

# Double DUTY

Closed crawl spaces do double duty as a moisture solution and as an energy saver, according to research out of North Carolina.

By Cyrus Dastur and Bruce Davis

Last year we reported on closed crawl spaces as a technology that can dramatically improve the control of moisture in crawl spaces (*PCT magazine, June 2003*). Closed crawl spaces represent both a new business opportunity and a risk management tool for pest management firms, as the increase in complaints and legal action related to mold growth in homes has made homeowners, tenants and the home construction industry much more aware of the need to control moisture in homes. A growing number of homeowners and builders are investing the additional time and money required to install closed crawl spaces in both new and existing homes. In North Carolina, where we have a humid climate and plenty of termite risk, more than 16,000 homes are built on a crawl space every year. Nationally, more than 250,000 new homes per year are built on a crawl space, with an estimated 26 million crawl space homes existing nationwide. The latest findings from Advanced Energy's Princeville

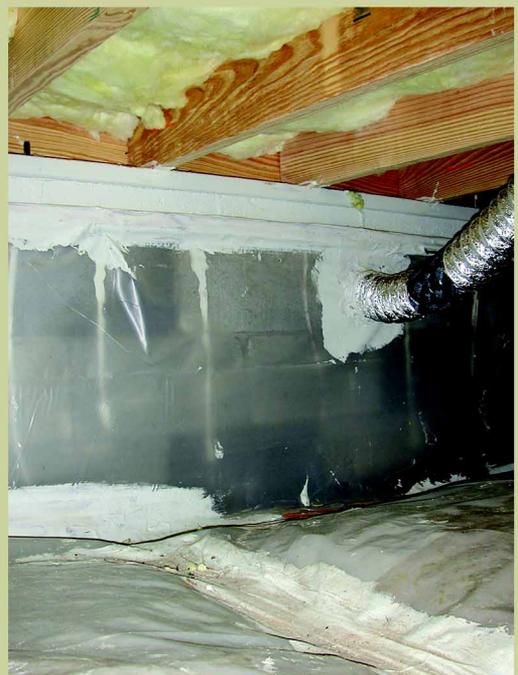


Figure 1 (top). This wall-insulated closed crawl space uses 2-inch thick, foil-faced polyisocyanurate insulation. The foam plugs in the band could be replaced by sections of R-19 batt insulation. A termite inspection gap is visible at the top of the wall insulation.

Figure 2 (bottom). This floor-insulated closed crawl space has a termite inspection gap at the top of the vapor retarder. Note that penetrations are thoroughly sealed with mastic.

Figure 3 (left). The butterfly damper of this crawl space supply opens while the system is running. The assembly is sealed with mastic and supported by strapping to ensure long-term proper operation of the butterfly damper.

Crawl Space Research project point to another benefit of closed crawl spaces: a significant reduction in the amount of energy needed to heat and cool homes built on this improved foundation design.

The following is a review of this research, which may be helpful to pest control firms that work in or close crawl spaces for customers.

**CRAWL SPACE RESEARCH.** Building professionals have long recognized that crawl spaces are prone to moisture problems and also may waste energy. In 1994, a national symposium on crawl space moisture problems concluded that crawl spaces are dangerously wet. In 1998, William Hill, a researcher at Ball State University, reported on the energy wasted in vented crawl spaces.

In the spring of 2001, Advanced Energy began a research project in the eastern North Carolina town of Princeville to compare the moisture and energy performance of closed crawl spaces to that of wall vented crawl spaces. Another main goal of the project is to demonstrate the practical application of closed crawl spaces using straightforward processes and readily available tools and materials. Co-funded by the U.S. Department of Energy and Advanced Energy, the project is directed by Bruce Davis and managed by Cyrus Dastur of Advanced Energy in Raleigh, N.C. The project team includes Dr. Achilles Karagiozis, Oak Ridge National Laboratory; Dr. Wayne Thomann, Duke University; Dr. John Straube, University of Waterloo, Canada; Architect Bill Rose, University of Illinois at Champaign-Urbana; Dr. Joe Lstiburek, Building Science Corp.; Physicist Anton TenWolde, U.S. Forest Products Laboratory; Environmental Scientist Terry Brennan, Camroden Associates; and Project Consultant Bill Warren, Bill Warren Energy Services.

The 12 homes studied in this project are located in the same development, with six houses built side-by-side on each side of one street. All are the same size at 1,040 square feet, with the same floor plan and window schedule (see Figure 4 above). After seeing the potential for energy savings during a billing analysis in early 2003, we outfitted all 12 houses with electric sub-meters to record exact energy consumption by each home's package-unit heat pump system (see Figure 6 on page 4).

