14. STANDARDS AND CODES

14.1 HOUSING STANDARDS

Historically, the Building Research Program at NBS had a strong component addressing technology and standards for housing. Following Operation BREAKTHROUGH of the early 70s, CBT continued housing research at the request of and with the support of the Department of Housing and Urban Development (HUD).

In order to stimulate technical innovation in housing, a project led by Thomas Faison was undertaken to develop Performance Standards for Special and Innovative Construction. This document was prepared to provide a performance approach to the more prescriptive Minimum Property Standards of HUD. The results were published in 1977 as an NBS Interim Report [1]. Numerous HUD-sponsored projects continued over the years. Of particular note were projects on mobile home performance, lead paint mitigation, wind and earthquake performance and structural requirements, and energy conservation and plumbing system requirements.

In the early 1990s it remained evident that prescriptive U.S. codes and standards were barriers to housing innovation [2]. Also, there was much interest in export of U.S. building products, housing systems and knowledge, but there were no international performance standards as the basis for sale of these products. U.S. housing innovation was limited and occurred mostly in relation to amenities and popular styles rather than in the development of long-term performance and increased value. While the housing industry has performed well in the United States, it has had very limited success in exporting housing systems, housing products, and housing know-how.

To a large extent, the constraints on acceptance of housing innovation in the United States and the acceptance of U.S. products and know-how in the global marketplace could be overcome by the development of consensus performance criteria for housing. An international consensus would need to recognize differences in cultural and economic capability and would specifically address innovation; i.e., nonstan-

dard products and systems. The best opportunity to develop such a consensus would be in the development of national and international performance standards for housing.

A program to develop a comprehensive set of national and international performance standards for specifying and evaluating dwelling construction was proposed by BFRL. This goal had two objectives:

- ***stimulate and remove barriers to innovation in the design and construction of U.S. housing; and***
- ***provide the basis for increased global trade in housing products, components, systems, and know-how.***

Performance has meant different things to different people, including those in the field of construction. For purposes of this work, the performance concept was defined as a framework for specifying and evaluating qualities of building products and systems to meet user needs without limiting ways and means [3].

Some considered the performance concept to be based upon general goals with nonquantitative objectives and subjective evaluation, which might be termed the "wish list" approach. However, the performance concept, as developed and applied to this standards program was based upon specific criteria with a rigorous methodology dependent upon quantitative criteria, measurable responses, and objective evaluation.

At the October 1995 meeting of the ASTM E6, Performance of Buildings, James Gross made a proposal for a new standards activity on Performance Standards for Dwellings which was endorsed along with the concept of providing a technical advisory group to ISO, providing that ISO develops a counterpart standards activity. A similar proposal had been discussed with ISO. An introductory meeting to launch standards development was conducted in March 1996 at the regular semiannual meeting of ASTM E6 in Orlando.

In October 1996, the first working meeting of ASTM Committee E6.66 was held in New Orleans, James Gross was elected chairman. The Building and Fire Research Laboratory of NIST provided a report for Committee consideration entitled Resource Document for Performance Standards for One and Two Family Dwellings. The report had been prepared with the assistance of consultant, David Hattis. The Committee decided to develop a series of Standard Guides around the attribute chapters in the Resource Document. These were Functionality, Structural Safety and Serviceability, Fire Safety, Accident Safety, Health and Hygiene, Indoor Environment, Illumination, Acoustics, Aesthetics, Durability, Maintainability and Accessibility. Since that time the committee expanded the list to include Security, Economics, Adaptability and Sustainability.

The Building and Fire Research Laboratory (BFRL) of NIST took the technical lead in the development of prestandardization documents with assistance from consultants, both in the drafting of documents and in their review [4)]. Further, this activity identified research needed to fill gaps found in the development of these prestandardization documents. The documents themselves were based upon current building technology and the state-of -the-art with further research undertaken for maintenance and improvement of these standards over time.

