WINTER 1996

FENESTRATION R&D

LAWRENCE BERKELEY NATIONAL LABORATORY ENERGY & ENVIRONMENT DIVISION

Taking an Integated Systems Approach for Energy Savings

Developing and Promoting the Integration of High-performance Envelope and Lighting Technologies

The practice of window and lighting systems design in commercial buildings is typically a non-interactive process. Architects, who are responsible for the shell of the building, rarely explore the full integration of the solar heat and daylight-admitting window system with their lighting and mechanical system consultants.

Survey data reveals the shortcomings of the resulting built product in terms of energy efficiency and comfort. In a recent study of federal buildings in the Pacific Northwest, 55-65% of office workers had complaints regarding thermal or visual discomfort due to the envelope design, despite the provision of space-conditioning.

Energy-efficient electric lighting, glazing, and daylighting control technologies have the potential to significantly reduce the peak demand and total electricity use of commercial buildings – if these technologies are designed as integrated systems and the process is supported by appropriate design tools. Since lighting and cooling in commercial buildings constitute the largest portion of energy use and peak electrical demand, promotion of such integrated systems could become a cost-effective option for owners and utilities.

As an additional significant benefit, although difficult to quantify, these integrated systems can also provide higher quality work environments that are more comfortable for the occupants and also provide owners with higher value space.

Approach

In 1991, the California Institute for Energy Efficiency, a consortium of California utilities and agencies, began support of this multi-phase R&D program, which has focused on bringing together viable envelope, daylighting, and lighting solutions from traditionally disparate disciplines. As such, the approach differs substantially from conventional research in that it cuts across traditional narrow areas of building research and is intended to directly lead to near-term solutions for commercial buildings. Prototype designs have been exposed to more complex and realistic environmental conditions as research has progressed; e.g., field tests versus simulations, in-situ building installations versus scale models. Development of paper-based design guidelines have been initiated; the transition to computer-based design tools will be made in the next phase of work.

Accomplishments

Two integrated systems have been developed for cooling-load dominated commercial buildings: 1) dynamic systems and 2) advanced optical systems. Dynamic systems, such as automated venetian blinds (functional precursors to the switchable electrochromic glazings) with a dimmable electric lighting system, actively balance daylighting and

*(See **Integrated Systems**, page 2)*

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BUILDING TECHNOLOGIES PROGRAM
WINDOWS & DAYLIGHTING GROUP

The **Fenestration R&D** newsletter provides a periodic update on U.S. Department of Energy-sponsored windows and glazing research at Lawrence Berkeley National Laboratory. Future issues will be expanded to include other DOE-supported windows R&D activities.

Fenestration R&D is made possible with support from the U.S. Department of Energy, Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technology, State and Community Programs, Office of Building Systems

Samuel J. Taylor
Program Manager
Building Systems and Materials Division

LBNL's **Windows and Daylighting Group** develops advanced optical materials, studies fenestration performance, and creates computer-based tools and applications guides for improving the energy-related performance of windows.

Stephen E. Selkowitz
Program Head
Building Technologies

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ENERGY & ENVIRONMENT DIVISION
BUILDING TECHNOLOGIES PROGRAM
WINDOWS & DAYLIGHTING GROUP

INTERNATIONAL ENERGY AGENCY
Solar Heating & Cooling Programme

IEA/SHC Task 18

Representatives met for the IEA/SH&C Task 18: Advanced Glazing Materials 8th Experts' Meeting in Thun, Switzerland, February 26 - March 1, 1996. Progress will be reported in the Spring 1996 issue.

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Meetings Scheduled

23 - 27 September 1996
9th Experts' Meeting, Rome, Italy

17 - 21 March 1997
10th Experts' Meeting, Nagoya, Japan

IEA/SHC Task 21

Representatives for the IEA/SH&C Task 21: Daylight in Buildings will meet at Lawrence Berkeley National Laboratory, April 10-13, 1996. Progress will be reported in the Spring 1996 issue. The United States is formally participating in Subtask C: design tools, and Subtask D: case studies.

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World Wide Web Connection

For more information and task group research and activities, an IEA Web site has been installed on the Internet. To connect, use the following URL: *http//www-iea.vuw.ac.nz:90/*

Publication Requests

IEA Task 18 regularly publishes documents that might prove useful to your needs. Occasionally we highlight some of these publications in an issue of this newsletter, but we encourage you to use the Web address above to inquire about IEA publications currently available.

Keeping Track of THERM/WINDOW Software Progress

Windows & Daylighting Group researcher Dariush Arasteh attended a meeting of the International Standards Organization (ISO) TC163/WG2 Thermal Transmission Properties of Windows working group in Delft, The Netherlands.

The ISO is developing a detailed calculation procedure for determining the thermal properties of fenestration products, similar to that being developed by ASHRAE SPC142. This will ensure that the National Fenestration Rating Council (NFRC) rating process will be compatible with future ISO standards.

WIS Software

Arasteh also participated in a review of the WIS (Window Information System) software being developed at TNO in Delft. Intended for the European market, WIS is similar to WINDOW and collaborative opportunities were discussed.

Russian Translation

Berkeley Lab researchers recently hosted Russian colleagues Vladimir Tchernorucky and Konstantin Korolev of the Sol Company to plan a translation of THERM into Russian. Working in conjunction with the Russian Ministry of Construction, the Sol Company has already translated WINDOW 4.1 into Russian and has helped to get the NFRC rating system recognized in Russia.

THERM Update

In collaboration with Dragan Curcija at the University of Massachusetts, a condensation resistance module is also being developed for THERM.

THERM 1.0 is now available. To order, please see Software, page 11.

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Integrated Systems...

(continued from page 1)

thermal heat gains while addressing comfort issues. Advanced optical systems, such as light shelves and light pipes, passively extend the depth of daylighting penetration to approximately 10 m beyond a conventional sidelight window, and distribute daylight more uniformly to achieve a higher level of visual comfort.

