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Workshop On Fire Testing Measurement Needs: Proceedings

William Grosshandler
(Editor)

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National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

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Workshop On Fire Testing Measurement Needs: Proceedings

William Grosshandler
(Editor)
Building and Fire Research Laboratory

August 2001

U.S. Department of Commerce
Donald Evans, Secretary

National Institute of Standards and Technology
Dr. Karen H. Brown, Acting Director

ABSTRACT

Whether it is performance-based standards, ISO 17025 accreditation, or the harmonization of standards for international trade, commercial fire testing laboratories and their customers are challenged by the changing marketplace and regulatory climate. This report describes the proceedings of a workshop held on June 18 and 19,2001, at NIST in Gaithersburg to identify where science and technology can better prepare fire testing laboratories and their customers to meet these challenges. Topics that were covered include the following: most common and significant fire test methods (by frequency of performance and/or economic impact); uncertainty limits and calibration practices; laboratory accreditation; incorporating new measurement techniques into old test protocols; the role of numerical simulation in interpreting/displaying results; implications of global markets; and needs of code officials and manufacturers of regulated materials and products. Speakers represented codes and standards organizations, regulators and authorities having jurisdiction, laboratory accrediting bodies, laboratories engaged in best practices, materials and products manufacturers, large commercial fire testing organizations, and small commercial fire testing organizations. Major issues of concern to fire testing laboratories and their customers were prioritized. Although the concerns of these different interest groups were not fully congruent, three pathways forward were proposed:

- Develop a rational means to quantify uncertainty that is relevant to fire testing.
- Explore alternative mechanisms for accrediting fire testing laboratories that are consistent with the North American business model, and that lead to acceptance by international markets of the products certified by North American testing organizations.
- Invest in research to better relate the behavior of products measured during standard testing to their performance in realistic fire scenarios, and vice versa.

ACKNOWLEDGEMENTS

The success of any workshop is dependent upon the hard work of the individual speakers and facilitators, and the efforts of participants motivated toward a common goal. These proceedings are an assimilation of tlie contributions from the workshop participants, with some of the text coming directly from the presentations of tlie invited panelists from the following organizations:

American Association for Laboratory Accreditation -- Peter Uiiger
American Council of Independent Laboratories -- Joan Walsh Cassedy
American Plastics Institute -- Jesse Beitel
Armstrong World Industries -- Thomas Fritz
Boeing Airplane Company -- Michael O'Bryant
European Group of Official Laboratories for Fire Testing, and Warrington Fire Research Centre -- Janet Murrell
FM Global -- John deRis
Hardwood, Plywood and Veneer Association -- Kevin Haile
Hughes Associates, Inc. -- Jesse Beitel (past chair, National Fire Protection Association Fire Test Committee)
International Conference of Building Officials Evaluation Service; and National Cooperation for Laboratory Accreditation -- Chuck Ramani
National Association of State Fire Marshals -- Donald Bliss
National Evaluation Services -- David Bowman
National Institute of Standards and Technology -- William Pitts, Richard Gann, Anthony Hamins, Kevin McGrattan, Jack Snell and William Grosshandler
Nationally Recognized Testing Laboratories Program, and U.S. Mining Safety and Health Administration -- Kenneth Klouse
Southwest Research Institute -- Alex Wenze1
Underwriters Laboratories -- Gordon Gillerman and Martin Pabich
U.S. Consumer Product Safety Commission -- Andrew Stadnik

Professors Marc Janssens, and Fredrick Mowrer of the Universities of North Carolina-Charlotte and Maryland-College Park, respectively, and Dr. Richard Gann of NIST served as chairs of the breakout sessions and helped bring focus to the discussions. Verbatim copies of the presentations are included in the appendix. In addition, the editor wishes to acknowledge the assistance of Ms. Wanda Duffin of NIST, who helped with the planning, organizing and running of the workshop, and the advice provided by James Lawson of NIST on equivalent fire standards.

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BACKGROUND

Evaluating the performance of a system, product, or material in response to a real fire is a technical challenge. The actual fire threat can be difficult to define; and once defined, standard test methods may not exist that effectively emulate the threat. When a suitable test method has been developed, or is specified by the building code, monitoring and controlling accurately the harsh environment created by the simulated fire during the test can be problematic, especially in an environment unfriendly to measurement devices. Feedback may occur between the product under test and the fire, modifying the conditions in a difficult to predict manner and making the results sensitive to the details of the setup. Measurements sometimes are based upon observations of rapidly changing conditions, such that the interpretation of the results may depend upon the experience of the operator.

Many of the most common fire tests conducted in North America today (e.g., ASTM E84 [1], "Test Method for Surface Burning of Building Materials," or ASTM El 19 [2], "Test Methods for Fire Tests of Building Construction and Materials") were developed in the first half of the 20th century. While revisions to these test methods have been adopted and improvements have occurred, difficulties such as those mentioned above have not all been eliminated. A test method may have been originally developed in an optimal fashion to maximize control and minimize uncertainty of the test results, however the products and systems to be tested and the context of their use evolve, possibly resulting in a sub-optimal test method some time later. For example, plastic materials are commonly used today for interior finishes where previously, at the time ASTM E84 was developed, wood-based materials were the choice. An example of evolving context is the move towards a performance basis for building design. This evolution causes the primary output of the prescriptive test method (e.g., a flame spread index in the case of E84 or an hourly rating in the case of El 19) to have less value to the designer in demonstrating an equivalent level of safety. Growing global markets are also changing context. In this case, the difficulty is relating the result of a particular product tested according to the requirements of country **A** to the rating system required to sell the product in country B. While this is more a problem for the manufacturer of the product undergoing test than for the fire test laboratory, those testing laboratories that develop the ability to predict the behavior of their customers' products in foreign jurisdictions could gain competitive advantage.

Building codes and standard fire test methods are typically adopted on the time scale of a decade. Because our knowledge of fire behavior was primitive and fire measurement capabilities limited up to tlie time of World War II, technological advances during the test method development period provided little in the way of advantage. Today, substantial advances in materials, sensing and data processing are observed to occur on the time scale of a year; and new milestones in computing power are reached every few months. Since new codes and standards are developed through a methodical consensus process with a time scale that is difficult to shorten, tlie technology and knowledge available by the time a new test method has been adopted might substantially exceed that which is written into the standard.

