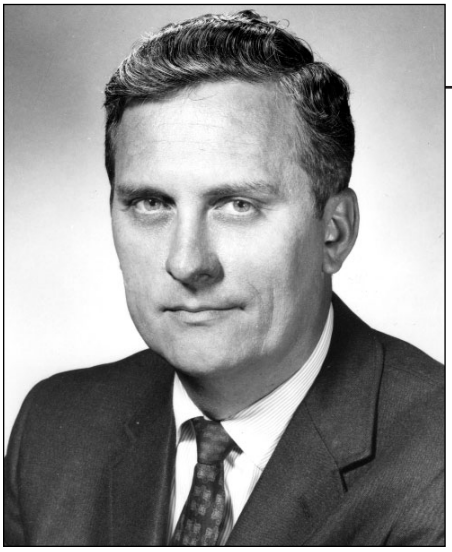
7. ARCHITECTURE, ENVIRONMENTAL PSYCHOLOGY, AND ACOUSTICS

From the time in the late 60s when John Eberhard and James Wright began to rebuild the Division of Building Research, Architectural Research and Environmental Psychology were seen as important program and growth areas. CBT was formed in 1972 with an Architectural Research Section in its Technical Evaluation and Applications Division and a Sensory Environment Section in its Building Environment Division. Most Acoustics research had been transferred to the Engineering Mechanics Division, but this returned to CBT in 1978 with the establishment of the National Engineering Laboratory and the elimination of the Engineering Mechanics Division. Eberhard was a strong advocate for advancing NBS's building technology program and worked hard to understand users needs for technologies. He said, "We don't produce cities as abstract things, but as places people can use. Yet even today (late 60s) we don't know how to relate the human to their environment (in urban areas)."

CBT management continued to believe in the importance of this work. Quantitative knowledge of how the built environment affects human health, safety and behavior is essential to providing functional, safe and economical constructed facilities. Architects are responsible for many or most of the early decisions affecting the usefulness, safety and economy of buildings. CBT should work closely with architects to identify and provide the measurements, performance prediction methods and standards they need. Throughout the 70s these areas received very little directly appropriated funding and CBT received no support from NBS for initiatives to increase their funding. Nevertheless, CBT and its staff members were recognized well in the architectural and environmental psychology communities for their leadership in research.

However, when the Reagan Administration imposed staffing cuts on NBS in the 80s, NBS felt it should focus its limited personnel resources on measurement-oriented physical sciences and engineering. CBT was directed by NBS management to eliminate its work in architectural research, environmental psychology and psychoacoustics.



John P. Eberhard, director, Institute for Applied Technology 1966-1970.

7.1 STAIR SAFETY

Stair safety was a major topic in architectural research [1,2]. Within CBT, the research was led by John Archea with collaborations from Belinda Collins, Steven Margulis, and Frederick Stahl. The team made extensive video studies of how people used stairs and the apparent causes for accidents and near accidents. The user's approach and orientation to the stairway was found critical to safety: the beginning of the stair should be clearly defined and distractions to the user's attention minimized. Stairs should be regular; the user expects tread height and depth to remain the same and is likely to be tripped up by changes. This, other CBT safety research, and research elsewhere was prepared for dissemination to architects and builders under a contract from CBT [3], although the original CBT reports continue to be requested to this day. The model building code organization, Building Officials and Code Administrators, International, cited this research as a major contribution to stair safety [4], and the results were incorporated in the 1982 edition of Architectural Graphic Standards. In January 1981, Progressive Architecture, awarded a research prize to CBT and BOSTI (Buffalo Organization for Social and Technological Innovations) for the Home Safety Guidelines for Architects and Builders.

John Archea videotaping persons ascending and descending stairs to evaluate possible barriers to slips and falls.

7.2 SECURITY

John Stroik led CBT's research on burglar resistance of doors and ASTM's development of security standards for doors [5]. Criteria were established by analysis of available data on burglars' methods, duplication of the attacks, and measurements of effects of the duplicated attacks.

7.3 HUMAN RESPONSE IN FIRES

Frederick Stahl, in support of the Center for Fire Research's research to quantify fire hazards, developed, and verified through observations of human behavior, a computer program BFIRES for simulation of human movements during building fires [6,7]. The model postulates that people construct their emergency responses and behavioral decisions dynamically in response to what they observe themselves and observe others doing. This work was incorporated in HAZARD, CFR's computer program for predicting the hazards produced by fire scenarios, and is used in its successors.

