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I AM PLEASED TO REPORT THAT THE BEST2 Conference, held April 12-14 in Portland, Oregon, was a complete success. Congratulations to the program and conference committees. I also would like to thank the many sponsors, supporting organizations and exhibitors for their support of this event. Based on the many conversations I had with attendees, they gained exceptional information and knowledge from the many presentations and displays at the conference.

The members of the Portland Building Enclosure Council (BEC) served as great hosts for the City of Roses, which proved to be an excellent venue for the discussion of a New Design Paradigm for Energy Efficient Buildings. I would again like to single out the principals who assembled the conference, Conference Organizing Chairman Rob Kistler and Program Chairs Drs. Mark Bomberg and Donald Onysko. Their work assembling a world-class program was nothing less than exceptional. I am confident the BEST3 Conference in Atlanta in 2012 will be equally beneficial for all attendees.

General Services Administration (GSA) Chief Architect Leslie Shepherd provided an excellent opening discussion to set the tone for the overall BEST2 Conference. He focused on the work of GSA and how it fits in the development of energy-efficient building strategies and supplying credible evidence for achieving efficiency in both new and existing buildings. Thank you, Les, for your support and providing this most appropriate start to the conference.

When BEST1 was held two years ago, it was an experiment that proved to be worthy of repeating. BEST2 confirmed our belief that the program was instructional and provided a forum to explore in greater depth issues affecting building enclosures. BEST2 had two-fold the attendance of BEST1, a testament to the value industry members have given to this topic.

In this issue of JBED, Building Enclosure Technology and Environment Council (BETEC) Chair Wagdy Anis will cover the overall BEST2 Conference. However, I want to emphasize here the caliber of sessions presented and thank each of the speakers for their thought-provoking presentations. To view BEST2 program papers, please visit www.thebestconference.org.

We look forward to the 2012 meeting in Atlanta, Georgia. I am confident the Atlanta-BEC under the leadership of Larry Ray, who serves as Conference Chair, along with Program Chairs Mark Bomberg and David Yarbrough, will provide an equally informative and instructional program.

As the BETEC advances its work and the BECs grow throughout the United States, their efforts, combined with the work achieved in the BEST Conferences is nothing short of a recipe for success to improve building enclosures. I would encourage all BECs to continue the discussions addressed at this latest conference and identify new issues for BEST3.

If you are not already a member of a local Building Enclosure Council, please consider becoming a member and engaging in the discussions offered by these all-inclusive groups. I am confident you will find the relationships you build engaging and beneficial. Members of local BECs include architects, engineers, contractors, consultants, material suppliers, students and others.

To learn more about connecting with a local chapter, visit the Institute’s website at www.nibs.org and select Building Enclosure Council. There you’ll find information on current chapters as well as a number of resources on building enclosure design.

I hope you find the coverage in this issue informative.

Henry L. Green, Hon. AIA
President
National Institute of Building Sciences
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*Reed Construction Data, April 6, 2010
Message from the Building Enclosure Technology and Environment Council

Heat and moisture flow in buildings are definitely three dimensional. However, we tend to get boxed into thinking in one or two dimensions because of the limitations of the tools we have available, usually 1D and 2D tools. The problem is that some of the situations we encounter on projects are not reasonably examined using 1D or 2D tools. That is when 3D tools become essential; hence this very limited foray into simulations.

WELCOME TO THE SUMMER 2010 edition of JBED, the Journal of Building Enclosure Design. In this edition, we will introduce you to some of the sophisticated work being done using simulation tools. We will bring you samples of the cutting-edge simulation activities going on that use whole building, transient, hygrothermal tools and more advanced 3D, finite element analysis tools.

Heat and moisture flow in buildings are definitely three dimensional. However, we tend to get boxed into thinking in one or two dimensions because of the limitations of the tools we have available, usually 1D and 2D tools. The problem is that some of the situations we encounter on projects are not reasonably examined using 1D or 2D tools. That is when 3D tools become essential; hence this very limited foray into simulations.

On a different topic, the BEST2 Conference was a resounding success, as you will read in the synopsis included in this issue. We departed from the usual format of bringing you samples of the excellent papers and research presented by the U.S., Canadian and international participants. Instead we provide a synopsis of the overall conference message. Generally speaking, the plenary presentations included and identified visionary directions for the industry not contained in the technical presentations. These overall messages are predominantly what we tried to bring you in this issue. Just as the BEST1 proceedings are now online, you will be able to download a copy of the BEST2 technical proceedings from www.thebestconference.org in the near future.

The Building Enclosure Technology and Environment Council (BETEC) Board met in Portland subsequent to the BEST2 Conference. I would like to bring you some of the highlights covered at that meeting:

• BEC National wanted to test if BEC education programs can be more economically effective when nationally known speakers present webinars. On May 4, BEC National held a webinar with the American Institute of Architects entitled Deep Energy Retrofits for Existing Homes, with speaker Betsy Pettit, FAIA.
• A workshop targeting high-performance buildings entitled Why Green Buildings Cannot Be Built without Air Barriers, is planned for October 2010.
• Buildings XI Conference, “the conference of conferences of building science,” is on schedule for December 2010.
• Larry Ray, Chair of the Atlanta Building Enclosure Council (BEC) announced that the BEST3 Conference will be held in Atlanta in 2012. Preparation for the event is already under way.
• BETEC has started an outreach program starting with a meeting with the American Architectural Manufacturers Association (AAMA). Dave Altenhofen will formulate a plan for future outreach efforts to coordinate within the industry.

The next BETEC Board meeting and annual BETEC meeting will be held in Clearwater, Florida, at the Whole Buildings XI Conference, in December. I hope to see you there.

Wagdy Anis, FAIA, LEED-AP
Chairman, BETEC Board
Chairman, JBED Editorial Board
Principal, Wiss Janney Elstner
Judd Allen Group specializes in helping our clients achieve the highest level of quality, design, and energy efficiency by focusing on exterior envelope assessments, thermal analysis, & design recommendations that comprise many exterior components, such as waterproofing, masonry, window/curtain wall installation, metal panels, rain screen & many other exterior envelope materials.

We pride ourselves in being up-to-date with all exterior materials and methods to help guide our clients with attention to efficiency and aesthetics.
Assessing Moisture Performance of Exterior Wall Assembly Design in Wood-frame Construction in Beijing, China

By Curt Copeland, Paul Newman, Phalguni Mukhopadhyaya, David van Reenen, Kumar Kumaran, Ramez El Khanagry and Ehab Zalok

THE CANADIAN FORESTRY INDUSTRY, REPRESENTED by Canada Wood, is working with Asian governments to establish wood frame construction in those countries. The objectives are to provide competitive and quality housing to meet housing needs and to develop growing and sustained markets for Canadian wood products. While there are numerous challenges, those relating to building envelope design and construction are the most serious. Among them, the hygrothermal characteristics of exterior wall and roof design in the hot/humid and mixed climates of southern Asian regions, and the concomitant risk of issues related to molds, decay and termite infestations within the wood frame assemblies, are the most insidious. In some ways, they are the most serious threat to achieving Canada Wood objectives in specific regions of China and Taiwan. North America has limited experience in providing adequate answers to this threat.

As a result, Canada Wood has joint ventured with the National Research Council Canada – Institute for Research in Construction (NRC-IRC) to examine the performance of selected wall and roof designs in the Beijing and Shanghai climates of China and in several regions of Taiwan using the hygIRC-2D simulation tool. While Canada Wood has begun to monitor moisture levels within a few wood building assemblies and to examine already-constructed wood-frame structures for moisture-related problems where feasible in China, more time and research is required to obtain credible field performance data.

Simulation results and subsequent analyses have helped to provide guidance on the relative performances and suitability of these assemblies for wood frame construction in the regions (for example, Guides to Good Practice for Wood-frame Construction in China and Taiwan and other similar advisories; regional training programs; the development of appropriate sections of the Shanghai Local Code on Wood Frame Construction; and standard design drawings).

This paper presents the findings of one aspect of this research project: three exterior wall designs in the Beijing region. For information on an earlier phase of this research project, which focused primarily on Shanghai and Taichung, Taiwan, please refer to the publications mentioned above (Mukhopadhyaya et al 2008; Mukhopadhyaya et al. 2009).

RESEARCH OBJECTIVES AND SCOPE

The research objective of the overall project is to evaluate the hygrothermal performance of alternative wood-frame building envelope designs in these Asian regions using the hygrothermal simulation tool hygIRC-2D, combined with subsequent analyses. Six exterior wall designs and unvented roofs of varying designs have been tested in the regions.

Exterior walls were tested for vapor diffusion and also for three levels of air leakage combined with vapor diffusion. Walls were also tested for vapor retarding versus normal latex finishes on the interior surface, different moisture loadings of wood members before enclosure with drywall, rain screen versus no rain screen and varying assumptions of interior climatic conditions (RH and temperature).

The simulation results were processed to provide extensive information including the RHT index (moisture response indicator) and moisture content readings in wood structural members (upper and lower plates) and wood structural sheathing.

SIMULATION TOOL hygIRC-2D

The hygrothermal simulation tool hygIRC-2D, is a computer-aided numerical model that can predict the moisture response of building envelopes (Hens 1996). It was developed by researchers at NRC-IRC. The hygIRC-2D is continuously upgraded to meet new requirements and provide additional analytical information. Interested readers can refer to publications by Karagiozis (1997) and Djebbar et al., (2002), which outline the formulation of the combined heat, air and moisture transport equations used in hygIRC-2D and the techniques used to solve them numerically.

The reliability of hygIRC-2D outputs has been established through laboratory measurements and benchmarking exercises (Maref et al. 2002; Maref et al. 2004; Hagentoft et al. 2004). The effective use of hygIRC-2D to analyze and obtain meaningful results, however, demands a proper physical understanding of the problem, an appropriate definition of input parameters and the ability to judiciously interpret the outputs from the simulation tool (Mukhopadhyaya and Kumar, 2001; Mukhopadhyaya et al. 2001; Kumar et al. 2003).
Basic inputs and assumptions for modelling

Construction details

Three exterior wall designs were tested in Beijing: SuperE®, low cost and cool climate.

- **Wall 1 – SuperE®**: This wall uses 25 mm XPS (extruded polystyrene rigid insulating panels) on its exterior side, underneath the rain screen and exterior finish and over the sheathing membrane. The wall cavity is filled with glass fiber insulation and the interior finish is painted dry-wall without polyethylene underneath. This wall has been used successfully in Japan, including the hot/humid and mixed climatic regions of its southern regions, for a number of years under Canada’s SuperE® housing program (www.super-e.com). The sheathing or drywall may be installed as the air barrier.