In North America, building code adoption and enforcement are done predominantly at the local government level. The authority having jurisdiction **(AHJ)** usually relies on a third party to certify that a product/system meets the minimum fire safety requirements for that jurisdiction. Various laboratory accreditation organizations exist, but there is no national edict that fire testing laboratories be accredited.

Thus, the potential exists for variability from jurisdiction to jurisdiction not only in testing requirements, but also in which laboratories are deemed qualified to perform the fire test method. Manufacturers who use products or materials that are subject to fire test standards, and who adhere, or aspire to ISO (International Organization for Standardization) 9002 **[3]** ("Quality Systems -- Model for Quality Assurance in Production, Installation and Servicing"), are limited to fire testing laboratories that meet the requirements of ISO 17025 [4] ("General Requirements for the Competence of Testing and Calibration Laboratories"). The variations in jurisdictional requirements and the quality control imposed by ISO are challenges for commercial fire testing laboratories.

A workshop was held recently at the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland, to focus attention on non-proprietary technical problems common to commercial laboratories engaged in fire testing. (See Appendix I for a partial list of commercial laboratories conducting a significant amount of fire testing.) Those invited were primarily from the U.S. and Canada, and the agenda, reproduced in Appendix II, was set with that in mind. Many of the issues raised and the ensuing discussion, however, should resonate with fire test laboratories outside of North America, as well. Topics that were covered included the following:

- most common and significant fire test methods (by frequency of performance and/or economic impact)
- uncertainty limits and calibration practices
- laboratory accreditation
- incorporating new measurement techniques into old test protocols
- the role of numerical simulation in interpreting/displaying results
- implications of global markets
- needs of code officials and manufacturers of regulated materials aiid products

Speakers represented codes and standards organizations, regulators and authorities having jurisdiction, laboratory accrediting bodies, laboratories engaged in best practices, materials and products manufacturers, and both large and small commercial fire testing organizations. The format for the workshop included a combination of invited talks from experts in various fields, informal presentations from participants, focused group discussions in breakout sessions, and general consensus building. Major issues of concern to fire testing laboratories and their customers were prioritized. These proceedings summarize the discussion of the panelists and participants. A complete list of workshop attendees and addresses is included as Appendix III. Full presentations are included in Appendix V.

PANEL ON CODES AND REGULATIONS

How the needs of building code officials, regulators, and other authorities having jurisdiction might impact the operation of fire test laboratories was discussed by a panel representing the National Fire Protection Association (NFPA), the National Evaluation Services (NES), the U.S. Consumer Product Safety Commission (CPSC), and the National Association of State Fire Marshals (NASFM). According to Beitel [5] representing NFPA, the need for a test and the required level of performance are driven by the specifications in the codes and regulations, where the codes are either building, fire or mechanical in nature, and the regulations are established for the commercial/industrial sector, specified in the *US. Code of Federal Regulations,* or developed for other governmental agencies (e.g., Department of Defense, NASA). The total number of standard tests published by NFPA, the American Society for Testing and Materials (ASTM), Underwriters Laboratories (UL), aiid Factory Mutual (FM) relating to fire safety exceed 500, although many of these are not run routinely. In addition, ad hoc tests are devised to assist product development and to extend the design envelope. When a specific test is required by the code, it typically is conducted in accordance with the written standard and performed by an accredited laboratory. (What it means to be "accredited" is discussed later.) In the future, Beitel[6] believes that there will be a greater reliance on ad hoc tests and on new large-scale fire tests that are more fully instrumented. The expectation of the code officials and regulators is that the laboratories will maintain the needed level of quality in the performance of the test, that the results will be meaningful, and that the results from one laboratory will be equivalent to the results from the same laboratory at a different time or from a different qualified laboratory. Laboratory participation in standards making organizations such as NFPA or ASTM is essential to capture the laboratory's expertise and concerns in establishing the "How & What" of a standard fire test, and to benefit from the expertise of others on the committee.

The mission of the CPSC is to protect the public against unreasonable risks of injuries and deaths associated with consumer products, to develop safety standards (mandatory and voluntary), to minimize conflicting state and local regulations, to provide comparative safety information, and to promote research and investigation into the causes and prevention of injuries [6]. CPSC fire test standards are based on real life hazard, documented risk reduction potential, economic considerations, and ease of conduct/repeatability. They typically require that records be kept and certification documentation be available or submitted. Specific products addressed in existing CPSC regulations include clothing, textiles, children's sleepwear, carpets and rugs, mattresses and mattress pads, vinyl plastic films, cellulose insulation, matchbooks, cigarette lighters, multi-purpose lighters, flammable contact adhesives, coal and wood burning appliances, fire extinguishers, volatile flammable materials (flashpoint), extremely flammable and flammable solids, and self-pressurized containers (flammability and flashpoint). Current major fire test standard development efforts in the regulatory arena include upholstered furniture (draft standard presented for small open flame test), polyurethane foam in furniture (petition under evaluation), general wearing apparel (considering updating requirements, e.g. detergent and cleaning method changes), and mattresses (petition under evaluation, industry sponsored work at NIST). Voluntary standards activities include range fires (requests made to UL and ANSI, the American National Standards Institute), clothes dryer fires (CPSC and industry efforts underway), and fire sprinklers (industry study underway). Stadnik[7] remarked that many firms and testing laboratories often do not understand requirements in standards; that testing, certification, and record-keeping requirements are often complicated; and that feedback and communication help when questions or problems arise with a test method. There is a need for laboratories to develop full understanding of requirements, to develop proficiency in testing samples, and to take advantage of ASTM training (clothing and sleepwear) and other accreditation programs. A proactive interaction with the clients ensures that the right test is conducted (e.g., clothing vs. sleepwear). An adequate number of specimens to complete the tests should be supplied, and the testing organization should know lot, shipment, etc. Meaningful records with a consistent description of the specimen are needed to provide a clear link between the test and production. The laboratories are urged to call the CPSC, office of compliance, if questions arise, and to recognize that products are always changing and being used in ways not envisioned when the regulation was originally issued.[6]

