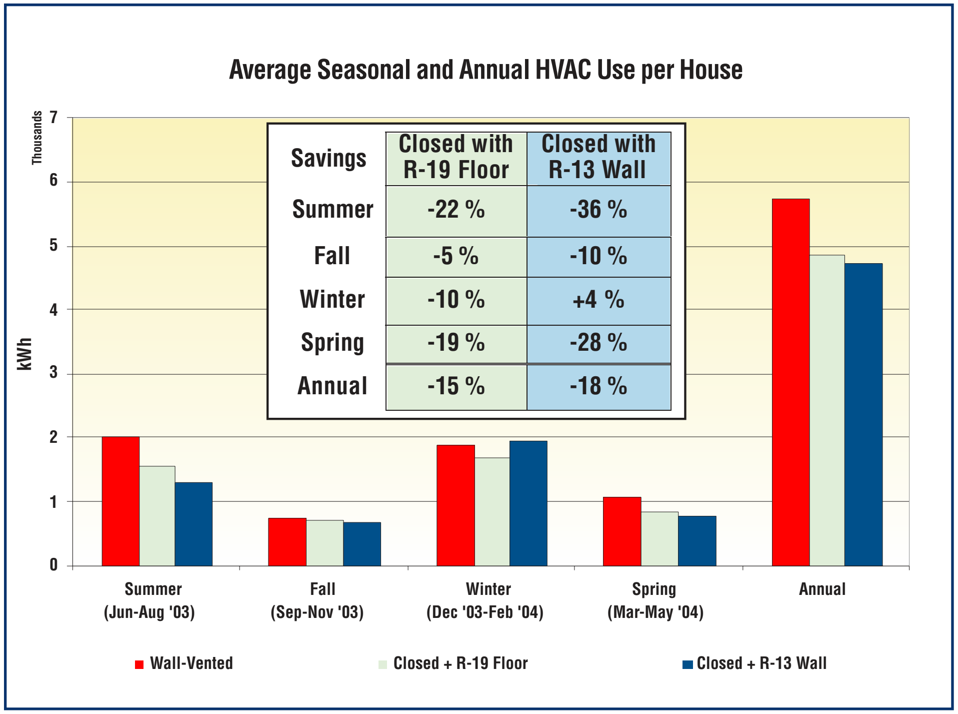


We did not sub-meter the appliance, lighting, water heating or exhaust fan loads, but noted that the total base load use in the control homes was significantly higher (10-20% in any given month) than that of the experiment homes over the entire year. By luck of the draw, the control homes had higher occupancy numbers and greater numbers of children relative to the experiment houses. The extra occupant and base load in the controls would theoretically increase the need for cooling in the summer and decrease the need for heating in the winter. The difference in base load usage between the controls and the floor-insulated experiment houses is about the same in both summer and winter, which suggests that the surpluses offset each other in terms of heat pump energy used/saved in the control houses to compensate for the difference. However, there is a greater difference in base load consumption between the control houses and the wall-insulated experiment houses in the summer than there is in the winter, which makes the summertime wall-insulated house performance look better.

Impact of Moisture Load on Comfort and Energy Use

A review of the interior house data indicated that the control houses were operated 1° to 2° F cooler than the experiment houses in the summer of 2003 and 1° to 2° F warmer than the experiment houses in the winter of 2003-04. This behavior could account for a portion of the energy savings we recorded, or it could be another indicator of the moisture benefits of the closed crawl spaces, since humidity levels play a large role in occupant comfort and the data shows that the dew point temperatures in all the homes were very consistent.