We reduced duct leakage and house leakage to comparable levels across all the houses. Insulation deficiencies were corrected in all houses and heat pump refrigerant charge and system airflow were measured to be consistent among all houses. All the houses have a



Figure 4. One of 12 identical homes on the same street in the Princeville crawl space project.

fresh air ventilation intake integrated with the HVAC ductwork. A 6-inch insulated flex duct from outside routs air through a 1-inch pleated media filter and then connects directly to the return plenum. Whenever the HVAC system is operating, 40 cubic feet per minute (cfm) of filtered fresh air is mixed into the return air stream, conditioned, then distributed to the house.

The 12 homes in the study are broken into three groups of four homes each: one control group and two experimental groups. The four control houses have conventionally vented crawl spaces, with 11 8-inch by 16-inch foundation vents. Although the building code allows a reduction in the amount of wall venting when a ground vapor retarder is present, all 11 foundation vents were retained (see Figure 5 on page 3). (Current North Carolina code would not require the ground vapor retarder since these vents provide the net free area to meet the 1:150 ventilation requirement.) Each house has a 6-mil polyethylene ground cover that is mechanically secured to the soil with turf staples. The seams are lapped approximately 6 inches but are not sealed. The ground cover extends completely to the foundation wall and intermediate piers, covering 100 percent of the soil. The floors of the control houses are insulated with R-19 Kraft-faced fiberglass batts.

The crawl space vents of the experiment homes were sealed with rigid polystyrene foam and mastic or spray foam. Each of these closed crawl space houses has a sealed, 6-mil polyethylene liner covering the floor and extending up the foundation wall to a height 3 inches from the top of the masonry. The seams of the liner are sealed with fiberglass mesh tape and mastic and the edges are sealed with mastic to the foundation wall or intermediate piers. The liner is mechanically secured to the soil with turf staples and to the foundation wall with a furring strip.

Moisture control in the closed crawl spaces is provided by a small duct that provides 35 cfm of air to the crawl space from the supply plenum whenever the air handler is running (see Figure 3 on page 1). No fan-timing or fan-cycling controls are used in the mechanical system and no stand-alone dehumidifiers are used for moisture control. A balancing damper permits adjustment of the flow and a back-flow butterfly damper prevents movement of air from the crawl space into the supply plenum when the system is off.

Four of the closed crawl spaces are insulated with R-19 Kraft-faced fiberglass batts (see Figure 2 on page 1) in the floor above the crawl space and the other four are insulated with 2 inches of R-13 foil-faced polyisocyanurate foam (see Figure 1 on page 1) on the perimeter wall and on the band joist. The foam was installed such that there is a 3-inch gap between the top of the foam and the bottom of the sill plate to allow for monitoring of termite activity and there is a second gap at the bottom of the foam insulation to prevent ground contact and wicking of moisture into the foam insulation. The ground vapor retarder is attached to the inside surface of the foam insulation.

The crawl space experiment has been monitored for nearly three years. Ongoing results clearly indicate that the closed crawl spaces consistently outperform the wall vented crawl spaces in terms of both moisture control and energy use.

**ENERGY SAVINGS.** Total energy used for heating and/or cooling for the houses in each group during the four seasons and the year as a whole is shown in the "Seasonal and Annual Energy Comparison" chart (on page 4). The percentage of savings as compared to the control houses is reported in this table.

Going beyond the expectations of some in the building science industry, the closed crawl space homes exhibit clear energy savings over the control houses. This is true even for the four closed crawl space houses with wall insulation where we provided a termite inspection gap and did not continue the insulation down 24 inches below grade or out 24 inches horizontally onto the crawl space floor, as is typically recommended.

For the 12 months displayed, the floor-insulated closed crawl space houses have used an average of 15% less energy for space conditioning than the control houses, which represents a savings of approximately 870 kWh (or roughly \$87) per year for each household.

The wall-insulated closed crawl space houses have used on average 18% less energy

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than the control houses over the same 12-month period, which represents a savings of approximately 1025 kWh (or roughly \$103) per year for each household.

The energy performance for both the experiment groups has been substantially better than was expected. Reviewing the data, we hypothesize three possible reasons for the energy performance improvement in the closed crawl space houses. First, the control of moisture levels in the crawl space results in a reduction of the latent load on the house; second, the whole house as a system improved by virtue of the closed crawl space; and third, the houses are more closely coupled to the ground temperature.

We have looked carefully at the performance of the heat pumps on each house to ensure that individual variations are not skewing the energy results. One variable that remains to be reconciled is the effect of homeowner operation: indoor temperatures vary from 1°F to 2°F among the groups, with the residents of the control houses keeping their homes slightly cooler in the summer and slightly warmer in the winter. We are analyzing this data in depth to determine its impact on the overall efficiency results and expect a slight reduction in the savings that we have seen thus far.

**MOISTURE RESULTS.** Despite 2003 being the wettest year in recorded history in much of North Carolina, the closed crawl spaces continued to demonstrate excellent moisture control. Daily average relative humidity remained below 70 percent for the entire summer, actually getting lower and lower from June through August. Dew points in the closed crawl spaces were controlled below 60°F all year long, while the control crawl spaces experienced relative humidity near 90 percent and dew points higher than 70°F for most of the summer.

**INDUSTRY RESPONSE.** The traditional “improvement” for a vented crawl space has been to add more ventilation, either in the form of additional ventilation openings or by installing a fan to intentionally move more air through the crawl space. The Princeville research has confirmed over the long term

what Advanced Energy and other building science specialists have measured in many investigations of crawl space failure: In many regions, the outside air contains more moisture than the air in the crawl space during the warm seasons and has no potential to dry the crawl space. In fact, it often ends up *contributing* moisture. Consider this: The average dew point of the outside air at Princeville during the summer of 2003 was 73°F. This corresponds to relatively moderate conditions of 88 degrees and 60 percent relative humidity. When that air goes into the crawl space and encounters anything cooler than 73 degrees, the relative humidity peaks at 100 percent and the water vapor in the air condenses on that object just like it would on a cooldrink set out on the porch railing. Supply ducts, water pipes, water tanks and even the floor of the crawl space and the wood framing above can experience this condensation, es-

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pecially if the homeowners like to condition their house to very cool temperatures. If conditions aren’t bad enough for condensation, the relative humidity of the air entering the crawl space will still easily reach levels of 90 percent or higher for prolonged periods of time.

Besides the increased risk of moisture damage and mold growth that results from this high relative humidity and condensation, the heat that is transferred from the water vapor to a supply duct when the vapor condenses on the duct is fighting the efforts of the air conditioner to remove heat from the house. Poorly insulated ductwork only makes these problems worse. The closed crawl spaces don’t experience any of this condensation, even in the most humid times of the year. As another benefit, when the air in the crawl space stays dry, the wood in the crawl space stays dry. Average wood moisture content in the closed crawl space houses (measured in 10 different locations in each house every 60 days) remains below 12 percent year round.

Crawl space air can move easily through the numerous typical holes in the subfloor between the crawl space and the house and duct leakage often drives this flow when the duct system is located in the crawl space. Humid air entering the house from the crawl space results in more work for the air condi-



Figure 5. The wall-vented control houses in this study are much better than the typical crawl space we encounter in the field. They have well-installed insulation and 100 percent ground vapor retarder coverage of the soil, and no problems with intrusion of liquid water from outside.

tioner as well as homeowner complaints of discomfort and odors.

At a minimum, every crawl space should have a ground vapor retarder covering 100 percent of the soil. Adding ventilation openings or crawl space ventilation fans is much more likely to hamper moisture control and increase energy use unless you are in a very dry climate like the Southwest.

**NEXT STEPS.** The findings of this study would transfer well to houses of similar geometry and geography to the study homes. However, there are many other types of houses in other locations. Given the experiment design we expect considerable transfer of results for both moisture control and energy savings, but we will not know how well the moisture and energy performance can be replicated in mainstream production houses until a number are constructed and evaluated.

Currently the energy benefits of closed crawl spaces are not correctly predicted by

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popular energy analysis software, so it may be some time before closed crawl spaces get their due respect when builders choose house specifications aimed at achieving a certified minimum energy rating. We believe that our research findings will spur new refinements in the analysis tools and that in the meantime the data will reinforce the argument that consumers can improve their homes by build-

ing or retrofitting a properly closed crawl space. Planning is in process for expanding the current research into additional locations to determine whether closed crawl spaces will produce similar energy savings in other climate zones. Advanced Energy is already working on two new crawl space research projects; both are targeted at further understanding the impacts of wall vented and closed crawl spaces on indoor air quality and one specifically seeks to identify and explore any human health impacts that could be correlated to the type of construction used.

Professionals seeking to install closed crawl spaces face a formidable learning curve to be successful. As with all aspects of the construction industry, choosing the correct materials, tools and techniques is only half the battle; training and quality assurance are also critical to ensure that the right work is performed the right way at the right time. Besides proper pest management, a good closed crawl space needs to be designed properly with regard to control of internal and external water sources from the very start of construction. A drying mechanism (e.g. conditioned air supply, a dehumidifier, etc.) must be chosen for long-term, active moisture control. Other important design issues include combustion safety, fire safety, proper insulation and radon control if applicable.