ISO is a worldwide federation of national standards bodies that promotes standardization to facilitate the exchange of goods and services. ISO is the major international organization for the development of building and construction standards with approximately 30 technical committees devoted to building and construction. These comprise approximately 20 percent of all the ISO standards committees. One of the standards committees in ISO is TC 59 - Buildings. TC 59 is a broad-based committee quite comparable to ASTM E6 on Performance of Buildings. In an April 1995 meeting of the full committee of TC 59, an informal proposal was presented to develop performance standards for dwellings

with the possibility that this activity could be within TC 59. TC 59 approved, in principle, this informal proposal providing a formal proposal was made and the activity was assigned to TC 59.

In May 1996 at a meeting of ISO TC 59 Subcommittee 3 in Stockholm, a new Working Group on Performance Standards for One and Two Family Dwellings was approved (WG 10). Australia and the United States took this action following expressed support for this activity. Australia was assigned the responsibility of conveyor. In 1998 the activity was raised to subcommittee status (ISO-TC59-SC15). The principal work to date has been on Structural Safety and Serviceability and Durability guides.

The ASTM E6.66 subcommittee has continued to develop standard guides, four of which reached the balloting process by January 2001. Main committee E6 had approved the Durability Guide, and the Indoor Air Quality, Economics and Functionality guides were in the ASTM balloting process. Task groups were named to develop the Fire Safety and Acoustic standard guides.

James Gross was a sustained and forceful proponent of housing research in CBT and BFRL in his successive capacities as chief of the Office of Housing Technology, chief of the Building Economics and Regulatory Technology Division, deputy director of CBT and associate director of BFRL. Following Gross' retirement in 1997, Joel Zingeser led BFRL's housing research and standards activities which were diminished substantially with Zingeser's departure from BFRL in 2000.

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14.2 MOBILE HOME RESEARCH

BFRL conducted research on mobile homes (currently known as manufactured housing) in the mid to late 1970s as concerns surfaced about their safety and durability. Research was conducted in the areas of maintenance and durability, structural performance, thermal performance, and the response of mobile homes to fire. HUD funding was the primary sponsor for this research in support of its Federal Manufactured Home Construction and Safety Standard. However NIST and other Federal agencies also supported the program.

Damage to housing in the Wilkes-Barre, Pennsylvania area caused by Hurricane Agnes in 1972 provided an opportunity to study the performance of over 17,000 mobiles homes which were used as temporary housing by the U.S. Department of Housing and Urban Development (HUD) following the disaster. Comprehensive maintenance records were available for these mobile homes which represented a broad population of manufacturers, locations of manufacture, and ages of units. The objective of the project was to study the performance records of the units to (1) identify and document mobile home performance problems, (2) determine the relationship of the identified problems to provisions of the ANSI A119.1 Standard for Mobile Homes, and (3) identify areas of needed research. The results of this study [1,2,3] were used by HUD to prepare the Federal Manufactured Home Construction and Safety Standard to which mobile homes are currently constructed. This research resulted in James Gross and James Pielert receiving a Department of Commerce Silver Metal in 1977 for "significant contributions in increasing the safety, livability, and durability of mobile homes."

Research aimed at providing windstorm protection for manufactured homes' located in hurricane-prone regions.

The BFRL Structures Division conducted research on the structural performance of mobile homes when subjected to wind, flood and seismic forces. In addition to NIST funding, this research was supported by HUD and the U.S. Agency for International Development. Richard Marshall conducted research on the effects of wind on mobile homes including both wind tunnel [4] and full scale testing of instrumented units [5]. This research lead to recommended changes to the Federal Manufactured Home Construction and Safety Standard [6]. Felix Yokel led a research team investigating the performance of mobile home foundation systems when subjected to wind, flood and seismic forces [7,8].

Research in BFRL on the performance of mobile homes in fires involved a series of full-scale fire tests under the direction of Edward Budnick. Specific issues investigated included fire spread along a mobile home corridor [9] and interior finish as a fire safety consideration [10]. Fire detector issues related to mobile homes were investigated by Richard Bright and Richard Bukowski [11]. The 17,000 mobile homes used as temporary housing in Wilkes-Barre after Hurricane Agnes were used to evaluate the effectiveness of smoke detectors. Each unit was equipped with a smoke detector and fire safety performance was closely monitored. Based on the resulting excellent fire loss history, the mobile home industry in 1975 voluntarily adopted the requirement that a smoke detector be placed in each unit. This preceded ordinances requiring smoke detectors in conventional housing. BFRL's fire related research resulted in recommendations for changes to the Federal Manufactured Home Construction and Safety Standard [12].

