Taking the Pain Out of Testing

Tackling the defrost cycle dilemma makes metering a practical tool to use when choosing which refrigerators to replace.

by Thom Knoll

Nearly two years ago, Michigan's Weatherization Assistance program undertook a concerted effort to develop procedures to monitor, identify, and replace refrigerators. Because each of our Weatherization clients gets only one retrofit opportunity, it is important for us to catch all of the cost-effective replacements that we can. While program returns might be improved by looking for such outward signs as a gold or avocado color, you can miss some very hungry refrigerators that way (see "The Avocados, the Golds—the Replaceables?" *HE* Jan/Feb '03, p. 31). Rather than trying to judge by appearances, we chose to work on taking the pain out of testing.

MARCIA FERRIS

This defrost timer is very serviceable; most are. Simply advance the clock for a clean metering interval.

More than half of the 33 local Weatherization agencies in Michigan got involved in some aspect of fashioning evaluation, supply, and disposal methods for our program. The supply question was resolved when we established a relationship with Whirlpool Corporation, headquartered in Benton Harbor, Michigan, that allows us to order and document delivery using their Partner Store software on the Internet (see "Partner Store and More"). Creating an evaluation protocol was more complicated. Hoping to exceed the accuracy of rules-based evaluations, we developed a two-hour metering protocol that fits within most agencies' inspection procedures. Using a simple watt-hour meter during a pre-inspection site visit, we have found that we can identify appliances that might look good but aren't.

Automatic Defrost

The automatic defrost cycle accounts for a significant portion of the energy consumed by a frost-free refrigerator in a year. Figuring out exactly how much energy it consumes was one of the first hurdles we had to clear. Given that our crews get only a two-hour glimpse of the meter, the first question to sort out is, Has a defrost cycle occurred during the measurement period? If we don't know that a defrost cycle is included in a two-hour measurement period, the skewed data will probably lead us to replace the refrigerator, right or wrong. In other words, not knowing that a defrost cycle has taken place could result in replacements that are not cost-effective. We eventually found two ways to cope with this issue—one mechanical and one electronic.

During our learning phase, we visited Frigidaire's manufacturing plant in Greenville, Michigan. There we discovered that most frost-free refrigerators have an electromechanical clock that determines the frequency and timing of the automatic defrost cycle. We also found out that you can frequently advance this clock to ensure a defrost-free metering interval.

According to an engineer at Frigidaire, most frost-free refrigerators built in the last 20 years use a clock to accumulate compressor run time. When 10 or 12 hours of run time accrue, a resistance heater in the coil compartment kicks on to create heat. This heat melts any frost that has accumulated on the evaporator coil. As this melted frost runs down, the defrost timer continues to count down the defrost cycle—usually about 30 minutes total. The compressor then resumes making cold for a longer-than-normal cycle, as all that extra heat is pumped back outside. On a normal compressor duty cycle of about 20 minutes on, 20 minutes off, the defrost cycle will occur about once a day.

Most of these clocks can be serviced without taking anything apart. Many freezer-on-top, or top-mount, models have a small hole in the roof of the fresh food compartment. (That's the lower, bigger box where you keep the beer.) Stick a wide, straight screwdriver blade through that hole, and you can advance the defrost timer. One side of the slots is ramped, so you can't turn the timer backward. As you rotate the timer shaft, you will hear an audible "click" as the defrost cycle

begins. If your wattmeter is attached (and the door open), you'll see consumption jump from 40 to very near 440 watts—the sum of the energy used by the heater and the lightbulb. The compressor, if it is on, will stop. Crank the timer shaft a bit farther (about 20°) and a second audible "click" will signal the end of the defrost cycle. If the thermostat is calling for cold, the compressor will start and another refrigerator day will begin.