Dynamic Systems

DOE-2 simulations of an automated venetian blind with daylighting controls indicate that 16-26% total energy savings can be attained with the blind system compared to a conventional insulated window system in Los Angeles. These savings have been corroborated with outdoor field test data gathered this past year in a 1:3 reduced-scale office module. If the blinds are operated to block direct sun and optimize interior daylight levels, a lighting energy savings of 37 - 71% is attained on clear sunny days over a fixed blind system for south to southwest-facing windows. These savings were accomplished using as-is or modified commercial lighting products or prototype solutions. On the cooling side of the equation, results from the Mobile Window Thermal Test Facility (MoWiTT) indicated that the blind system with a less optimal control algorithm was more than *twice* as effective at reducing solar heat gains under clear sky conditions as a static unshaded bronze glazing, while providing approximately the same level of useful daylight.

Advanced Optical Systems

Using measured bi-directional illuminance data in combination with mathematical algorithms, the daylight output of several advanced optical technologies was shown to be significantly more effective at distributing useful daylight than

*(See **Integrated Systems**, page 4)*

http://eande.lbl.gov/BTP/BTP.html

Building Technologies Jumps on the Web

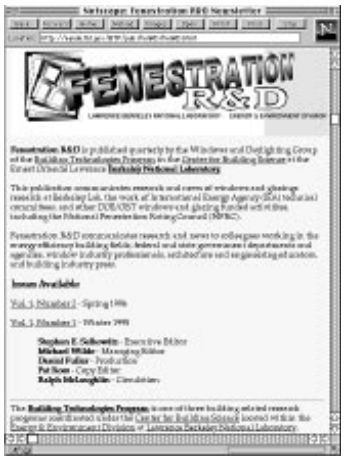
You can now find us on the Internet. Our location is *http://eande.lbl.gov/BTP/BTP.html*.

Over the past six months, we have been publishing more of our work on the World-Wide Web. The Fenestration R&D

quarterly newsletter, the Building Technologies Program's annual report, and the list of publications for the Windows and Daylighting Group are now accessible.

To view our Web pages, we recommend that you use Netscape Navigator 1.1 browser software or later. You can download a free copy of version 1.1 from Netscape's Web site.Web: *http//www.netscape.com/comprod/mirror/index.html*

The Mosaic browser is also available from NCSC's Web site. Web: *http//www.ncsa.uiuc.edu/SDG/Software/SDGSoftDir.html*



With the publication of the first issue of the Fenestration R&D newsletter, we have started to use Adobe's Portable Document Format (PDF). To view and print these files, you will need the Adobe's free Reader software, which is available from Adobe's web site. A link to the Reader software is available from any of our PDF archive pages or directly from Adobe: *http://www.adobe.com/Acrobat/Acrobat0.html*.

The Microsoft Windows version of RESFEN, our residential fenestration calculation tool, is now available via our web server. In the future, we plan to distribute other software products such as WINDOW 4.1 and

the Building Design Advisor (BDA) in this manner.

The National Fenestration Rating Council's (NFRC) Spectral Data Library is now available from the Web. The location is *http://eande.lbl.gov/BTP/WINDOW/NFRCsdlib/s95.html*.

This data library, the March 1996 update to WINDOW 4.1 spectral data, was created through a collaborative effort between the individual glass and coating manufacturers involved, the NFRC, the Primary Glass Manufacturers Council (PGMC), and Berkeley Lab.

More Web Sites to Explore

Washington State Energy Office
Web: *http://www.wseo.wa.gov*

California Energy Commission
Web: *http://energy.ca.gov/energy/cectext/ETEC.html*

U.S. Department of Energy's EREN: Energy Efficiency and Renewable Energy Network
Web: *http://www.eren.doe.gov*

U.S. Department of Energy
Web: *http://www.doe.gov*

U.S. Government's Federal Information Network
Web: *http://www.fedworld.gov/*

National Technical Information Service (NTIS)
Web: *http://www.fedworld.gov/ntis/ntishome.html*

IEA's Center for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET)
Web: *http://www.ornl.gov/CADDET/caddet.html*

American Council for an Energy-Efficient Economy (ACEEE)
Web: *http://solstice.crest.org/efficiency/aceee/index.html*

American Society of Heating, Refrigeration and Air-Conditioning (ASHRAE)
Web: *http://www.ashrae.org*

Center for Renewable Energy and Solar Technology's Greening of the White House
Web: *http://solstice.crest.org/environment/gotwh/index.html*

National Research Council of Canada's Institute for Research in Construction (IRC)

Web: *http://www.cisti.nrc.ca:80/irc/irccontents/html*

Lawrence Berkeley National Laboratory
Web: *http://eande.lbl.gov/CBS.html*

Oak Ridge National Laboratory
Web: *http://www.ORNL.gov*

National Renewable Energy Laboratory
Web: *http://www.NREL.gov*

Florida Solar Energy Center
Web: *http://www.fsec.ucf.edu*

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1996

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BUILDING TECHNOLOGIES PROGRAM
WINDOWS & DAYLIGHTING GROUP

Fenestration Facts

"Design for daylight should be modified by, and integrated with, other environmental concerns. View, natural air movement, acoustics, and electric lighting are all elements which must be considered when designing openings for daylight."

Daylight in Architecture
Benjamin H. Evans, AIA
1981

Integrated Systems...