Mobile home research in the Building Environment Division led by Douglas Burch was concerned with interior ventilation requirements and controlling moisture build-up in walls and roofs in various climatic conditions [13,14]. Much of this research was funded by HUD and resulted in changes to the Federal Manufactured Home Construction and Safety Standard.

In summary, BFRL's research has had a major impact on improving the quality and performance of manufactured housing which is a significant portion of the nation's housing stock.

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14.3 BUILDING REHABILITATION STANDARDS

In the late 1970s, there was increased awareness of the need to more fully utilize existing buildings. It was recognized that existing structures were assets that can be renewed creatively to provide shelter for people, commerce, and industry. Such reuse is beneficial since it avoids the dislocations of razing structures and building from the ground up, and provides urban variety and continuity with our past.

The Building Economics and Regulatory Technology Division under the leadership of James Gross initiated a project to study how building regulations and the regulatory process impact building rehabilitation. The building code is the primary regulatory device used to assure that minimum requirements for public health, safety, and welfare are met in the design and construction of buildings. Initial work in this area was on the impact of building code provisions on the rehabilitation of historic buildings [1]. Testimony given at Senate hearings in 1978 pointed out that building codes oriented toward new construction impede rehabilitation work by adding unnecessary project costs (estimated at 10 percent to 20 percent of total project costs), delaying project approval times (as much as 16 months over comparable new construction projects), and discouraging otherwise feasible rehabilitation projects [2].

BFRL began a study in 1977 to determine the need for improved regulations for rehabilitation of existing buildings. Several reports were published [3,4] which included, among other recommendations, the need to develop technical information pertaining to the building rehabilitation process and to prepare improved regulations for rehabilitation of existing buildings.

Technical Note 998 [3] identified the following specific technical needs to support the building rehabilitation process:

a) techniques for evaluating the condition of existing buildings;
b) guidance on the selection of appropriate materials and repair methods;
c) methods for identifying, ranking, and scheduling required maintenance and repair activities; and
d) methods for predicting remaining service life of materials and systems.

In response to the first need, NIST prepared NBSIR 80-2171 which contained available methods for assessing building components and systems [5]. At the urging of NIST in 1983, ASCE formed a standards committee to respond to the need for information on the condition assessment of building [6]. The scope of the committee was "to identify specific needs and to develop consensus standards for the condition assessment and evaluation of existing buildings including both the documentation of available methods and the formulation of new procedures."

Under the chairmanship of James Pielert of NIST, ASCE 11 "Standard Guideline for Structural Condition Assessment of Existing Buildings" was published in 1990, and an updated standard was published in 1999 [7]. ASCE 11 quickly became one of the most popular ASCE standards. The committee also prepared ASCE 30 "Standard Guideline for Condition

Assessment of the Building Envelope" in 2000 [8].

NIST Technical Note 998 concluded that the building code and its enforcement were impediments to the rehabilitation of buildings. At the time, application of existing codes for new construction to buildings being considered for rehabilitation was based on the dollar amount of work being planned. An example of such a requirement is the "25-50 percent rule" which can be summarized as follows. The alteration must be restored to at least its original condition if the renovations are less than 25 percent of the building's value. When the amount of renovation is between 25 percent and 50 percent, it is up to the building official which portion of the renovation must conform to new construction requirements. When the amount of renovation exceeds 50 percent, the entire building must be brought up to new construction standards. These requirements, which often delay or prohibit rehabilitation activities, exert a negative impact on both public safety and quality of the existing building stock.