Implementation requires close coordination with building officials, since building codes are lagging behind this technology and many current codes provide only a tortuous



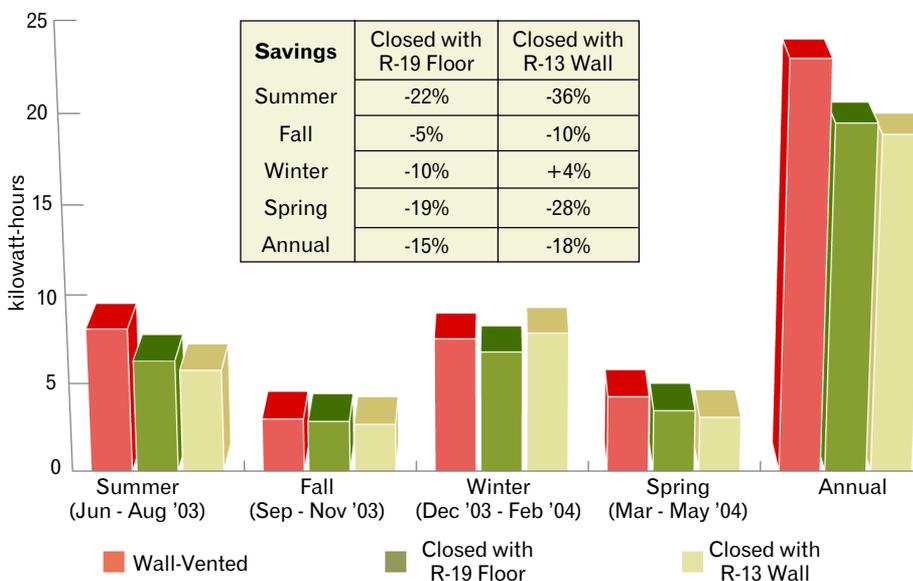
Figure 6. The sub-meter that measures electricity used by this heat pump is visible to the left of the duct cowling.

compliance path for closed crawl spaces. During our work to set up the houses in this study the scattered and conflicting nature of different building code elements governing closed crawl spaces became evident. For closed crawl spaces to be practical for both builders and code enforcement officials we are recommending a separate section in the code that is

specifically dedicated to these construction methods. We have helped the N.C. Building Code Council and code services staff to draft new code language for closed crawl spaces with the assistance of the North Carolina Structural Pest Control Board, the National Pest Management Association and several installers of closed crawl spaces across the state. The draft language is currently under review for adoption by the Council.

Pricing contracts and managing the safety and training of your employees is especially important when developing and offering any new service. In closed crawl space work, coordination with other trades becomes an even greater factor since they will be literally walking all over your work to do their own. As one example of pricing, closed crawl spaces in one North Carolina market (assuming a 2,000-square-foot house) range from \$4,200 for a simple, new-construction project to \$6,700 for a complex retrofit project. Including wall insulation adds \$1,500 to \$3,000 to the sale for these examples. Complexities that increase the price over the “simple” baseline include the extra length of perimeter for houses with lots of angles, the number of support columns that break up the floor of the crawl space and sloping grade, which requires additional material and fitting on the crawl space walls. Retrofit complications can also include existing water problems, contaminated or damaged materials and debris that must be removed prior to work commencing.

## SEASONAL AND ANNUAL ENERGY COMPARISONS



Source: Advanced Energy Princeville Crawl Space Research Project

Closed crawl spaces represent a new business opportunity and risk management service for the pest management industry. Pest management firms that rise to the challenge of implementing specifications and procedures for installing closed crawl spaces as a moisture control technique will be able to take satisfaction in the knowledge that they are also providing their customers with the benefit of energy savings. 🌱

*All photos are courtesy of Advanced Energy.*

*Cyrus Dastur is Princeville crawl space project manager and Bruce Davis is research director.*

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**Resources:**

Issues in Crawl Space Design and Construction, American Society of Heating, Refrigeration and Air-Conditioning Engineers Inc., winter meeting, January 1994.

“Measured Energy Penalties from Crawl Space Ventilation.” *In Proceedings of the 1998 Summer Study on Energy Efficiency in Buildings*, Vol. 1. Washington, D.C., American Council for an Energy Efficient Economy.

“Moisture Solution Becomes Efficiency Bonanza in Southeastern United States.” *In Proceedings of the 2004 Summer Study on Energy Efficiency in Buildings*, Vol. 1. Washington, D.C., American Council for an Energy Efficient Economy.



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