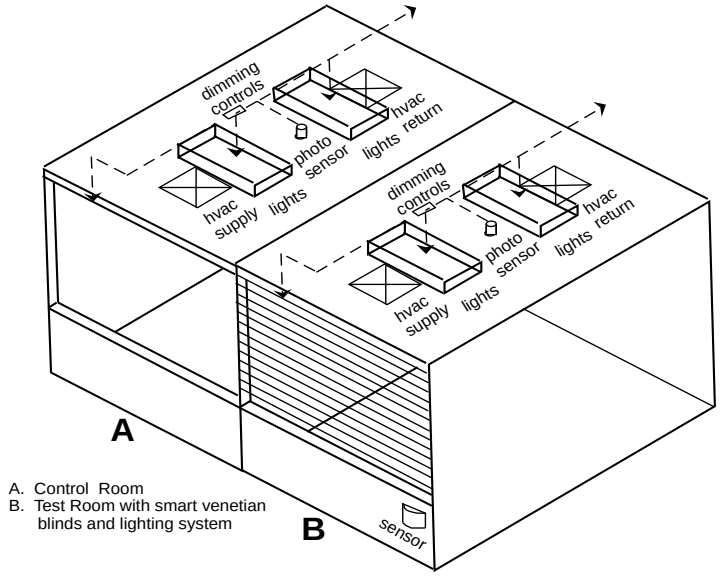
(continued from page 2)

conventional technologies. For example, the south-facing lightshelf produced daylight illuminance levels that were two to four times greater than a conventional flat light shelf at a depth of 8.38 m from the window wall, during clear sky conditions from 9:30-14:30, February to October. Cooling loads were of minor concern since the daylighting aperture was 40% smaller in area than the base case light shelf.

A prototype skylight system, a derivative of the light-redirecting concepts of the basic perimeter daylighting systems, was designed, installed, and demonstrated at full-scale at the Palm Springs Chamber of Commerce, in collaboration with Southern California Edison (SCE). The design was highly effective at distributing daylight throughout the entire room cavity and produced a uniform workplane illuminance throughout a partly cloudy winter day. Practical experience gained working with the contractor, 3M, and SCE led to further refinement of the underlying conceptual designs and a greater understanding of the practical issues surrounding fabrication and construction. Occupant feedback has also been useful in refining the design concept.

Design Tools

Successful implementation of these integrated systems will require better design data and tools. As a first step, we are developing a twelve-section daylighting design guideline that provides a quick and easy reference to integrated design principles. The approach has been tailored to the architectural design process, from programming though building occupancy, in a series of concise how-to bullets and supporting reference material. Design guidelines will need to be expanded to computer-based tools, to put a decision-making capability in the hands of the architect and engineer. We expect to build these new capabilities into versions of the Building Design Advisor (BDA) and PowerDOE design advice modules to be described in future articles.



Showcasing the "Office of the Future"

New energy-efficient technologies must be well tested and proven before they are introduced to the building industry in order to ensure performance and to reduce real and perceived risk. Small-scale tests in actual buildings can provide utility program managers with energy savings verification data, and can help design professionals, who need data to assess the aesthetics, cost, and energy performance of the technology.

Two office modules were built-out for full-scale measurement and verification of the dynamic system's performance at the Oakland Federal Building in California, in cooperation with Pacific Gas and Electric and the U.S.A. General Services Administration. Industry support includes equipment donations from Pella, LiteControl, and Lightolier.

This testbed demonstration is both an R&D facility to help answer research questions and a limited proof-of-concept test, allowing practical "bugs" to be worked out of an innovative building system. Energy monitoring and occupant evaluations will be performed in the coming year.

References

Beltrán, L.O., E.S. Lee, K.M. Papamichael, S.E. Selkowitz. **"The Design and Evaluation of Three Advanced Daylighting Systems: Light Shelves, Light Pipes and Skylights."** Proceedings of the *Solar '94, Golden Opportunities for Solar Prosperity*, American Solar Energy Society, Inc., June 25-30, 1994, San Jose, CA. LBL Report 34458, Lawrence Berkeley Laboratory, Berkeley, CA.

Lee, E.S., S.E. Selkowitz, F.M. Rubinstein, J.H. Klems, L.O. Beltrán, D.L. DiBartolomeo, R. Sullivan. 1994. **"Developing Integrated Envelope and Lighting Systems for New Commercial Buildings."** Proceedings of the *Solar '94, Golden Opportunities for Solar Prosperity*, American Solar Energy Society, Inc., June 25-30, 1994, San Jose, CA. LBL Report 35412, Lawrence Berkeley Laboratory, Berkeley, CA.

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Proving Energy-Efficient Windows Save Energy and Money

Researchers at Berkeley Lab's Mobile Window Thermal Test Facility (MoWiTT) are working with the window industry to measure net energy flow through windows under realistic outdoor conditions.

Low-E, gas-filled windows have revolutionized the window business and provided savings that we estimate at over $1.8 billion. But some skeptics still maintain that the "emperor has no clothes." Perhaps it should not be surprising that some homeowners and builders want scientific "proof" that these innovative materials and designs provide the savings promised. While computer tools and continued indoor laboratory tests provide enough useful information for researchers and manufacturers, field tests of product performance under realistic outdoor conditions play an essential role in validating the computer tools, in testing novel designs and materials, and in building confidence in an ever-skeptical public. The MoWiTT was designed and built to fulfill this role.

The MoWiTT is

- A pair of outdoor, room-sized calorimeters capable of accurately measuring the net energy flow through two window samples in side-by-side tests utilizing ambient weather conditions.
- A heavily-instrumented, research grade facility that measures the temperatures, solar fluxes and wind conditions to which the samples are exposed.
- A dynamic non-steady-state facility capable of characterizing accurately net heat flow as a function of time.
- A mobile facility that can study window performance in any orientation.

Window Performance is Complex

The net energy flowing through a window results from a combination of temperature-driven thermal flows and transmission of incident solar energy, both of which vary with time. The window properties that modulate these flows, U-value and Solar Heat Gain Coefficient, themselves depend somewhat on ambient conditions. The impact of window energy flows on the energy usage of a building space depends significantly on the timing of those energy flows relative to other energy demands within the building.

A significant energy-saving opportunity lies in utilizing the solar gain available through a window, either for winter heating or for daylighting. Successful pursuit of this strategy requires knowledge of the time-dependent energy flows.

Users of fenestration are generally interested in both the overall average energy flow, which ultimately is related to annual operating costs, and to peak energy demands, which influences the size and cost of heating and cooling systems. These performance results are frequently obtained from a complex set of calculations such as a computer-based building simulation model. In many cases the information available to characterize a fenestration may be limited, it may be inadequately described in available simulation models, or the user may be skeptical of the calculation results. In these cases, the ability to make direct performance measurements under well-characterized outdoor conditions is of tremendous value.