After reviewing NIST Technical Note 998, the Massachusetts State Building Code Commission, with enthusiastic support of then Governor Michael Dukakis, determined that the State could benefit from a review of its existing building code and the adoption of building rehabilitation regulations. A project was started under the leadership of the National Conference of States on Building Codes and Standards (NCSBCS) with support of NIST, the Commonwealth of Massachusetts, and seven other interested organizations. NIST support was provided by James Gross and James Pielert. The objective of the project was to produce an interim code document containing code provisions for alterations and additions to existing buildings. The final draft of the interim code provisions was completed in August 1978, and after various workshops and code hearings, was incorporated as Article 22 of the Massachusetts State Building Code in June 1979 [9]. Experience with Article 22 showed that it allowed building officials more leeway in accepting design alternatives when rehabilitating buildings, reduced the number of appeals on modifications to existing buildings, and generally expedited the rehabilitation process.

The concept included in Article 22 of the Massachusetts State Building Code has had a significant impact on building codes in the United States. Variations of the approach have been incorporated by the International Conference of Building Officials (ICBO) in their Uniform Code for Building Conservation [10]. The State of New Jersey adopted rehabilitation code provisions that provide a method to balance the need for code compliance and the need to encourage and permit building rehabilitation. These concepts were expanded by the U.S. Department of Housing and Urban Development which developed the Nationally Applicable Recommended Rehabilitation Provisions (NARRP).

In summary, NIST has had a significant impact on the more efficient reuse of the nations' building stock by providing resources needed to make technical decisions, and by supporting the development of innovative regulatory approaches to building rehabilitation.

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14.4 DETENTION AND CORRECTIONAL FACILITIES

Because of the rapid increase in new jail and prison construction in the 1980s, and the lack of performance criteria and standards for building materials, equipment and systems, many correctional agencies have experienced equipment and system performance problems in their facilities. In some instances, these problems have necessitated expensive facility retrofits, repairs, or other fixes. In September 1986, the National Institute of Corrections (NIC), U.S. Department of Justice, initiated a study at NBS, which was led by Robert Dikkers. The general objective of the study was to develop guidelines, test methods and the technical bases for standards which would assist in the selection, application, and maintenance of building materials, equipment and systems for use in detention and correctional facilities.

During the first year of the study, the primary focus was on determining the state-of-the-art in the design of detention and correctional facilities. Specific emphasis was placed on identifying performance problems associated with various materials, equipment and systems, as well as reviewing available guidelines, standards, etc. which are or can be used by architects and correctional officials in the planning and design of new correctional facilities. During the conduct of the study, valuable information, comments, and recommendations were received from many individuals involved in the planning, design and operation of jails and prisons.

The conclusions and recommendations of the initial study were published in 1987 [1]. In brief, it was concluded that were many important criteria and standards that needed to be developed for improving the state-of-the-art of selecting materials, equipment and systems for use in detention and correctional facilities. Nineteen criteria and standards development activities were identified and prioritized by a review committee of correctional officials, consultants, and designers. One of the high priority activities, performance criteria for detention and correctional facilities, was selected and funded by NIC for study in the second year.

Performance criteria, which were developed using a performance format

Robert Dikkers, program manager for correctional facilities standards.

previously used by NBS for industrialized housing systems [2] and solar energy systems [3], had the following objectives: (1) establish performance criteria for materials, equipment and systems which are consistent with the security and custody levels used in detention and correctional facilities; and (2) establish standard performance measures with regard to security, safety, and durability of materials, equipment and systems. The preliminary performance criteria were prepared with the assistance of several consultants and were published in 1989 [4]. They covered the following three areas: (1) facility and site - facility mission, security levels, operational considerations, and site selection; (2) perimeter systems - climate and site, perimeter fencing, and intrusion detection systems; and (3) building systems - structural systems, doors, windows, glazing, locks and locking systems, control center, alarm, and communication systems. After additional development, the performance criteria were intended to serve as a technical resource and reference for correctional officials, architects, engineers, material and equipment manufactures, contractors,

and standards writing organizations. The criteria were also expected to benefit jail and prison programs by providing a technical performance assessment base from which project specifications and uniform methods for evaluating materials, equipment, and systems could be developed.

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14.5 NATIONAL CONFERENCE OF STATES ON BUILDING CODES AND STANDARDS

The National Conference of States on Building Codes and Standards (NCSBCS) was formed by the nation's governors in 1967 in response to "the need for intergovernmental reforms in the area of building codes," as recommended by the Advisory Commission on Intergovernmental Relations.

