoke movement; elevators (lifts); fire safety; handicapped; elevator shafts; wind; stack effect

Studies have been undertaken to develop a fire-safe elevator for evacuating handicapped people and for aiding firefighters. This paper describes the methods developed for predicting adverse pressure differences across the walls of the elevator shaft and lobbies caused by wind and building stack action and in combination with those caused by a fire. The predictions were verified by tests that were conducted in a 10-story experimental fire tower. The level of mechanical pressurization required to prevent smoke contamination of elevators could be determined by summing the pressure differences caused by these forces. Tests demonstrated that mechanical pressurization of the elevator shaft can be effective in preventing smoke contamination of these shafts and lobbies.

### **Thomas, W. C.**

Thomas, W. C.; Burch, D. M.  
Experimental Validation of a Mathematical Model for Predicting Water Vapor Sorption at Interior Building Surfaces.  
National Institute of Standards and Technology, Gaithersburg, MD  
ASHRAE Transactions, Vol. 96, No. 1, 1990.  
mathematical models; moisture sorption; building surfaces; validation; equations; implicit finite-difference method; surface coatings; gypsum board; paints; moisture content; heat transfer; desorption experiments; wood; ventilation  
A mathematical model for predicting moisture sorption rates at building surfaces is presented. The governing heat and moisture transfer equations are solved by an implicit finite-difference method. The effects of surface coatings are included in the formulation. Laboratory experiments were conducted to verify the model. Disk-shaped specimens of unpainted gypsum board, gypsum board painted with a latex paint system, and unpainted white pine were used. Sorption isotherms and diffusion coefficients for these materials were independently measured. The specimens were initially conditioned to a uniform moisture content and then moved to an environment with a lower relative humidity. The moisture transfer rates at the surfaces of the specimens were determined as a function of time and compared to predictions by the mathematical model. The validated mathematical model was used to estimate sorption rates at interior surfaces of a building during a summer diurnal schedule with day space cooling and night ventilation. The effect on the space-cooling load is discussed.

### **Thorpe, M. F.**

Thorpe, M. F.; Garboczi, E. J.  
Elastic Properties of Central-Force Networks With Bond-Length Mismatch.  
National Institute of Standards and Technology, Gaithersburg, MD  
Physical Review B, Vol. 42, No. 13, 8405-8417, November 1, 1990.  
elastic properties; Hooke springs  
We study a triangular network containing two kinds of Hooke springs with different natural lengths. If the two spring constants are the same, we can solve the model exactly and show that Vegard's law is obeyed, irrespective of whether the bonds are arranged randomly or in a correlated way. A more complete description of these networks is obtained through the mean lengths, the length fluctuations, and the strain energy. The complete distribution of bond lengths is obtained numerically and shows an interesting and unexpected symmetry for the random case. Finally we show that numerical results for a similar system, but with different force constants as well as different natural lengths, can be well accounted for by using an effective-medium theory that reduces to the exact results when the two spring constants

are made equal. These lattices can be described very accurately up to about 50% length mismatches, when "pleating" occurs and the lattices develop local instabilities.

### **Treado, S. J.**

Treado, S. J.; Bean, J. W.  
Experimental Evaluation of Lighting/HVAC Interaction.  
National Institute of Standards and Technology, Gaithersburg, MD  
ASHRAE Transactions, Vol. 96, No. 2, 773-779, 1990. SL-90-12-1.  
lighting; heating; ventilation; air conditioning; cooling; test facilities; large scale fire tests  
The interaction of building lighting and HVAC systems and the effects on cooling load and lighting system performance are being evaluated using a full-scale test facility at the National Institute of Standards and Technology. The test facility and measurement methodology are described, along with sample test data, results, and conclusions.

### **Villa, K. M.**

Villa, K. M.; Krasny, J. F.  
Small-Scale Vertical Flammability Testing for Fabrics.  
National Institute of Standards and Technology, Gaithersburg, MD  
Fire Safety Journal, Vol. 16, No. 3, 229-241, 1990.  
fabrics; flammability testing; small scale fire tests; self-extinguishment; ignition source; char length; thermoplastics; textiles; heat release  
Many small-scale vertical flammability tests have been designed to assess 'self-extinguishment' of fabrics after exposure to a small flame, where self-extinguishment refers to the cessation of flaming or glowing of the specimen upon removal of the ignition source. The specimens are held vertically in a U-shaped metal frame and ignited at the bottom. The criteria chosen for these tests are char length, afterflame, afterglow, and melt drip. These tests were first promulgated in the 1930s for use on flame-retardant cellulose and wools. The applicability of the test to char-forming as well as thermoplastic fabrics will be discussed.