MoWiTT Research

The MoWiTT researchers carry out a DOE-funded program of research on the generic characterization of fenestrations systems and the development of publicly-available calculation methods for predicting fenestration thermal performance. The goal of this research is to assess the performance of energy-efficient windows currently available or under development, to identify opportunities for new development, and to create the knowledge base that will encourage rational selection of optimal windows in the design process. A number of organizations have collaborated in this research activity, including Andersen Corp., ASAHI Glass Co., ASHRAE, Cardinal IG, LOF Glass Company,

*(See **Mobile Window Thermal Test Facility**, page 6)*

Fenestration Facts

Visible transmittance (T_{vis}) is the percentage of light energy striking a given glazing that is passed through. Higher numbers mean more light will enter a space and views out will appear brighter.

"Technics: Cool Daylight"
Progressive Architecture
April 1992

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Mobile Window Thermal Test Facility...

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The Moore Co., Rollscreen Co., and Southwall Technologies.

The first target of this research program was to verify the heat transfer model used to calculate the energy performance of simple, unshaded windows. An early result of this effort produced the first demonstration that, under realistic outdoor conditions, the then-newly-introduced low-e coatings produced the expected reduction in the heat loss through a double-glazed window. This research also produced the unexpected result that for the simplest windows—single glazing and, to a lesser extent, double glazing—the MoWiTT measured U-values were significantly smaller than those measured in test laboratories or calculated using the standard assumptions.

Subsequent research verified the researchers' initial suspicions that the problem lay in the "exterior film coefficient," which is the insulating value of the thin layer of stationary air that clings to the outside surface of any glazing. The thickness of this layer depends on the wind blowing on the window, and it turned out that the laboratory tests and calculations assumed much windier conditions than are typical for 1-2 story residential buildings. The research produced a set of equations that more correctly predict the exterior film coefficient for realistic conditions. This gave an ironic solution to a puzzle of the mid-1970's: In numerous residential retrofit programs it had been found that among a long list of energy savings measures introduced, adding storm windows (to single glazing) achieved only about 50% of the expected energy savings. The MoWiTT work showed that this had been the case not because the storm windows performed much more poorly than expected, but because the original single glazing had been considerably better than the calculations (which were based on laboratory test data) had assumed! Today it is possible to do correct window energy savings calculations—an important advance, since window retrofits are a costly but frequently worthwhile energy efficiency investment.

MoWiTT research has continued to track developments in a window market where both energy-efficiency improvements and performance calcula-

Fenestration Facts

The *shading coefficient (SC)* is a measure of total solar heat that is transmitted by a given glazing. Lower numbers mean less energy is transmitted. *SC* does not distinguish among wavelengths within the solar spectrum, therefore a low coefficient can be achieved through reducing transmission of any combination of visible and near infrared energy.

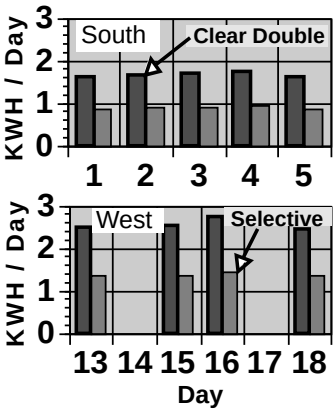
"Technics: Cool Daylight"
Progressive Architecture
April 1992

Hardcoat Low-E Performance

Sponsor: LOF Glass Company

New low-E hardcoats (E = 0.2) perform well in both IG and storm window applications. Side-by-side MoWiTT comparisons of a pre-production hardcoat low-E with then-current (emissivity = 0.1) softcoats showed that winter solar heat gain through the high-clarity hardcoat could more than offset the small difference in U-value in some climates, to give comparable performance. The hardcoat performance in a removable storm window (an application not possible with softcoats) was not significantly degraded by air flow through weep holes in the storm window frame for a well-sealed primary window. The figure shows in-place diagnostics using IR thermography conducted on both windows to check the interpretation of the MoWiTT measurements.

References: A report is currently being prepared.



Selective Low-E Performance

Sponsor: Pacific Gas & Electric Co.

Collaborators: Cardinal IG, LOF Glass Company, and PPG Industries

Visually clear or faintly tinted selective glazings produce significant cooling savings, and their properties are accurately calculated by WINDOW 4. In a series of side-by-side MoWiTT tests, the selective glazing systems of several manufacturers were found to give comparable and significant cooling energy savings on any sunlit orientation (bar graphs). The measured Solar Heat Gain Coefficients (SHGC) showed the expected dependence on incident angle, and accurately matched WINDOW 4 calculations.

Reference: Klems, J.H. et al, **Measured Performance of Selective Glazings.** Thermal Performance of the Exterior Envelopes of Buildings VI Conference Proceedings, December 4-8. 1995, Clearwater Beach, Florida. LBL-37747, Mo-337.

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tions are growing increasingly sophisticated. Performance studies have included improved "hard" low-e coatings, which make low-e storm windows a new retrofit option, "selective" low-e coatings for reduced summertime solar heat gain in addition to lower wintertime heat losses, and "superwindows," which can have better average energy efficiency than an insulated wall. Studies of heat transfer in complex fenestration systems (e.g., interior, between-pane or exterior venetian blinds, shades) have been used to develop a new method of determining solar heat gain through these systems. The NFRC voluntary rating systems have been a direct beneficiary of this research.

MoWiTT Services

In addition to DOE-supported research, the MoWiTT is also available for privately-funded studies of specific products or window improvement options. It can

- provide direct comparative performance of alternative window systems,
- determine effective U-values and Solar Heat Gain Factors under realistic conditions,
- provide verification of energy-savings calculations, and
- measure energy performance of new window technology for which calculations are unavailable or unreliable.

Results of these studies provide the project sponsors with valuable information for energy savings program design (utilities) and for further product development (manufacturers). Test results are often made available to a wider audience through conferences and journal articles.