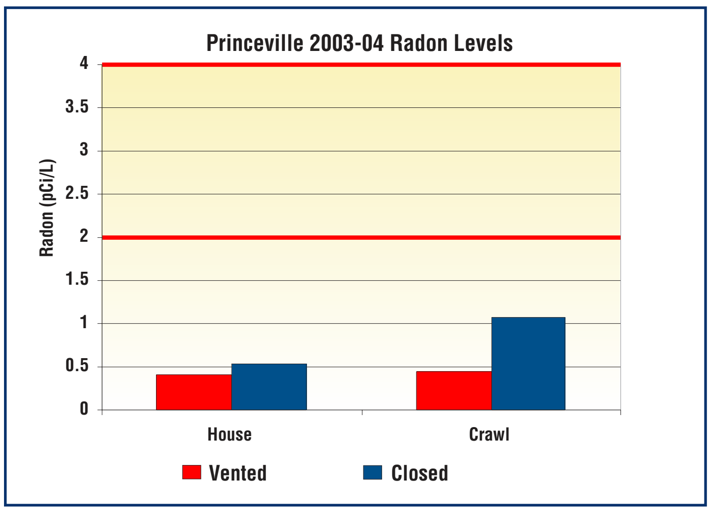
We have not administered a formal survey of occupant comfort, but had an experience that indicated the impact of crawl space performance on occupant thermostat settings: in June of 2004 we upgraded three of the four wall-vented control crawl spaces to test a new version of closed crawl space. We installed a crawl space supply duct to provide supplemental drying, as was done in the other closed crawl spaces. When we returned to the site four days later, one resident (who rarely adjusts her thermostat) excitedly let us know that the night after we closed her crawl space, she turned up her thermostat because she felt too cold in the house. This anecdotal evidence suggested that the difference in indoor set point temperatures may not be a simple matter of homeowner preference that reduces the measured energy savings, but instead be a result of the improved performance of the closed crawl spaces which deserves more detailed investigation. Subsequently, in July and August of 2004, the occupants of the three upgraded crawl space homes operated their homes within an average of 0.5 degrees of the temperatures in the other closed crawl space homes, while the occupants of the last remaining wall-vented crawl space home continued to operate their house an average of 2 degrees cooler than the occupants in the closed crawl space homes.

Radon Measurements

To ensure that these closed crawl space designs were not negatively impacting the health of the homeowners with regard to radon exposure, we conducted radon monitoring in the crawl spaces and the living areas from the summer of 2003 to the summer of 2004.

According to the EPA's "A Citizen's Guide to Radon" homes should be remediated when radon levels are above 4 pCi/L. One should consider fixing the home when levels are between 2 and 4 pCi/L. Reducing radon levels below 2 pCi/L is difficult.

The measured 2003-04 long-term results indicate slightly higher average concentrations in the closed crawl spaces, with measurements averaging 0.5 pCi/l in the vented crawl spaces and 1.1 pCi/l in the closed crawl spaces. The radon measurements in the living space do not show a difference correlated with foundation type; all houses average approximately 0.5 pCi/l with a maximum reading of 0.7 pCi/l in any house. The three highest crawl space measurements all occurred in closed crawl spaces, with values of 2.0, 1.5 and 1.4 pCi/L. All other measurements were below 1.0 pCi/L.



While the crawl space levels were all below the EPA action threshold, the higher measured radon levels do appear to correlate to the closed crawl spaces. Advanced Energy recommends treating closed crawl spaces like a short basement with regard to radon testing and mitigation. If the closed crawl space is being built in a radon risk area, the same measures used for radon assessment and control with a basement or slab foundation are applicable.

Mold Sampling Results

Anderson samplers were used to measure viable spores in the crawl spaces, outside, and in the living spaces in 2001 and 2002. Measurements in the living spaces were significantly lower than the outside measurements, but measurements in the living space above two of the wall-vented crawl spaces were the highest of the group.

Total spore counts, measured with Burkard samplers, were significantly higher in the wall-vented crawl spaces than in the closed crawl spaces, but large numbers of mold spores were measured in all the crawl spaces during the first round of sampling in 2001. Generally, viable and total spore counts as high as were measured in this project are found only in the presence of very large sources – e.g. harvesting fields, contaminated rooms, or composting facilities.

In the case of these crawl spaces, there were two contributing factors. First, the surrounding area was deluged by heavy rains shortly before the samples were made. This is reflected in both the crawl space and outdoor air data. Second, the sampling procedure required the technician to enter the crawl space, stirring up settled dust, and this likely contributed to the sampled levels being as strikingly high as they were.

In subsequent testing, we inserted the sampler into the crawl spaces on a long cantilever so that the technician would not have to enter and stir up settled dust. These readings were in fact much lower than the initial samples. After the cantilever sample was complete, we verified the impact of entering the crawl space by having a technician crawl inside the crawl space and take a followup sample. These followup samples, whether in the closed or wall-vented crawl spaces, showed a large increase in airborne spores. Most importantly, these findings point to the need to wear respiratory protection in all crawl spaces, even if there is no visible mold.

See Section 7 for background information on molds and health impacts of mold exposure.