- **Wall 2 – low cost**: This wall differs from the SuperE® wall in that it does not use XPS on its exterior side. The material and installation costs of the XPS are therefore eliminated, although these may be offset somewhat by the need for more glass fiber insulation and therefore wider studs and plates to achieve the same level of thermal performance.

- **Wall 3 – classic cold weather**: This wall differs from the low cost wall in that it uses polyethylene under the drywall. It is traditionally constructed in most regions of Canada, where climates are essentially in the cool category with heat and humidity limited to relatively short summer periods. The polyethylene is installed as the air barrier but also acts as a Type I vapor retarder.

Air leakage

The performance of all three walls was tested for vapor diffusion independent of air leakage, followed by simulations with varying levels of air leakage. Varying the rates of air leakage helps explain the relationship between air leakage rates and hygrothermal response.

An air leakage path was created through the wall assembly. The air enters/exits, depending on the nature of indoor and outdoor pressure, through a crack at the exterior top of the wood-framed wall and then travels through the insulated cavity and exits/enters through a crack at the interior bottom of the wall. The size of the cracks was changed to simulate various levels of air leakage. This size is based on the normalized leakage area (NLA), which is the area of the crack in cm² divided by the area of the wall in m². For Beijing, two levels of air leakage were examined for each of the three walls: 0.7 and 1.5 NLA.

An air leakage of 1.5 NLA was assumed to approximate building practices without any attempt at an air barrier. It therefore represents a worse case scenario. An air leakage of 0.7 NLA was assumed to approximate the installation of a poor air barrier. It therefore represents a worse case scenario for air barrier installation.

Material properties

The *hygIRC-2D* simulation tool requires eight sets of material properties. These properties are air permeability, thermal conductivity, dry density, heat capacity, sorption characteristics, suction pressure, liquid diffusivity and water vapor permeability. These materials’ properties were obtained from the NRC-IRC’s hygrothermal materials’ properties database (Kumaran et al (2002); Kumaran et al (2004); Mukhopadhyaya et al (2004)) and were determined in the IRC’s Insulation and Building Materials Laboratory.

Environmental conditions

Hourly recorded Beijing weather data was used as outdoor/external boundary conditions. The *hygIRC-2D* simulation tool requires the following hourly-recorded weather components: temperature, relative humidity, wind velocity, wind direction, rainfall, solar radiation and cloud index. Weather data for Beijing from the year 2004, used in the simulations, was obtained from the weather bureau of China. Compared to Shanghai or Taiwan, the Beijing climate is much drier and cooler in the winter period when heating is necessary. Summers are similar to those of Shanghai, with high humidity and temperatures, but are less severe and for shorter periods. **Figure 1** shows a graph of the

![Figure 1. Temperature, relative humidity and rainfall from Beijing weather data for 2004.](image)
temperature, relative humidity and rainfall for Beijing for the year 2004.

The indoor conditions (temperature and relative humidity) used in the simulations were for a controlled indoor environment based on summer and winter seasons, according to criteria specified in the Specifications to National (Canada) Energy Code for Houses, (Swinton and Sander, 1994). Indoor conditions for Beijing were developed based on conversations with building science professionals who had knowledge of building practices in China. In the summer, the indoor temperatures were 78.8°F (26°C) and 65 percent relative humidity. In the winter the indoor temperatures were 64.4°F (18°C) and 40 percent relative humidity.

Assumptions of indoor climatic conditions have been refined in more recent simulations for Shanghai and regions of Taiwan as the hygrothermal response within the exterior wall cavity is highly sensitive to variations in interior climatic conditions. Moreover, the assumption of a sudden shift in interior climatic conditions from winter to summer and vice-versa causes a sudden shift in the moisture levels calculated for the various materials, including wood products. In addition, air conditioning and natural ventilation practices vary significantly between regions. More work is required in this area.

**SIMULATION RESULTS**

HygIRC-2D simulations have generated a significant amount of data for this project which, subsequently, has been post-processed for the detailed evaluation of the hygrothermal response of the building envelopes. Post-processing produces the following graphical displays: (1) RHT analysis for 80 percent RH and 32°F (0°C) temperature, hereafter referred as RHT80. The second set was with an RH of 95 percent 32°F (0°C) temperature, hereafter referred as RHT95. The cumulative RHT was a summation done on an hourly basis for the final two years of the simulation.

The RHT index has limitations and is intended to be used with other analytical outputs. For example, different walls with similar cumulative RHT values may have different hygrothermal responses. Similarly, different climates can produce similar cumulative RHT values. The threshold RHT index value that defines safe and unsafe hygrothermal designs of a wall system is yet to be determined. IRC researchers will work on this issue in the near future.

**Wood moisture content trends**

Moisture content of wood structural members and sheathing products within the wall and roof assemblies is also a useful output. Moisture content can be measured on site with moisture meters and with sensors within assemblies periodically over extended periods. This enables comparisons of actual measurements with simulated results. Moreover, the relationship between moisture content by wood species and the risk of molds, decay-inducing fungi and even termites is more apparent for those involved with wood products and wood product research (Clark et al. 2005).

The hygIRC-2D simulation tool is able to calculate and record moisture content hourly at any location for any wood component in the building assembly, including those areas particularly prone to moisture accumulation. This enables trend analysis showing peak levels, periods when threshold levels are exceeded and periods when drying occurs.

The RHT index, as defined in this, study is:

$$\text{Cumulative RHT} = \sum (RH-RHX) \times (T-TX)$$

for RH>RHX% and T>TX°C at every hour of the simulation where RHX and TX are the threshold values for relative humidity and temperature respectively.

In this set of simulations two sets of threshold levels were used. The first set was with an RH of 80 percent at 32°F (0°C) temperature, hereafter referred as RHT80. The second set was with an RH of 95 percent 32°F (0°C) temperature, hereafter referred as RHT95. The cumulative RHT was a summation done on an hourly basis for the final two years of the simulation.

The RHT index has limitations and is intended to be used with other analytical outputs. For example, different walls with similar cumulative RHT values may have different hygrothermal responses. Similarly, different climates can produce similar cumulative RHT values. The threshold RHT index value that defines safe and unsafe hygrothermal designs of a wall system is yet to be determined. IRC researchers will work on this issue in the near future.

**RHT index – hygrothermal performance indicator**

It is widely accepted that wood building materials may be subject to deterioration under the combined effects of temperature and moisture. The most deleterious conditions are those in which moderate or high temperature is coupled with high humidity for extended periods (Nofal and Morris 2003). This study uses a long-term hygrothermal response indicator, called the RHT index, derived from the relative humidity (RH) and temperature (T) conditions inside the building envelope cross-section over a period of time for any specific area of the cross-section. The RHT index is an indicator used to quantify and compare the hygrothermal response of the wall assembly. This index captures the duration of moisture and thermal conditions coexisting above threshold RH and T levels. Generally speaking, a higher value of RHT index indicates a greater potential for moisture-related deterioration. While RH and T are given linear weight in the RHT index, this may not always be the case for some materials when assessing their long-term performance under varying and elevated moisture conditions. An appropriate weighting for RH and T can be determined only through controlled long-term experiments.

![Figure 2. RHT80 for Super E® wall with no air leakage.](image)
DISCUSSION

This section focuses on the results of testing three exterior wall designs in the Beijing climate and how these particular results have been incorporated into guidelines for construction design and on site building practices in that region of China.

Wall 1: SuperE®

The RHT index (RHT) showed low levels of hygrothermal intensity for this wall when tested in the Beijing climate. When tested for diffusion only, RHT was at the lowest range throughout the cavity [FIGURE 2]. Even when tested with diffusion and high air leakage (NLA 1.5 no air barrier; worst case scenario), there was some, but limited, hygrothermal intensity in the path of the air leak over the bottom plate [FIGURE 3]. When tested with diffusion and reduced air leakage (NLA 0.7 limited quality air barrier), the RHT was at proportionately lower levels.

Under all scenarios for this wall in Beijing, moisture content levels in top plates and plywood sheathing remained under 15 percent for every month of the year. Under the high air leakage scenario (NLA 1.5) the moisture content in the bottom plate did rise marginally above 20 percent from May to October. In these circumstances there may be some (but limited) risk of biological activities in the wood.

In Beijing, the rain screen made no appreciable difference to vapor-induced moisture levels within this wall cavity. As a result, consideration will be given to not recommending the rain screen for Beijing as it is not a high rainfall area and the rain screen is a cost factor. Similarly, vapor retarding paint over the drywall made no appreciable difference to the Beijing simulation test results.

As with Shanghai and Taiwan, the SuperE® wall outperformed the others in every category in Beijing. It is the recommended wall in the Guide for Beijing as well as elsewhere. It is considerably less sensitive to air leakage than the other two walls, although an effective air barrier is still recommended.

Wall 2: low cost

When tested for diffusion and no air leakage [FIGURE 4], RHT showed some (but limited) hygrothermal intensity in the cavity behind the wood sheathing. This would have taken place during the winter heating period, given the relatively low vapor diffusion permeance of the wood panel sheathing and the cooler temperatures without the XPS that is on the SuperE® wall. Painted drywall, on the other hand, facilitates greater drying to the building interior during the hot and humid summer cooling period. However, when diffusion was combined with high air leakage [FIGURE 5], RHT showed high hygrothermal intensity, concentrated in the bottom plate near the leak at the drywall/plate interface. This would occur during the summer cooling period. As air leakage was reduced, the RHT reduced as well.

The moisture content of sheathing and top plate was well below 20 percent for the entire year, except in the case of the wood panel sheathing under the no rain screen scenario when moisture content marginally exceeded 20 percent for a short period in the winter heating period. However, moisture content in the bottom plate showed particularly high levels (for example, above 30 percent, under high air leakage during the summer cooling period). The levels of moisture content reduced considerably as air leakage was reduced. Without air leakage, moisture content was constant at 15 percent over the full period.

The Guide will recommend the low cost wall only as a higher-risk wall in comparison to the SuperE® wall and only when an effective air barrier is installed.