If you intentionally advance the timer past the end of the defrost cycle, you can be sure that your meter reading will not be skewed by the heat cycle, or by the increased cooling load caused by the shedding of defrost heat. But although you have avoided an erroneously high consumption estimate in your short metering interval, in extrapolating from the metered data to annual energy usage, you will have to adjust the data to account for the fraction that a defrost cycle would consume. Based on Larry Kinney's work at Synertech Systems in the late 1990s an increase of 8% has come to be the standard adjustment factor.

To get an estimate of annual consumption from what is typically two hours of metered data, we calculate a unit's average kWh per hour and then multiply that figure by 8,766 hours (or 365.25 days) in a year. If no defrost cycle has occurred, we then increase that product by 8%. Finally we also include an adjustment to our meter readings if the temperature in the kitchen is more than 75°F. A refrigerator's compressor works longer than usual in a particularly warm kitchen, so we reduce the metered energy use by 2.5% per degree above a normal kitchen temperature to avoid obtaining an unrealistically high annual energy consumption.

A Metered Solution

We also spent time finding the right meters for our program—ideally ones that would identify whether a defrost cycle had occurred during the monitoring period. Thanks to Larry Myhier, at that time Michigan weatherization manager at the state Family Independence Agency office (FIA), I was blessed with a healthy budget, and was allowed to order four different watt-hour meters from three manufacturers. I spoke with Phil Kaluza at EnergyTools.com and Alex Moore at D & R International before ordering, and ended up with Brueltech's ECM-1200, the Watt Stopper PL-100 Plug Load Analyzer, and two Brand Electronics Digital Power Meters (models 4-1850 and 20-1850). The four units cost between $150 and $250 each (see "Meter Comparison").


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U.S. Congressman Fred Upton (Michigan 6th District) congratulates the first Michigan recipient of a replacement refrigerator at Whirlpool World Headquarters.

The cost difference between the two Brand Meters was $100. The more expensive model, the 20-1850, has a number of additional measurement capabilities, including power factor and a peak wattage memory. Great, I thought. This last feature would show me if a defrost cycle had occurred. I would just see if the peak was 400 watts or more, compared to the compressor load of 125 to 250 watts. Unfortunately, the peak memory was always full of the compressor start-up spike (recorded as 750 to 1,200 watts), so there was never a place for the meager 400W heater.

After talking to Phil at EnergyTools.com, the Brand distributor, I began bugging Ethan Brand directly. Whether he felt sorry for me, or because he's a homeboy (born in Michigan), he agreed to design a new chip that would ignore the instantaneous peak of the compressor spike. By comparing consecutive readings, the meter generates a peak wattage reading that gradually approaches the highest indicated wattage reading, and after a defrost cycle occurs, reads just about 400 watts. With this new chip, model 4-1850 WX includes the defrost feature for only $20 more than its original price.

Since Ethan was so accommodating, we pushed the envelope several more times, requesting changes to output for-

Partner Store and More

We had decided early on in our protocol process that units removed should not only be deactivated but also, as often as possible, should be recycled. It was equally important that the purchase be made as simple as possible for the local agency. The procurement committee decided upon a statewide bid process that would ensure an established price including delivery, removal, and certified recycling. (These standards go beyond the DOE requirement noted in the October 6, 2000, Weatherization Program Notice 00-5 that the process comply with Clean Air Act Section 608 requirements).

Several manufacturers expressed interest in the estimated 1,500-unit annual market, but only one met all of our specifications. Whirlpool Corporation, with world headquarters on the shore of Lake Michigan near Benton Harbor, proposed statewide prices with acceptable delivery terms and timing. They also agreed to certify deconstruction. An added feature was their Web-based Partner Store purchasing and delivery documentation. Our agencies, once their credit is approved, can order a replacement refrigerator, specifying delivery address, model, and door swing; obtain a confirmation with an estimated date of delivery; and, upon receipt of invoice, verify delivery, including a printable electronic facsimile of the client-signed delivery receipt from Quality Express.

mats and tab order. For the 170 meters Michigan ended up purchasing for their inspectors, the default screen displays both current watts and (modified) peak watts. One keystroke brings up NEAT inputs in appropriate units for the metering interval: kWh and minutes. The next extrapolates to annual cost and kWh, although we don't use it in replacement decisions. The algorithm used for this extrapolation does not include several important assumptions and so returns a lower-than-realistic estimate on short metering intervals. With a 24-hour metering period, however, these annual estimates should be very close.