### **Villa, K. M.**

Textile Test Methods for Protective Clothing Standards.  
National Institute of Standards and Technology, Gaithersburg, MD  
Clemson University. Protective Clothing: A New Review of Applications, Materials Used, Needs, Concerns, and Trends. Annual Conference, 4th. April 24-26, 1990, Charlotte, NC, X/1-5 pp, 1990.

protective clothing; standards; textiles; test methods  
Current editions of test methods and specifications and their use in protective clothing standards, April 1990.

### **Walton, G. N.**

Walton, G. N.

Computer Program for Simulation of HVAC/Lighting Interactions: Initial Report.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 4472; 98 p. December 1990.

Available from National Technical Information Services PB91-144386

computers; energy calculation; HVAC; lighting; modeling; transient simulation

This report describes the initial release of the HLITE program, which simulates the thermal interaction of lighting and HVAC systems. This program was developed to extend the results of an experimental study in HVAC/lighting interaction being conducted at the National Institute of Standards and Technology (NIST). It will serve in planning future experimental test cases and in the development of algorithms that can be incorporated into larger building energy analysis programs. This interim report covers the first phase of the development of HLITE which simulates the NIST HVAC/lighting test facility. Future planned developments will expand its capabilities to larger facilities with more complete thermal interactions. The computer program is based on a simple combined explicit and implicit time integration scheme for a finite volume model which may be applicable to a much broader range of building simulations.

### **Watanabe, H.**

Watanabe, H.; Rossiter, W. J., Jr.

Effects of Adhesive Thickness, Open Time, and Surface Cleanness on the Peel Strength of Adhesive-Bonded Seams of EPDM Rubber Roofing Membrane.

National Institute of Standards and Technology, Gaithersburg MD

American Society for Testing and Materials. Roofing Research and Standards Development. 2nd Volume, 1990. Philadelphia, PA, American Society for Testing and Materials, Wallace, T. J.; Rossiter, W.J., Jr., Editor(s), ASTM STP 1088, 21-36 pp, 1990.

adhesive thickness; contamination; EPDM rubber; open time; peel test; roofing; seams; single-ply membrane

A laboratory study was conducted to examine the effects of adhesive thickness, open time, and surface cleanness on T-peel strength of EPDM (ethylene propylene diene terpolymer) rubber seam specimens. Seam specimens

bonded with butyl-based contact adhesive were tested after a 2-week cure time. The peel strength generally showed a positive dependency on the adhesive thickness except that it tended towards a plateau value for thick adhesive layers. The leveling of peel strength at large thickness might result from the presence of small voids in the adhesive layer. The peel strength was not dependent on the open times used in this study. Increased levels of surface contamination lowered the peel strength and changed the failure mode from cohesive to adhesive.

Watanabe, H.; Rossiter, W. J., Jr.

Pulse-Echo Ultrasonic Evaluation of the Integrity of Seams of Single-Ply Roofing Membranes: Laboratory Evaluation of a Prototype Test Apparatus.

Takenaka Corp., Tokyo, Japan

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 4424; 46 p. December 1990.

Available from National Technical Information Services PB91-157172

adhesive-bonding; EPDM rubber; field inspection; membranes; nondestructive testing; pulse-echo method; roofing; seams; ultrasonics The feasibility of using NDE (non-destructive evaluation)

methods to detect voids in adhesive-bonded seams of single-ply membranes has been under investigation at the National Institute of Standards and Technology (NIST). This report covers the first phase of a two-part study to investigate the applicability of a pulse-echo ultrasonic method for this purpose. A prototype pulse-echo ultrasonic apparatus, called the field scanner and suitable for testing of single-ply seams in the field, was developed. A series of laboratory experiments was conducted using the field scanner to investigate: 1) optimal operating conditions, 2) sensitivity and practical limitations for detecting voids, and 3) variables affecting its response. The equipment was found to be effective in maintaining coupling between the transducer and seam specimens. Two 5-MHz transducers (focusing and non-focusing types) were selected as the most suitable for void detection in the seams. Voids incorporated in laboratory seam specimens were readily detected. The results of the Phase 1 investigation provided guidelines on the optimum conditions for use of the field scanner. Although not without limitations, encouraging evidence was obtained indicating that the field scanner should be applicable to inspections of EPDM seams in service. Consequently, field investigations are being conducted, as planned, in Phase 2 of the study.

Watanabe, H.; Rossiter, W. J., Jr.