Wall 3: classic cold weather

As expected, when tested for diffusion and no air leakage [FIGURE 6], RHT was relatively high within the cavity behind the poly with its very low vapor permeance. This, of course, would take place in the summer cooling period. While these RHT levels appear significant, they are far less serious in comparison to comparable tests of this wall design in Shanghai.
or Taichung, where it is not recommended under any conditions. Interestingly, under high air leakage (FIGURE 7), the RHT in the region of the poly is reduced when compared to the low air leakage scenario. However, as with the low cost wall, RHT is concentrated over the bottom plate near the plate/drywall interface. Moreover, the moisture content trends for this wall are similar to those for the low cost wall, where increasing rates of air leakage correlate with increasing moisture content in the bottom plate.

As with the low cost wall, The Guide will recommend the classic cold weather wall only as a higher risk wall in the comparison to the SuperE® wall and only when an effective air barrier is installed.

CONCLUSIONS

The following conclusions can be drawn from this study; however, it is to be noted that these conclusions are dependent on the assumptions outlined in the paper and relative comparisons of numerically simulated performance of wall assemblies.

- In the Beijing climate, under conditions of no air leakage, the SuperE® wall showed the lowest intensity of hygrothermal response and lowest moisture content levels, with the low cost and classic cold weather walls showing higher levels.
- Under conditions of high air leakage (worse case scenario) according to the leakage path introduced into the model, the increases in RHT and moisture content levels in the SuperE® wall were at the minimum level. However, this same path and magnitude of high air leakage increased RHT and moisture content levels of bottom plates significantly in both the lower cost and classic cold weather walls. However, these levels were reduced as the air leakage was reduced.
- As a result, the SuperE® is recommended as the high-performance wall with respect to hygrothermal intensity and the concomitant risk of issues associated with biological activity. The other two walls are recommended as higher risk and only when an effective air barrier is installed.

- The presence of the pressure moderated rain screen had virtually no impact on the hygrothermal response of the SuperE® wall, whereas the moisture content of the sheathing increased in the winter heating period for the other two walls, but not enough to cause concern.
- The presence of vapor retarding latex paint in lieu of normal latex paint over the drywall had no significant impact on the hygrothermal response for any of the wall designs.

A full list of references for this article is available upon request. Please email ssavory@matrixgroupinc.net.

Curt Copeland and Paul Newman are with Canada Wood and the Council of Forest Industries. Phalguni Mukhopadhyay, David van Reenen and Kumar Kumaran are with the Institute for Research in Construction, National Research Council, Canada. Ramez El Khanagry and Ehab Zalok are from Carleton University.

Figure 5. RHT80 for low cost wall with high air leakage (1.5 NLA).

Figure 6. RHT80 for classic cold weather wall with no air leakage.

Figure 7. RHT80 for low cost wall with high air leakage (1.5 NLA).
Airtightness Testing - Not Just for Homes Anymore

Airtightness testing of homes has been around for more than 20 years. Various energy programs and fluctuating energy bills have provided homeowners an incentive to improve the airtightness of their homes. Energy tax credits can also be received by the homeowner but only if the house airtightness has been verified that it is less leaky after remodeling than before.

In England, airtightness testing of buildings over 10,000 square feet was the first regulation initiated to reduce energy consumption. Efforts to make commercial buildings more energy efficient in the U.S. has only recently been incorporated into various “green” initiatives. Tests of commercial buildings show that they tend to be more leaky than the average house, based on air leakage per square foot of surface area. That means that commercial buildings are less energy efficient than the average house.

To measure the actual airtightness of a large building means more air is needed to maintain a reasonable test pressure. The Energy Conservatory, a leader in airtightness testing, has kits available to directly measure more than 18,000 cubic feet per minute of air leakage. Multiple kits and fans can be used simultaneously to generate more air for accurate and reliable measurements of air leakage for testing before and after retrofitting.

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THE GROWING PERFORMANCE REQUIREMENTS introduced gradually in building codes has forced architects to include engineering in the early phases of the architectural design to address potential vulnerabilities and efficiencies of the design. This article illustrates such a process using the example of a curtain wall design. The efficiencies identified by the process may serve as an indication of the efficiencies possible in the future mainstream facade system design. In the illustrated case I present here, the curtain wall was re-integrated into the main load-resisting frame of the building, closing the 140-year period of decoupling of the lateral load resistance as a principle of the curtain wall design.

BACKGROUND INFORMATION
This project consisted of a high-budget remodeling of an existing single family residential house, including the replacement of the curtain wall facing the Atlantic Ocean. The building is located in Climate Zone 4B (ASHRAE 90.1), in very close vicinity to the shore, making it subject to Windborne Debris Region code requirements. The existing curtain wall was approximately 50 ft (15.24 m) tall and 150 ft (45.72 m) long, with vertical mullions hidden behind flanges of steel “W” sections of structural columns. This article describes the initial engineering efforts undertaken in the late design development (DD) and early construction document (CD) stages to assist the architect in design.

GOAL
The goal of the architectural design was to increase the overall transparency of the curtain wall. Columns and mullions were omitted in architectural renderings and engineers were instructed likewise.

CHALLENGES
The project team encountered several challenges, ranging from the ratcheted structural and thermal code requirements and ending with the difficulties to find any off-the-shelf components suitable for the incorporation in the design.

1. Architectural emphasis on the transparency of the wall was found to be in acute conflict with the structural support requirements. This resulted in the early decision to integrate the curtain wall mullions into the main structural load resisting frame of the building load. However, the architect limited the width of the curtain wall mullions, now performing the structural column function in order to keep sightlines tight and increase the transparency of the wall. The width limit was 2.5 in (6.35 cm).

2. The existing curtain wall was designed and built to resist fraction of the current design load. By the time we designed the new wall, the code requirements recognized the unique challenges associated with high-wind environments and windborne debris, causing the need for substantially bulkier structural components.

3. The current code also included more stringent energy requirements, including the fenestration U-value and the solar heat gain coefficient (SHGC). These increased requirements made the achievement of the structural goals more challenging.

4. The existing curtain wall was built very efficiently, with vertical mullions hidden behind flanges of steel “W” sections of structural columns. This made the goal of increased transparency tougher to achieve.

5. The structure of the roof was modifiable only in a very limited area adjacent to the curtain wall.

6. The roof features a 20 ft (6 m) deep cantilevered overhang above the curtain wall. This overhang collects and transfers large forces onto the curtain wall mullions, which now perform the function previously performed by structural columns (FIGURE 1).

7. The architectural design featured glass panes installed alternatively onto either the front or the back faces of the mullions. The resulting offset of the heat flow control layer resulted...
in the thermal bridging and risk of condensation at the intermediary mullions and at the intersections. Also, the drainage and ventilation of the joinery became unwieldy (FIGURE 2).

8. The architectural design featured several adjacent glass panes installed onto the back faces of the mullions, which left the entire sections of mullions on the exterior. This configuration turned these mullions into heat sinks, creating a risk of condensation on the interior glass edges. The structural adhesive mode of glazing support and size of glass put the warrantability of the sufficiently warm insulated glazing units (IGU) spacer in question (FIGURE 3).

9. The architectural design featured several inconspicuous pivot doors. The doors’ sashes were to be visually unobtrusive and the door size was to conform with the curtain wall panels, 10 ft by 10 ft (3 m by 3 m) (FIGURE 4).

10. Pivot doors are challenging to airproof and waterproof due to their shape and mode of operation that prevents a seal in the neighborhood of the pivot hinges.

11. Research on the market found that none of the components considered met the design requirements available.

The entire curtain wall, including doors and hardware, would have to be custom designed, tested and made. This caused difficulties in estimating and verifying the budget goals.

12. The size of the job was relatively small for its level of sophistication. Manufacturers and installers of custom curtain walls are generally not interested in production, testing and installation of a glazing for a single-family house. Conversely, available installers normally occupying the single-family residence (SFR) corner of the market would be unable to deliver the desired product.

13. The custom curtain wall would need to be individually tested to verify the design assumptions at a cost roughly equivalent to the cost of the entire wall if it were an off-the-shelf system.

A DESCRIPTION OF THE PROCESS

The architectural goal on the transparency of the wall conflicted with the structural support requirements. This resulted in the early decision to incorporate the curtain wall mullions into the main structural load resisting frame of the building load. The design team decided that glazing would need to be laminated and insulated and adhered structurally to the framing in order to meet the structural, thermal and impact requirements.

The curtain wall was designed as a barrier wall, due to the difficulties associated with the offsets of glazing planes. The framing material of choice was stainless steel, due to weathering and constructability issues. The framing was coated by intumescent paint to meet the required fire rating. The sections needed to be built up by continuous welding to achieve an efficient use of the restricted space. A stiffening beam was designed and re-designed within the depth of the roof assembly, along the curtain wall’s head to distribute the load, bridging the roof trusses and curtain wall mullions.

As the architect clarified and changed his designs, the structural engineer designed and re-designed the curtain wall mullions and connections in order to meet the structural requirements, including the wind, snow and dead-load resistance of the wall and the
roof, as well as the maintenance loads in numerous iterations.

The thermal bridging at the glazing plane offsets required close coordination between the architect, structural engineer and the in-house building enclosure consultant responsible for the air, water and thermal performance. Several iterations of design of the split mullions incorporating continuous molded plastic foam thermal breaks were modeled and simulated structurally and thermally in the 2D steady-state software (FIGURE 3). The 2D modeling was performed at this phase due to its relatively fast modeling speed.

The curtain wall is built of relatively low heat-storage materials, therefore, only the steady state simulations were performed, assuming the winter design temperatures and compared with the interior design dew point. The dark sky radiation was pre-set at the level set by the National Fenestration Rating Council (NFRC) model (FIGURE 3).

The curtain wall is built of impermeable materials: stainless steel, glass and EPDM gasketing. Therefore, no hygrothermal analysis were performed, other than comparisons of the internal surface temperatures obtained from the steady-state simulations with the dew point calculated on the basis of the range of the interior design, humidity and temperature. The dew point was calculated to be approximately 42°F (5.5°C).

3D MODELING
Curtain wall bay

Once a structurally safe configuration was found that passed the 2D steady state simulations, the design was slated for the 3D thermal modeling. The unique configuration of the curtain wall made it impossible to assess the temperatures of the interior surfaces in the vicinity of the four-way mullion intersections at the glazing offsets.

Addressing the thermal bridging required interrupting the vertical mullions to prevent the heat transfer between the exterior and interior portion of the mullion. Since the mullions were not only subjected to the lateral wind load and glazing dead load, but also to the structural loads transferred from the roof, the load was transferred by a moment-connection featuring the central stainless steel fin encapsulated in two plastic foam shells and transferring the load via four massive stainless steel pins onto the stainless steel mullion shells (FIGURE 5).

