Thermal imaging helps make Energy Idea House a "zero hero"

Application Note

Testing Functions
Case Study

One glance shows this isn't your typical suburban house. Look east—there's a stunning, 180° view of mountains and the lake 100 feet below. Look up and you see rooftop photovoltaic panels, a wind turbine, a solar water heater and a rooftop carpet of live plants.

Tools: TiR32 Thermal Imager

Operator: Shirey Contracting, Inc.; Mike Lubliner, senior building science specialist at WSU; Andy Gordon, WSU energy specialist; DOE Building America

Measurements: Blower door air leak test with thermal imaging

Veterans of the homebuilding and remodeling industry and owners of Shirey Contracting, Inc. of Issaquah, Wash., the Shireys decided they would use the most sustainable methods and materials, push advanced construction techniques and HVAC technology to the limit—and drive energy costs to near zero. Adopted as a case study by the U.S. Department of Energy (DOE) Building America program and sponsored by many material and product suppliers, the Zero Energy Idea House was on its way.

Planning and developing the project took three years and construction another 12 months. In July 2009, with the building shell complete, it was time to use other advanced technology—a computer-controlled blower door and Fluke's new, high-resolution TiR32 Thermal Imager—to determine exactly how airtight the Shirey home was, and where problems might still exist.

The home rests on a massive, earthquake-resistant steel-and-concrete foundation. The design challenge was compounded by the steep slope of the site (the foundation columns include steel rings where landscapers can clip their safety ropes) and the need to control the flow of water during the famously rainy winters in Bellevue, Wash., just east of Seattle. Special compost-filled retaining walls do the job.

The small home (1630 square feet, two bedrooms) is built of structural insulated panels (SIPs) that combine framing, polystyrene insulation and exterior sheathing in one system for roofing, walls, or floors over crawl spaces. Built off-site, SIPs save time, labor and waste on the site and produce a structure that is tight and well insulated. Windows are fiberglass, with double panes.

Recycled and sustainable materials such as local, fast-growing alder wood are used throughout. Beams and joists are built of structural composite lumber made up of wood strands from relatively small trees, glued together and cured.

Toward zero energy

Mechanical systems are just as eco-friendly. According to the Zero Energy House website, "The term 'zero energy' doesn't mean a house uses no energy—it means the house combines on-site power generation with efficiency measures so that it meets its own energy requirements. In the case of the Zero Energy Idea House, the home's electrical needs will be met by rooftop solar panels, and the home's domestic hot water will also be heated by the sun."

However, living with absolutely no outside energy resources—what some call "off the grid"—is almost impossible in the Pacific Northwest. Summer air conditioning may be optional, but winters are cool and cloudy. So the home has a hydronic in-floor radiant-heating system fueled by natural gas, and utility power supplements its photovoltaic panels and wind turbine. Computer models by the Northwest Energy Star Homes program at the Washington State University (WSU) Extension Energy Program predict the home's energy bills will total less than $500 a year. (Energy Star is the U.S. government-backed program that helps businesses and individuals protect the environment through superior energy efficiency in buildings and appliances.)

"We talk about system engineering, how to make everything work as a whole," said Mike Lubliner, senior building science specialist at WSU and a member of the DOE Building America team. "That's where we started with Shirey, and we were fortunate to have Building America's support for that. Then, over time, we helped do energy analysis of some different options. As the home got built we did some preliminary testing. Now the goal is to do the commissioning of the mechanical systems. We'll put in some monitoring equipment and we'll spend a couple of years monitoring the energy performance of the home."

Achieving breakthrough energy performance requires attention to every detail. The building envelope and ventilation system are critical. With its space-age walls up, Sheetrock® installed and windows sealed, the house of the future was ready to prove it could limit energy losses by controlling the flow of outside air into the building shell.

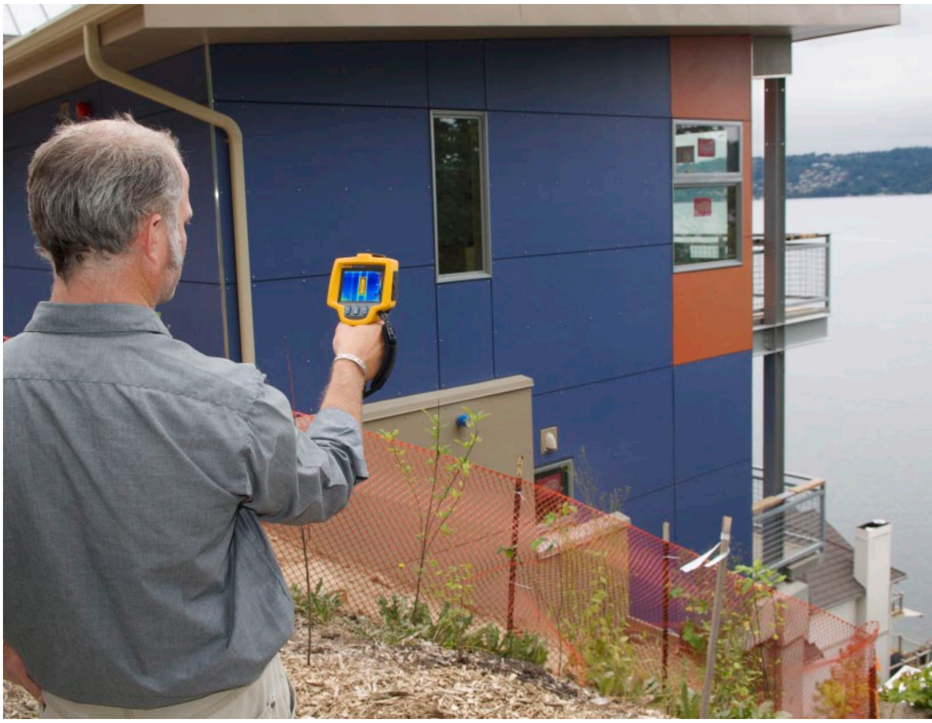
"Control" is the key word. In every home, outside air and inside air continually change places. Ventilation fans in kitchens and bathrooms exhaust warm, moist air, which is replaced by outside air coming through open doors and windows. When doors and windows are closed, that outside air gets in anyhow, through cracks and gaps. Even with fans off, wind can push cold outside air through those gaps into the living space. Minimize this random flow of cold air into the house and you can reduce the energy you need to heat it.