The role of the state fire marshal, as described by Bliss [7] of NASFM, is to investigate fires and crimes related to fires, apprehend arsonists, adopt and enforce fire safety codes, inspect buildings for hazards, review construction plans, manage fire incident data systems, administer public fire education programs, certify fire investigators and fire inspectors, manage fire fighter training academies and training programs, and provide policy recommendations to governors and state legislatures. The mission of NASFM is to assist and support the state fire marshals, and in so doing reduce deaths, injury, property loss, and environmental damage caused by fire in the United States. As their activities relate to product testing and certification, fire officials and the general public are highly dependent upon independent testing, listing and certification services to ensure the safety of consumer products and building construction materials. Testing must reflect real-world scenarios, and product standards must be based on good science. The fire marshals would like the standards development process to be transparent and push for higher levels of safety, rather than lower. [7] Standards making bodies and testing organizations perform an essential service for government and tlie public, and as “quasi-governmental” organizations, the fire marshals expect them to perform to a high standard of openness, transparency, and ethics. The challenges for standards making organizations and testing laboratories are to establish an integrated, national system for oversight and accreditation; to educate fire and building officials so that they have a comprehensive understanding of testing standards, certification programs, and the laboratory accreditation process; and in the effort to respond to issues such as competition, globalization, aiid environmental concerns, to ensure that fire safety in consumer products and building construction materials is not sacrificed.[7]

The National Evaluation Services (NES) is concerned with development of the international code and changes needed to support tlie new performance code. They view themselves, according to Bowman, [8] as the eyes and ears of the code enforcement community. As such, their concerns are with the code requirements for fire testing. The fire testing called out in the International Building Code [9] is becoming increasingly difficult to apply to new technology and new thinking on building sciences. ASTM E84 is referenced throughout the code, for interior finishes, plastics, foam plastics, and other insulation materials. However, E84 is a poor test for measuring flame spread of foam plastics and does not accommodate new thicker materials that are being used today. [8] Melting and dripping cause huge variations in interpretation of results. Any replacement for E84 should produce engineering data relevant to performance assessment, such as ignition temperature, rate of heat release, and smoke density. This would lead to a true assessment of life- and health-safety applicable to realistic fire scenarios, rather than a rating relative to commonly accepted materials. Another test method of concern to NES is the classification of a material as combustible or non-combustible (ASTM E136).* While the code requires noncombustible building framing materials for larger buildings, examples exist where buildings that are noncombustible do not necessarily perform as well in fires as their combustible counterparts. [8] E136 only gives a rough indication of the fuel load that a material provides. What is needed is the use of rate of heat release as a measure of material performance, and to change the code logic to place a value on material performance rather than level of combustibility. Performance codes are producing new testing challenges. The International Code Council (ICC) will issue its first performance code at the end of 2001. [10] It places different types of demands on materials manufacturers aiid testing agencies. The need is for fire tests that provide data that can be used in predictive modeling software. Fire testing laboratories should get involved in the code development process, where changes in code logic are fair game. [8]

PANEL ON MATERIALS AND PRODUCT MANUFACTURERS

Panelists representing the wood products industry (Hardwood, Plywood and Veneer Association), the plastics industry (American Plastics Council), a floor covering manufacturer (Armstrong World Industries), and an airplane manufacturer (Boeing Airplane Company) discussed fire testing issues important to their organizations. Fritz [11] from Armstrong listed the international fire test methods shown in Table 1 as currently applying to building materials. In addition, the following proposed European (prEN) ISO standards could apply in the future:

prEN ISO 1182 Non-combustibility
prEN ISO 1716 Calorific Value
prEN ISO 13823 Single Burning Item (SBI)
prEN ISO 11925-2 Ignitability
prEN ISO 9239-1 Flooring Radiant Panel

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* Reference is made to ASTM, NFPA, UL, ANSI, FM, ISO and various other international standards in that are not all included in the list of references. Refer to Appendix I for complete citations.

Table 1. International fire tests for building materials [11]

IGNITION	FLAME SPREAD	HEAT RELEASE	COMBUSTIBILITY
UL 94	ASTM E84	BS 476, Part 6	BS 476, Part 4
	ASTM E162	JIS 1321	ASTM E136
DIN 4102 B2 Burner	ASTM E648	NFPA 259	French MO
	BS 476, Part 7	ISO 5660 ASTM 1354	German A0
	DIN 4102 Brandschacht	NFPA 264	

test method (ASTM 1354, Cone Calorimeter). By focusing on the critical early period in the test, a reasonable correlation (for a particular class of materials) between the flame spread index (FSI) measured in E84 and the integrated heat release rate (HRR) measured in the cone calorimeter could be attained.

PANEL ON MEASUREMENT UNCERTAINTIES IN STANDARD FIRE TESTS

Panelists from Underwriters Laboratories, Southwest Research Institute (SwRI), FM Global, and NIST discussed issues relating to uncertainties in fire measurements and test methods. Wenzel [12] of SwRI described uncertainty as the "doubt that exists about the result of any measurement at any level, i.e. national laboratories, test laboratories, calibration laboratories, and end users. Tolerances are not uncertainties, but are acceptance limits. Specifications are not uncertainties. Specifications tell you what you can expect for a group or type of instruments." He distinguished between Type A uncertainty, which is based upon a classical statistical analysis of a series of discrete observations, and Type B uncertainty, where subjective scientific judgment built upon relevant experience is the basis. Test labs very seldom have enough data to make a Type A estimate, and manufacturers of instruments do not always provide complete uncertainty statements. Some test equipment is unique, has no means of outside calibration, and must rely on calibration of components and subsystems. The equipment may have embedded sensors or transducers that cannot be removed and reinstalled without destruction. Using heat release rate measurement as an example, Wenzel [12] demonstrated how estimates based upon the manufacturers' specifications alone can produce a misleadingly small uncertainty in heat release rate (HRR). In his example, accounting for the uncertainty in the standard value of oxygen consumption quadruples the naive estimate of uncertainty, and indicates where one should invest to increase certainty, if needed. The motivation for fire test laboratories to quantify properly the uncertainty in their measurements is extremely compelling since ISO 17025 requires that a documented, defensible procedure be in place by the end of 2002. A concern is that calibration laboratories may require more than two years to comply, resulting in a shortage of accredited calibration laboratories to meet the demand of the test laboratories. Inter-laboratory proficiency testing (round robin) was suggested [12] as an option, but it has associated cost to the laboratories.