Research Implications

The Princeville field demonstration project is scheduled to conclude in April of 2005. During the winter of 2004-05 Advanced Energy will test a new crawl space configuration to assess the energy impact of a 24-inch wide strip of R-10 foam insulation installed horizontally on the ground of the wall-insulated, closed crawl space houses. Final results and additional analysis will be posted on the project website, **www.crawlspaces.org**.

The performance improvement shown by the closed crawl spaces is impressive, especially considering that the control houses likely represent the best possible performance of wall-vented crawl spaces. The vast majority of newly built wall-vented crawl spaces are not installed or maintained to the standards used for this project.

We believe the findings of this study will transfer well to houses of similar geometry and geography to the study homes. However, additional consideration and study are required for houses in other locations and with different geometry. The energy results seem to indicate that wall-insulated closed crawl spaces will perform best in cooling-biased climates while floor-insulated closed crawl spaces will perform best in heating-biased climates. Of course, these homes have shallow foundations, and we have not tested crawl space foundations with deeper footing depths such as may be found farther north. A wall insulation strategy may also prove to perform best in such houses.

We won't know with any certainty how well the improvements in moisture and energy performance will transfer to houses in other climates until a number are actually constructed and monitored. Advanced Energy has begun a new project to gather that data in multiple climate zones while demonstrating the ability of the production housing market to incorporate closed crawl space technology into its construction processes.

Currently we find that the energy benefits of closed crawl spaces are not accurately predicted by popular energy analysis software, so it may be some time before closed crawl spaces get their due respect when builders are choosing house specifications aimed at achieving a certified minimum energy rating. Future research will include a detailed analysis of a variety of software tools, with the goal of identifying improvements needed in the tools and to reinforce the finding that consumers can improve the efficiency of their homes by building or retrofitting a properly closed crawl space.

Two of the field study homes were highly instrumented and monitored by Oak Ridge National Laboratory (ORNL) throughout the duration of the field study. The data collected from these houses has been used to calibrate and validate a computer-based hygrothermal modeling software tool. This software tool can now predict the hygrothermal performance of different crawl space designs when given basic thermal and moisture characteristics of the materials to be used in the design, along with environmental conditions.

Section 7

Common Questions About Mold

This section summarizes detailed mold information that is presented in several of the technical references, specifically ACGIH, 1999; Davis, 2002; Burge, 2004; Fallah, 2004 and Brennan, 2005. In addition, we offer recommendations based on Advanced Energy research findings and building investigations.

What is Mold?

Mold, together with mushrooms, bracket fungi, and puffballs are classified as fungi. These organisms consist of a mat of hair-like strands called hyphae that form both the main body and fruiting bodies that make spores. Spores are essentially baby fungi with a lunch box. Mushrooms, puffballs, and bracket fungi have large, easily seen fruiting bodies, while molds have tiny fruiting bodies that are visible as a surface discoloration only when there are many of them. Mold coverage ranges from light spotting to thick blooms that cover large areas. They can range in color from black to green to white, yellow and red and be present as discrete speckles or large fuzzy masses.

Mold reproduces by sending microscopic spores sailing on the air or floating on water. Mold spores are typically in the range of 3 to 40 microns in size; for reference, a human hair is typically 100 to 150 microns in diameter. A small colony may release millions of spores. When it is above freezing, a sample of outdoor air almost anywhere in the United States is likely to contain hundreds or thousands of mold spores per cubic meter. Consequently, almost all environmental surfaces have spores attached – it is virtually impossible to avoid them.

In order to sprout and grow into a colony, most spores need to be in a location that provides oxygen, liquid water and/or relative humidity greater than 70%, a source of carbon, and temperatures between 45° F (7.2° C) and 100° F (37.8° C). Once most molds have germinated, they do not need liquid water to continue growing. Unfortunately, these conditions are found in nearly every wall-vented crawl space in the southeast for much of the year. Because crawl spaces have numerous air path connections to the house via plumbing penetrations, electrical penetrations, leaky ductwork, and more, we could say that the crawl space is "MADD" – a Mold Amplification and Delivery Device.

Because spores, carbon sources, warmth, and dark spaces are found in all houses, the only realistic strategy for controlling mold growth is to control moisture levels. Eliminating liquid water is the first step. Controlling relative humidity is the second step and fortunately, most people are more comfortable at relative humidity levels below the 70% threshold required by most molds.

Hyphae exude enzymes that may decompose organic materials so the nutrient can be absorbed into the hyphal mat. That, in fact, is their ecological job – to decompose dead plants and animals. Molds are essential to the proper workings of the natural world.