From the inception of NCSBCS to October 1976, the National Bureau of Standards provided NCSBCS Secretariat services. These services included administrative and technical support. The authority to furnish this support is contained in the NIST Organic Act. NBS Building Science Series 75 provides background on the formation of the National Conference of States on Building Codes and Standards. Also, discussed is the working relationship with CBT during the period when NBS provided the secretariat and staff for the NCSBCS.

By 1976 with growth and development, NCSBCS matured to the stage of becoming an incorporated entity with administrative self-sufficiency and independence. When NCSBCS entered into contractual agreements with HUD to develop a National Mobile Home Regulatory Program and monitor the enforcement under the National Mobile Home Construction and Safety Act of 1974 and other Federal Government agencies, it realized, as did NBS, that administrative and logistical support by NBS should be transferred to NCSBCS, while technical research support should be enhanced so as to further the goals of both organizations. In September 1976, NCSBCS opened offices in McLean, Virginia. The organization continues to prosper carrying out programs on behalf of the States. NCSBCS in 2000 had a staff of 70 people.

In 1978 NCSBCS and NBS entered into a Memorandum of Understanding that detailed a series of areas in which each organization would provide the other with mutual support. James G. Gross, who had managed the NCSBCS secretariat at NBS, was named senior technical advisor to the conference under this agreement. The purposes of this agreement were to: (1) set forth a commitment of continued mutual support between NBS and NCSBCS; (2) establish a procedure for appropriate joint Program planning and continued technical cooperation between the two organizations; (3) outline the general conditions under which NBS and NCSBCS cooperative efforts will be formulated and conducted; and (4) set forth those technical and other services to be provided either organization by the other.

Through this cooperative effort, both organizations continued to work together toward the common goal of improving the building regulatory system through the application of research and technology. This contributed to the public welfare by providing a safer, more healthful built environment at less cost. BFRL and NCSBCS also cooperated to improve the international competitive climate for U.S. industry by providing technology and regulatory procedures to remove barriers to the export of building products, systems, and know-how.

Both organizations contributed to international acceptable standards and mutual recognition procedures that help U.S. industry and professionals gain access to global markets.

Many technical studies and much research have been carried out in the Building and Fire Research Laboratory (BFRL) as direct result of stated needs by NCSBCS. Examples of such programs include the Laboratory Evaluation and Accreditation Program, Coordinated Evaluation System, Uniform Regulation of Manufactured Buildings and Mobile Homes, design standards for wind and seismic resistance, programs to reduce moisture problems in buildings, and programs to reduce loss of life and property from fire. The use of these results by NCSBCS has contributed to the NIST goal of transferring research findings and up-to-date technology to the States and ultimately the building owner and user.

Beginning in 1976 NCSBCS and NIST sponsored 15 joint technical research conferences addressing improvement of the building regulatory system. The results were published. Some of these conference proceedings are available from NCSBCS.

In 1986, NCSBCS, NBS, The American Society of Civil Engineers (ASCE) and The Association of Major City Building Officials (AMBCO) signed and released a "Model Agreement on the Investigation of Structural Failures." Under the conditions spelled out in this agreement, a jurisdiction may call on NIST to investigate major structural failures.