Pabich [13] of UL emphasized the need to know what you are looking for (i.e., timing, temperature, velocity, heat flux, species generation), and what you will be doing with the data (report as fact, or use in calculations). The test operator generally has wide discretion in large-scale fire testing. The data are reported as fact (e.g., extent of fire spread through an array, number of sprinklers operated), and not typically used in calculations. Small-scale fire test operations are more constrained since the event occurrences have a greater probability of being used in computations (e.g., time to ignition, heat release rate). It is imperative that the equipment be calibrated to known standards over the expected range of results, and that accurate calibration records be maintained.

According to Pitts [14] real-scale fire experiments are seldom designed to minimize uncertainties (e.g., through statistical designs) and the maximum level of uncertainty that is acceptable is not specified. As a result, data are often reported with an improper number of significant digits and without meaningful uncertainty limits. It is NIST policy that a measurement is only complete when accompanied by a quantitative statement of uncertainty. [15] Thermocouple measurements were given as an example where significant uncertainty remains, in spite of their simple construction, wide use, and decades of experience with them. Little guidance is provided in the literature as to the level of accuracy required, although it obviously depends upon the use of the data. As an indicator of a flashover event, precision is not an issue; but for accurate assessment of doorway flows as input to model validation, or in predicting the concentration of CO, errors in temperature propagate throughout the calculations. **A** second example presented is smoke measurements, which are treated in a qualitative manner because quantitative extinction by smoke has not been well characterized. **In** a study recently conducted at NIST, [14] measurements with a smoke meter based upon He-Ne laser light extinction were compared to gravimetric extraction measurements and found to agree within 20 %. When used as part of a formal uncertainty analysis, the smoke yield from a heptane fire was estimated to be certain within 28 % of the reported value (expanded uncertainty at a 95 % confidence interval, with a coverage factor of 2). Although 28 % uncertainty may appear large, similarly large values of uncertainty are likely when a thorough quantitative analysis is applied to other key fire parameters, such as heat flux and heat release rate.

deRis [16] of FM Global laid down three specific needs for fire testing laboratories in the realm of measurement uncertainty:

- understanding the relationship between laboratory measurement and actual fire hazard
- availability of a standard smoke density meter
- standardized calibration procedures for heat flux gages

The first need provides tlie technical foundation for the fire test industry, and it was suggested [16] that the NIST fire program had a primary role in acquiring that understanding. Past examples where this has been accomplished are Ingberg's E-119 test [17], the fabric flammability test, tlie NBS smoke chamber, flooring aiid the LIFT radiant panel tests, and the cone calorimeter. Candidate test methods for future examination include the cigarette ignition test and a new furniture flammability test. The second need is to fill the void **in** approved smoke density meters; as a consequence of the void, laboratories are forced to build their own. The need for heat flux gage calibration facilities is currently being addressed by NIST, although technical and financial issues remain to be resolved and an approval standard has not yet been developed.

IMPLICATIONS OF GLOBALIZATION ON U.S. FIRE TESTING

Gann [18] explained that globalization of markets has begun to affect directly and significantly U.S. manufacturers of materials and products subject to fire test standards, and indirectly to the laboratories that conduct them. **As** of 1999, the sum of U.S. imports plus exports exceeded the total sales of products to the domestic market. Selling into multiple markets is difficult if each country's market has different product descriptors and/or standards. Many countries subscribe to international standards, so that even though the U.S. does not, the products sold to those countries must still accede to tlie international standard. Many ISO committees, including TC92 on Fire Safety, are dominated by European countries. U.S. participation in ISO committees is not government-sponsored, but led by representatives who choose to, and can afford to, attend aiid is supported by those who respond to ballots, contribute at TAG meetings, etc. There are real differences in some U.S. and ISO standards with substantial financial implications.

For example, ASTM E119 and ISO 834 use different measurement devices and employ different metrics; ISO proposes a different approach for smoke toxic potency measurement than NFPA 269/ASTM E1678, a major difference being a tube furnace vs. a radiant furnace. The introduction of more international standards and the increase in international commerce require that U.S. manufacturers and the laboratories that test their products have a thorough understanding of what Beitel [5] called the "when, what, how and why" of codes and regulations, which is **a** problem for smaller companies. The options for the manufacturers are to make different products for export, to make a single product that passes multiple tests (with the potential for a cost disadvantage), or to drop out of the international (or domestic) market. For the fire testing laboratories, more tests imply more business, but larger investment in capital equipment, a greater understanding of similarities and differences among related tests, and agreements for cross-border acceptance of results.[18]

The issue of cross-border acceptance was one of the drivers for the European Community to form the European Group of Official Laboratories for Fire Testing (EGOLF) in 1988. As explained by Murrell, [19] tlie group is technically oriented not commercial, with 47 laboratory members from 22 different countries. Interest areas include buildings and structures (testing, assessment, certification, research), building contents, active fire protection, and transport. The strategic aims of EGOLF are the mutual acceptance of test reports; unified fire testing and laboratory quality procedures, including issuing interpretations, technical resolutions and standards where none exist; promotion of research and testing; training for technicians; specifying minimum level for equipment and expertise, and setting improvement targets; providing a forum for collaboration on fire matters in Europe (with legislators, industry and other European or non- European bodies); and cooperation with inspection and certification bodies (towards product approval in tlie European Economic Area, EEA). Within EGOLF mutual confidence is fostered by long term experience in cooperation and working together, known security of existing informal arrangements, developing and using the same technical standards, peer audit, inter-laboratory training and proficiency testing programs, and knowledge that the official members are wholly independent fire test laboratories. The enforcement of ISO 17025 is problematic. This stems from the impracticability of calibration to national standards, the lack of availability of reference materials of sufficient size and variety, uncertainty of measurement determination, application of variable interpretations by national accreditation bodies, and the inexperience of some technical assessors. To help address this EGOLF is creating interpretation guidelines for ISO 17025. Murrell [19] suggested a framework for a global approach to harmonized fire testing, to build confidence in each other's abilities and the ability to work together as a team.