Users of the MoWiTT under this arrangement have included Bonneville Power Administration, LOF Glass Company, Cardinal IG, Andersen Corporation, and Pacific Gas & Electric Company.

The MoWiTT facility is available on a cost-sharing basis for fenestration testing and performance evaluation. To discuss in more detail, please contact the following:

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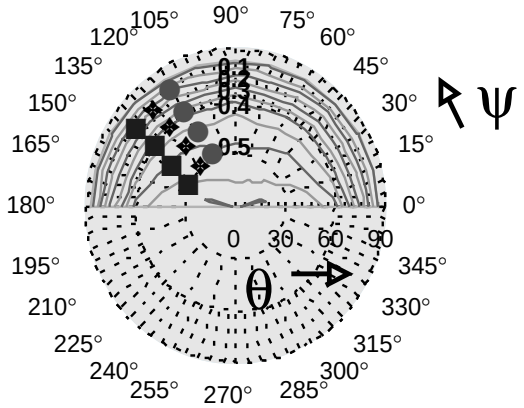
Winter Superwindow Performance

Sponsors: DOE, BPA

Collaborators: Southwall Technologies, Rollscreen Co., Andersen Corp., Cardinal IG

Even facing north, a superwindow can—on average—outperform an insulated wall in wintertime. Side-by-side MoWiTT tests tracing the net energy flow through a north-facing superwindow as a function of time in comparison to that through an R-15 wall showed that under cold, overcast conditions the nighttime advantage of the wall was more than offset by diffuse daytime solar energy gained by the window. Under many conditions the superwindow provides net energy benefits to the building and will outperform the insulated wall over the entire heating season.

Reference: A report is currently being prepared.



Window Attachments Performance

Sponsors: ASHRAE, DOE

Collaborator: Rollscreen Co.

Solar performance of complex window systems with shading attachments can be built up from the separate performances of subunits. This is the conclusion of a lengthy ASHRAE/DOE study using the MoWiTT to develop and test a methodology based on the idea of combining thermal and optical properties by calculation and building up the latter layer-by-layer. The MoWiTT was used both to measure the fraction of device-absorbed solar energy that gets into the room and to check the final calculation. The calculated SHGC for a system such as double glazing with venetian blind can have a complicated dependence on the incoming solar direction (polar plot, contours of constant SHGC).

Reference: Klems, J.H., et al. **A Comparison Between Calculated and Measured SHGC for Complex Glazing Systems.** ASHRAE Transactions 102(1) (1996). 1995. LBL-37037, Mo-345.

Fenestration Facts

Glazing luminous efficacy (K_e) describes the relationship between total solar heat transfer and visible transmittance for a given glazing. Sometimes called "coolness index," K_e is calculated as visible transmittance divided by shading coefficient ($K_e=T_{vis}/SC$). Glazing with a low K_e means the shading coefficient of that glazing is achieved with a penalty in visible light transmittance, whereas a high K_e means light is not sacrificed for solar control.

"Technics: Cool Daylight"
Progressive Architecture
April 1992

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Fenestration Facts

"The development of tinted glass helped make the new glass-walled buildings possible. The metallic oxides that gave tinted glass its gray, blue-green, or bronze color admitted light while reducing solar brightness and glare. The oxides in the glass also absorbed up to 35 percent of the sun's heat. They reradiated it back into the atmosphere, thereby lowering the demands on a building's air-conditioning equipment."

Let There Be Light
James Cross Giblin
1988

WINTER
1 9 9 6

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Thermal VI Conference

Fenestration Research Results

The Sixth Thermal Performance of the Exterior Envelope of Buildings Conference was held in Clearwater Beach, Florida on December 4-8, 1995. The conference focused on the building science of envelope performance from research to practice and application.

Thermal VI was jointly sponsored by the U.S. Department of Energy (DOE), American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), Oak Ridge National Laboratory (ORNL), and the Building Environment and Thermal Envelope Council (BETEC).

The full proceedings (792 pages) is available from the ASHRAE, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, for $111.00 plus $3.00 shipping charge. Listed below are paper titles, authors and edited abstracts for papers that directly addressed fenestration technology and performance.

A Wall and Edge Guarded Hot Box for Fenestration Testing. S.D. Gatland II and R.G. Miller. Center for Applied Engineering, Inc., (813) 578-4332, Fax (813) 576-0318; W.P. Goss, University of Massachusetts, Mechanical Engineering Department, Amherst; R.L. Baumgardner, Rollin Inc., Stroudsburg, PA; and R.G. Williams, Division of Quantum Metrology, National Physical Laboratory, Teddington, U.K.

Abstract: A unique guarded hot box that incorporates several new design concepts from guarded hot plates, namely wall and edge guards, is described in detail. This new approach to the guarded hot box operates with improved temperature and power control.

The test facility is rotatable, with the ability to provide upward or horizontal heat flow. Both the climatic and metering chambers provide variable air velocities parallel to the specimen surface.

Active Computational Support for Concurrent Building Envelope and Lighting System Design. Ardeshir Mahdavi, Liana Berberidou-Kallivoka, and Zhonghu Li. Carnegie Mellon University, Department of Architecture, (412) 268-6389, Fax (412) 268-6129.

Abstract: This paper introduces an active computational tool to generate and comparatively evaluate integrated building envelope and interior lighting system designs. The "generate-and-test" method is adopted to realize this active system feature. The tool is intended to facilitate the comparative evaluation of the generated envelope and room-lighting schemes in view of daylight utilization potential, visual performance criteria, and energy consumption levels.

Advancements in Thermal and Optical Simulations of Fenestration Systems: The Development of WINDOW 5. Finlayson E., Arasteh A., Rubin M., Sadlier J., Sullivan R., Lawrence Berkeley National Laboratory, (510) 486-6844, Fax (510) 486-4089; Huizenga C., Center for Environmental Design Research, University of California, Berkeley; Curcija D., Department of Mechanical Engineering, University of Massachusetts, Amherst; and Beall M., Scientific Computation Research Center, Rensselaer Polytechnic Institute, Troy, New York.

