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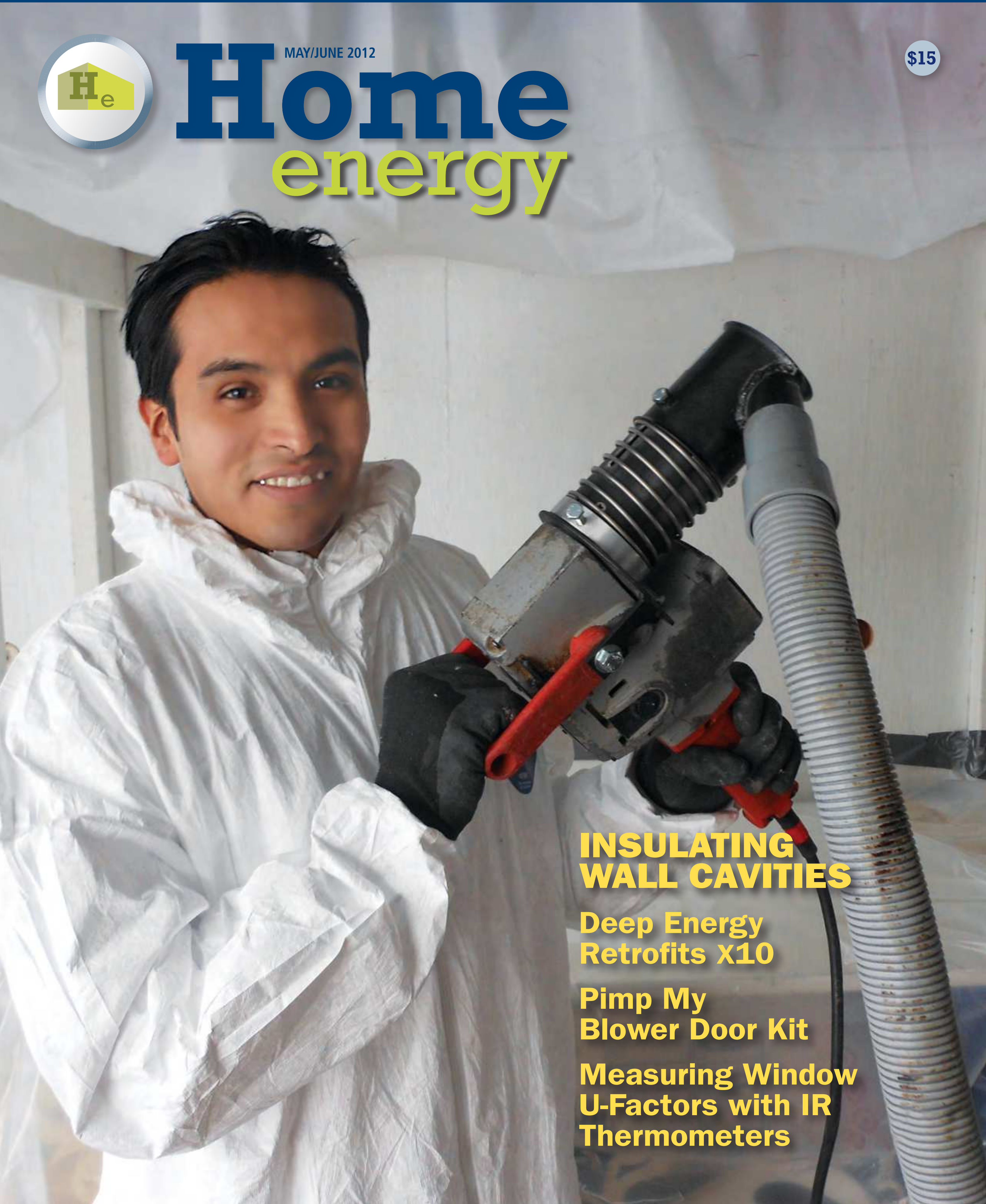

INSULATING WALL CAVITIES

Deep Energy Retrofits X10

Pimp My Blower Door Kit

Measuring Window U-Factors with IR Thermometers

Measuring Window U-Factors with IR Thermometers

Measuring indoor air temperature with a window-mounted temperature target.