Most molds are not good at digesting cellulose. Wood decaying fungi (soft rot, white rot, or brown rot) are the organisms that actually decompose solid wood, and they generally require very wet wood with a moisture content of 30% or more. Soft rot requires the continual presence of liquid water. Brown rot usually occurs on wood in contact with damp soil or a continuous water source, but can also be caused by molds that transport moisture from some other location (this latter type is typically referred to as "dry rot"). Crawl spaces with long-term condensation, standing water, or exposed soil are vulnerable to any of these molds, especially at low temperatures caused by air conditioning below 72° F (23° C) or in colder climates with low soil temperatures.

Sap stain or blue stain fungi may cause discoloration of cut lumber but are not reported to lead to rot or structural damage and probably do not present an air quality concern. Sap stain fungi can be mistaken for Stachybotrys species due to their dark coloration, but scientists note that the growth of Stachybotrys species on wood is extremely poor and rarely occurs. Stachybotrys species (e.g. S. atra or S. chartarum) typically occur on fiberboard, gypsum board, paper, dust or lint. These molds are associated with constant high levels of moisture resulting from flooding, unrepaired plumbing leaks or standing water. They are not often found in crawl spaces.

Growth of other fungi on solid wood in drier conditions (19-30% wood moisture content or ambient relative humidity above 70%) is generally limited to the surface and does not cause structural damage. Composite materials like engineered wood products consisting of bits of wood and adhesives can be structurally degraded by molds because the mold can often digest the adhesives. Composite materials must be dried and cleaned very quickly to prevent damage.

Should I Test for Mold?

Advanced Energy does not recommend mold testing unless there is a specific need to identify samples by species. As detailed below, it is generally expensive and time-consuming to get reliable mold sampling and analysis. Visible mold, regardless of species, indicates a moisture problem that requires attention. In some cases, molds are located in hidden areas or are simply not visible to the naked eye. Whether visible or not, the key to suppressing mold growth is to remove the mold's moisture source.

The generally accepted practice for bioaerosol sampling, as laid out by the American Conference of Governmental Industrial Hygienists (ACGIH), is to compare indoor samples with outdoor samples taken at the same time. If the spore concentrations are significantly higher indoors than outdoors or the species mix is significantly different indoors than outdoors, it is evidence that mold is growing inside the building.

Unfortunately, interpreting the results of bioaerosol sampling is fraught with sources of uncertainty:

- In sample sets taken at a few locations over an interval of hours or days, false positives and false negatives are common. To reduce the chances that something important has been missed, numerous samples must be made over extended time periods.
- Bioaerosol sampling requires trained technicians with specialized equipment, and even then, measurements vary significantly over short time frames. In controlled air sampling during the field research described in Section 6, outdoor viable spore count samples taken within hours of each other varied by a factor of five.

Ideally, mold samples should be "speciated," or counted and categorized by individual species of mold present in the sample. Speciation provides better evidence for distinguishing whether there is independent mold growth in a building (or part of the building) or whether the mold in the building simply reflects the mold present in the surroundings. "Viable" spore counts are easier to speciate than total spore counts, but viable spore samplers may be biased towards smaller species, and growth conditions can vary depending on the lab doing the analysis.

Tape lifts and direct microscopic examination of surfaces are other techniques to identify the presence of mold and, to some extent, identify the mold. These techniques also require trained specialists and do not generally allow for speciation.

Finally, even if sampling is detailed and comprehensive enough to provide confidence in the measured results, there is no consensus on numerical standards to which test results can be compared to indicate a dangerous condition. Human reaction to mold varies greatly from individual to individual.

Should I Clean Up Existing Mold in My Crawl Space?

Mold does not necessarily have to be cleaned up as part of a strategy to improve a crawl space. Molds go dormant as their environment dries out. However, dormant mold can still trigger allergies, asthma events, or other symptoms in susceptible individuals. Potential health impacts and the reporting of mold by private home inspectors prior to home purchases is causing more and more homeowners to consider removing or "remediating" mold from their crawl space. The homeowner's choice of whether or not to clean up mold depends on their level of concern about the potential health impacts of leaving the mold in place or the impact on the value of their home. One specific benefit is that cleaning out existing mold will make it easier to detect a recurrence in the future.