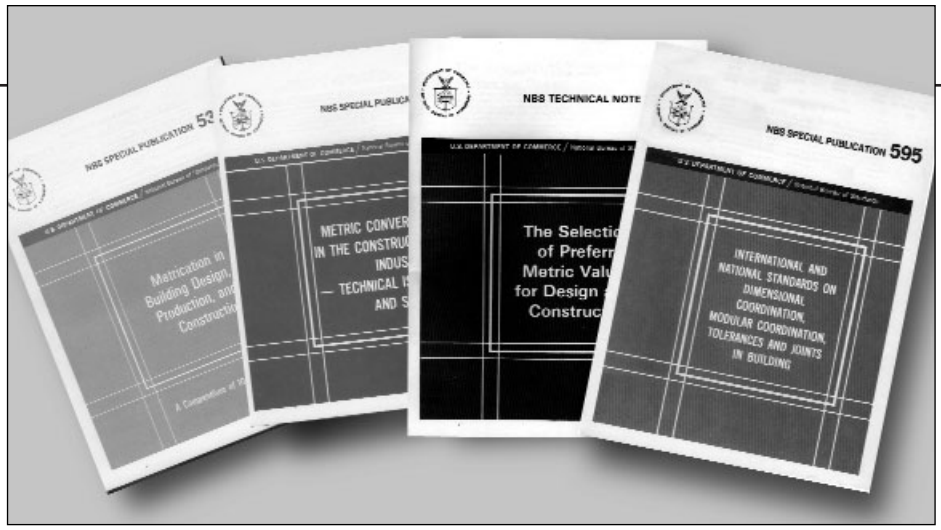
In 1996 NIST and NCSBCS signed an agreement under which the Parties seek to assist the U.S. construction industry in major markets to avoid technical barriers to trade and to promote the application of U.S. technology through the development of appropriate building and construction practices, codes, specifications and standards. It is intended that these efforts will assist in bringing about the establishment of U.S. building and construction codes and standards in international markets. Major projects were undertaken to assist Saudi Arabia and the Caribbean region. The project with Saudi Arabia produced a draft building code for Saudi Arabia based upon the Uniform Building Code produced with the administrative and technical support of ICBO. A Caribbean Region Conference was held in 1997 during which numerous recommendations were put forth to improve building regulations in the region. Some of the recommendations have been acted upon, particularly those recommending revision of regulations and practices to provide greater hurricane resistance in buildings.

In 1996 NCSBCS, with support from NIST and the cooperation of over 50 public and private organizations, embarked upon the Building Regulatory Streamlining project. The project's mission is to enhance public safety, environmental quality, and economic development in states and localities by helping each level of government (federal, state, and local) adopt and implement streamlined administrative procedures, processes, rules, and regulations. The project is intended to eliminate existing areas of regulatory overlap and inefficiency, which have created barriers to safe, affordable, and environmentally sound construction. Through this effort, the project also is designed to support U.S. international economic competitiveness in the construction industry.

Among the goals of the 5 year project are a 60 percent reduction of the regulatory processing time for construction projects and support for the fulfillment of the National Partners in Homeownership Goals and the National Construction Goals for the National Science and Technology Council. The project examined over 200 building regulatory processes and procedures. Fifty-nine models for improvement have been approved by the project participants for implementation. Several states are using the approved models.

14.6 METRICATION FOR CONSTRUCTION

The Metric Conversion Act of 1975 (Public Law 94-168) established a United States Metric Board to provide planning, coordination and public education for the voluntary conversion to metric measurement from U.S. customary units of measurement. At that time there was considerable enthusiasm



A series of CBT reports on metric conversions for the construction sector.

in the building industry for conversion to the Metric (SI) system of measurement. The building industry and the States as represented by the National Conference of States on Building Codes and Standards requested NBS to develop a program to assist in the conversion.

Early it was recognized that one benefit of metrication was the opportunity to select new sizes and dimensions so that products would fit in a coordinated way to reduce job site cutting and fitting which would reduce waste and save time and money. In 1975 CBT started a project "Coordinated Metric Dimensions for Building" to develop information to help industry select new product sizes in a systematic coordinated manner so as to foster efficiency in the building process. Also, the CBT accepted the role of secretariat for the Design, Codes and Standards and the Products Sectors of the Construction Industries Coordinating Committee of the American National Metric Council (ANMC).

Although the U.S. was the first nation to go to the decimal monetary system, it is the last major nation to go to the metric system of measurement. Thus, there was opportunity to learn from others such as England, Australia and Canada. Hans Milton was Chairman of the Government Construction Sector Committee on Metric Conversion in Australia from 1970 to 1975. Australia completed its metric conversion problem in a most effective manner. Milton was recognized as the prime mover in Australia's conversion. In late 1976, CBT arranged a contractual agreement with the Australian government to have Mr. Milton serve as a guest worker in the CBT Building Economics and Regulatory Technology Division to assist the U.S. in metric conversion. This arrangement continued for three years during which Mr. Milton provided technical studies on dimensional coordination and planning for metric conversion to assist the building community.