Once the configuration was determined to be acceptable structurally, the 3D simulation was performed. The parametric solid model was built using flat profiles imported from the architectural software (FIGURE 2).
The model was initially meshed in a draft resolution to allow for an early verification. Boundary conditions and materials were defined on the basis of the previously-built 2D models. The meshed 3D model, with defined boundaries and materials, was simulated in the steady state and the results at the extremes were compared and validated by comparison with the previously built 2D models (FIGURES 3, 8, 9).

The 3D model was also used for static simulations, with simple 2D calculations compared with the results obtained on the continuous sections used to validate the overall results. The resulting mullion size was 8.5 in by 2.5 in (21.59 cm by 6.35 cm) (FIGURES 6, 7).

**Pivot door**

The pivot door was statically modeled on the basis of the predetermined sash configuration to verify its soundness (FIGURE 4). The door wind-load and slamming resistance were modeled with the assumption of the sash being welded at its corners and multi-bolting perimeter hardware. The water and air performance would be achieved by bulb gaskets engaging continuous stainless steel “lips”. These gaskets would overlap in elevation at the pivot locations, creating discontinuities.

The architect had not allowed drip edges, therefore the head of the outward swinging half of the door and the sill of the inward swinging half of the door, would be vulnerable to leakage. The IGU was designed structurally to adhere to the front of the sash, therefore, the sash would deliver heat to the glass edges, helping to prevent the winter condensation. This condition was assumed to be much better than the previously-described components of the curtain wall, that thermal modeling was not performed on the doors.

**RESULTS**

The results confirmed early predictions of the condensation risk associated with the discontinuities of the thermal control layer of the facade and the discrepancies in the areas of the exterior and interior curtain wall surfaces (FIGURES 8, 9). The 3D modeling was found necessary to assess these conditions because they were impossible to predict when interpolating 2D results.

The 2D modeling was found useful in assessing the continuous sections of the details (for example, in the middle of mullion section lengths). The 2D modeling software (THERM) used in this example was validated by the NFRC, therefore its material and boundary conditions were in-turn used to model and validate the 3D model and its results were used to validate the results of the simulations (FIGURE 3).

**CONCLUSION**

The analyses identified the condensation risk and yielded recommendations for addressing the identified
condensation risk by addition of either interior drainage (sill pans) or sources of heat (heat tracing wiring) and avoidance of moisture-sensitive materials in the wet areas. A change in the architectural design was not considered a viable alternative at the time.

The procedure was a useful illustration of the process of finding seldom-explored efficiencies in the design and construction processes. In this illustrated case, the curtain wall was reintegrated into the main load resisting frame of the building, allowing for the desired transparency and eliminating the redundant vertical load bearing members.

The design team left some design options on the table. Utilization of strain-oriented fiber composite materials would allow for more optimal addressing of the loads within the restraints placed by the architectural design. Placement of a structural exoskeleton above the roof overhang would be another way of addressing some of the loads.

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The Evolution of Hygrothermal Design: WUFI to WUFI-Plus

By Achilles Karagiozis, Andre Desjarlais, Hartwig Kuenzel and Andreas Holm

OUR CURRENT STATE-OF-THE-ART construction design approach is to integrate principles of sustainable design. The philosophy of sustainable building construction relies on designing physical objects, the built environment and services to comply with the principles of economic, social and ecological sustainability. This requires the architect to design with low-impact environmental materials, energy-efficiency (embodied and operations) and quality and durability (longer-lasting and higher-performance) to create healthy buildings (a good indoor environment) and recycling potential.

From the above disciplines of sustainable design, heat, air and moisture processes (HAM) play a critical role in developing the necessary yardstick for energy-efficiency, durability and healthy buildings. Energy-efficiency and comfort have recently been two main considerations in building designs, while durability has always been a critical parameter. Yet, until recently, no HAM design tools/methods were readily available.

Recently, the increasing demand for better-performing calculation methods to assess the moisture behavior of building components prompted an international collaboration between the Oak Ridge National Laboratory (ORNL) in the United States and the Fraunhofer Institute for Building Physics (IBP) in Germany to develop a hygrothermal design tool named WUFI-ORNL/IBP. This hygrothermal design model can assess the response of building envelope systems in terms of heat and moisture loads and can also provide a very useful and fair method for evaluating and optimizing building envelope designs. Today, if architects and engineers do not use the WUFI (Wärme und Feuchte instationär) hygrothermal model for building envelope design, or WUFI-Plus for the whole building design, they are assuming unnecessary field failure risks for themselves and their clients.

HISTORY OF WUFI AND WUFI-PLUS

Building envelopes respond to thermal, moisture and pressure excitations in a very dynamic fashion each hour of the year. Over the past 10 years, a number of U.S.-based standards organizations such as the American Society for Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) and ASTM International, as well as international-based organizations such as the International Energy Agency (IEA), have recognized the critical importance of hygrothermal analysis.

Simply put, the major changes in building codes that require more insulation, vapor retarding and drainage and cavity ventilation, and the continuous introduction of newly-reformulated construction materials or improved materials and systems, makes it an insurmountable task to understand building physics. Hygrothermal models have become mainstream in the United States and Canada and the WUFI-family models developed by ORNL (Karagiozis et al, 2001) and IBP (Kuenzel et al, 1994) (Holm et al 2003), have become our current industry standard for the design of building envelope systems and buildings.

The predecessor of the WUFI-program was released in Europe in 1994 by Dr. Hartwig Kuenzel. In 2000, a North American version was developed by joint research collaboration between the ORNL in the United States, Dr. Achilles Karagiozis and the Fraunhofer Institute for Building Physics in Germany.

This article presents an overview of the WUFI-ORNL and WUFI-Plus model, the basic fundamentals, the required material and construction input data, the existent exterior and interior environmental loading and the description of the output results from the heat and moisture transfer models. A few example cases are also presented that demonstrate how moisture problems may be investigated and how better design alternatives can become possible using hygrothermal analysis. Finally, the limits of the current state-of-the-art simulation models are described and future trends and developments are presented.

WHAT CAN WUFI-ORNL AND WUFI-PLUS DO?

Solutions to moisture-induced problems may be difficult when several interacting mechanisms of moisture transport are present, making it impossible to make ends meet without the use of combined heat and moisture models. Experimental investigations are almost-always very expensive and have limited transferability to other climatic locations and interior boundary conditions. The purpose of the WUFI-ORNL software is to assist the building envelope design during the design-stage to optimize the heat and moisture performance of the envelope. In the same context, WUFI-Plus includes the ability to predict a building’s energy and moisture transport through all the building envelope components (including windows) and including the occupant-induced loads (thermal/moisture loads and ventilation requirements). WUFI-Plus, an essential upgrade, allows the designer to size-up the thermal and moisture equipment based on hourly predicted thermal and moisture exchanges.

WUFI-ORNL is an easy-to-use, menu-driven PC program, which can provide customized solutions to moisture engineering and damage
assessments of building envelope systems. The user is allowed to work in either SI or IP unit systems (SI refers to the Systeme Internationale units, which is just the Metric System updated and made more complete. IP refers to inch-pound.) and data can be entered in either unit without conversion to the desired output system. The software is based on an understanding of building physics regarding sorption and suction isotherms, vapor diffusion, liquid transport and phase changes. This model is well-documented and has been validated by multiple comparisons between calculated and field performance data (Kuenzel et al 1996).

The model requires a number of material properties which are not always readily available. A material database is part of the program and includes a range of materials commonly used in North America. Exterior hourly weather data, such as temperature, relative humidity, wind and solar radiation, are employed in the hygrothermal calculations. These data are available for a wide-range of North American climate zones.

WUFI-ORNL can be used to estimate the drying times of masonry and light-weight structures with trapped or concealed construction moisture, can investigate the danger of interstitial condensation or can study the influence of driving rain on exterior building components. The software can also determine the sensitivity of the envelope system to water penetration and will assist the designer in selecting the most optimum weather resistive barriers, insulation systems and cladding.

The program is also able to help select, repair and recommend retrofit strategies with respect to the hygrothermal response of particular roof or wall assemblies subjected to various climates. This allows the comparison and ranking of different designs with respect to total hygrothermal performance.

WUFI-Plus takes the results from the hourly analysis of all the 1D wall, roof and basement systems for each orientation of the building, including the ventilation strategy and occupant behavior, and solves for the whole energy and moisture balance of the building. Important occupant thermal comfort and equipment capacity data is generated, as well as predictions on the hygrothermal performance for each envelope part.

**BRINGING BUILDING PHYSICS TO PRACTICE**

Almost all construction materials are porous in nature. Water can exist inside a building material in three states: solid (ice), liquid (water) and gas (vapor). Moisture can migrate by various modes of moisture transport, such as vapor transport, liquid transport and phase changes due to evaporation/condensation and the freeze/thawing processes. Different types and shapes of pores, exist (FIGURE 1). Their characteristic is the large range of diameter which can vary from 10^{-11} in to 10^{-4} in (10^{-9} m to 10^{-3} m). These transport mechanisms are dependent on the driving potentials and the transport coefficients for each mode of transport.

**Moisture storage**

The combined heat and moisture performance of a particular building envelope system is dictated by the individual and collective transport/storage for all building envelope layers. A building material is dry when it contains no (or only chemically bounded) water. When a material is in contact with moist air, hygroscopic materials absorb water molecules at the inner surfaces of their pore system until they reach equilibrium with the humidity of the ambient air.

If a building material absorbs water by capillary forces, then the material is called capillary active. Once in contact with water, such a material may reach an intermediate state of saturation called the free water saturation or capillary saturation ($w_c$) It is equal to the moisture storage function at a relative humidity of 100 percent.

**Moisture transport**

In principal, any transport process is brought about by a driving force or a potential. However, only gas diffusivity and liquid transport as a consequence of capillary forces (capillary flux) are of interest for calculations in building physics.

**Vapor diffusion**

The most common version of the transport equation is provided below, leading to the following flux equation for vapor flow:

$$ q_v = -\delta_p \nabla P_v $$

In the measurement of the water vapor permeability or water vapor permeability (permeance multiplied by thickness), using the ASTM E96 standard or the EN 12086:1997, the factor water vapor permeability $\delta_p$ is used and that is equivalent to:

$$ \Delta P_v = \frac{D_v}{\mu} \frac{M}{RT} $$

Where:
- $q_v$: Mass flux rate of vapor flow, kg/m²·s, (grains/ft²·hr)
- $D_v$: Diffusion coefficient of vapor air, m²/s, (ft²/hr)
- $R$: Universal gas constant, 8.314 J/(mol·K)), (1543.3 ft·lb/lb mol R)
- $P_v$: Partial vapor pressure, Pa, (lbf/ft²)
- $M$: Molar weight of water, 0.018 kg/mol, (lb/mol)

This is termed the water vapor permeability and has units of kg/(Pa·m·s) or (perme in) or (grains/hr·ft·inHg) (Note, 7,000 grains equals 1 pound of water). The diffusion resistance factor $\mu$ of a dry material is a basic material parameter.