LABORATORY ACCREDITATION AND PRODUCT CERTIFICATION

No single body accredits North American fire test laboratories; rather, accreditation takes several forms and involves multiple organizations, depending upon the location, customer base, and the particular test methods that are routinely performed. The American Council of Independent Laboratories (ACIL) is the national trade association representing independent, commercial engineering and scientific laboratory, testing, consulting, product certifying, and R&D firms; manufacturer's laboratories; and consultants and suppliers to the industry. [20] ACIL's membership is comprised of over 350 organizations who operate over 1,500 facilities across the United States and abroad, ranging in size from the one-person specialty laboratory to multi-disciplined, international corporations employing thousands. Fire testing falls within the Conformity Assessment Section. ACIL promotes ISO 17025 accreditation for U.S. and international testing and calibration labs to demonstrate that they operate a quality system, are technically competent, and are able to generate technically valid results. In the opinion of ACIL's executive director, [20] "accreditation of labs is never more vitally important than when a lab's testing results and/or certification concerns itself with a product whose failure would adversely affect the public's safety, health, or the environment. Fire testing is such an area."

The American Association for Laboratory Accreditation (A2LA) is a non-profit, public service, non-governinental membership organization that operates the largest multi-discipline laboratory accreditation system in the U.S. [2 13 In particular, A2LA accredits laboratories to the requirements of ISO 17025, plus the requirements of desired test methods. A2LA uses assessors from the International Conference of Building Officials Evaluations Service, Inc. (ICBO ES) for many of the fire tests for which it accredits. ICBO ES was described by Ramani [22] as a nonprofit organization controlled by over 3000 city, county, state and federal agencies involved in enforcement of building/construction regulations, and in publishing technical reports on new and innovative building materials. The International Code Council (ICC) was created by the three model building code agencies in the United States (ICBO, Building Officials and Code Administrators International, Inc. (BOCA), and Southern Building Code Congress International, Inc. (SBCCI)) with the main objective of publishing a single family of building, plumbing, fire and related construction codes. The first family of International Codes was published in 2000. [9]

The National Cooperation for Laboratory Accreditation (NACLA) [22] was incorporated in 1998 with the objective to bring together various parties in the U.S. who require accreditation of testing and calibration laboratories, who perform accreditation and who are accredited, and to develop and administer common accreditation procedures that can be reciprocally accepted via a mutual recognition arrangement (MRA). The initial signatories to the NACLA MRA are the A2LA, the ICBO ES and the NIST National Voluntary Laboratory Accreditation Program (NVLAP), the latter which was formed to respond to Congressional mandates or administrative actions by the U.S. Government, or to requests from private-sector organizations. The International Laboratory Accreditation Cooperation (ILAC) and the Asia Pacific Laboratory Accreditation Cooperation (APLAC) are both signatories to MRAs with A2LA, ICBO ES, and NVLAP. In addition, A2LA has a bilateral MRA with the European Cooperation for Accreditation.

The Nationally Recognized Testing Laboratory (NRTL) Program was described by Klouse [23] as consisting of third-party organizations recognized by the U.S. Occupational Safety and Health Administration (OSHA) to test and certify a wide range of products for use in the American workplace. The testing and certifications are based on product safety standards approved by national standards organizations. Products certified safe by the NRTL program include electrical equipment, fire detecting and extinguishing equipment, liquefied petroleum gas utilization equipment, equipment to be used in hazardous locations, and fire doors and materials. Product safety standards accepted by OSHA under the recognition process must be "appropriate". An appropriate standard is a "document that specifies the safety requirements" for a specific type of product approved and issued by a US-based standards organization and providing an adequate level of safety.[23] Standards are developed under a method providing for input by a broad spectrum of those experienced in the safety field involved, and maintained current with revisions of applicable codes and installation standards. Some of the standards developing organizations whose standards have been accepted under the NRTL program include ANSI, ASTM, SwRI, UL, and FM. However, the NRTL Program officially recognizes testing and certification organizations, and any organization that tests and certifies products may apply for recognition as a Nationally Recognized Testing Laboratory. There are presently seventeen organizations that are recognized by the US Government to test and certify products for US workplaces. Examples of the commercial products tested for use in the industrial workplace with NRTL approved standards include enclosures for electrical equipinent (ANSI/UL 50), Carbon Dioxide Extinguishing Systems (ANSI/NFPA 12), LP-gas fueled industrial trucks (FMRC 7812), nonmetallic safety cans for petroleum products (ANSI/UL 1313), and household cooking gas appliances (ANSI Z2 1.1). [23]

Underwriters Laboratories has its own conformity assessment program for assuring that manufacturers comply with the safety standard, and maintain compliance. [24] Over 80 % of UL standards are also ANSI standards; some are harmonized with ISO/IEC. Authorization to apply the UL mark requires an initial and periodic production inspections at identified factory locations. Follow-up services include frequent and unannounced product based inspections, witnessing of production tests, countercheck testing, aiid market sampling. [24]

CONCLUSIONS AND RECOMMENDATIONS

Of the original topics listed for discussion at the workshop, the following generated the greatest concern among the participants:

- uncertainty limits and calibration practices
- laboratory accreditation
- implications of global markets
- needs of code officials and manufacturers of regulated materials and products

From the test laboratories' perspective, ISO 17025 provides the motivation to get uncertainty estimates and calibration procedures well in hand. (January 1, 2003, has been established for all laboratories doing business with ISO 9002 organizations to meet the requirements of ISO 17025.) From the manufacturers' perspective, it is the enticement of the global market, the need to avoid multiple designs for different jurisdictions, and the desire to reduce the total number of tests necessary to certify products that motivates their interest in uniformity of fire test methods and universal acceptance of test laboratory results. Code officials and government regulators are concerned that the test methods be representative of the real-scale fire threat, and that the fire test laboratories be capable of conducting the tests in a precise, repeatable manner.

Although the concerns of these different interest groups are not fully congruent, neither are they mutually exclusive. Three pathways forward are proposed:

- Develop a rational means to quantify uncertainty that is relevant to fire testing.
- Explore alternative mechanisms for accrediting fire test laboratories that are consistent with the North American business model, and that lead to acceptance by international markets of the products certified by North American testing organizations.
- Invest in research to better relate the behavior of products measured during standard testing to their performance in realistic fire scenarios, aiid vice versa.