The first effort was to identify potential conversion problems in the construction codes and standards sector. The results of this study, conducted by Charles T. Mahaffey, were published as NBS Technical Note 915[1].

In response to a request by ASTM Committee E6-Performance of Building Constructions and the American National Metric Council, Hans Milton prepared a Recommended Practice for the Use of Metric (SI) Units in Building Design and Construction [2]. The study results were widely circulated for comment and were processed by ASTM Committee E6 to become an ASTM standard that is widely used and referenced through 2000.

To assist the building community to locate definitive information on metrication and dimensional coordination, a bibliography was prepared and published as a NBS Special Publication [3].

In 1977 at the American Institute of Architects headquarters, the AMNC Design and Construction Products Sectors (CBT held secretariats) sponsored a joint conference to develop background and information on building standards in the metric building world and to examine the opportunity for an industry-wide system of dimensional coordination. Three international speakers were featured. The conference proceedings were published at the request of the attendees' [4]. Many nations recognized the unique opportunities presented by a common measurement system (SI). A study was conducted to identify developments which would impact the U.S. construction community, particularly those related to international trade and competitiveness. Of much interest were European activities and standards development through ISO Technical

Committee TC-59-Building Construction. The identified international trends and developments were distributed to the building community and presented to the National Institute of Building Sciences (NIBS) [5].

During 1977 and 1978, Hans Milton was in high demand as a speaker at national building community meetings. Ten of his papers, each prepared for a different audience, were edited into an authoritative compendium of information on various aspects of metrication from managing the change to training and specific product format [6].

The Naval Facilities Engineering Command (NAVFAC) requested and partially funded a study to provide a rational basis for the evaluation and selection of preferred numerical values associated with metric sizes and quantities. This study was published as a NBS Technical Note [7].

To aid decision making relative to U.S. standards on dimensional coordination, a study was conducted of related standards from other countries, regions and ISO. Standards from over 50 countries were identified. The study showed widespread adoption of 100 mm as a basic building module. Fortunately, this dimension is close to the U.S. accepted building module of 4 inches. The study was sponsored by the Office of Policy Development and Research of the Department of Housing and Urban Renewal and was published as a NBS Special Publication [8].

The National Institute of Building Sciences requested a comprehensive report to provide information on then current technical issues and status of metric conversion in the construction industries as background for a December 1980 national conference "Metric Conversion in the Construction Community." This report was given to all attendees and widely circulated in the construction community [9].

Although metrication was not widely embraced by the construction community, some progress continued. In 1988 Congress amended the Metric Conversion Act of 1975 by the Omnibus Trade and Competitiveness Act (P.L. 100-408). This act made the metric system the preferred system of measurement for the United States. The subsequent issue of the Presidential Order 12770, required the federal agencies to convert federal procurement to the metric system. This led to the formation of the Construction Metric Council of the National Institute of Building Sciences. James G. Gross, who had managed the Metrication for Construction Program as Chief of the CBT Office of Building Standards and Codes and Chief of the Building Economics and Regulatory Technology Division, was named to the Board of Directors. The Construction Metric Council continues to lead metrication for construction. It publishes the "Construction Metrication" quarterly newsletter. This newsletter is available free to interested parties. The documents referenced herein continue to serve as a valuable resource.

In response to requests from ASTM Committee E6-Performance of Building Construction, CBT prepared two draft standards addressing recommended practice for use of metric units in building design and construction [10] and guidance for scales used in building drawings [11] which, after going through the consensus process, became ASTM standards. These standards are still promulgated by ASTM and are widely referenced. Also, CBT led the revision of two standards to include metric dimensions [12,13].