**Liquid transport**

Liquid flow is defined in two ways since it is transported differently within...
the two regions of interest. The first region is defined as the capillary water region. It follows the hygroscopic sorption region and extends from above 95 percent RH until free water saturation. The supersaturated capillary region follows the capillary region. In it, normal suction pressures are zero and therefore liquid flow is not physically plausible.

The continuous potential relative humidity $\psi$ is related to the capillary pressure by Kelvin’s law. The transport is then described in the following form:

\[ g_w = -D_w \nabla w \]

Where:
- $g_w$: Liquid transport flux density, kg/m²s or (lb/ft² hr)
- $D_w$: Liquid transport coefficient, m²/s, or (ft²/hr)
- $w$: Moisture Content, kg/m³ or (lb/ft³)

The liquid conduction coefficient is related to the liquid transport coefficient by:

\[ g_w = -D_\psi \nabla \psi \]

Where:
- $D_\psi$: Liquid conduction coefficient, kg/m s or (lb/ft s)
- $D_\psi$: Derivative of the moisture storage function (kg/m³) or (lb/ft³)

**GOVERNING TRANSPORT EQUATION**

The governing equations employed in the WUFI-ORNL model for mass and energy transfer are:

**Moisture transfer:**

\[ \frac{\partial w}{\partial t} + \nabla \cdot (D_\psi \nabla \psi + \rho g \nabla \psi p_{sat}) = 0 \]

**Energy transfer:**

\[ \frac{\partial H}{\partial t} + \nabla \cdot (\lambda \nabla T) + h_v \nabla (\rho c_w \nabla \psi p_{sat}) = 0 \]

Where:
- $\psi$: Relative humidity, percent
- $t$: Time, s or (hr)
- $T$: Temperature, K or (F)
- $c$: Specific heat, J/kgK, or (Btu/lb °F)
- $w$: Moisture content, kg/m³, or (lb/ft³)
- $p_{sat}$: Saturation vapor pressure, Pa, (inHg)
- $\lambda$: Thermal conductivity, W/(mK), or (Btu/hr ft °F)
- $H$: Total enthalpy, J/m³, or Btu/ft³
- $\rho c_w$: Liquid conduction coefficient, kg/ms or (lb/ft hr)
- $\rho c_w$: Latent heat of phase change, J/kg, or (Btu/lb)
- $h_v$: Vapor permeability, kg/(msPa) or (perm in) or (grains/hr ft² inHg in) (Note, 7,000 grains equals 1 pound of water)
- $h_v$: Latent heat of phase change, J/kg, or (Btu/lb)

A control volume formulation solves the governing equations and **FIGURE 2** shows the software inputs and solution procedure.

**WUFI-FAMILY HYGROTHERMAL MATERIAL PROPERTIES**

In order to solve the moisture and energy transfer equations, the material properties must be known. New data measured at ORNL will be included in version 5.2.

The minimum material properties required for the simulation are bulk density [kg/m³] [lb/ft³], which serves to convert the specific heat by mass to the specific heat by volume, porosity [m³/m³] [ft³/ft³], which determines the maximum water content, heat capacity [kJ/kgK] [Btu/lb °F], the specific heat capacity by mass, heat conductivity dry [W/mK] or [Btu/hr ft °F], the heat conductivity of the material in dry condition (a moisture-dependent heat conductivity is optional), water vapor permeance entered in I-P units, the permeability [perm in] of the material is needed, sorption/suction Isotherms, [kg/m³] or [lb m/ft³], that give the equilibrium moisture content of materials as function of relative humidity in both hygroscopic, liquid diffusivity [m²/s] or [ft²/s], both for uptake and redistribution of materials as a function of moisture content w.

As an example of a typical data-sheet, **FIGURE 3** displays material properties for Brick Old (a Winnipeg brick dated 1880), as required by WUFI.

**WUFI-FAMILY BOUNDARY CONDITIONS FOR INDOOR AND OUTDOOR**

The heat and moisture exchange between a building assembly and its environment can be rather complex (**FIGURE 4**), where convection (in-contact with air or water), conduction (in-contact with earth or snow), short- and long-wave radiation and moisture
enthalpy and phase change can occur simultaneously.

The moisture exchange is governed by vapor convection (in-contact with air), vapor diffusion (in-contact with earth or snow), precipitation and drainage or ground water absorption. A unique feature of the model is the capability to include the effects of wind-driven rain. The model incorporates a set of equations to predict the amount of wind-driven rain on the exterior facade of a building system. Extensive experimental work has validated the approach.

The ASHRAE 160 standard option for the indoor climate was incorporated in the software. Currently, unacceptably high indoor conditions are produced for some climates and a research project undertaken by the U.S. Department of Housing and Urban Development (HUD) will be used to provide guidance to adjust the indoor climate parameters.

In general, the interior temperature and relative humidity of different conditioned buildings shows relatively minor variations. Therefore, it is sufficient to differentiate four different interior climates: a) heating conditions, b) cooling conditions, c) mixed conditions and d) constant controlled conditions.

WUFI-ORNL includes features to generate the interior temperature and relative humidity from a sine wave with a period of one year, whose mean value, amplitude and date of maximum are set automatically. The data may be modified by the user. At present, the model includes the

three indoor environmental classes in accordance to WTA Guideline 6.2/ASHRAE SPC 160P (TenWolde, 2000). The indoor environment is not used as an input for the WUFI-Plus but it is calculated based on the moisture and energy-exchanges of the envelope. This is the main advantage of investigating the building in a holistic manner.

**RECENT FEATURES OF WUFI-ORNL AND WUFI-PLUS**

A number of new features have been included into the WUFI-family of software during the past year.

1. The user may add moisture sources and sinks within the building envelope, simulating either additional loads or conditions found in the field.
2. The software includes the ability to include cavity ventilation and allows the users to specify cavity ventilation with air either from the interior or exterior environment.
3. The complex radiative exchange between the wall and the ground is now incorporated into the software.
4. The software includes a new method to accelerate convergence in difficult cases.
5. WUFI has included the capability to not only handle cartesian coordinates but also radially symmetric geometry.
6. Materials exhibiting a phase change, the latent heat released or absorbed, are now handled by tabulating the temperature dependent enthalpy content of the material.

**APPLICATION CASE: WUFI-ORNL**

To demonstrate the use of the WUFI-ORNL software, two cases were prepared. A stucco-clad wall was simulated that includes 60-minute building paper as the weather-resistant layer, a 2 x 6 stud cavity, gypsum board and a 20-perm coating. Two types of insulations were investigated for use: one was glass fiber and the other was closed cell polyurethane foam. FIGURE 5 shows the makeup of the wall system.

A 2004 analysis of stucco wall performances in the Northwest, with Washington State University, showed...
that cracks are present. A 0.5 percent water penetration (percentage of wind-driven rain striking the exterior wall) to the inner layer of the stucco was deployed in the hygrothermal simulations. The results (FIGURES 6 to 9), show that the fiberglass insulation has a net drying effect during the three years of simulation, while the foam had a net accumulation. It is clear that the closed cell spray polyurethane foam (CCSPF) insulation is not a good candidate for this stucco wall, located in Seattle.

The moisture content of the oriented strand board exceeds 20 percent by mass for a large portion of the year, making the CCSPF insulation not a valid candidate for use. In contrast, the fiberglass insulation system performed very well and was able to handle the hygrothermal loading.

APPLICATION CASE: WUFI-PLUS

In this next example, chosen to showcase the flexibility of the whole simulation model, the building is a new school made out of reinforced acrylic stucco (0.393 in/10 mm) with aerated concrete (14.370 in/365 mm) and interior gypsum plaster (0.590 in/15 mm) (FIGURE 10).

This type of construction has a large amount of moisture stored as initial construction moisture. The
The performance of the school building was investigated for seven different climates (FIGURE 11); the yearly average temperatures are shown.

The school was operational all year between 8:00 a.m. and 4:00 p.m., with 160 students. The operational temperatures were kept between 70°F and 77°F (21°C and 25°C) (occupied) and 66°F and 81°F (19°C and 27°C) (unoccupied), while the relative humidity was maintained between 30 percent and 50 percent when occupied and 20 percent and 70 percent when unoccupied.

FIGURE 12 shows the hourly energy demand predicted for heating and cooling for two of the selected cities, Seattle and Chicago. FIGURE 13 shows the complete performance of the schools in these seven climates and the resulting relative humidity. Finally, the impact on moisture on the energy consumption is shown in FIGURE 14. The presence of initial construction moisture is critical for a number of cooler climates.

**LIMITATIONS OF WUFI ORNL**

All software has its share of limitations and WUFI-ORNL and WUFI-Plus is no exception. Results must be checked for plausibility and there are numerous circumstances that can degrade the quality of a calculation or even render it worthless. A slightly inaccurate result may be more difficult to diagnose than a totally wrong one since it may not be easily recognized as wrong.

The main limitation of the WUFI-ORNL is that it only treats the envelope in 1D. Several transport phenomena have been neglected, such as air flows in the component, uptake of ground water under hydrostatic pressure, gravity effect and conditions with extremely high temperature ranges (fire conditions).

The interface between two capillary-active materials (for example, rendering/brick) is treated as ideally conducting, whereas in reality there is often a transfer resistance, which may reduce the moisture transport considerably. The same limitation applies for the WUFI-Plus software. Additionally, the equipment response is not included in the calculations.

Material aging and hysteresis is not considered along with temperature dependencies of the sorption isotherms.

This program was a collaborative work between the Fraunhofer Institute for Building Physics and the U.S. Department of Energy (DOE) Oak Ridge National Laboratory (ORNL). The authors would like to acknowledge Mark LaFrance, DOE Program Manager, for his support.

A full list of references for this article is available upon request. Please email ssavory@matrixgroupinc.net.