The first aiid last pathways are technical and scientific in nature; economics and politics control the middle pathway, although technical progress on the other two could increase the number of palatable mechanisms suitable for accreditation.

Three activities are already underway to better quantify uncertainty: the guideline to implementation of ISO 17025 being prepared by EGOLF; the investigation into heat **flux** measurement uncertainty being conducted by members of the FORUM for International Cooperation on Fire Research; and the ongoing, systematic analysis of fire measurement methods (temperature, smoke density, HRR, artifacts) by NIST. Close collaboration among commercial and government fire testing and research laboratories (in North America, the FORUM, EGOLF, and elsewhere) is required to prioritize the specific test methods and systems to be tackled, and to develop the scientific basis for meeting the requirements of ISO 17025. Based upon the response of the workshop participants, ASTM E84/NFPA 255, ASTM E119/NFPA 251, ASTM E1354/NFPA 271, ISO 9705/NFPA 265/NFPA 286, and ASTM E108 are good candidates because of their economic importance to materials manufacturers and fire test laboratories, and their wide spread reference in building codes.

Options for fire test laboratory accreditation could take several forms: under the umbrella of or building from non-governmental organizations such as those represented at the workshop (e.g., A2LA, ICBO ES, NACLA, NFPA); borrowing from the EGOLF concept; forming new associations with ties to governmental (e.g., NIST, CPSC) or non-governmental (e.g., UL, FM, SwRI) independent fire testing laboratories; or a combination (e.g., FORUM) might all be considered. Assured fire safety of the products and systems that are certified by the test laboratories must be the top goal for an accreditation program in order to attain the confidence and support of the state fire marshals, building code officials, and international authorities having jurisdiction. Possible economic and administrative burdens of an accrediting program on the fire testing laboratories and their customers must also be considered.

Accurate prediction of the behavior of materials, products and systems in an actual fire requires an integration of the information gained from well-designed tests, a fundamental understanding of fire dynamics and the behavior of material in a fire, and a clear idea of the environment in which the materials will be placed and of the hazard to be avoided. The need for a fire test method invariably precedes the understanding necessary to design it properly, so we are left with an imperfect test method that ends up in a code or regulation and that must be passed by the regulating authority. The value of predictive models based upon modern computational methods and key property measurements to supplement a standard prescriptive test has already been demonstrated in a specific application. [25] The number of applications and the generality of the predictions will increase if the research base is maintained. Maintaining the research base will lead eventually to tools for training test operators and accreditors, tools to enable fire safe product design and fabrication, tools to promote harmonization and international trade by linking products certified according to one test method in one jurisdiction to the requirements of the second party, and tools for code officials and AHJs to interpret equivalency of performance-based designs.

REFERENCES

1. ASTM E84-00a, *Standard Test Method for Surface Burning Characteristics of Building Materials,* American Society for Testing & Materials, West Conshohocken, PA, 2001.

2. ASTM E119-00a, *Standard Test Methods for Fire Tests of Building Construction and Materials,* American Society for Testing & Materials, West Conshohocken, PA, 2001.

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5. Beitel, J., Appendix V-B.

6. Stadnik, A., Appendix V-B.

7. Bliss, D., Appendix V-B

8. Bowman, D., Appendix V-B

9. *International Building Code,* International Code Council, Inc., Falls Church, VA, 2000.

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12. Wenzel, A., Appendix V-D.

13. Pabich, M., Appendix V-D

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18. Gann, R., Appendix V-E.

19. Murrell, J., Appendix V-E.

20. Walsh Cassedy, J., Appendix V-F.

21. Unger, P., Appendix V-F

22. Ramani, C., Appendix V-F.

23. Klouse, K., Appendix V-F

24. Gillerman, G., Appendix V-F.

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APPENDIX I. List of Commercial Fire Testing Laboratories Interested in Workshop

A. Independently Operated

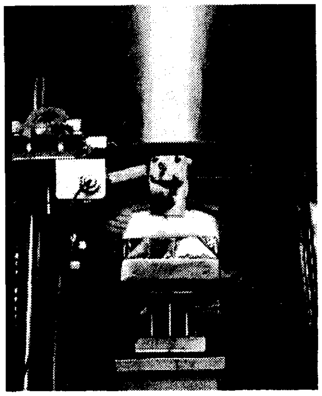
Anter Laboratories, Inc., Pittsburgh PA
Bodycote/Ostech, Dearborn MI
Commercial Testing Co., Dalton GA
Crane Engineering and Forensic Services, Plymouth MN
Delsen Testing Laboratories, Inc., Glendale, CA
Edward Orton Jr., Ceramic Foundation, Westerville OH
ELTEK International Laboratories, St. Louis MO
FM Global, Norwood MA[*]
The Govmark Organization, Inc., Farmingdale NY
Harwood Plywood & Veneer Assoc., Reston VA
Intertek Testing Services, Inc., Boxborough MA
Intertek Testing Services, Inc., Coquitlam BC
MET Laboratories Iiic., Baltimore MD
National Technical Systems, Boxborough MA
Nevada Automotive Test Center, Carson City NV
NGC Testing Services, Buffalo NY
Pacific Fire Laboratory, Kelso WA
Pedneault Associates, Inc., Bohemia NY
Phoenix Chemical Laboratory, Inc., Chicago IL
Polymer Diagnostics Inc., Avon Lake, OH
Product Safety Consulting, Iiic., Bensenville IL
Omega Point Laboratories, Inc., Elmendorf TX
Resources Applications, Designs and Controls, Inc., Long Beach CA
Sherry Laboratories, Noninetallics Division, Tulsa OK
SGS US Testing Co., Fairfield NJ
Southwest Research Institute, San Antonio TX
Trace Laboratories, Hunt Valley MD
Underwriters Laboratories, Northbrook IL
Underwriters Laboratories of Canada, Toronto Ontario
Western Fire Center, Inc., Kelso WA
Wyle Laboratories, Huntsville AL

B. Manufacturer Operated

Armstrong World Industries, Lancaster PA
BASF Corp., Wyandotte MI
Boeing Airplane Co, Seattle WA
Fenwal Safety Systeins, Holliston MA
EI duPont de Nemours & Co., Wilmington DE
KoSa, Wilmington NC

[*] Note: Organizations represented at workshop are in italics.