Abstract: WINDOW 5 scheduled for release in 1996 is the latest version of a tool now widely used by industry, the NFRC, and researchers, to design and rate windows. It will provide increased accuracy, a flexible and state-of-the-art user interface, and the capabilities to handle more product types.

WINDOW 5 includes THERM, a new 2D finite element thermal model with the capabilities to define and model the thermal performance of frames/dividers and their associated edge effects.

WINDOW 5 also will include a built-in version of RESFEN that calculates the orientation-dependent annual energy impacts of a given window in a typical residence in various U.S. climates, an improved angular/spectral model for coated and uncoated glazings, the ability to analyze the optical properties of nonhomogeneous layers, and the ability to model the effects of laminated glazing layers.

An Assessment of Interlaboratory Repeatability in Fenestration Energy Ratings—Part 1: Interlaboratory Comparison of Simulation Results. R. Christopher Mathis and Daniel J. Wise. National Fenestration Rating Council, (301) 589-6372, Fax (301) 588-0854.

Abstract: This paper presents the results from the first interlaboratory comparison (round-robin) of fenestration thermal transmission ratings (U-factors) acquired in accordance with NFRC 100-91$^{SM.}$ Procedure for Determining Fenestration Product Thermal Properties. The round-robin involved nine thermal testing laboratories and 18 certified simulators from 14 simulation laboratories. Each simulation laboratory used the same computer tools to calculate total product U-factor, center-of-glass U-factor, frame and edge-of-glass U-factor, surface temperatures, and other required information. This paper presents only the results from the simulation laboratory round-robin.

An Assessment of Interlaboratory Repeatability in Fenestration Energy Ratings—Part 2: Interlaboratory Comparison of Test Results. Daniel J. Wise and R. Christopher Mathis. National Fenestration Rating Council, (301) 589-6372, Fax (301) 588-0854.

Abstract: This companion paper to Part 1 above, presents the results from the test laboratory round robin portion of the first interlaboratory comparison of fenestration thermal transmission ratings (U-factors) acquired in accordance with NFRC 100-91$^{SM.}$. The results of the round-robin testing show fairly good agreement among laboratories for the window specimen.

Edge Conduction in Vacuum Glazing. Simko T. and Collins R.E., University of Sydney, Beck F.A,. and Arasteh D. Lawrence Berkeley National Laboratory, (510) 486-6844, Fax (510) 486-4089. (See Fenestration R&D, Fall 1996, p. 6.)

Abstract: Vacuum glazing achieves very low conductance by using an internal vacuum between the two glass sheets to eliminate heat transport by gas conduction and convection. Infrared thermography was used to analyze the thermal performance of prototype vacuum glazings, and for comparison, atmo-

*(See **Thermal VI**, page 10)*

Berkeley Lab photo by Don Fike

DOE Assistant Secretary Christine Ervin was presented with a sample of a low-emissivity window glazing by Andersen Window's Mike Koenig, and Cardinal IG's Jim Larsen, representing the one billionth square foot sold.

DOE's Ervin Briefed on Advanced Glazing Research and Industrial Partnerships

DOE Assistant Secretary for Energy Efficiency and Renewable Energy Christine Ervin recently got a first-hand look at Berkeley Lab's energy efficiency research and the industrial partnerships that help make it possible.

During her visit, Ervin was briefed on the latest advanced windows research by Building Technologies Program Head Steve Selkowitz and researchers Mike Rubin and Dariush Arasteh.

One billionth square foot of low-e glazing sold.

As a highlight of the briefing, a sample of low-emissivity glass was presented to Ervin by Mike Koenig of Andersen Corp., and Jim Larsen of Cardinal IG. The one-square foot sample of low-e (low-emissivity) window glazing, which represented the one billionth square foot sold, was intended to acknowledge the broad industry partnership with DOE over the last 15 years, which has lead to new markets for low-e glass and windows, and consumer energy savings of over $1.7 billion.

Koenig, who chairs NFRC's technical committee, and Larsen, who chairs the annual energy committee, described the latest advances in the National Fenestration Rating Council's (NFRC) rating and labeling program, and displayed a window bearing the NFRC label. Larsen focused on the importance of the newly developed Annual Energy Rating, which for the first time will provide a potential buyer with a comparative indicator of annual heating and cooling costs. Berkeley Lab researchers are directly supporting these efforts with the development of the computer tool RESFEN, which calculates a supplemental energy rating number.

An electrochromic prototype "smart window" from a recently launched electrochromics initiative was unveiled during Ervin's visit. The prototype, a key milestone for the first six months of the 50/50 DOE-industry cost-sharing program, was presented by Steve Sapers, Optical Coating Laboratory, Inc. (OCLI), who developed it in partnership with Andersen and Cardinal IG.

Visiting Researchers

Michael Donn, professor of architecture, Centre for Building Performance Research, School of Architecture, Victoria University, New Zealand, is spending his sabbatical leave with the Windows & Daylighting Group, conducting interviews with expert users about their use of simulation programs. The project explores the role that simulation may have in improving design through involvement of designers directly in evaluation of the performance of their buildings.

The principal outcomes expect to include better data for the improvement and development of simulation programs as design tools, a report describing the maintenance of quality assurance, and a brief for improvement of the education of new users of simulation software.

Donn's premise in this project is that while architects and clients are interested in environmental design, the simulation programs currently available often do not directly address their specific design tool needs.

Rosinde Duarte, a graduate student at the University of Coimbra, Portugal, worked with the Radiance lighting analysis software toward completion of her masters thesis. In collaboration with researchers Charles Ehrlich and Greg Ward, she developed a lighting-accurate model of the Coimbra classrooms.

These classrooms were recognized in "Building 2000" for their innovative use of daylighting features, including skylights with operable baffles and daylight redirection "tubes," which bring light from the second floor roof down to the first floor classrooms.

The results of her study will help the school's facilities managers predict the potential energy savings of the lighting system retrofit.