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SOME TIME AGO, I REMEMBER PARTICIPATING IN A
discussion about a heavy steel beam that projected through
an insulated wall into an unheated exterior soffit. It was obvi-
ously a big thermal bridge but it was not so obvious what to
do. I like to think that I advocated insulating it on the exterior,
but, “to keep the cold out”, the consensus was to insulate on
the interior with sprayed fibrous insulation. Perhaps the in-
door humidity was so low in winter that no harm came from
that decision.

The right choice seems obvious today, although even now
buildings sometimes include features that waste energy or
risk condensation because designers don’t have the tools
needed to think about them:

- Cantilevered balconies;
- Insulated parapets;
- Wing walls, with or without insulation;
- Structural intrusions into otherwise insulated assemblies;
- Ties and connections between structure and cladding, de-
  signed without regard to heat conduction.

Conventional methods of calculating heat loss through
a building enclosure have evolved for the task of sizing the
HVAC equipment and these methods serve that purpose well.
But, as designers work to devise more energy-efficient enclo-
sure designs, existing methods are less applicable. They do
predict overall heat flows and temperatures where the direc-
tion of heat flow is straight through the enclosure but they
don’t cast any light on patterns of heat flow or temperature
distributions in thermal bridges.

Traditionally, enclosure designers take a 1D, steady-state
view of the thermal resistance of a wall or roof, through the
most resistive part of the assembly, ignoring all thermal
bridges. This works well for cold climates when the poten-
tial for harmful condensation is the main concern because
this view is usually located where the risk of condensation
is greatest. However, for energy-efficiency, optimizing the
design of thermal bridges is a more effective approach than
adding more insulation. Zone methods of adjusting for ther-
mal bridges don’t help with understanding how to improve
designs and, as insulation is added, heat loss through ther-
mal bridges becomes more significant. When we don’t have
the tools to think about things, we ignore them or take them
for granted.

Over the last two decades, computers and software have
advanced so that almost any designer can afford to solve heat
flow problems, even in 3D with parameters changing in time,
on a desktop computer.

FIGURE 1 illustrates results from a thermal model of a wall
framed with steel studs, supported by a concrete structure
and clad with EIFS. The model represents a section of wall

Figure 1. Results from a thermal model of a wall framed with
steel studs, supported by a concrete structure and clad with
EIFS.

Figure 2. The temperatures in a section midway between
studs, from a 3D model of an RSI 6.5 (R37) wall that, because
of the ledger, has an effective resistance of RSI 1 (R5.4).
that is one floor high and one stud-space wide. The exterior temperature is 0 degrees; the interior temperature is 1 degree (Celsius or Fahrenheit, take your pick) and the top, bottom, back and side boundaries are adiabatic—no heat flows across them.

The stud, tracks, cladding and floor slab are represented as transparent grey ghosts. Each colored surface in the figure indicates a given temperature. In addition to the temperatures needed for this plot, the model reports heat flow and calculates effective thermal resistance (R-value). You can see that the stud cools the interior surface and warms the exterior and that the intrusion of the slab causes the temperature to fall from interior to exterior over a shorter path—not only at the slab edge but also above and below the slab for some distance.

The stud distorts the distribution of temperature similarly. Is this a good design? With 6 in (15.24 cm) studs filled with batt insulation and 1.496 in (3.79 cm) of EIFS, this is an RSI 5.8 (R33) wall, if we add the resistances up along a line at the near corner of the model. If we take the thermal bridging of the studs into account, we get RSI 3.9 (R22) but the model tells us that the effective resistance of the full wall, including heat lost at slab edge, is RSI 2.9 (R17).

What if we put all the insulation on the outside? EIFS fire safety tests limit us to a maximum of a 5 in (12.7 cm) thickness—that will give us only RSI 3.9 (R22), which is not good compared to RSI 5.8 (R33). Or is it? A model will tell us that the effective resistance of the whole wall is hardly different—RSI 3.93 vs. 3.95 (R22.3 vs. R22.4). Both walls have roughly the same effective thermal resistance. But, with this design, the minimum temperature in the stud space and sheathing is increased from about 0.2 to more than 0.9 and interior surfaces are nearly uniform in temperature. The risk of condensation is reduced and occupant comfort is improved, and no dust marks will appear over time, marking the locations of the studs.

A model of a brick veneer clad wall will quickly reveal that the configuration of the shelf angle and its connections to the structure are far more important to overall heat loss than the location and amount of insulation in the wall. FIGURE 2 shows temperatures in a section midway between studs, from a 3D model of an RSI 6.5 (R37) wall that, because of the ledger, has an effective resistance of RSI 1 (R5.4). Seemingly obvious solutions, like knife plate supports for an outboard ledger, may not do much better unless modeled in 3D, improved and modeled again until a satisfactory performance is achieved. FIGURE 3 shows an unsuccessful design.

Temperature as well as heat flow is an important consideration. Are masonry ties cold where they or their connectors might be exposed to humid air in the stud space? Or, are they warmer than the back of the sheathing midway between studs? What slab temperatures are exposed to indoor humidity?

FIGURE 4 illustrates a parapet. The conventional solution in cold climates is to wrap such projections with insulation. Everything on the inside is thought of as being warm and everything on the outside is thought of as being cold, as if all the change in temperature between interior and exterior occurred through the insulation. However, this is not so. Cold temperatures and condensation inside such projections are common and this 2D heat flow model shows why.

Are 3D models too exotic for ordinary building design? Do they require expensive computers, software and specialist operators? Not really. Most building enclosure design professionals could produce the models illustrated with an ordinary PC or Mac desktop. Limitations in memory and time dictate that most 3D models be simplified. This can be done by building detailed models of small elements and then creating geometricaly less complicated models of larger assemblies, with simplified representations that have similar properties in the bigger picture. Sheet steel, for example, can be represented as a material of greater thickness with proportionally reduced conductivity, after testing in a small scale model where the simplification is not necessary. A composite material, like zinc-coated sheet steel, can be represented as a uniform material of equivalent conductivity.

A simple 3D model can be used to determine the effects of elements that can only be represented in 3D, for input into

Figure 3. An unsuccessful design.

Figure 4. An illustration of a parapet.
a more detailed 2D model. **FIGURE 5** illustrates a simplified model of a metal building roof with a rib in the roofing at right angles to the supporting purlin and a supporting clip at the intersection. By running the 3D model both with and without the rib and clip, their effect on heat flow can be determined and plugged into the calculation of overall effective resistance in a 2D model where more complicated geometry and varying conductivity of insulation with compression can be represented.

Many thermal bridges are 2D in nature and can be easily modeled using THERM (http://windows.lbl.gov/software/therm/therm.html), which is not only free but fairly easy to use. Still, the thermal bridges most in need of improved design need to be modeled in 3D. Enclosures that store and release heat over a diurnal cycle will need to be modeled in 2D or 3D and require time. The tools are not expensive or difficult to master and using them will lead to a new understanding of how thermal bridges work.

A paper presented at the 10th Canadian Conference on Building Science and Technology offers additional information about desktop software for thermal models. It can be downloaded as a PDF from Posey’s website: http://bricks.bricks-and-brome.net/Paper_S03_Final.pdf

James B. Posey is the owner of Posey Construction Specifications. He sits on the Executive of the Alberta Building Envelope Council South, in Alberta, Canada.

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**Figure 5.** A simplified model of a metal building roof with a rib in the roofing at right angles to the supporting purlin and a supporting clip at the intersection.
THE BEST2 CONFERENCE WAS A resounding success! The Building Enclosure Council (BEC) of Portland, Oregon, hosted the event, held April 12 to 14 at the Oregon Convention Center. Portland turned out to be a wonderful, friendly host city, with free public transportation available via the light rail system within the city center. Attendance at the conference was an impressive 353 people; BEST1 in Minneapolis had 158 attendees.

Robert Kistler (FIGURE 1), AIA, Conference Chair, opened the conference. “There is growing interest in the country for building enclosure knowledge,” said Kistler. “While most of the country is feeling the grip of a weak economy that has a substantial percentage of architects unemployed, the attendance at BEST2 exceeded expectations.”

Kistler thanked the main organizers, Building Enclosure Technology and Environment Council (BETEC) Board Members and Drs. Mark Bomberg and Donald Onysko, who put together a truly impressive program. With the conference theme of A New Design Paradigm for Energy Efficient Buildings, BEST2 presented 70 peer-reviewed, high-quality papers on the current knowledge of building enclosures. The presentations were intended to provide direction for the new paradigm for design in our energy-conscious world. The attendees spoke with enthusiasm about the information they were learning.

The encapsulating theme was that our awareness of buildings has become very complex. We understand today that the multiple systems that make up a building are all interrelated. The solution to one problem may create a problem for a different system. We also understand that the earlier a decision is made, the easier it is to implement through the design process.

Kistler also thanked the National Institute of Building Sciences leadership, Henry Green and Earle Kennett, and the Institute staff for their professional and financial assistance and support. Kistler then introduced Leslie L. Shepherd (FIGURE 2), AIA, Chief Architect of the General Services Administration (GSA) and recipient of the American Institute of Architects (AIA) Thomas Jefferson Award. During his keynote speech, Shepherd reviewed the impressive $12 billion program and array of projects the GSA has undertaken. He cited examples of enormous developments underway, such as the $1 billion new Food and Drug Administration (FDA) campus and $3 billion for the Department of Homeland Security. He noted the importance of meeting both the Energy Policy Act of 2005 (EPACT) and Energy Independence and Security Act of 2007 (EISA) energy targets, dropping energy consumption from an average of 83 KBTu/ft²/year to 38 KBTu/ft²/year and heading towards net zero, reducing fossil fuel use by 100 percent by the year 2030, and truly requiring a new design paradigm.

Tony Colantonio (FIGURE 3), of Natural Resources Canada, gave a presentation on the impressive energy efficiency programs underway in Canada for upgrading existing homes. He stated that 85 percent of the housing stock in Canada is greater than 15 years old and that 59 percent of it is single family homes. What is being retrofitted is high-efficiency furnaces, insulation,
Air-tightness is being improved between 0.6 and 0.15 ACH50, necessitating mechanical ventilation.

Sam Rashkin (FIGURE 4), National Director of the Environmental Protection Agency (EPA) Energy Star for Homes Program, talked about the impressive evolution of the program and its focus on controlling air flow, thermal flow and moisture flow. He explained how some builders were offering warranties from 30 to 60 years.

Henry Green, President of the National Institute of Building Sciences, made a presentation about the Institute. Green previewed the various councils and programs at the Institute and provided an overview of the enabling legislation, the operating principles and mission of the organization. The Institute includes programs addressing facility performance and sustainability, information resources and technology, and security and disaster preparedness. Attendees learned about current Institute program initiatives and how to utilize these programs and projects to improve the knowledge base of building science in their respective projects and organizations.

