interested in paying full value and acquiring the entire company," says Celotex CEO John Borreca. "As it turns out, after a very broad and public auction process, the marketplace has told us the highest value for our company is in the sum of its parts, rather than in the whole." Borreca says that the vast majority of jobs in the company will be preserved through the transitions.

ALBUQUERQUE, NM — Companies that make and sell photovoltaic (PV) cells, modules, and systems have teamed up with Sandia National Laboratories to publish *Power Where You Need It: The Promise of Photovoltaics.* The 52-page, richly illustrated document presents a wide variety of PV installations and is intended to encourage potential users. The publication is available free by writing Connie Brooks, Photovoltaic Systems Assistance Center, Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185-0753. Tel: (505) 844-3698; E-mail: pvsac@sandia.gov. The publication is also available on Sandia's PV Web site at www.sandia.gov/pv; click on "Publications."

GAINSVILLE, FL — The National Energy Raters Association (NERA) announced the formation of the National Energy Raters Foundation, a nonprofit organization that will work to educate the public on the uses, benefits, and advancements in home energy rating. NERA spokesman Jon Klongerbo tells ***EDU*** that the foundation will serve to encourage and promote improved cooperation between energy raters and other sectors of commerce and industry, and will also serve the industry as a forum for the exchange of ideas and experiences. For more information, visit www.energyraters.com.

MINNEAPOLIS, MN — The Minnesota Department of Commerce (Energy Division) has released a literature review that neatly summarizes dozens of field studies and other information related to water intrusion in exterior insulation finish systems (EIFS) and stucco finishes. The report *Literature Review of Exterior Insulation Finish Systems and Stucco Finishes* was prepared by Marilou Cheple and Patrick Huelman, both professors at the University of Minnesota. While the report offers no new research or interpretation on moisture-related failures in EIFS and stucco cladding, it contains the best bibliography on the subject that we've seen to date. The 40-page report, including 68 references, is available on the Web at www.commerce.state.mn.us.

FACTOID DEPARTMENT: The Home Improvement Research Institute reports that only 30% of consumers consider environmental issues in their purchasing decisions, with the majority citing the high cost of "turning green" as a negative.

RESEARCH AND IDEAS

If Only We Could Quantify Human Comfort

LBNL Researchers Explore New Ways of Modeling Window Performance

So much effort has been invested in improving and promoting the energy savings associated with high-performance windows that the attendant comfort advantages have gotten the short shrift. In large part this is because the improved comfort associated with high-performance windows hasn't been tested and quantified with the same precision that's used to quantify energy savings.

We know for a fact that human comfort can be strongly affected by the exchange of longwave electromagnetic radiation with a window, especially when the inner face of the glass becomes really hot or cold and a person is in close proximity. Direct sunlight pouring though a window or skylight onto a person's skin can also be a powerful influence on comfort. The convective air currents that sometimes form around windows (as distinct from infiltration drafts) also play a role, albeit not as important. The problem is that the building science community doesn't know how to integrate and quantify these various factors. (See sidebar, "Some Obvious [and Not So Obvious] Facts About Windows and Comfort.")

But suppose that researchers came up with a software program that could accurately model the way that people feel in proximity to a window, under changing conditions? And suppose we had a "window comfort index" that could quantify the comfort advantages associated with high-performance windows?

That, in short, is what researchers Charlie Huizenga and Dariush Arasteh are hoping to achieve. Huizenga works at the University of California (UC — Berkeley, California) Center for Environmental Design Research, specializing in thermal comfort and its relationship with building energy efficiency. Arasteh, a researcher with the Windows and Daylighting Group at Lawrence Berkeley National Laboratories (LBNL), examines all aspects of windows and energy. By teaming up, the two researchers plan to develop tools that will allow researchers and ultimately practitioners to better understand how window properties influence human thermal comfort over a variety of realistic conditions.