Of course, there is no point in cleaning up surface mold without improving the moisture conditions that allowed the mold to grow in the first place. The mold would simply grow back. Any activity to clean up surface mold should be part of an overall plan to close the crawl space permanently.

Mold-contaminated ductwork also presents the question of whether to leave the mold in place, clean the ductwork, or replace the ductwork. Flexible duct and fiberglass-lined ductwork is very difficult, if not impossible, to thoroughly clean. Other options include leaving the duct as is, replacing the ductwork or spraying fungicides or encapsulating materials to isolate the mold in the duct from the air stream. Sheet metal ductwork is generally more feasible to clean and reuse without encapsulation.

Advanced Energy recommends that you seal ductwork and seal holes between the house and the crawl space whether or not the mold is cleaned up. This air-sealing work reduces the chance that mold, mold byproducts or other contaminants in the crawl space can enter the living area of the home by air transport. It is also critical to help prevent new or cleaned ducts from becoming recontaminated. For additional protection, the homeowner can upgrade air filtration in the house with stand-alone HEPA units or HEPA air handler/duct system filters, and/or apply a fungicide over the existing mold to provide short-term anti-fungal activity and some level of continued suppression.

Advanced Energy has received several reports of strong ammonia-like odors associated with the drying-out of existing crawl spaces in North Carolina, which may be the result of the mold slowly dying or going dormant. The odors persisted for weeks or months without dissipating. Application of a fungicide in conjunction with reducing moisture levels has been reported to eliminate or prevent this problem.

If a property owner does decide to clean up existing mold, work can range from spot cleaning of affected areas to comprehensive cleaning of most, if not all surfaces. Large jobs are likely too labor-intensive and time consuming to do as a home project. In these cases, property owners can contract for professional cleanup services from water damage or mold remediation companies. Building performance or other contractors may also offer this service.

This guide is by no means a complete reference for doing safe and effective mold remediation, but simple advice is provided below. See the Resources and References section for several published sources of mold cleanup procedures.

During any cleanup, Advanced Energy recommends the following steps to help reduce the chance of cleaning materials, mold toxins, mold spores, mold fragments, or other contaminants moving from the crawl space to the living space:

- Turn off any heating and cooling system that utilizes ductwork in the crawl space.
- Reduce or stop the use of exhaust fans and clothes dryers in the living space.
- Pressurize the living area with HEPA-filtered air and/or depressurize the crawl space.

Additional notes on cleaning mold:

- Remove as much contaminated material as possible before beginning cleanup.
- Remove contaminated or damaged insulation. Porous insulation that has been wetted should be replaced, since it will likely never recover its designed R-value, even when thoroughly dried.
- Not all fungicides are effective on all materials. Follow all manufacturers' recommendations for application and safe handling. Swimming goggles can provide eye protection when working overhead.

- Chlorine bleach is not a long-term fungicide. If you use chlorine bleach, never mix it with ammonia because toxic gas can be produced in fatal levels.
- Liquid cleaning or dry scraping may not remove all staining caused by surface molds.
- HEPA vacuums can be used to collect surface mold removed by scraping, and are recommended instead of sweeping to clean up debris on surfaces or the crawl space floor.
- Pressure washing, sanding or blasting with baking soda or dry ice are cleaning options that may remove staining. Residual materials should be removed afterwards.
- Application of sealants, primers, and paint topcoats may be required to completely cover stains and resist bleed-through.
- Replace the ground vapor retarder after a cleanup operation.
- Air-sealing and subfloor repairs are easier while insulation is removed.
- Fungicides can be applied after cleaning to encapsulate mold spores that were not removed and to provide some level of continued mold suppression.
- Monitor and control relative humidity below 70% after cleanup to reduce the risk of mold growth recurring.

Does Mold Make People Sick?

At the time of this writing, the scientific and medical research communities have not documented a causal relationship between mold growth in residences and human illness. There is an association between damp home environments and occupant medical conditions like allergic rhinitis and asthma, however it is unclear whether mold or some other substance or organism (for example, bacteria) that exists in the same conditions is responsible for the symptoms.

The bottom line is that it is clearly less healthy for humans to live in homes with moisture problems, and strategies that eliminate the potential for such problems are beneficial.