APPENDIX II. Workshop Agenda



WORKSHOP ON FIRE TESTING MEASUREMENT NEEDS: June 18-19, 2001

Building and Fire Research Laboratory
National Institute of Standards and Technology
Gaithersburg, MD

NIST ADMINISTRATION BLDG. (101), LECTURE ROOM A

AGENDA

Monday, June 18

8:30 Welcome, Jack Snell, NIST

8:45 Introduction, William Grosshandler, NIST

9:00 Codes and Regulations
- Jess Beitel, Hughes Assoc./NFPA
- Don Bliss, NASFM
- Andy Stadnik, Consumer Product Safety Commission
- Dave Bowman, National Evaluation Services

10:00 Materials and Product Manufacturers
- Tom Fritz, Armstrong World Industries
- Kevin Haile, Hardwood Plywood & Veneer Association
- Jess Beitel, American Plastics Council
- Mike O'Bryant, Boeing Airplane Company

11:00 Break

11:15 Laboratory Certification and Accreditation
- Chuck Ramani, ICBO ES/NACLA
- Ken Klouse, OSHA/NRTL
- Gordon Gillerman, Underwriters Laboratories
- Joan Walsh Cassedy, ACIL

12:15 Lunch

1:00 Measurement uncertainties in standard fire tests
- William Pitts, NIST
- Martin Pabich, UL

John deRis, FM Global
Alex Wenzel, SwRI

2:00	Open forum for fire test laboratory presentations
3:30	Break
3:45	Identification of issues
4:30	Breakout Groups to work issues in parallel Marc Janssens, UNC-C Richard Gann, NIST Fred Mowrer, University of Maryland
6:30	Dinner - informal group discussions

Tuesday, June 19

8:30	Implications of Globalization on U.S. Fire Testing Richard Gann, NIST Janet Murrell, EGOLF/Warrington Fire Research Centre
9:00	Breakout Sessions Continue
10:15	Break
10:30	Report From Breakout Groups Marc Janssens, UNC-C Richard Gann, NIST Fred Mowrer, University of Maryland
11:30	Priorities and Responsibilities William Grosshandler, NIST
12:30	Lunch
1:30	Advanced Fire Measurement and Prediction Methods Anthony Hamins, NIST Kevin McGrattan, NIST
2:00	Tour NIST fire facilities
3:30	Adjourn

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APPENDIX IV. Fire Test Standards

Three fire test methods were singled out at the workshop as being performed most often and as generating more than $1 M annually. In decreasing economic importance, these are

- ASTM El 19, *Standard Test Methods for Fire Tests of Building Construction and Materials*
- ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*
- ASTM E108, *Standard Test Method for Fire Tests of Roof Coverings*

El 19 is a building system endurance test originally developed by Ingberg [16], and can be compared to NFPA 251, *Standard Methods of Test of Fire Endurance of Building Construction Material;* ISO 834, *Fire resistance tests -- Elements of Building Construction,* is a variant of El 19, but uses different performance criteria. E84 (also called the "tunnel test") is classified as a medium-scale, flame spread test, and is similar to NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials.*

Three other fire tests were mentioned because of their technical relevance and likely role in performance-based design:

- ASTM E1354, *Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*
- ASTM E2058, *Standard Test Method for Measurement of Synthetic Polymer Flammability Using a Flame Propagation Apparatus (FPA)*
- ISO 9705, *Fire tests -- Full-scale room test for surface products*

NFPA 271, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter,* is equivalent to E1354, and both are referred to as the "cone calorimeter." E2058 operate on the same principle as the ASTM E1354, with a variation in geometric details, and is equivalent to the FM 4910 test and NFPA 287, *Standard Test Method for Measurement of Materials in Cleanrooms Using a Fire Propagation Apparatus* .

NFPA 286, *Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth,* is conducted within a room with dimensions similar to ISO 9705, but with a less aggressive gas fire exposure. NFPA 265, *Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings,* is the equivalent of 286 for textile coverings.

Of the more than 500 standard fire test methods that are currently on the books, several dozen were identified by name in the presentations and ensuing discussions during the workshop. These are listed in Table 2, grouped by phenomena and increasing magnitude of the contribution of the test article to the total test heat release rate. Where applicable, equivalent test methods are referenced.

Table 2. Common Fire Test Standards

Test Grouping	Test Number	Title	Equivalent[1] Tests
Non-combustibility	ASTM[2] E136	*Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*	
Non-combustibility	prEN ISO[3] 1182	*Fire tests -- Building materials -- Non-Combustibility test*	
Non-combustibility	BS[4] 476-4	*Fire tests on building materials and structures. Non-combustibility test for materials*	
Non-combustibility	French[5] M0		
Non-combustibility	German[6] A0		
Ignition	UL[7] 50	*Enclosures for Electrical Equipment*	ANSI 50
Ignition	ASTM E1352	*Test Method for Cigarette Ignition Resistance of Mock-up Upholstered Furniture Assemblies*	NFPA 261
Ignition	ASTM E1353	*Test Methods for Cigarette Ignition Resistance of Components of Upholstered Furniture*	NFPA 260
Ignition	NFPA[8] 260	*Standard Methods of Tests and Classification System for Cigarette Ignition Resistance of Components of Upholstered Furniture*	ASTM E1353
Ignition	NFPA 261	*Standard Method of Test for Determining Resistance of Mock-up Upholstered Furniture Material Assemblies to Ignition by Smoldering Cigarettes*	ASTM E1352
Ignition	prEN[9] ISO 11925-2	*Reaction to fire tests--Ignitability of building products subjected to direct impingement of flame--Single flame source test*	
Ignition	DIN[10] 4102, B2 burner	*Fire Behavior of Building Materials and Building Components*	
Ignition	UL 94	*Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*	
Flame Spread	ASTM 162	*Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source*	
Flame Spread	ASTM E648	*Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source*	NFPA 253
Flame Spread	NFPA 253	*Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy System*	ASTM E648