Using NEAT Software

Michigan's agencies do not rely exclusively on metered data when making replacement decisions. Instead, they use either Oak Ridge National Laboratory's (ORNL's) National Energy Audit Tool (NEAT) or D & R International's Replace? Tool—and sometimes an agency will compare results from both software tools. NEAT's new Access-based version 7.1 has several baseload measure assessments, including the ability to determine a savings-to-investment ratio (SIR) for replacement refrigerators. Once your list of potential replacements is entered in setup, you can compare their installed cost with energy savings that would accumulate by replacing the existing appliance.

A NEAT user can arrive at an energy consumption estimate for the existing appliance by using either as-built or metered data. NEAT's as-built data comes from the Association of Home Appliance Manufacturers (AHAM) energy consumption data, which are theoretically available for thousands of refrigerators, indexed by manufacturer and model number. These energy consumption estimates are the same ones that appear on the yellow tag last seen on the appliance showroom floor.

Although this database is theoretically very helpful, locating a specific refrigerator in the database can be quite difficult.

THOM KNOLL

The "plug-and-play" Brand 4-1850WX watt-hour meter (bottom) and a Taylor multi-channel thermometer determine the fate of Michigan refrigerators during pre-inspection (in two hours).

For instance, a J.C. Penney unit could show up in one of three separate lists, with each list including spellings of this brand name that vary only by the spacings between the initials. Watch closely; these differences are difficult to detect. J. C. Penney includes only 1975 models; J.C.Penney lists only 1976 models; and J.C. Penney lists models from a number of years including 1976. The same confusion crops up with GENERAL, GENERAL ELECT, and GENERAL ELECTRIC; with two apparently identical spellings of KELVINATOR; with MONTGOMERY WA versus MONTGOMERY WARD; and with O'KEEFE & MER versus O'KEEFE-MERRITT models. There is no way of knowing in which list a particular year or model will be found. Each search begins with Manufacturer, so it is impossible to avoid these aggravations.

Finding the right model number is also problematic, and a difference of just one digit can take you from an annual estimate of 847 to an annual estimate of 1,239. Because there are thousands of entries, and frequently a wild card, or "*", as the third or fourth digit, typing in the number rarely works. You can find yourself scrolling through many similar-looking alphanumeric choices. Sometimes even the same number from successive years of production will have significantly better performance in the later-model years. With some practice, a success rate in the 80% range can be achieved.

When using this tool, be aware that NEAT has a built-in algorithm that adjusts a model's energy consumption estimate for the ravages of time with the precision of a meat cleaver. For refrigerators over 5 years old, NEAT adds 10% to the consumption, for those 10 to 15 years old, 20%, and for those over 15 years old, 30%. Although refrigerators do tend to degrade over time, many refrigerators that we have tested don't follow this pattern.

NEAT's metered data calculation contains another anomaly that, right or wrong, ratchets up consumption. A factor of 0.882 is applied to every annual

Meter Comparison

The Brand meters are simple to operate and understand. Unplug the refrigerator and plug the line cord into the meter. Then plug the meter's 3 1/2-ft cord into the appliance receptacle. Reset by holding enter and pressing reset, and you are ready to collect data. Arrow keys scroll you back and forth though the various display screens.

The Brueltech has a separate power supply, requiring a wire and another electric receptacle. The refrigerator line cord requires an adapter that provides access to one side of the AC wiring, to which a separate wire and clip is attached to sense current. This same meter, with an additional current clip, can monitor two loads or both sides of a 220V load. Operation requires various combinations of the four buttons. For example, all four are used for resetting. Pushing the left two buttons displays voltage, while depressing the right two allows the user to enter setup. Elapsed time flashes days, then hours and minutes.