"When I talk to people a year after they have installed energy-efficient windows, they don't talk about their lower utility bills," Arasteh says. "They always talk

Some Obvious (and Not So Obvious) Facts About Windows and Comfort

- Researchers believe that current assessment methods probably underestimate the discomfort that windows can cause. (See main story.)
- Windows aren't the primary factor that affect occupant comfort — indoor temperature and humidity usually dominate. However, when a window is very hot or cold, and the occupant is close to it, the window becomes very influential, especially when other indoor comfort conditions are near the edge of the comfort zone.
- Sunlight falling directly on a person is the most potent determinant of comfort associated with windows (see Figure 2). Of course, this direct solar gain could be either a positive or negative influence, depending on the season and indoor conditions. The exchange of longwave radiation between a person's body and the window glass is the second most powerful determinant. For most residential-sized windows, draft effects exist but are typically small.
- People often mistake longwave heat loss to a cold window for a draft (see Figure 2).
- When drafts do affect comfort, they are usually caused by direct infiltration related to poor weatherstripping, not to local convective currents.
- The percentage of people dissatisfied due to convective currents does not exceed 10% and for high-performance windows is insignificant.
- Tests have shown that occupants are acutely aware of radiant asymmetry and will move away from the window.
- High-performance windows with low U-factors will result in a higher interior window temperature in winter and thus greater comfort.
- In Sunbelt climates, windows with low solar heat gain coefficients will reduce the solar radiation coming through the glass and associated discomfort.

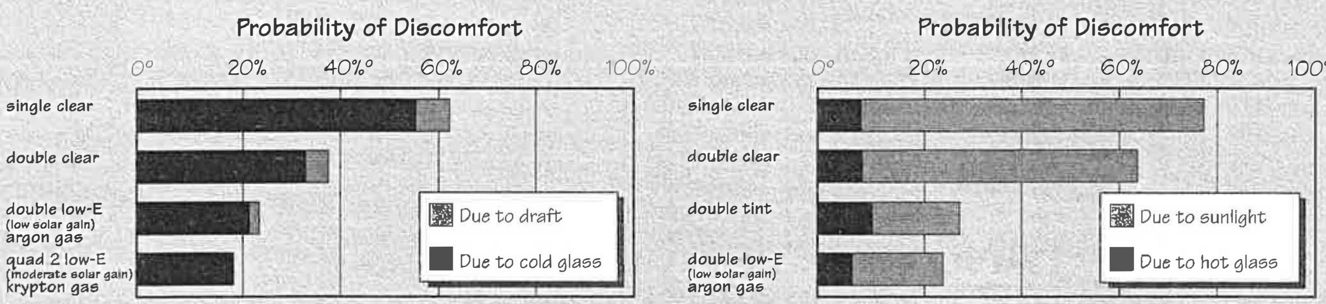

Figure 2 — How different types of window glazings can affect human comfort. (Source: Lawrence Berkeley National Laboratories)

about how their spaces are so much more comfortable, how they can use the whole space all year long and not have to avoid sitting near a window during part of the year." Arasteh is convinced that if high-performance windows were given a comfort value, along with their energy savings value, it would help home builders and buyers to justify paying a higher initial cost.

Wanted: A Dynamic New Tool

Currently, there is no procedure for realistically predicting the impact that windows have on human comfort. One of the best available tools (the ASHRAE Thermal Comfort Tool) models a person as a simple plane set parallel to the plane of the window — kind of like a small paper doll suspended parallel to the glass. But our bodies are large, three-dimensional, and geometrically complex. Moreover, we generate our own heat, vary our activities (e.g., sleeping, typing, aerobics), and wear different types of clothes (with various insulation levels).

While the Thermal Comfort Tool can work well under uniform, steady state conditions, it can't accurately model the dynamic conditions that exist inside our homes, especially the radiant asymmetries that exist around windows. "Radiant heat transfer is very dependent on the details of which surfaces see which other surfaces and is therefore quite sensitive to the body's shape and orientation," Huizenga explains. "This is one reason why we believe current assessment methods, which use averages, probably underestimate the discomfort caused by poor quality windows."

To address these shortcomings, Huizenga and his UC colleagues are developing a detailed 3-D model of the human body that uses 5,000 polygons to calculate the radiant heat transfer between each area of the body and the surrounding environment. The new comfort model defines 16 key body parts (head, chest, arms, legs, etc.) and further segments each of those parts into core, muscle, fat, skin, and clothing (see Figure 3).