Cory Vanderpool (FIGURE 5), Executive Director and co-founder of GreenLink Alliance, talked about the importance of educating building owners regarding green practices. She reviewed proposed legislation that would provide tax deductions for improving the energy-efficiency of existing buildings and briefly discussed the Building Star program proposed for commercial buildings.

From their vantage-point as chairs of the tracks, Dr. Mark Bomberg provided an introduction to the Energy-Efficiency track; Dr. Don Onysko provided an introduction to the Whole Building track; and Stanley Yee provided the introduction to the fenestration sessions within the Whole Building track.

The abstracts submitted for consideration reflected the current approaches professions involved in design and construction of buildings have taken in response to our current energy situation. The reality is that we must reduce the energy used by buildings, whether as individuals or as businesses—and not just because this affects the bottom line for the owners and occupants. We also need to look ahead at the demands that these buildings will impose on owners in the future. Every building embodies a legacy with respect to the energy required to operate and maintain it. The future security of supply, whatever its form and source, is now a concern for most nations. The conference was an attempt to bring together a reaffirmation of knowledge that would guide us in achieving durable, energy-efficient buildings. The conference also provided a forum for presenters to provide new information and technologies to assist in meeting that goal.

From a technical point of view, the conference zeroed in on air-tightness, thermal performance, durability and fenestration. It was clear, from the totality of the presentations, that integration of design is critical to achieving the desired end of energy-efficiency. This is not achievable without good control of air-tightness. Also, durability and thermal efficiency cannot be achieved without control of air-tightness. But using appropriate materials in appropriate ways is needed to assure the construction will be durable. Effectively integrating fenestration within the building enclosure and selecting properties that best suit the climate not only impacts energy-efficiency but also the comfort and effectiveness of work and living spaces.

To achieve this integration requires discipline. That discipline can be summarized by one word—commissioning. If the discipline of commissioning is accepted by the design team right from the initiation of a project, constructability, air-tightness control, thermal efficiency and durability issues can all be ironed out on paper before a shovel is put to ground. Carrying on with commissioning through construction assures that the building is put together in the way that the owner and designers intended. Finally, commissioning of the building operations during occupancy brings the design to a final conclusion. This, then, is the new design paradigm. It is not new for some, but it is essential that it becomes a routine and essential working model for the design and building professions.

The final plenary was delivered by Dr. Joseph Lstiburek, Principal with Building Science Corporation. Dr. Lstiburek raised a red flag regarding the upcoming United States Cash for Caulkers program. His talk was based on his paper We Need to Do it Differently (sic) This Time. He noted that Physicist
Amory Lovins, who wrote a seminal paper in 1976 entitled *Energy Strategy: the Road not Taken*, produced shock waves in the government; nobody had seriously considered energy-efficiency as a strategy until then. A very insightful examination ensued about the Canadian government programs of the 1970s, including the Canadian Home Insulation Program (CHIP), designed to insulate attics, and the Canadian Oil Substitution Program (COSP), designed to replace oil furnaces with gas.

Dr. Lstiburek explained that the Canadian government’s intention was to improve the energy-efficiency of homes after the oil embargo and reduce dependence on oil. However, the building science problems created by the unintended consequences of implementing programs without looking at the performance of the house as an inter-related whole system resulted in many failures, such as condensation, rot and indoor air quality problems, which helped fuel building science research in Canada.

Adding attic insulation without controlling air leakage made the attic colder and increased condensation, which caused rotting sheathing. Increasing attic ventilation sometimes worked and sometimes made things worse by increasing air infiltration from the house, with moisture and energy penalties. Chimneys that previously promoted a large air exchange with dry outside air now had lesser flow, caused condensation and damage to the chimney so that they might have to be lined. Furnaces need make-up air, so tightening the house put the house at risk of negative pressure, which caused back-drafting of combustion equipment and resulted in indoor air quality problems.

So, in order of priority, Dr. Lstiburek wanted attendees to:
- Make sure all combustion appliances have make-up air. The easiest way is to use sealed combustion units.
- Make sure all combustion appliances are vented correctly. Follow the *International Mechanical Code* (IMC) and avoid back-drafting.
- Make sure houses have controlled mechanical ventilation. Follow *ASHRAE Standard 62.2*.
- Make sure attics that will be insulated are ventilated. Follow the *International Residential Code* (IRC) for both vented and unvented attics.
- Then insulate and air-tighten to your heart’s content.

Notice the order. First we get it right—then we insulate and caulk and implement energy conservation measures. It is imperative that the very substantial Cash for Caulkers program not repeat the problems of the past and that we use the lessons learned.

Ryan Dalgleish, Chair of the National Building Envelope Council of Canada’s 13th Conference on Building Science and Technology in Winnipeg, Manitoba on May 10 to 13, 2011, stated that the call for papers was out and invited attendees to participate in that conference. Larry Ray, Chair of BEST3, closed the BEST2 program. He announced that BEST3 will be in Atlanta in 2012.

Complete coverage of BEST2, including photos and presentations, is available at www.thebestconference.org.

Wagdy Anis, FAIA, LEED-AP, is a principal in the Boston office of Wiss, Janney, Elstner Associates, Inc. and Chairman of BETEC. He can be reached at wanis@wje.com.
BEC Corner

ATLANTA
By John Preece, AIA, LEED-AP, 90 ten Architects and Ed Seiber, AIA, Seiber Design, Inc.

"Y'all've been invited now. I hope to see you down in Atlanta in 2012." With those words, Larry Ray of BEC-Atlanta closed the BEST2 Conference in Portland this past April and kicked-off official activities to host the BEST3 Conference in Atlanta in 2012. With great enthusiasm we have begun a two-year planning effort to continue the momentum started by our friends in Minneapolis and Portland. With the leadership of Dr. Mark Bomberg and Dr. Don Onysko, and the guidance and assistance of the National Institute of Building Sciences, the Building Enclosure Technology and Environment Council and the local BEC chapters, we are dedicated to making the BEST3 Conference the biggest and most exciting ever.

The conference will focus on a continuum of the design paradigm for energy-efficient buildings with emphasis on application and assessment. This will be the first such conference in the region and we invite all of our colleagues to attend and engage in the study of high-performance building science and energy-efficient design.

BEC-Atlanta will also continue its monthly activities. To date, our 2010 roundtable presentations have been: Single Component Exterior Wall Systems; Spontaneous Breakage of Glazing; and Legal Issues Related to Building Envelopes: An Attorney’s Perspective. Coming up, we will be talking about security and blast resistance of glazing systems, commissioning and field testing, roofing issues, and the ASHRAE Building Energy Quotient (EQ) Program.

Starting in March 2010, we began holding monthly meetings at the ASHRAE national headquarters. The building was significantly renovated in recent years and achieved a LEED Platinum Certification from the United States Green Building Council. We are grateful to ASHRAE for their hospitality and for providing us with such wonderful, state-of-the-art accommodations. Meetings are held the second Wednesday of each month, from 4:00 p.m. to 5:30 p.m.

CHARLESTON
By Whitney E. Okon, BEC Charleston Chair, Applied Building Sciences, Inc.

BEC-Charleston’s first meeting of 2010 was held in late January and featured a presentation from Bob Duke of the Spray Polyurethane Foam Alliance and Carolina Comfort Foam. He gave the presentation Spray Foam: Details & Myths Explored! Chemistry, Application and Field Performance to over 50 attendees. In February, the presentation was given by Richard Cook of ADC Engineering and RCI. He presented Sealants: The Common Denominator. In March, we welcomed Brian Stroik, the Senior Quality Process Manager for Oscar J. Boldt Construction and BEC-Wisconsin Co-Chair, who presented Commissioning the Building Envelope. Finally, in April, Larry Elkin, P.E., of Applied Building Sciences, Inc., presented to over 60 attendees (and over 10 local building officials) on the topic of Solutions to Underfloor Moisture Problems.

BEC-Charleston has forged an alliance with the East Cooper Breakfast Construction on BEC-Charleston’s Net Zero Energy House will begin in October.
Rotary Club and the East Cooper Habitat for Humanity to build a Near Net Zero Energy House in Charleston. We hosted Jeff Christian from the Oak Ridge National Laboratory last year to educate us on the endeavor and have since gathered over $80,000 in money and in-kind gifts to make the project possible. Construction is scheduled to begin this October and we hope to schedule a series of work days for our BEC members to participate in various building enclosure-related activities, such as SIPs installation, window flashing and air tightness testing. Financial donations are still needed. Anyone interested in the project should contact Charles Muldrow, AIA, at c.muldrow@smha.com.

We look forward to an educational and successful summer/fall with presentations on residential energy retrofits, the condensation potential between wood windows and metal sill pans in hot, humid climates and restoration as the ultimate act of sustainability. We will complete our program year on October 28th, with a full-day seminar by Betsy Pettit, FAIA, of the Building Science Corporation, presenting on best practices for energy retrofits.

BEC-Charleston has over 200 professionals on our membership list and greets about 40 members at each meeting.

For information, contact Bryan Bolin at bryan@thomasanddenzinger.com or Whitney Okon at wokon@appliedbuildingsciences.com.

CHICAGO
By Richard E. FencI; AIA, CSI, LEED-AP, Gensler

BEC-Chicago elected new officers in the Fall of 2009 and they became effective January 1, 2010. They are Richard FencI (Gensler), Chairperson; Kevin Kalata (Wiss, Janney, Elstner Associates, Inc.), Vice Chair/Chair Elect; Elizabeth Ordner (Wiss, Janney, Elstner Associates, Inc.), Secretary; and Jim Cogdill (Centria), Treasurer. BEC Chicago is on a campaign to become “organized”:

• A new Charter and By-Laws have been developed and was presented to our local membership in June.
• BEC-Chicago is in the middle of developing ground rules to raise money for an improved website. Our hope is it will be thoroughly interactive, with links to members, other allied organizations and other BEC sites.

• We have an ambitious monthly schedule of programs with the most recent being an update of the proposed façade changes to the 2010 Version of ASHRAE 90.1. In May the Council Members will tour the recent “Modern Wing” addition to Chicago’s Art Institute, designed by Renzo Piano, with the project’s Architect of Record, IDEA 8.

• Attendance at meetings has been between 30 and 50 people. The goal is to regularly engage 100 local architects in building envelope issues.