High-rise window example of temperature targets—IR thermometer in foreground.

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KAPIL VARSHNEY,
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Imagine standing next to a single-pane metal-frame window in a multifamily building in winter, and putting your hand on the window. It's cold, right? Now imagine a triple-pane R-5 window. Put your hand on that—much warmer, right?

These facts—that a poor window is cold to the touch and a high-performance window feels much warmer—were put to use in a yearlong research project done by our company, Taitem Engineering. Taitem (also an acronym for Technology As If The Earth Mattered) is an Ithaca, New York-based consulting engineering firm specializing in mechanical, electrical, and structural design; energy studies; and energy research. In this project, we examined the feasibility of using window surface temperatures to back out U-factors. Would it not be useful to be able to measure window U-factors right in buildings, just by measuring window surface temperatures? Infrared (IR) thermometers sure make surface temperature measurements fast and easy. Our company decided to look further.

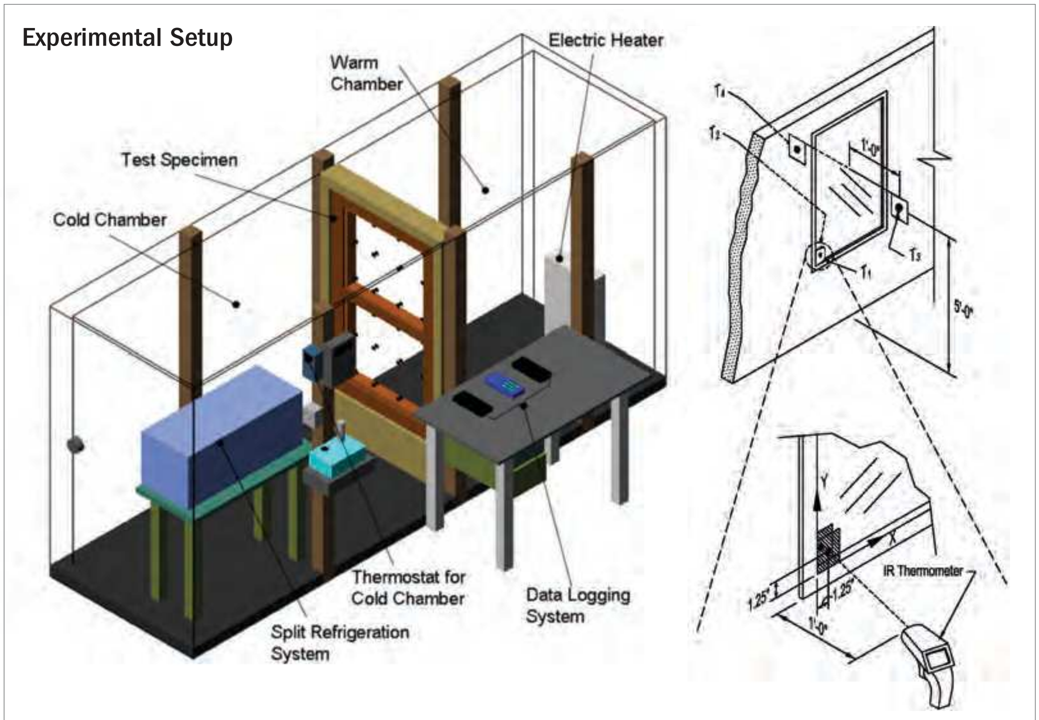

Figure 1. Experimental setup (left) and procedure to measure comparable window U-factors on-site (right).

RESEARCH PROCESS, METHODOLOGY, AND RESULTS

To start the project, we built a two-chamber setup, put a heater in one side and called that indoors, put a refrigeration unit in the other side and called that outdoors (with temperatures down to 0°F), and tested a variety of windows using IR thermometers to measure glass temperatures on the warm (indoors) side of each window. The test setup is shown in Figure 1 and the results are shown in Figure 2. Note how single windowpanes are indeed colder and high-performance windowpanes are indeed warmer, for any given wintertime outdoor air temperature.