Pulse-Echo Ultrasonic Evaluation of the Integrity of Seams of Single-Ply Roofing Membranes:

**Results of Field Investigations and Recommendations.**

Takenaka Corp., Tokyo, Japan  
National Institute of Standards and Technology,  
Gaithersburg, MD  
NISTIR 4425; 41 p. November 1990.

Available from National Technical Information  
Services PB91-159731

adhesive-bonding; EPDM rubber; field inspection;  
membranes; nondestructive testing; pulse-echo method;  
roofing; seams; ultrasonics

This report describes the second and final phase of a study to develop an ultrasonic NDE method for evaluating the integrity of seams of single-ply roofing membranes. The results of the laboratory evaluation of a prototype pulse-echo apparatus (the field scanner) were positive in that voids could be distinguished from well-bonded sections of the specimen using the intensity of the echo from the adhesive layer. In the Phase 2 study, seams of existing EPDM single-ply membranes were examined by roof-top scanning to evaluate the performance of the field scanner in practice. This was followed by laboratory tests to confirm and explain observations made during the field tests of the seams. The field scan was sensitive to micro-cavities, which could be generated in adhesive layers. This resulted in a number of "faositive" readings. The formation of micro-cavities was attributed to the temperature-induced volatilization of residual solvent remaining in the adhesive layer after its application on the membrane material. It was concluded that the field scanner technique had limited applicability for assessing the condition of solvent-adhesive seams because it could not readily differentiate between the micro-cavities and voids and delaminations in the adhesive layer. The results also implied that the field scanner might be applicable to seams formed using other techniques and that the addition of data recording and processing equipment would enhance the operator's ability to interpret the pulse-echo data obtained.

Watanabe, H.; Masters, L. W.; Seiler, J. F., Jr.  
**Quality Assurance Tests for Adhesion of Paint on  
Tactical Rigid Wall Shelters.**

National Institute of Standards and Technology,  
Gaithersburg, MD

Takenaka Corp., Tokyo Japan

NISTIR 90-4276; 46 p. April 1990.

Available from National Technical Information  
Services PB90-219825

adhesion; adhesion tests; bond strength; paints; tactical rigid  
wall shelters; test methods

This document was prepared at the request of the U. S.  
Army Natick Research, Development and Engineering  
Center to provide assistance in identifying or developing a  
better method(s) for assuring adequency of paint adhesion  
on aluminum-faced sandwich panels of portable rigid wall

shelters. The preferred requirements developed for the  
quality assurance tests are that the tests be quantitative,  
reliable, suitable for in-situ testing, low cost, and  
non-destructive. Currently available methods were surveyed.  
Both destructive and non-destructive techniques were  
examined. Among them, a button pull-off test was found to  
be most advantageous. Preliminary laboratory experiments  
using a button pull-off test to measure the bond strength of  
painted specimens provided by a shelter manufacturer  
showed the average bond strength of the exterior and the  
interior paints to be 7.27 Mpa (1050 psi) and 9.29 Mpa  
(1350 psi), respectively. Other experiments examined the  
feasibility of a semi-nondestructive button pull-off  
techniques, which, by using certain materials to reduce the  
adhesive/paint bond strength, was capable of testing a paint  
without damaging it. Two of the three "bond controllers"  
tested were found to be effective. The recommendations for  
future research include: 1) establishing a technical basis for  
a minimum acceptable bond strength of paint; 2) developing  
and standardizing a improved button pull-off test; and 3)  
carrying out a feasibility study on non-destructive methods.

**Wright, R. N.**

Wright, R. N.

**Conclusions and Recommendations.**

National Institute of Standards and Technology,  
Gaithersburg, MD

National Institute of Standards and Technology.  
**Performance of Structures During the Loma Prieta  
Earthquake of October 17, 1990,** Lew, H.,  
Editor(s), NIST STP 778, 7/1-7 pp, 1990.

earthquakes; building codes; fire safety; damage; bridges  
(structures); highways; structural engineering; housing;  
geology; lifelines; seismic; specifications; viaducts

The Loma Prieta earthquake of October 17, 1989, can  
provide significant lessons for public policies and construction  
practices throughout the United States. While it was the  
largest earthquake to strike Northern California since the  
great San Francisco earthquake of 1906, earthquakes of  
similar or larger magnitude are expected to affect 46 of the  
50 states, Puerto Rico and the Virgin Islands (Federal  
Emergency Management Agency, 1988). Thus, lessons of  
structural performance, seismology, and geology which can  
be learned from the Loma Prieta earthquake, can be used to  
reduce earthquake hazards throughout the United States and  
the rest of the world.