DALLAS
By George M. Blackburn, III, AIA, NCARB, Construction Consulting International

BEC-Dallas had a “Reboot” meeting at the end of January 2009 to discuss the reorganization of our chapter. It was held at the Dallas Center for Architecture. Two presentations on Commissioning (Cx) the Building Exterior Enclosure were given; one for new buildings given by Fiona Aldous of Wiss, Janney, Elstner Associates, Inc. and one on retro commissioning existing buildings, which I presented.

The second BEC-Dallas meeting of the year was held at the Construction Consulting International (CCI) Laboratory facility in Carrollton. The new Tyvek Fluid Applied Weather Barrier System was introduced, which was preceded by an AIA-CEU presentation called Choices of Air Barriers for Commercial Building Enclosures, given by Casey Robb of DuPont Tyvek Weatherization Systems. There was also a tour of the CCI Laboratory’s building envelope and fenestration testing facility. Burgers, chips and drinks were provided by Weatherization Partners and CCI. There were over 50 in attendance including real estate developers, architects, engineers, manufacturer representatives, material suppliers, consultants and contractors. We are hopeful that we can continue to rebuild BEC-Dallas from these programs. Several others that include internationally recognized building scientists are now in the planning stages.

KANSAS CITY
By Dave Herron, herron + partners

The Kansas City BEC Chapter continues to host a variety of sessions, from walking tours of buildings under construction to the proper design and installation of roofing curbs. Upcoming presenters include Peter Poirier, Technical Director of Building Envelope Solutions for Tremco Incorporated and John Edgar, Technical Manager of Building Science for Sto Corp.

MIAMI
By Karol Kazmierczak, AIA, ASHRAE, CDT, CSI, LEED-AP, NCARB

Miami-BEC continues to meet monthly on every third Tuesday and we are attracting an increasing number of individuals. The attendance is free of charge but the number of seats is limited and distributed on a first-come, first-served basis. We hit a room occupancy limit with almost every meeting we hold.

Recent speakers and topics have included Tom Schwartz, PE, of Simpson Gumpertz & Heger, on Architectural Glass – What Every Designer Should Know and E Carter (Bud) Karins, PE, of Karins Engineering Group, on Building Enclosure Specific Concrete Deterioration. We also conducted a tour of a factory producing exterior windows, doors and glass railings in Hialeah, Florida. In addition, I gave a lecture titled Review of Curtain Walls at the BEST2 Conference in Portland, Oregon.

In June, we heard from Charles E. Rogers, Esq., a partner in the Atlanta office of Smith, Currie & Hancock LLP, about The Professional Liability and the Building Enclosure. The AIA Convention was also in June and I spoke about facade engineering. I have also published facade engineering trivia, which can be accessed at http://karol.us/quiz.html. Click on the respective links provided there.

The employment market is still quite tough in south Florida. Knowing that BEC-Miami is currently the largest organization dedicated to building

Terms and conditions are described on our webpage.

MINNESOTA
By Judd Peterson, AIA, Judd Allen Group

In November, BEC-Minnesota worked with Stanley Gatland, Manager of Building Science Technology for CertainTeed Corporation, who developed and presented a seminar on *Thermal and Moisture Properties in Building Envelopes* and how this relates to Minnesota’s recent air barrier code requirements for the AIA Minnesota Annual Convention.

In December, as Chair of BEC-Minnesota, I met with Senator Al Franken while at the EcoBuild Conference and the BETEC Board Meeting in Washington, D.C. Doug Read, Chairman of the High-Performance Building Congressional Caucus Coalition (www.hpbccc.org) and I are working to enlist Senator Franken to co-chair a new High-Performance Building Senate Caucus, to match the existing High-Performance Building Caucus in the House of Representatives.

In an effort to expand the video teleconferencing capability of the National Institute of Building Sciences (the Institute) and the American Institute of Architects (AIA), to provide educational seminars, technical help and discussions throughout the state of Minnesota, we are arranging to have Penny Dickhaut, Director of Video Conferencing for Minnesota State Colleges and Universities, discuss possibilities with John Lloyd, who coordinates video conferencing for the Institute. At our December 2009 meeting, Paul Doud, Product Specialist with Protective Coatings Technology (PCT), discussed fluid-applied thermoplastic coatings as vapor permeable and/or impermeable air barrier systems.

In January 2010, Greg Reedy of A-1 Glass, Inc. (out of Englewood, Colorado) presented the *Art of Wall Selection*, which described factory-fabricated, unitized curtainwall construction.

In February, BEC-Minnesota was treated to some in-depth information on passive house construction by one of our own members, Tim Delhey Eian, technical expert on passive houses. He led a discussion with us about the best approach for energy-efficient construction in residential projects, both new and rehabilitated.

In March, Jeff Jackson with Excel Energy presented their state-mandated programs to encourage energy-efficiency, explaining Excel’s incentives, recommendations and assistance to design teams for both rehabilitated buildings and new buildings. In addition, Michael Gainey, Warm-Light® Business Manager for Azon International and veteran in the architectural and structural glazing industry, presented the use of polyurethane thermal barrier aluminum fenestration and structural warm-edge spacers for insulating glass units.

This spring, BEC-Minnesota presented the *Top Ten Recommendations for Each of 8 Fundamental Building Enclosure Areas* at the University of Minnesota’s Student Exhibition. This was done at the request of the event’s sponsor, the Construction Specifications Institute (CSI). By popular demand, this presentation was also delivered to the Northern Chapter of AIA Minnesota in Duluth, Minnesota, to help get the information to the outreach of the state. I also presented information on the BECs and their connection with the Institute and the AIA.

In April, Chad Roste and Todd Olson of Cold Spring Granite, met with our BEC-Minnesota group to discuss stone construction and stone veneer detailing, while a contingent of BEC-Minnesota members also traveled to the BEST2 Conference in Portland, Oregon.

Finally, for our May meeting, Patrick Higgins, Director of Building Inspections for Minneapolis, came to our group to enlighten our members on the interpretation of Chapter 26 and foam plastic insulations in exterior wall construction. This topic was presented by popular demand and was well-attended with many well-informed members. Higgins was very informative about the good, the bad and the ugly requirements that these exterior walls have to meet. We had a lively discussion about the specifics of detailing and applying these requirements, including valuable input from Kevin Slattery, independent technical rep for Dow Insulation systems through Edward Sales. Slattery provided insight as to the current status of NFPA 285 testing of certain wall assemblies.

Congratulations to the PortlandBEC for the excellent BEST2 Conference event!

PORTLAND
By David C. Young, P.E., RDH Building Sciences, Inc.

BEC-Portland was proud to host the BEST2 Conference, welcoming everyone to our wonderful city of Portland! We want to thank everyone at the National Institute of Building Sciences, the Building Enclosure Technology and Environment Council, and the American Institute of Architects, who helped us organize the conference. We particularly wish to thank all of the vendors who helped sponsor the event and make it financially feasible. Of course, there would have been no conference were it not for the hard work and excellent presentations of the speakers in each track and the organization of the track chairs. In addition, we wish to thank Seattle-BEC for their help organizing the Oregon vs. Washington BEST Beer Sampling event.

The BEST2 Conference featured a *New Design Paradigm for Energy Efficient Buildings*. The three themes in the concurrent tracks included *Energy Efficiency in Buildings: Where should we be going?*, *Fenestration: Solution to energy concerns*; and *Whole Buildings:*

![Dr. Mark Bomberg and Lew Harriman, outside the Exhibit Hall at BEST2.](image-url)
How do we measure performance? It was a difficult task trying to choose from these tracks, but it is clear that energy-efficiency needs to be a major focus in building design and retrofitting in the coming years. With 40 percent of energy consumption originating from buildings, we need to lead the charge in the new design paradigm. And, since most of the building stock comprising this energy use is in the form of existing buildings, we must consider new and innovative ways of improving energy-efficiency in these buildings, yet with care not to create other unwanted results. We need to remember some of the ramifications of past energy improvement initiatives that led to some of the most significant building enclosure failures of our recent history. We have the knowledge and the tools to do it right this time.

The BEST2 Conference was a great success, with total attendance exceeding 350. That represents an increase of 230 percent from BEST1 and we’ve had great feedback from attendees. We hope that everyone enjoyed a fabulous experience in Portland and we hope that you will return to visit soon. BEST1 set the stage for our success. We now hand the reins over and look forward to the 2012 BEST3 conference in Atlanta, Georgia.

WASHINGTON, D.C.
By Fiona Aldous, Wiss Janney Elstner Associates and Paul E. Totten, PE. (MD, VA), LEED-AP, Simpson Gumpertz & Heger

BEC-Washington, D.C.’s spring sessions have concentrated on building technology and the building enclosure. The co-chairs began 2010 with a brief presentation and discussion on air barriers. The discussion focused on the various types, applicability and permeability, and overall performance intent of the materials and assemblies.

Our monthly meetings continued in March when Bill Nash from Whitlock Dalrymple Poston & Associates, P.C., discussed the affects of construction tolerances of different materials that comprise the exterior enclosure. The issue is of great significance as contractors attempt to decipher the inconsistencies between industry standards, specifications and design details.

In April, we brought Bruce Werner of the Centers for Disease Control back to our community and housed our first meeting at the D.C.-AIA chapter house. Werner’s presentation identified the importance of design and fabrication of four-sided structural silicone glazing. Werner gave an interesting presentation on the fabrication of unitized systems and the shop quality control process.

In May, the presentation was given by Donald Scheuerman, Jr. from Montgomery County’s Division of Building Design and Construction. Scheuerman spoke on Montgomery County’s “green” roof efforts to decrease heat island effect and reduce storm water runoff.

WISCONSIN
By Brian Stroik, Boldt

BEC-Wisconsin has just completed its second year of educational programs. Our group continues to meet from September through May on the third Tuesday of the month, starting at 3:00 p.m. This year, not only did we have a variety of topics including EFIS, Curtain Wall Construction; Commissioning the Enclosure; Roofing Failures; Failures Witnessed by the State of WI; Movement Joints in Masonry; and the Effect of Fenestration on HVAC Loads, but BEC-Wisconsin also went digital by hosting over half of these presentations over the web to four or five host sites throughout the state, including a few universities.

We are excited about this format as it allows for great presentations, topics and discussions to take place among a larger diversified group. If you’re interested in attending a meeting, please visit our website at www.bec-wi.org or contact one of our co-chairs. Our doors are open to anyone who is interested in learning, as our current membership includes architects, general contractors, engineers, manufacturers and specialty contractors.

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