Health effects generally attributed to mold exposure are of four types: allergy, irritation, infection, and toxicity. The most common health effects are allergic reactions and asthma events. The symptoms can include runny nose, eye irritation, sinusitis, and difficulty breathing. A tiny fraction of allergy sufferers may develop more serious, chronic lung disease from chronic exposures. Most molds release alcohols and sulfur compounds, which can irritate mucous membranes and the trigeminal nerve ending in the back of the throat, which reacts to pungency and irritation. People are sometimes infected by molds, but generally, people become colonized by molds only if their immune system is not functioning well.

Some molds produce toxins called mycotoxins. Mycotoxins are not produced as part of the act of living, as are the compounds from respiration and nutrient decomposition. They are produced only occasionally by some mold species. It is thought that molds are most likely to produce toxins when in competition with other molds or bacteria for habitat. In this case, people are collateral damage in chemical warfare between microscopic creatures. The best-documented cases of mycotoxin poisoning are from veterinary medicine when livestock eat mold-contaminated material. There is not much human data to help us understand the risks from mycotoxin exposure, however, the toxins do exist and some of them are similar in toxicity to nerve gases.

Section 8

Resources and References

Online Resources

American Conference of Governmental Industrial Hygienists

www.acgih.org

American Red Cross

www.redcross.org

"Repairing Your Flooded Home"
www.redcross.org/services/disaster/afterdis/reptoc.html

Canada Mortgage and Housing Corporation

www.cmhc-schl.gc.ca/en/index.cfm

Measuring air flow with plastic bags: Search for "garbage bag"

Centers for Disease Control and Prevention (CDC)

www.cdc.gov

Mold information
www.cdc.gov/nceh/airpollution/mold

Products and Services

The following is a list of the manufacturers or providers of products and services used in Advanced Energy projects discussed in this guide.

Product/Service	Manufacturer/Provider
Anemometer/air flow meter	TIF
Backflow dampers	Famco
Carbon monoxide monitors	CO-Experts
Constant airflow regulators	American Aldes
Duct mastic	RCD Corp.
Flood vents (FEMA/NFIP-compliant)	Smartvent, Inc.
Fire-rated foam insulation	Dow Chemical (Thermax brand)
Fuel gas leak detectors	S-Tech
High performance vapor retarder	Raven Industries
Liquid water alarms	Basement Systems
Mold sample analysis	Environmental Microbiology Lab
Outside air intake and filter housing	Indoor Environmental Systems
Radon test kits and analysis	AccuStar Labs
Sump pumps	Basement Systems
Wireless Temperature/RH meters	Oregon Scientific
Wood moisture meters	Wagner, Delmhorst

Federal Emergency Management Agency (FEMA)

www.fema.gov

"Technical Bulletin 1-93, Openings in Foundation Walls"

Florida Solar Energy Center (FSEC)

www.fsec.ucf.edu

"Florida Home Mold & Mildew Guide for Consumers"
www.fsec.ucf.edu/bldg/science/mold

National Association of Home Builders (NAHB) Research Center – ToolBase Services

"Mold in Residential Buildings"
http://toolbase.org/index-toolbase.asp
(search for "mold" if necessary)

U.S. Forest Products Laboratory

www.fpl.fs.fed.us
(search for "wood handbook")

U.S. Environmental Protection Agency
www.epa.gov

"A Brief Guide to Mold, Moisture and Your Home"
www.epa.gov/iaq/molds/moldguide.html

"Mold Remediation in Schools and Commercial Buildings"
www.epa.gov/iaq/molds/mold_remediation.html

Indoor air quality
www.epa.gov/iaq/pubs/index.html#homes

Radon information
www.epa.gov/radon/

Technical References

ACGIH, 1999: "Bioaerosols – Assessment and control." American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio.

Brennan, Terry and Harriet Burge. 2005. "Assessing Mold in Buildings". ASHRAE Journal, January 2005. American Society of Heating, Refrigeration and Air-conditioning Engineers. Atlanta, GA.

Burge. 2004. "Wood Decaying Fungi – An Insight on Types and Roles in Wood Decay." The Environmental Reporter Volume 2, Issue 5. Environmental Microbiology Laboratory, Inc.

Davis, Bruce and William E. Warren. 2002. Field Study Pilot Report: *A field study comparison of the energy and moisture performance characteristics of ventilated versus sealed crawl spaces in the south.* Raleigh, N.C.: Advanced Energy.

Davis, Bruce, William E. Warren and William B. Rose. 2002. *Technology Assessment Report: A field study comparison of the energy and moisture performance characteristics of ventilated versus sealed crawl spaces in the south.* