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WINTER 2018

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# SOLVING the UNINTENDED CONSEQUENCES of a HOME PERFORMANCE RENOVATION

by LESLEY HERRMANN

Photos by ERIK DAUGHERTY, E3 INNOVATE

Tight homes are becoming more common around the country, even in the mid-South where many builders still believe that homes and crawl spaces should "breathe." And home performance, still not well understood in some markets, is becoming more common in high-end and custom homes. Is the workforce keeping up, and have builders and contractors learned how to design an integrated home?

E3 INNOVATE (E3) is a small business in Nashville, Tennessee, that provides home performance solutions for new and existing homes. Although we enjoy designing and installing integrated systems for new homes and major renovations, we also fix problems associated with home performance jobs.

Over the last ten years serving residents in middle Tennessee, E3 has fixed many failed attempts at tight, high-performance homes. Our experience suggests that builders, contractors, and homeowners need to be taught what works and what doesn't work to create and maintain a high-performance home. This article explains how system integration can make or break home performance, and why commissioning is important if you want to get it right.

## Another Case of Crawl Space Odors (and So Much More)

A tight home with proper ventilation is a durable, comfortable home, and one that provides a clean indoor environment. However, tight homes pose challenges, especially in our mixed-humid climate zone. If any part of the design is flawed or poorly executed, homeowners can face a whole new set of complicated problems.

Dave and Shirley Walton purchased their 1950s home in 2015 and added over 1,000 square feet of living space for a total of about 6,700 square feet. Their renovation created a tight home! The final testing report showed an air leakage rate of 2.7 $ACH_{50}$. This is much tighter than what we typically see in middle Tennessee. The current code in Davidson County, where Nashville is located, is 7 $ACH_{50}$ or less.

In the process of renovation, Dave and Shirley invested heavily in high-performance upgrades, including

- a geothermal heating-and-cooling system;
- whole-house steam humidifiers on the air handlers;
- whole-house air filtration systems on the air handlers;
- a sealed crawl space system;
- energy recovery ventilation (ERV);
- high-end bathroom exhaust fans with motion sensors; and
- spray foam on the attic roof deck.

This all sounds great; however, something just wasn't right. Eighteen months after completing the renovation, Dave called E3 with a complaint: Odors were coming from the return ducts in the living space. E3 investigated the situation and found a

*(left)* A sample area was removed from the exterior wall to verify the thickness of foam and assess evidence of moisture. *(right)* Water pooling on laminate in the crawl space.

number of issues that not only were leading to the "smelly gym bag smell," as Shirley described it, but were causing additional performance problems.

## What We Found During the Home Assessment

The crawl space encapsulation had been done incorrectly. Some areas had been left unsealed and others were underinsulated. Foam and laminate had been applied in a way that left large air gaps, preventing contact with the cement block walls. We observed signs of mold and mildew growth on the floor joists and on the laminate in the crawl space. We also found small puddles of standing water.

Air gaps in and around ductwork and the return air plenums provide pathways for odors and radon to migrate up into the living space. This migration is exacerbated in the winter, when the stack effect is most pronounced.

In the attic, there were a few thermal breaks in the spray foam that were causing stack effect problems and infiltration. We found crimping in the exhaust fan ductwork that was choking the airflow. We measured airflow rates of 10 and 30 CFM in two of the three bathrooms. (We like to see bathroom exhaust flow in the 50-60 CFM range.) We also found that the expensive motion sensors had been installed incorrectly, rendering the fan in the third bathroom nearly inoperable.

The steam humidifiers were installed on the return side of the air handler unit (AHU), before the air filtration system and the AHU coil, rather than on the supply side. This arrangement creates perfect growing conditions for mold and mildew, which may then be distributed throughout the house.

Radon levels had not been tested in the home, so we left testing devices in the crawl space and the living space for 21 days. Testing is not required in the state of Tennessee, but Nashville is located in a class 1 radon zone (high risk for high indoor radon concentrations). Not surprisingly, the results came back high—58.7 picocuries per liter of air (pCi/L) in the crawl space and 14.6 pCi/L in the living space—but the existing encapsulated crawl space had no active mitigation system. EPA recommends a mitigation system when levels are 4.0 pCi/L or above. Dave and Shirley were understandably horrified.

This home was built with great intentions, but the lack of integration, commissioning, and attention to detail resulted in unsafe conditions and costly repairs for the homeowners.

## Improvement Strategies

Our first goal always is to solve the homeowners' problem. Our second goal is to explain that a house operates like a system, each component affecting all the other components, so that the homeowners understand why repairs are necessary to address the underlying issues. We won't put a Band-Aid on a home to

make the symptoms go away. That's what we call short-term overpriced false hope. As building scientists, we put our heads together and come up with a plan that solves the problem at hand while improving the overall performance of the home for long-term comfort, efficiency, and indoor environmental gains.

To address the primary concerns of odor and radon, E3 completely reinstalled the sealed crawl space system and added a multibranch active radon mitigation system. The challenge with this design was the large segmented footprint of the crawl space. With about 6,700 square feet of floor area, this crawl space was divided into four compartments with four different access points. Two of these compartments (the primary and secondary crawl spaces) had a few smaller, very tight cavities that were left unsealed in the original encapsulation process.

After removing the existing spray foam and laminate, we installed multibranched radon piping. Then we applied new water-blown, ultralow-VOC spray foam and new clean laminate to every compartment and cavity in the crawl space. To further protect against high humidity levels, we added a designated crawl space dehumidifier to keep air conditions within acceptable ranges, especially during the summer months. Duct leakage and penetrations were also sealed.