Yet some air movement is essential—no one wants to live in a tin can. "We hear people say we're building houses too tight now," said Donna Shirey. "You know what? We're not building them too tight. Rather, they're under-ventilated."

In the Zero Energy House, ventilation is carefully planned and controlled. A centrally located ventilation unit runs constantly, blowing inside air out and replacing it with outside air. A heat exchanger captures energy from the exhaust side to warm the incoming air. When exhaust fans elsewhere in the house go on, creating a drop in interior pressure, small ducts distribute the fresh makeup air from outside into the rooms.

Put to the test

The best way to test the air tightness of a home is through a "blower door" test. Windows and vents are sealed, and an aptly named blower door, equipped with a calibrated exhaust fan, seals the door. In operation, the fan blows air out, creating a low-level vacuum inside the



Infrared inspection of all external windows and doors can often show defects in installation or materials that contribute to energy loss.

An unexpected area of air infiltration was found coming from behind a major support beam. This may have never been discovered without the use of the TiR32.

home. Technicians then search for places where air is entering, using smoke sticks and thermal imaging cameras to identify spots that need repair.

On July 22, the WSU Extension Energy team and thermographers from Fluke were ready to see if the Zero Energy builders had really built an "airtight case" for conservation. But a rare Northwest heat wave posed a challenge: overnight temperatures were forecast in the mid sixties °F. Yet, for the thermal imager to show where leaks were occurring, outside air seeping in would have to be significantly cooler than the air inside.

Things had to get hot before Zero Energy House could prove how cool it was. So overnight, in the warmest weather the Northwest had seen in years, the Shireys used space heaters (the radiant floor heat was not yet operational) to boost temperatures in the home past 90 °F.

Early the next day, WSU energy specialist Andy Gordon set up the blower door and adjusted it to maintain a pressure differential of 50 Pascals between interior and outside. He then measured how much air was passing through the door to maintain that pressure. A quick calculation using the home's interior volume would show how many air changes per hour were passing through the door at 50 Pascals of pressure. The calculation is written as X ACH @ 50.

How did Zero Energy do? The more air changes per hour, the leakier the house. According to Gordon, older houses can test at 20 ACH @ 50, or higher. Current building codes specify a maximum reading of 7 ACH @ 50. The standard for an Energy Star–rated dwelling is 4 ACH @ 50. The Shirey home performed far better, with a rating of just 2 ACH @ 50. But while Gordon was recording these impressive results, elsewhere in the house Michael Stuart, senior product manager at Fluke and certified Level II Thermographer and infrared energy auditor, was proving that even more was possible.

Using Fluke TiR32, TiR1 and Ti55FT Thermal Imagers, Stuart shot infrared and visual light images of the home's interior, focusing most attention on the usual suspects in air infiltration: windows, doors and baseboards. Inspection began on the main floor and proceeded clockwise around the walls of the main level. Then it was on to the lower level, beginning with the north bedroom and again moving clockwise. Stuart also inspected the loft area above the main floor.

The most efficient home

"Finding air leaks in a home this efficient is not simple," Stuart said. "But the sensitivity to temperature variation provided by thermal imaging technology makes little things much more apparent. Without an imager, it would be much more difficult to find all the leaks and nearly impossible to accurately document them."

The Fluke thermal imagers showed exactly what was happening. Though the Zero Energy House was twice as tight and leak-proof as the Energy Star standard requires, the thermal imagers revealed small leaks in door and window framing and caulking. Air was entering through a loft area electrical chase, from the southwest corner of a main floor, south wall steel support beam, and in an area between the main floor and lower ceiling. Stuart recorded and documented every cold spot to be followed up later and repaired.

An additional negative pressure test, a positive pressure test and a follow-up infrared inspection will be planned for later this year, once repairs and adjustments are made. After the repairs, Shirey Contracting is shooting for a new milestone—an air exchange rate of 1.5 or better.

Meantime, customer Donna Shirey is pleased. "Reducing airflow in a house is one of the best ways to conserve energy, and here we have built a home that exchanges air only twice every hour," she said. "We are encouraged with the thermal imaging test results and think we may have built the most energy efficient home in the Pacific Northwest."

Inspecting all windows, doors and envelope penetrations from the inside of the house also yielded interesting information that helped to further increase the home's energy efficiency.

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