Fenestration Facts

"A daylighted building, no matter how well designed, saves energy only if the daylighting can effectively and reliably displace electric lighting usage. Most daylighting designers agree that, in nonresidential buildings, no amount of provision for convenient manual switching (even for 50 percent reduction of fixtures in use) will result in useful energy savings."

Concepts and Practice of Architectural Daylighting
Fuller Moore
1985

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Thermal VI Conference...

(continued from page 8)

spheric pressure superwindows. Research focused on mitigating the edge effects of vacuum glazings through the use of insulating trim, recessed edges, and framing materials. Experimental measurements of edge conduction using infrared imaging were found to be in good agreement with finite-element modeling results for a given set of conditions.

Issues Associated with the Use of Infrared Thermography for Experimental Testing of Insulated Systems. Griffith B., Beck F., Arasteh D., and Turler D. Lawrence Berkeley National Laboratory, (510) 486-6844, Fax (510) 486-4089. (See Fenestration R&D, No.1, p. 8.)

Abstract: This paper discusses the accuracy of using infrared scanning radiometers to generate temperature maps of building envelope components under steady-state, controlled laboratory conditions. Infrared imaging, with a reference emitter technique, is being used to create a database of temperature maps for a range of window systems, varying in physical complexity, material properties, and thermal performance. The data base is to be distributed to developers of fenestration heat transfer simulation programs to help validate their models.

Measured Performance of Selective Glazings. Klems J.H., Yazdanian M., and Kelley G.O. Lawrence Berkeley National Laboratory, (510) 486-5564, Fax (510) 486-4089.

Abstract: Measurements of the net heat flow through four selective glazings in comparison with clear double glazing under late summer outdoor conditions are presented. The solar heat gain coefficient (SHGC) for each glazing is extracted from the data and shown to be angle-dependent. Good agreement is found between measured properties and calculations with WINDOW 4.1.

New Correlations for Convective Heat Transfer Coefficient on Indoor Fenestration Surfaces—Compilation of More Recent Work. Dragan Curcija and William P. Goss, Mechanical Engineering Department, University of Massachusetts, (413) 545-2251, Fax (413) 545-1027.

Abstract: Recommendations for indoor fenestration surface natural convection heat transfer coefficients are given as a function of temperature difference, fenestration surface length, and inclination angle from horizontal. The angles of inclination cover both "winter" (surface heated from below) and "summer" (surface heated from above) conditions. The impact of the new set of correlations is studied for several typical fenestration system configurations and compared to heat transfer results using the old correlations.

New Tools for the Analysis and Design of Building Envelopes. Papamichael K., Winkelmann F., and Selkowitz S. Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA 94720, (510) 486-6854, Fax (510) 486-4089.

Abstract: This paper describes the integrated development of PowerDOE, a new version of the DOE-2 building energy analysis program with enhanced calculation capabilities and a new graphical user interface, and the Building Design Advisor (BDA), a multimedia-based design tool that assists building designers with the concurrent consideration of multiple design solutions with respect to multiple design criteria early in schematic design. Each of these tools allows faster and more accurate analysis of the thermal and daylighting impacts of fenestration options.

Rating the Thermal Performance of Swinging Doors: The Canadian Experience. Stephen Carpenter, Enermodal Engineering Ltd., (519) 884-6421, Fax (519) 884-0103; and Roger Henry, CANMET, Natural Resources Canada.

Abstract: This paper discusses the recent development of the Canadian standard for rating the thermal performance of swinging doors. This standard (CSA A453) defines the methodology for determining the U-factor, solar heat gain coefficient and annual energy performance (energy rating, or ER). The door standard defines the products to be evaluated and the computer simulation and physical testing procedures to determine the performance parameters.

Reducing Residential Cooling Requirements Through the Use of Electrochromic Windows. Sullivan R., Rubin M., and Selkowitz S. Lawrence Berkeley National Laboratory, (510) 486-6843, Fax (510) 486-4089.

Abstract: This study investigates the energy performance of electrochromic windows in a prototypical residential building under a variety of state switching control strategies. The DOE-2.1E energy simulation program was used to analyze the annual cooling energy and peak demand as a function of glazing type, size, and electrochromic control strategy.

An electrochromic material with a high reflectance in the colored state provides the best performance for all control strategies. The space-cooling load-switching strategy provides the best performance for all the electrochromic materials. The comparative performance of clear low-E, tinted low-E, and overhangs are compared to electrochromic.

The Glass Roof: Sloped Glazing Need Not Leak. Chris B. Makepeach and John O'Connor, Alberta Public Works, (403) 427-7667, Fax (403) 422-9673.

Abstract: This paper reviews and summarizes results of investigations of more than 100 leaking sloped aluminum and glass roof installations. Sloped glazing designs that are based on sole reliance of the exterior seals to provide a single line of defense to water entry have repeatedly proved to be a flawed approach. Designs where the water-tightness seals are placed in a protected location, with minimal contact with water and where water is controlled and redirected to the exterior through the design of the framing, have provided watertight installations.

Thermal Performance of a Hybrid Double-Envelope Building Model. Emad M. Afifi, The Savannah College of Art and Design, (912) 238-2409, Fax (912) 238-2436.

Abstract: This paper introduces a conceptual building model that integrates passive and mechanical environmental control systems. The performance of three double-envelope variations of the proposed model is compared with two variations of a single-envelope model. Hour-by-hour simulations for the Phoenix summer and winter design days are performed for the five models and results analyzed and presented.

Fenestration Facts

After interviewing hundreds of successful burglars, among many conclusions, the authors found that burglars avoid houses with double-glazed windows and storm windows. Apparently, burglars fear that the double-crash caused by breaking these windows while gaining entry is more likely to catch a neighbor's attention than breaking a single-glazed window.

Burglars on the Job: Streetlife and Residential Break-ins
Richard Wright
and Scott Decker

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User Facilities

Industry is invited to collaborate in the use of these facilities. In each issue of **Fenestration R&D**, we will take a closer look at one of our user facilities. Please contact the individual researcher listed under each facility to discuss potential use.