The Watt Stopper plugs directly into the wall and, with its two receptacles, can combine two loads. It provides voltage, current, wattage, apparent power, and power factor, as well as power and energy consumption data. All this information is output through a crowded screen. Nine screens are accessible only in series. I find that reading the screen is very difficult when this meter is plugged into a wall outlet, particularly if it is near the floor.

consumption estimate, based on an assumption that the door of the refrigerator is left closed throughout the metering interval. This constant divisor has same refrigerator, but included a defrost cycle in the monitoring period. The extrapolated annualized energy cost increased 32%, from $77 to $102.

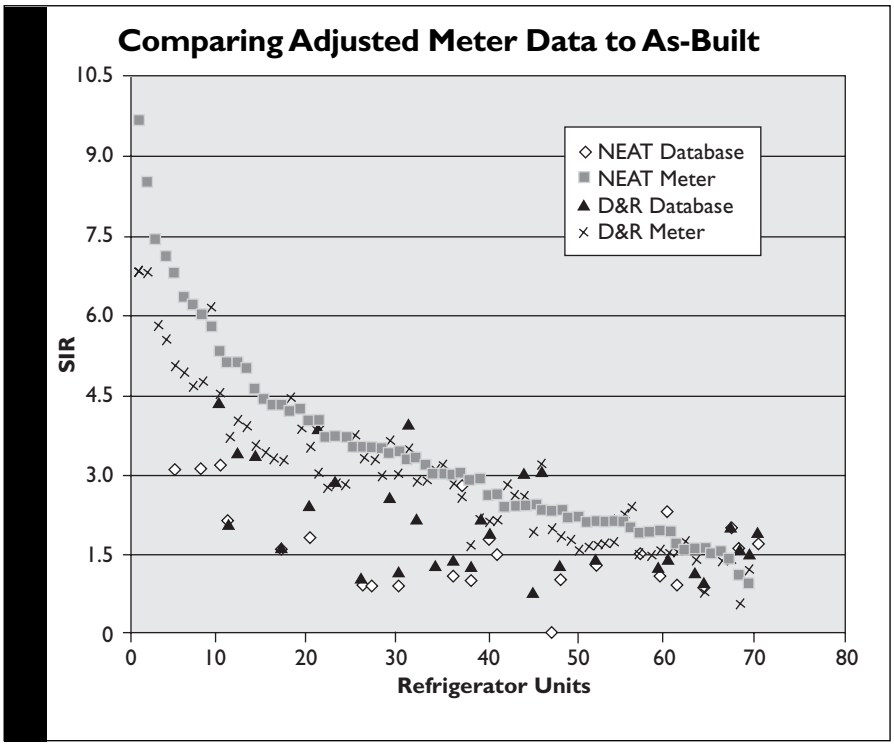

Figure 1. The graph shows both NEAT and D&R analysis, using metered and model information for 71 replaced units. Many models were not found in "as-built" consumption estimates.

the effect of increasing annual consumption by 13% (in place of the 10%, 20%, or 30% aging multiplier in the as-built equation). This number, which I call the Proctor factor, was taken from a table in a *Home Energy* article ("Other Methods of Shortening Refrigerator Monitoring Time," *HE* May/June '00, p. 34), where John Proctor was reporting hourly consumption factors. ORNL's Michael Gettings, NEAT's creator, is reconsidering the efficacy of this correction factor and may possibly adjust it in the next release of NEAT.

The standard 8% is added to the annual consumption estimate if the Includes Defrost Cycle box is unchecked. If you do check that box, NEAT lets you proceed with an SIR calculation after warning you that data including a defrost cycle can be highly inaccurate. To test how inaccurate these data can be, I collected meter data excluding a defrost cycle; then after 15 minutes I metered the

D & R International's "Replace?" Tool

As an alternative to the NEAT software, Alex Moore at D & R International created the Replace? Tool, which makes available a different set of consumption data in several formats, based on the California Energy Commission's *Directory of Certified Refrigerators and Refrigerator Freezers*. Replace? users can compute annual consumption estimates and SIR using either the PC version or a PDA-based tool that runs in Palm OS. Both are available from the Weatherization Assistance Program Technical Assistance Center, or www.waptac.org, for free download.