7.4 ENERGY CONSERVING DESIGN

One of the first issues for energy conservation in buildings was building fenestration - or windows. In the early 70s,the bulk of buildings used single-glazed, transparent materials, which allowed for significant energy losses in terms of excessive heat gain during the day, and heat loss at night. To solve the problem, some designers and engineers suggested reducing or eliminating windows. Others suggested analyzing all aspects of windows, including the positive lighting benefits provided by daylighting, more creative use of heat gains and losses, and consideration of any psychological benefits to building occupants.

The Center for Building Technology convened a multidisciplinary group to

S. Robert Hastings and an assistant are discussing methods to minimize unwanted solar heat gain.

evaluate all aspects of window performance. The group consisted of an architect, an economist, a psychologist, and a thermal engineer. Belinda Collins led the team. Collins, an environmental psychologist, led interdisciplinary studies of energy conservation in buildings and color rendering of lighting for safety symbols. Its publications [8, 9, 10] stimulated much greater national consideration of the benefits of daylighting, building orientation, usable solar gains, life cycle costs, and psychological responses.

As a result of the NBS research, building codes were modified to include the opportunity for daylight tradeoffs, solar and multi-layer glazing, solar controls, and utilization of beneficial solar heat gains, while minimizing unwanted heat loss. Building design became more flexible by allowing architects and designers to use building site and location more effectively, while continuing to meet occupant needs. Applications in Architectural Graphic Standards put the results on the desks of architectural designers while NBS's thermal load determination programs by CBT's Tamami Kusuda, enabled engineers to make the necessary thermal calculations and tradeoffs easily and accurately.

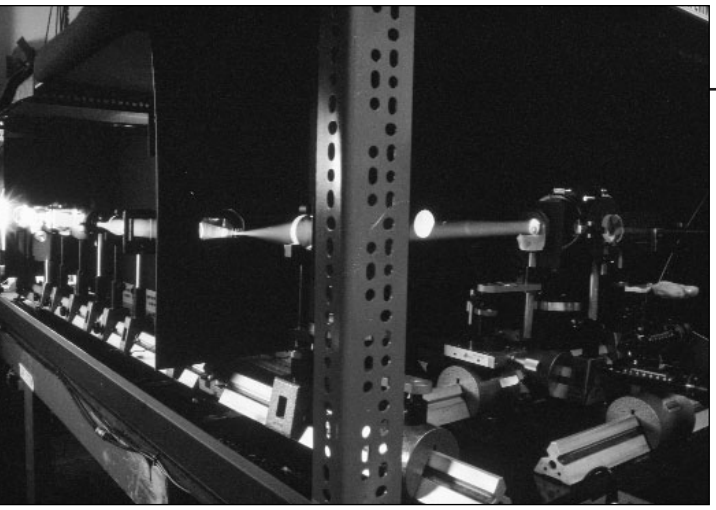
S. Robert Hastings provided architectural expertise to a variety of CBT programs for energy conservation and solar energy. His "typical houses" for assessment of energy conservation and solar energy options have been used extensively by researchers and practitioners, worldwide [11].

Edward Arens, an architect expert in wind and other environmental effects on people, collaborated with Preston McNall of the Building Environment Division and researchers from the J. B. Pierce Foundation to update the "bioclimatic" chart describing comfort as a function of clothing, activity level and the thermal environment [12]. This information was valued by researchers and designers dealing with the broader range of thermal environment encountered with passive solar energy systems.

7.5 COLOR AND SAFETY SIGNS

Kenneth Kelly continued and completed Dean Judd's many years of research at NBS to characterize color and issued the Universal Color Language and Color Names Dictionary [13].

During the late 1970s researchers became aware of the importance and effectiveness of both symbols and colors in communicating important safety-related information. The Center for Building Technology responded by directing resources toward research into the understandability of pictorial, safety symbols [14]. Research was conducted in support of programs at the Occupational Safety and Health Administration (OSHA), National Institute of Occupational Safety and Health (NIOSH), and the Bureau of Mines (BOM). In addition, CBT researchers, including Belinda Collins, Brian Pierman, and Neil Lerner worked with industry, which wanted to develop voluntary consensus standards for safety symbols to be used on equipment and in facilities. Following the initial research into symbols, Belinda Collins and her colleagues also investigated the role of both color and lighting spectrum to determine if safety colors could be detected and identified accurately under the newer, more efficient light sources being used in industrial and agricultural facilities [15]. Next, Jim Worthey and Belinda Collins extended these procedures to an evaluation of the visibility of diseases, defects and contamination in



CBT's illumination test facility is used to develop illumination/color criteria. The research facility provided a basis to better understand the interactions between the occupants and the illumination/daylighting systems of a building. It provides a realistic environment for studying color rendering (distortion) of energy-efficient lighting systems.

meat and poultry under different light sources [16]. Finally, Belinda Collins and her colleagues conducted investigations into the visibility of exit signs, symbols, and exit directional indicators in clear and smoky conditions, again to verify the understandability and visibility of different proposed standards for exit symbols and indicators [17]. The team involved research psychologists and safety engineers who conducted research in a variety of field conditions, including actual industrial facilities, meat and poultry processing facilities, and mine sites, as well as in laboratory conditions.

The data developed by CBT researchers were used as input into the set of ANSI Accredited Committee Z535 Standards for Safety Signs and Colors. In particular, Z535.3, 1979, Safety Color Code for Marking Physical Hazards, relied heavily on the NBS findings for the understandability of symbols in both workplaces and mines. At the same time, NBS also chaired the NFPA Committee on Life Safety Symbols, which developed a standard for life-safety symbols. That committee also relied on the NBS research on the visibility and understandability of an exit symbol - which eventually became an ISO symbol. In addition, OSHA referenced the NBS research in the Code of Federal Regulations. Finally, USDA issued regulations setting minimum color rendering guidelines for meat and poultry processing facilities based on the NIST research on detectability of defects and disease under different, energy-efficient light sources.

Belinda Collins received the Bronze Medal Award of the Department of Commerce in 1984 for her work on illumination engineering and safety symbols.

7.6 LIGHTING

Gary Yonemura [18] questioned the accepted psychophysical basis for lighting standards - the ability to just perceive an object (threshold visibility) does improve with increased illumination and led to the view "more light gives better sight." However, few visual tasks are carried out at threshold conditions. For normal, suprathreshold levels of illumination, Yonemura's work showed a definite maximum in visibility; for greater or lesser luminance more contrast being required for subjectively equal visibility. In recognition of this work and its influence on energy conserving lighting standards, Yonemura received the Presidential Award of the Illuminating Engineering Society of North America in 1981. Arthur Rubin led the work of CBT researchers with the lighting community to define the research, standardization and education efforts needed to improve lighting practices [19]; for these efforts he received the Presidential Award of the Illuminating Engineering Society on North America in 1982. Also, Richard Wright served as chairman of the Board of Directors

Steven Treado, mechanical engineer, is exchanging experimental luminaries in research to develop and verify models for the interaction between lighting and HVAC systems. Lighting quantity and quality affect safety, productivity, and the performance of HVAC systems.

of the Illuminating Engineering Research Institute and its successor the Lighting Research Institute from 1980-1983.

7.7 BUILDING FOR PEOPLE

Arthur Rubin and Jacqueline Elder capped many years of work with publication of the hardcover, well illustrated book *Building for People* [20]. It is a thoughtful manifesto for the potential contributions of the social sciences to the solution of building design problems. It received the 1981 Blue Pencil Publication Award from National Association of Government Communicators. However, because its intended audience of architects and architectural students generally seek actual rather than potential contributions to such solutions, the book's impact on practice seemed modest. In application of this work, in January 1982, a CBT-sponsored post occupancy evaluation of a federal office building by the University of Michigan's Institute of Social Research won a Progressive Architecture Award.

7.8 ACOUSTICS

Acoustics researchers in the Engineering Mechanics Division and architectural researcher Robert Wehrli of CBT collaborated to produce a design guide for reducing transportation noise in and around buildings [21]. It presented a unified procedure for selection of noise criteria, prediction of exterior and interior noise levels, and the evaluation of the adequacy of building designs. Collaboration in development of highway and building noise criteria [22, 23, 24, 25] continued for several years led by Daniel Flynn of the Center for Mechanical Engineering and Process Technology (a former member of the Division of Building Research) and Simone Yaniv of CBT. Results were used in ASTM standards.

John Molino, Neil Lerner and colleagues who joined CBT from the Engineering Mechanics Division [26] continued and reported psychoacoustic studies of the aversive effects of corona noise from electrical power transmission lines. Thomas Bartel used the CBT reverberation chamber to study the effects of edges on the acoustical absorption of materials [27]. This work received the "best paper" citation of the Technical Committee on Architectural Acoustics of the Acoustical Society of America. Simone Yaniv received the Bronze Medal Award of the Department of Commerce in 1986 for her work in characterizing semi-reverberant spaces.

Simone Yaniv making adjustment to test equipment in NBS Anechoic Chamber.

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