To examine if (and how) this could be put to use, we started by equating the conductive heat loss through the window (UA - (T-indoor air - T-outdoor air) to the convective heat loss from the window surface to the indoor air (hA - (T-indoor air - T-indoor window surface)). Here, U is the overall window U-factor (Btu/hr–SF–°F); A is the window area (SF); and h is the indoor surface convection heat transfer coefficient (Btu/hr–SF–°F). The A's cancel, and if we make a reasonable assumption for h, and use the measured air and window surface temperatures, we can solve for the overall window U-factor. Throughout the study, the U refers to an overall U-factor, including the frame, and not to a local U-factor.

By comparing U-factors derived from this method to the National Fenestration Rating Council (NFRC)-rated window U-factors, we found that taking measurements at the center of the window produced U-factors that were too low. Measurements at the edge of the window (immediately next to the frame) produced U-factors that were too high. But we found a sweet spot, 1.25 inches from the corner of the window, where U-factor measurements using this method came close to rated U-factors. Results are shown in Figure 3.

We have to confess that to get the temperature method U-factors to come close to matching the rated U-factors we had to make a correction for outdoor temperature. Our own U-factor measurements kept dropping as the outdoor temperature got warmer. But we found a way to make this correction, and the results shown in Figure 3 are in fact outdoor-temperature-corrected results.

Is our method accurate enough, for example, to detect whether an argon-filled window has lost its argon fill? Figure 3 shows results of a test where it did just that. We tested an argon-filled window, drilled a hole in its frame to let the argon leak out, and retested it. Sure enough, you see a little jump in the measured U-factor for the window where the argon was removed.

Now a little caution is in order. We won't say "Don't try this at home," but rather "Try this at home, but don't call your window NFRC rated." This method cannot be substituted for an NFRC rating. NFRC ratings are the only way to compare windows directly. Rather, the IR thermometer method produces a field-measured

Window Surface Temperatures

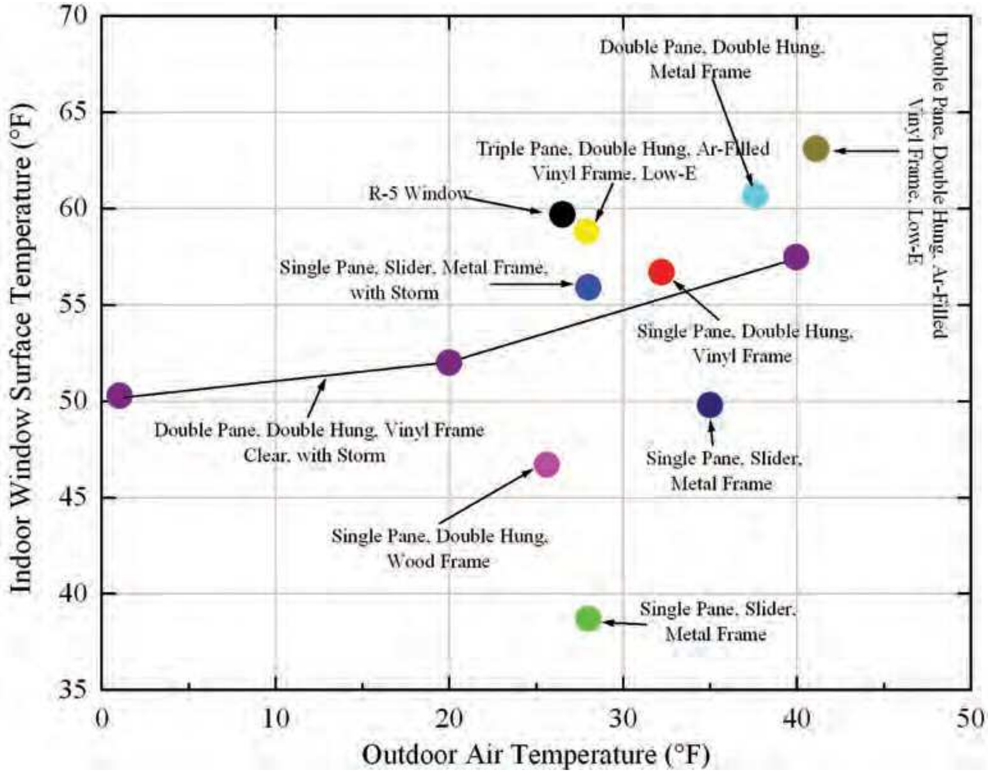

Figure 2. Results of indoor window surface temperatures under outdoor air temperatures for specific window types.