❒ ***Mobile Window Thermal Test Facility (MoWiTT)*** The MoWiTT facility contains two highly instrumented, side-by-side calorimetric test chambers that are used to test window and wall elements under actual outdoor conditions. The facility may be rotated to face in any direction and is currently located in Reno, Nevada, which experiences both summer and winter extreme climate conditions. It can directly measure solar heat gain and can be used to determine window and shading system properties for a wide variety of solar control options. With 200 data channels collecting data every few seconds, the facility can directly measure cooling load shapes on peak summer days with excellent time resolution. The facility can also be used to validate computer models and to compare various technologies in real time. Industry has used MoWiTT results to justify new product development.

Contact
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e-mail: JHKlems@LBL.gov

❒ ***IR Camera Test Facility*** This facility includes a high-resolution, infrared imaging camera, a computer processor/printer, and a cold/hot chamber to hold samples for testing. The camera system is portable and can measure surface temperatures that can then be correlated to various heat loss or gain parameters. The IR camera is useful for assessing heat loss from existing buildings in the field as well as from building components and appliances in the laboratory setting.

Contact
Dariush Arasteh
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❒ ***Thin-Film Materials Laboratory*** This laboratory includes a wide range of apparatus to deposit and analyze thin-film coatings for energy control purposes. The laboratory's thin-film deposition systems are used to make new types of selective and electrochromic coatings. The laboratory also includes spectrophotometers to measure solar, near IR, and far IR properties.

Contact
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❒ ***Sky Simulator*** The 24-foot-diameter sky simulator is a hemispherical facility used to test daylighting performance in scale-model buildings under controlled and reproducible conditions. Computerized control of light sources within the hemisphere can create luminous distributions typical of clear, uniform, or overcast skies representative of any desired location, orientation, climate, and season on Earth. It can also be used as a sun simulator to test shading strategies in scale models up to 1.5 square meters in size. Light levels within the models are measured by 60 photosensors and the measurements are used to predict daylight illuminance conditions within full-sized buildings. The facility is well-suited to test the effect of shading from overhangs, fins, awnings, shade systems, vegetation, and adjacent obstructions.

Contact
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❒ ***Solar Heat Gain Scanner*** This device is used to characterize the complex optical properties of glazings and shading systems that are geometrically complex, such as venetian blinds. The system measures transmitted and reflected energy and light at all incidence and outgoing angles. The scanner has been used to develop a new procedure to predict solar heat gain through complex shading systems.

Contact
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❒ ***Mulimedia Laboratory*** Design tools of the future will not only have faster and better modeling algorithms but will also have vastly improved user interfaces incorporating new multimedia software and hardware capabilities. The ability to integrate data and text with advanced graphics, animation, sound, and video will greatly enhance the value and usefulness of the next generation of design and analysis tools. The hypermedia computer lab contains the equipment needed to experiment with these emerging technologies and to prototype and test promising solutions.

Contact
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Software Available

❒ ***RESFEN 2.4*** is a WINDOWS-based PC program (RESFEN 1.4 for DOS) for calculating residential fenestration heating and cooling energy use and costs. This new program is currently being evaluated for possible use as part of a window rating system being developed by the National Fenestration Rating Council (NFRC).

❒ ***SUPERLITE 2.0*** is a PC program that calculates daylight illuminance distributions for complex room and light source geometries with tested accuracy. SUPERLITE will model daylight coming through as many as five openings and being reflected from as many as 20 opaque surfaces oriented in any direction.

❒ ***WINDOW 4.1*** is a thermal analysis PC program that is the de facto standard used by U.S. manufacturers to characterize product performance. The program is used by the National Fenestration Rating Council as the basis for development of energy rating labels for windows.

❒ ***THERM 1.0*** is a Microsoft Windows-based 2-D heat transfer analysis tool, based on finite element analysis and can model two-dimentional heat transfer with a minimum of simplifications to exact cross section geometries.

Contact
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Fenestration Facts

"In 1832 the Chance brothers of Birmingham, England, invented machine-rolled glass. Now instead of each sheet being made laboriously by hand, the molten glass could be squeezed between rollers onto a flat iron plate. No longer did windowpanes have to be small. The new rolling process produced sheets of sturdy plate glass that measured as much as 2 feet by 4 feet."

Let There Be Light
James Cross Giblin
1988

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NFRC Update

National Fenestration Rating Council

Technical Interpretations Policy Committee Formed

NFRC's newly formed Technical Interpretations Policy Committee (TIPC) met in Atlanta for the first time at the NFRC Task Group Meetings in February. The TIPC, a committee of seven representative members appointed by the NFRC, has the authority to act on and implement technical interpretations to questions regarding NFRC's technical procedures. The benefits of this new procedure are (1) a quicker turnaround on questions, which require an interpretation, and (2) more time available during regular committee meetings for the development of new procedures.

Other task groups, which met to discuss timely issues, included the Annual Energy Rating Task Group, the 100-96 (U-factor procedure re-write) Task Group, and the Recertification Policy Task Group.

A new *NFRC Certified Products Directory* has been published. To order a copy, contact NFRC.

The NFRC's Spectral Data Library is now accessible on the World-Wide Web. The location is *http://eande.lbl.gov/BTP/WINDOW/NFRCsdlib/s95.html.* (See page 3 for more Web details.)

NFRC Meeting Schedule

1996

April 16-20, 1996
NFRC Spring Membership Meeting
Royal Sonesta Cambridge
Cambridge, Massachusetts

June 18-19, 1996
NFRC Laboratory & IA Workshop
June 20-21, 1996
NFRC Task Groups Meeting
Sheraton Fiesta San Antonio
San Antonio, Texas

September 17-21, 1996
NFRC Fall Annual Meeting
Loews Ventana Canyon
Tucson, Arizona

November 7-8, 1996
NFRC Board of Directors Meeting
NFRC Offices, Silver Spring, Maryland
(301) 589-NFRC

For more information on:

- Administrative & Membership
- Certification Agency Program
- Communication and Education
- Compliance Assurance Program
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- Product Certification Program
- Publication Orders

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