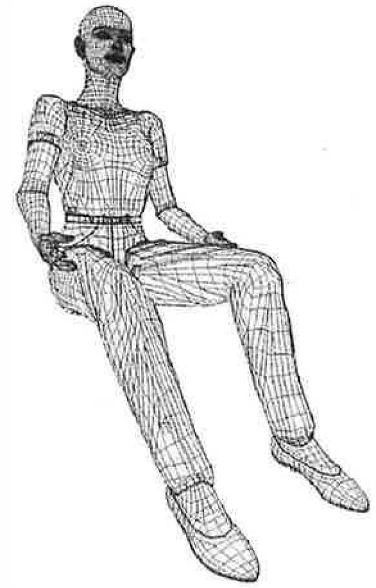

Figure 3 — A realistic, three-dimensional model of the human body, constructed of 5,000 polygons, is used to calculate radiation view factors between the body and surrounding surfaces. Future refinements to the window comfort model will probably use computational fluid dynamics to evaluate draft effects.

"Our new 3-D model can calculate the heat transfer between each area of the body and the surrounding room," Huizenga says. "For example, let's say the person's left side is facing the window. We can predict that the left arm will be radiating heat to the 50°F window surface and will be much colder than the right arm that faces the room." Huizenga tells *EDU* that the completed software will also be able to account for transient and time-varying effects, heat transport via blood flow around the body, and the heat loss that occurs through evaporation, convection, radiation, and conduction. The clothing model will include heat and moisture transfer.

As shown in Figure 3, the model uses rendering software to create a realistic, three-dimensional model of the human body in any desired pose. A matrix of view factors is computed for each body segment and surrounding surfaces, so that each radiation transfer can be explicitly calculated.

Dummies at Work

Using state-of-the-art computational techniques, Huizenga and Arasteh are creating new algorithms to calculate:

- The exchange of longwave radiation between the window and building occupants
- Room drafts caused by air drainage off a cold window surface
- The skin heating effect of direct-beam solar radiation
- The relative importance of, and tradeoffs among, the window's longwave, shortwave (solar), and draft effects in summer and winter conditions
- The effect of the occupant's proximity to a window (view factors, window size, and radiant temperature asymmetry)
- The sensitivity of comfort predictions to the subject's posture, clothing, and metabolic activity

The researchers are also sifting through a huge body of literature related to thermal comfort, human physiology, and modeling that spans several disciplines, including medicine, biology, engineering, architecture, and psychology. "The basis for our model actually comes from work that was done back in the 1960s by Stolwick and Hardy who developed a model of human thermoregulatory response for the National Aeronautics and Space Administration," Huizenga relates. "Sending astronauts into space required carefully controlled thermal systems in their suits."

The new window comfort model will also incorporate data from the many human-subject studies that have been done, including several performed at the Controlled Environment Chamber at UC-Berkeley. Some of these tests have concentrated on physiology (skin and body temperatures, sweating, shivering, etc.) while others have focused on peoples' subjective responses to the thermal environment.

Last but not least, the researchers plan to use a sophisticated thermal mannequin that was made in Denmark and has 16 separately controlled body segments that can accurately measure heat transfer between the body and the environment under a wide range of conditions. Huizenga tells *EDU* that the mannequin will be placed next to hot and cold windows to validate the model's predictions.

Within a year or so, the researchers expect to complete both the physical and psychological aspects of the model. But connecting the physiological model to the psychological perception of comfort will take much longer — perhaps another four years. One of the biggest near-term challenges facing the research team is deciding on the appropriate level of detail; it must be sufficient to accurately predict the behavior of the body, yet not so detailed that years will have to be spent collecting enough data to build the model.

"The whole point of building buildings is to create comfortable spaces," Huizenga concludes. "Thermal comfort is a significant subset of the concept of a 'comfortable space.' Housing construction is so expensive these days that it's important for people to get the right information into their decisionmaking process when specifying components."

Obviously, rating and standards bodies such as the National Fenestration Rating Council are keenly interested in the development of the new software because it could be used to create a simplified "window comfort index" for designers and consumers. But other entities outside the construction industry are also taking a profound interest in the research. For example, Delphi Harrison Thermal Systems, a General Motors spin-off, is interested in the new software to help it develop heating, ventilation, and air-conditioning systems for cars.