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14.7 MODELING STANDARDS

A standard should be complete (deal explicitly with all instances within its intended scope), clear (unambiguous in each instance as to whether the standard is complied with or not), correct (provide the outcome intended by the standard's writers), and well organized (guide the user to all provisions applicable to the instance). Moreover, standards should be correctly incorporated in computer-aided design software, and the difficulties in incorporating revisions of standards in such software should not be a barrier to the updating of standards. From the mid 70s throughout the 80s, CBT conducted and sponsored research on methods to assist standards writers in the formulation and expression of standards and to assist developers of computer-aided design software in the correct implementation of relevant standards.

Steven Fenves pioneered research on the formulation, expression and application of standards while at the University of Illinois in the 60s. Richard Wright had collaborated in some of this research and involved CBT in the work when he became director in 1974. The content of a standard was examined at four levels: the organizational network relating the requirements to be satisfied, the information network connecting interrelated provisions, the detailed level representing individual provisions in the form of decision logic tables, and the lowest level consisting of the input data for use of the standard [1]. As a guest researcher at CBT, 1975-76, Fenves studied the application of these techniques to the formulation of performance standards [2], mentored colleagues in the use of these techniques in CBT's work and was co-investigator in the application of the techniques to the development of a next-generation standard for the seismic design of buildings [3]. James Robert Harris joined BFRL in 1975 to conduct these studies and received the Ph.D. from the University of Illinois in 1980 for applying the sciences of classification and linguistics to develop a systematic method for outlining and indexing standards [4].

Harris worked closely with the team developing the tentative seismic provisions to assist in achieving a complete, clear, correct and well organized document. The experience gained in this effort was shared with the standards community through a cover story in ASTM's Standardization News [5]. When Harris left CBT in 1981 to start his own consulting engineering practice in Denver, the work on modeling standards was continued by Frederick Stahl and Kent Reed. A computer software system and tutorial was developed and published for Standards Analysis, Synthesis and Expression (SASE) [6] to make the techniques available to standards developers.

Cooperative research with Professor Leonard Lopez of the University of Illinois explored interfacing machine representations of standards with computer-aided design programs. This was called the Standards Interface for Computer-Aided Design (SICAD). The objective was to separate programming of the standard, which would best be done by the standard's developer, from programming of the computer-aided design system. Then the machine representations of standards would represent the standards correctly (a CAD programmer less familiar with the standard would be quite likely to misinterpret it). Also, a standard would not be "hard wired" into the computer-aided design system so that it could readily be used with different stan-

dards (such as for different countries) or updated as the standard was improved. Moreover, the standards development organizations could market the machine representations of their standards rather than ceding this market to CAD software developers. Lopez and colleagues developed and demonstrated the SICAD capability [7]. An important lesson learned in this research was the desirability of standard representations of the information contained in computer-aided design systems for buildings, which greatly reduced the amount of work required to develop SICAD implementation. This need resonated with the emerging national and international efforts to develop information interchange protocols in the mechanical and electronics manufacturing sectors.

CBT work on modeling standards dropped to a very low level as the Computer Integrated Construction Group focused its work on information interface protocols for exchange of data in architecture, engineering and construction in the late 80s. Fenves and colleagues summarized the work at CBT and elsewhere and assessed its impact [8]. CBT tried without success in the 80s to interest a major standards developing organization to conduct a pilot application of SASE in the development or revision of a major standard, but Fenves did apply the techniques with the American Institute of Steel Construction in the development of its standard for load and resistance factor design of steel structures. The American Association of State Highway and Transportation Officials applied the SICAD methods in its bridge design system. However, the principles and techniques are not yet widely implemented. They are well documented and available to assist those involved in development of standards and computer aided design systems.

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14.8 FIRE STANDARDS

Advancement of fire standards has been a continuing effort of CFR and BFRL. Research results are delivered to practice through improvements in standards of ASTM; the National Fire Protection Association; the American Society of Heating, Refrigerating, and Air Conditioning Engineers; the International Standards Organization; etc. Need for improvement of standards have been major drivers of the NBS/NIST fire research program. Department of Commerce Awards for advances in fire standards include the Gold Medal to Alexander Robertson in 1976 for career contributions, and the Bronze Medal to Richard Peacock in 1987 for safety of solid fuel heating appliances. Daniel Gross received the NBS Rosa Award in 1987 for his career contributions to fire hazard test method standards.