In the attic, the same water-blown spray foam was used to fill the gaps, helping to reduce the stack effect and minimize air moving upward through the house. In the bathrooms, new exhaust fans with hard piping and proper motion sensors were installed.

## Commissioning

Once the recommended improvements are completed in projects such as these, E3 commissions the home with follow-up testing and monitoring. This provides a quality check for us, and peace of mind for the homeowners. For this home, temperature and humidity sensors were placed throughout the house and crawl space and a digital radon monitor was placed in the master bedroom. Airflow rates were also taken on the ERV and the bathroom exhaust fans to make sure that they were working properly.

After nine days of monitoring, the homeowners were pleased that the odors had disappeared. The radon monitor showed that concentration was down from the original 14.6 pCi/L, but still high at 9.2 pCi/L in the master bedroom. We hadn't solved the problem yet, but thanks to the postmonitoring process, we were able to keep at it before stepping away from the project.

We went back through the design and identified a weak suction on the mitigation branch serving the secondary crawl (below the master bedroom). Gate valves were added to the system to help balance the suction across the large footprint. Further dilution was an obvious next step, but a fine balance needed to

Bathroom exhaust ducts had long runs, bends, and crimps, which choked air flow rates.

Whole-home humidifier installed on the return side of the air handler creates the potential for mold growth.

Spray foam gap in the attic creates leakage and increases the stack effect.

**Table 1. Average Temperature and Humidity Levels Postcommissioning**

| | Master Bedroom | Living Room | Primary Crawl Space | Secondary Crawl Space |
|---|---|---|---|---|
| Average temperature (°F) | 69 | 72 | 72 | 71 |
| Average relative humidity (%) | 51 | 52 | 52 | 53 |

**Table 2. Reductions in Radon Concentrations**

| Event | Average Radon Concentration (pCi/L) |
|---|---|
| Initial test result | 14.6 |
| Installation of multibranch radon mitigation system below encapsulated crawl space | 9.2 |
| Addition of gate valves on mitigation system to balance suction and installation of Radostat ERV controller | 4.4 |
| Further adjustment to gate valves | 4.1 |

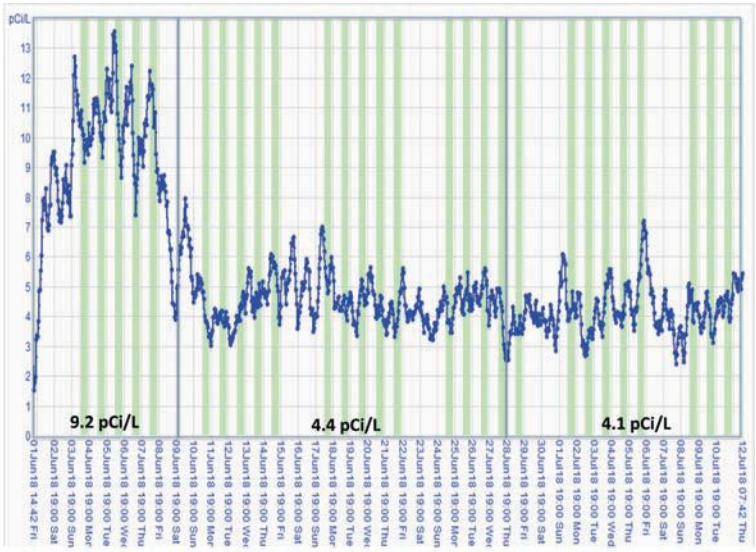


Figure 1. Digital radon devices monitor concentrations during the project and serve as a commissioning tool.

be reached. The ERV had two settings: Normal Operation mode (100 CFM) and Turbo mode (200 CFM). Turbo mode would provide too much outdoor air if run continuously, which in turn would increase indoor humidity.

To address this, a Radostat was installed as a permanent on-demand radon mitigation solution. When indoor radon levels rise to 4 pCi/L or higher, the wall-mounted sensor signals the ERV to ramp up to Turbo mode to increase dilution. In this way, the device balances the need for more outdoor air with energy efficiency and comfort. After these adjustments, average radon levels in the master bedroom dropped significantly but were still above 4 pCi/L on average (see Figure 1). Additional adjustments to the gate valves later dropped radon levels to 4.1 pCu/L.

We are continuing to monitor radon levels in this house. As we've seen from other studies, indoor concentrations can change significantly with weather patterns and from season to season. We have learned from these studies that a longer monitoring period (30–90 days) provides a better indication of seasonal average exposure.

## A Few Data Are Worth 1,000 Words

Table 1 shows average temperature and humidity levels after the final adjustments were made to all systems. The homeowners were pleased to learn that conditions in their crawl spaces are now better than those in many homes in Nashville! Table 2 and Figure 1 show how the adjustments to the radon mitigation system and the Radostat reduced concentration.

## Tight Homes Work Well but Getting Them to Work Requires Experience and Attention

Homes are getting tighter, and many builders and contractors don't yet have the expertise and experience required to integrate the components of a high-performance home. Home performance is an art and a science. It is critical to stay current with the latest techniques, products, and technologies that create efficient homes and healthy indoor environments.

Issues that arise because of improper installation or lack of integration can result in costly repairs and months of frustration for homeowners. Our experience with the design, installation, and balancing of systems, as well as data collection, gives us a rare beginning-to-end perspective on the science of home performance. When we aren't running load calculations or working in crawl spaces, we enjoy sharing our knowledge with others in the field to help move the industry forward.

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### >> learn more

For more information about E3 INNOVATE or to follow our blog on integrated home performance concepts, visit www.E3innovate.com.

To learn more about the variables affecting radon levels, check out our blog "Are you basing radon mitigation decision on short term results?"