Test Grouping	Test Number	Title	Equivalent' Tests
Flame Spread	ASTM E1321	*Test Method for Determining Materials Ignition and Flame Spread Properties (LIFT)*	
Flame Spread	BS 476-7	*Fire tests on building materials and structures. Method of test to determine the classification of the surface spread of flame of products*	
Flame Spread	DIN 4102 Brandschacht	*Fire Behavior of Building Materials and Building Components*	
Flame Spread	prEN ISO 9239-1	*Reaction to fire tests -- Horizontal surface spread of flame on floor-covering systems -- Part 1: Flame spread using a radiant heat ignition source*	
Flame Spread	NFPA 701	*Standard Methods of Fire Tests for Flame Propagation of Textiles and Films*	
Flame Spread	ASTM E84	*Standard Test Method for Surface Burning Characteristics of Building Materials*	NFPA 255
Flame Spread	NFPA 255	*Standard Method of Test of Surface Burning Characteristics of Building Materials*	ASTM E84
Toxicity	ASTM E1678	*Test Method for Measuring Smoke Toxicity for Use in Fire Hazard Analysis*	NFPA 269
Toxicity	NFPA 269	*Standard Test Method for Developing Toxic Potency Data for Use in Fire Hazard Modeling*	ASTM E1678
Smoke Release	ASTM E662	*Test Method for Specific Optical Density of Smoke Generated by Solid Materials (NBS smoke chamber)*	NFPA 258
Smoke Release	NFPA 258	*Recommended Practice for Determining Smoke Generation of Solid Materials (NBS smoke box)*	ASTM E662
Heat/Smoke Release	NFPA 259	*Standard Test Method for Potential Heat of Building Materials*	
Heat/Smoke Release	ISO 5660	*Reaction-to-fire tests -- Heat release, smoke production and mass loss rate from building products*	
Heat/Smoke Release	prEN ISO 1716	*Calorific Value*	
Heat/Smoke Release	BS 476, Part 6	*Method of Test for Fire Propagation for Products*	
Heat/Smoke Release	JIS[11] A1321	*Testing Method for Incombustibility of Internal Finish Material and Procedure of Buildings*	

Test Grouping	Test Number	Title	Equivalent[1] Tests
Heat/Smoke Release	ASTM E1354	*Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter (Cone Cal.)*	NFPA 271
Heat/Smoke Release	NFPA 271	*Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter (Cone Calorimeter)*	ASTM E1354
Heat/Smoke Release	ASTM E906	*Test Method for Heat and Visible Smoke Release Rates for Materials and Products (OSU)*	NFPA 264
Heat/Smoke Release	NFPA 264	*Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter (OSU)*	ASTM E906
Heat/Smoke Release	NFPA 268	*Standard Test Method for Determining Ignitibility of Exterior Wall Assemblies Using a Radiant Heat Energy Source (ICAL)*	ASTM E1623, prEN ISO 14696
Heat/Smoke Release	ASTM E1623	*Test Method for Determination of Fire Thermal Parameters of Materials, Products, and Systems Using an Intermediate Scale Calorimeter (ICAL)*	NFPA 268, prEN ISO 14696
Heat/Smoke Release	ISO 14696	*Reaction to fire tests -- Determination of fire parameters of materials, products and assemblies using an intermediate-scale heat release calorimeter (ICAL)*	NFPA 268, ASTM E1623
Heat/Smoke Release	prEN ISO 13823	*Reaction to Fire Tests for Building Products -- Thermal Attack by a Single Burning Item for Building Products Excluding Floorings (SBI)*	
Heat/Smoke Release	ASTM E2058	*Standard Test Method for Measurement of Synthetic Polymer Flammability Using a Flame Propagation Apparatus (FPA)*	NFPA 287, FM 4910
Heat/Smoke Release	NFPA 287	*Standard Test Method for Measurement of Materials in Cleanrooms Using a Fire Propagation Apparatus*	ASTM E2058, FM 4910
Contents	ASTM E1537	*Test Method for Fire Testing of Upholstered Furniture*	NFPA 266
Contents	NFPA 266	*Standard Method of Test for Fire Characteristics of Upholstered Furniture Exposed to Flaming Ignition Source*	ASTM E1537
Contents	ASTM E1590	*Test Method for Fire Testing Mattresses*	NFPA 267
Contents	NFPA 267	*Standard Method of Test for Fire Characteristics of Mattresses and Bedding Assemblies Exposed to Flaming Ignition Source*	ASTM E1590

Test Grouping	Test Number	Title	Equivalent[1] Tests
Room Fires	ISO 9705	*Fire tests -- Full-scale room test for surface products*	NFPA 286
Room Fires	NFPA 286	*Standard Methods of fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth*	ISO 9705
Room Fires	NFPA 265	*Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings*	
Endurance	ASTM El 19	*Standard Test Methods for Fire Tests of Building Construction and Materials*	NFPA 251, ASTM El 19, ISO 834
Endurance	NFPA 251	*Standard Methods of Test of Fire Endurance of Building Construction Material*	ASTM El 19, ISO 834
Endurance	ISO 834	*Fire resistance tests -- Elements of Building Construction*	NFPA 251, ASTM El 19
Endurance	ASTM E 108	*Standard Test Method for Fire Tests of Roof Coverings*	
Suppression	NFPA 12	*CO_2 Fire Extinguishing Systems*	ANSI 12
Special Hazard	FMRC[12] 7812	*LP-gas fueled industrial trucks*	
Special Hazard	UL 1313	*Nonmetallic safety cans for petroleum products*	ANSI 1313
Special Hazard	ANSI[13] 221.1	*Household Cooking Gas Appliances*	

[1] Equivalent tests are conceptually similar, but may differ in details that significantly impact the performance of the product under test.
[2] ASTM, American Society for Testing & Materials, West Conshohocken, PA.
[3] ISO/IEC, International Organization for Standardization/International Electrotechnical Code.
[4] BS, British Standards Institute, London, England.
[5] reference unavailable
[6] reference unavailable
[7] UL, Underwriters Laboratory, Inc., Northbrook, IL.
[8] NFPA, National Fire Protection Association, Quincy MA.
[9] prEN, proposed to European Committee for Standardization.
[10] DIN, Deutsches Institut fur Norinung e.V., Berlin, Germany
[11] JIS, Japanese Industrial Standards Committee, Tsukuba, Japan.
[12] FMRC, Factory Mutual Research Corporation, FM Global, Norwood, MA
[13] ANSI, American National Standards Institute, Washington, DC.