**Yokel, F. Y.**

Yokel, F. Y.

**Earthquake Resistant Construction of Electrical  
Transmission and Telecommunication Facilities  
Serving the Federal Government.**

National Institute of Standards and Technology,  
Gaithersburg, MD

NISTIR 89-4213; FEMA-202; 47 p. February 1990.  
Available from National Technical Information Services

central telephone offices; earthquake engineering; electrical power transmission; electrical substations; lifelines; seismic design standards; telecommunications

The vulnerability of electrical transmission and telecommunication facilities to damage in past earthquakes, as well as available standards and technologies to protect these facilities against earthquake damage are reviewed. An overview is presented of measures taken by various Federal agencies to protect electrical transmission and telecommunication facilities against earthquake hazards. It is concluded that while most new facilities which are owned and operated by Federal agencies are presently designed to provide some, though not necessarily adequate, earthquake resistance, there generally is no effort to retrofit existing facilities. No evidence was found of requirements to protect electrical transmission and communication facilities which have major contractual obligations to serve the Federal Government and only limited seismic design requirements are stipulated for electrical transmission systems constructed with Federal funding. It is recommended that Federal guidelines be developed for minimum levels of seismic design of electrical transmission and telecommunication systems.

Yokel, F. Y.

Proposed Design Criteria for Shallow Bridge Foundations.

National Institute of Standards and Technology, Gaithersburg, MD

NISTIR 90-4248; 56 p. February 1990.

Available from National Technical Information Services

bridges; capacity reduction factors; cohesionless soils; design criteria; design limit states; foundations; foundation settlements; load factors; sands; soil; soil exploration; spread footings

Criteria for the design of spread footings for highway bridges are proposed. The criteria address working load as well as load and resistance factor design (LRFD) procedures. Importance factors to be used in conjunction with the LRFD design format are proposed. The importance factors increase the design loads as the span length increases and also otherwise account for the severity of the consequences of a structural or foundation failure. Further data on LRFD design will be available from studies presently in progress. Available information on tolerances of highway bridges and other structures to foundation displacements are reviewed. On the basis of this information, allowable foundation-displacement limits are proposed. Unconditionally allowable foundation displacements will not affect the strength and serviceability of bridges and therefore do not require structural design modifications. These allowable displacements can be doubled if it either can be demonstrated, using criteria proposed in this report, that the strength and serviceability of the bridge is comparable to

that required in accordance with applicable American Association of State Highway and Transportation Officials (AASHTO) specifications, or if the design of the bridge is modified so that the predicted foundation displacements can be accommodated.

Zhou, L.

Zhou, L.; Fernandez-Pello, A. C.

Concurrent Turbulent Flame Spread.

California Univ., Berkeley

U. S./Japan Government Creative Program on Natural Resources (UJNR). Fire Research and Safety. 11th Joint Panel Meeting. October 19-24, 1989, Berkeley, CA, Jason, N. H. and Cramer, D. M., Editor(s), NISTIR 4449, 122-129 pp, 1990.

flame spread rate; turbulence; polymethylmethacrylate; flame length; fire models; flow velocity

The rate of flame spread over the surface of thick PMMA sheets has been measured as a function of the velocity and turbulence intensity of a forced air flow concurrent with the direction of flame propagation. It is shown that the flow turbulence has a strong influence on the flame spread process. For all turbulence intensities, the flame spread rate increases approximately linearly with the flow velocity, although the slope is smaller for larger turbulence intensities. For a given flow velocity, the spread rate decreases as the turbulence intensity is increased, the effect being more pronounced for larger flow velocities. These effects appear to be due to a strong influence of the turbulence intensity on the flame length, which decreases as the turbulence intensity is increased, thus reducing the net heat flux from the flame to the unburnt combustible. The results are significant since the prediction of the flame length and spread rate as a function of the problem parameters are important factors in the development of room fire models.

Zukoski, E. E.

Zukoski, E. E.

Scaling Rules for Smoke Movement in Corridors. Annual Report.

California Institute of Technology, Pasadena Annual Report; 47 p. June 1990.

corridors; scaling; smoke movement; ceilings; heat transfer; smoke layers; experiments; viscosity

We are still attempting to develop a model for predicting the properties of smoke which flows under the ceiling of a corridor in a gravity current when heat transfer to the ceiling is important. The type of flow under study is illustrated in the sketches of Figure 1 which represent the history of the development of a smoke layer in a corridor produced a fire in an adjacent room.

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