For more information, we recommend *Window Performance for Human Thermal Comfort* by Arasteh, Huizenga, and Peter Lyons, published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Two other recent ASHRAE papers also address issues related to mean radiant temperature and thermal comfort: *Direct Calculation of Mean Radiant Temperature Using Radiant Intensities* by Jeanne Palmer and Kirby Chapman, and *A Database of Window Annual Energy Use in Typical North American Single-Family Houses* by Arasteh, Joe Huang, and Robin Mitchell. Copies can be obtained by writing ASHRAE at 1791 Tullie Circle NE, Atlanta, GA 30329, or by calling its publication office at (800) 527-4723 or (404) 636-8400. Enclose $4 per copy. Web site: www.ashrae.org.

The Quest for Self-Powered Heating Systems

A hellacious ice storm that ripped through the Northeast a couple of years ago planted the seeds for a new research project aimed at developing heating systems that use less electricity and can be self-powered if the grid goes down. During the ice storm of 1998, tens of thousands of homes across New York, New England, and eastern Canada were left without power and heat — some of them for weeks — while utility crews scrambled to rebuild the shattered grid. Many homeowners, left with frozen pipes and no heat, were forced to stay in motels and community shelters.

To help prevent a repeat of that disaster, the New York State Energy Research and Development Authority (NYSERDA) has awarded $344,000 in cost-sharing research grants to Davis Aircraft Products (Bohemia, New York) and ECR International, Dunkirk Division (Dunkirk, NY) to design energy-efficient, self-powered heating systems. Davis Aircraft Products will focus on oil-fired boilers, while Dunkirk works with gas-fired technology.

"Our first challenge, in phase one of this research, is to cut the electrical load," explains Doug Davis, president of Davis Aircraft Products. "Currently, oil-fired boilers run the fan and pump with one big motor, which is a pretty inefficient approach. We plan to split the fan off and replace that conventional reciprocating pump with the new electromagnetic fuel pump we're developing." (See Figure 4.)

The electromagnetic fuel pump will use an oscillating piston that's driven by an electromagnetic coil surrounding it, representing a more efficient use of electricity than conventional, gear-driven pumps. Davis tells *EDU* that the new design could cut heating-related electrical consumption for a one-zone hydronic system from 350 watts (W) to about 125 W. According to NYSERDA, the average household in New York State could save $50-$75 a year in electricity by adopting the new technology.

"We believe we can get the load down to the point where a homeowner could run the boiler off a 12- or 24-volt battery for several days, if power from the grid were lost," Davis says.

Researchers at Brookhaven National Laboratory, which is supporting the project, have already built a prototype oil burner that uses just 30 W of electricity, so the potential electrical and money savings may be even greater than those suggested above.

If the prototype works out, the new low-power burner could be ready for field tests by the middle of next year. According to Davis, the new burner shouldn't add much, if any, to the cost of a new boiler. In retrofit applications, the new technology should pay for itself in saved electricity in less than three years, he says.

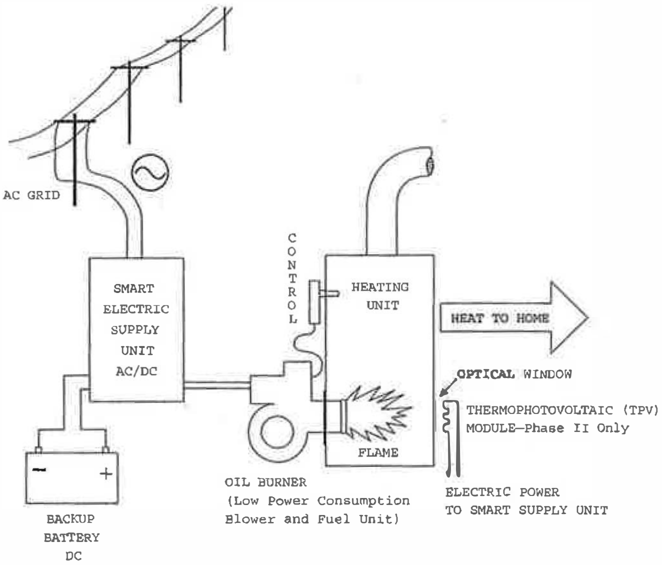

Figure 4 — Diagram of the low-energy, self-powered, oil-fired boiler under development at Davis Aircraft Products. The research is being funded by the US Department of Energy, New York State Energy Research and Development Authority, and the participating contractors.