Both the PC-based calculator, which requires MS Access to operate, and the PDA-based Palm tool will compare the energy usage of selected replacement refrigerators to the ratings in the California database (by make and model) or to meter results. Most of NEAT's assumptions (including adjustable discount rate, age degradation, defrost, and Proctor factor) are mirrored in Replace? One exception is fuel escalation rates—set increases in electricity prices over time—which Replace? does not factor into its calculations.

Results are quite similar in terms of SIR for data run through each system, though some units on the cusp of a decision cutoff could fall either way. After running about a hundred units through all four possible iterations (NEAT versus Replace? and database versus metered) one lesson became apparent: Cost-effective replacements were missed using as-built data. The Michigan protocol allows the use of either tool in determining a replacement, as long as the SIR is above 1.5. In one dataset of 71 units identified for replacement, the metered data led to an SIR greater than 1.5 in the vast majority of the cases (see Figure 1). A technician relying solely on information from one of the two database lists would have generated an SIR of less than 1.5 in many of the cases. To be prudent, in 22 of these cases the technicians used both the database and metered consumption data run through the computerized calculation. In 45 cases, the decisions were based solely on metered data.

A Last Check

Finally, although we mostly replace refrigerators in order to save energy, our protocols permit replacement for health and safety reasons as well. If the unit is unable to maintain 38°F–40°F in the main compartment or 0°F–5°F in the freezer, it gets recycled. To easily monitor and document food storage temperatures, the state provided Weatherization agencies with remote-sensing thermometers. These are really just wireless digital thermometers sold for indoor/outdoor use. The manager at BoatUS, in Ft. Lauderdale, Florida, agreed to call Oregon Scientific (one of several suppliers) to try to determine for me whether these tiny transmitters would send signals through the refrigerator walls. I was assured that, though I shouldn't expect the stated range of 100 ft, the data would make it out.

Sending units are placed in the freezer and fresh-food compartments,

and the base unit, which can be located up to about 20 ft away, displays internal and ambient temperatures without opening the door. These recording thermometers may be overkill, but the large digital display encourages delivery of an energy education module discussing the correlation between temperature settings and energy consumption. It also, quite frankly, impresses the client.

Where the Rubber Meets the Road

After all of this information gathering, a committee of Michigan Weatherization coordinators devised, and the state FIA office published, a two-hour metering protocol and implemented this protocol on a pilot basis in seven agencies across Michigan starting in April of last year. Initially planned to last six months, the pilot period was extended primarily because of an early-out budget-saving measure that resulted in the retirement of over 6,000 Michigan employees, including three of four Weatherization technical staff. Statewide implementation, including equipment and continued support from Whirlpool Corporation, began April 1 of this year.

With a cost of $500, more or less, for installing a new refrigerator and certifying that the old one is processed for recycling, savings of about $50 per year are required to meet the Michigan SIR of 1.5. Other states (and some utility programs) are satisfied with an SIR of 1 and would need to save only $33 a year. In data gathered during the pilot phase by Capital Area Community Services, SIRs averaged 2.9 for 69 refrigerators replaced, indicating annual savings much closer to $100. Experience during the pilot has shown that about 30%–40% of refrigerators in low-income households meet Michigan's 1.5 SIR.

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Whirlpool hosted a kickoff celebration that included John Millhone, Program Manager, U.S. DOE Office of Weatherization and Intergovernmental Program.

The two years we invested in making refrigerator testing a less painful procedure appears to have been a worthwhile investment. We are now confident that, when we yank an existing refrigerator, the replacement is going to be cost-effective and an efficiency improvement for our clients—as well as for the state.

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For more information:

See *Refrigerator Replacement in the Weatherization Program* at www.waptac-pic.org/baseload.htm.