Window U-Factor Measurements

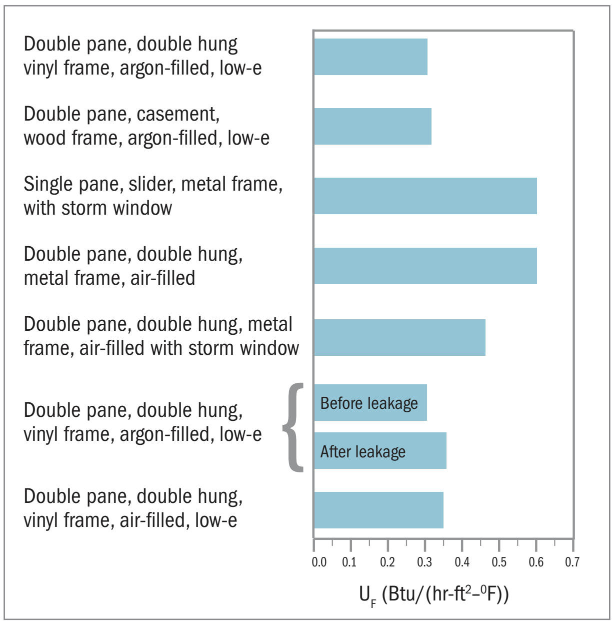

Figure 3. Obtaining comparable window U-factor measurements using an IR thermometer.

U-factor, which might be useful, for example, when estimating an unknown U-factor for an old or unusual window.

OTHER RESULTS

The project also generated some interesting tangential results. Here is what we learned.

1. Storm windows lower window U-factors. For example, a single-pane window, which has an ASHRAE-estimated U-factor of approximately 1.1, has a U-factor of approximately 0.6 when a storm window is added. Similarly, a double-pane window (no argon, no low-e), which has a rated U-factor of approximately 0.5, has a U-factor of approximately 0.36 when a storm window is added.
2. By our method, the U-factors of windows are lower when the outdoor air temperature is warmer. NFRC rates windows at a very cold 0°F outdoors. If our measurements are any indication, it is possible that NFRC's ratings may be overpredicting window U-factors on a year-round basis. In other words, windows may actually lose less heat than an estimate based on a rated U-value might predict.
3. The spacing of a storm window to a prime window does not affect the U-factor very much. In fact, as the spacing increases from 3 inches to 9 inches, the U-factor of the assembly goes up slightly, from U = 0.35 to U = 0.37.
4. The U-factor of single-pane windows appears to rely primarily on the surface heat transfer coefficients. In other words, the glass barely does anything other than stopping the air from just wafting in and out.
5. Metal frames are as bad as we all think they are. Single-pane metal-frame windows have overall window U-factors approximately 15% higher than single-pane wood-frame windows.

>> learn more

For a full description of the method and findings of this project, please contact Ian Shapiro at imshapiro@taitem.com.

For more information on Taitem Engineering and its research, visit www.taitem.com.

Ian Shapiro, *P.E., is the president of Taitem Engineering, which he founded in 1989. Since then, he has led several energy research projects and done many energy audits, and has always wondered why most (but not all) windows feel so cold in winter.* **Kapil Varshney,** *research engineer, leads Taitem's research efforts. He is currently studying distribution losses in energy-efficient homes through a method known as coheat testing, and is leading a project examining deep energy retrofits in homes.* **Javier E. Rosa,** *P.E., senior engineer, has been doing structural engineering design since 1993 and energy work since 2000.*

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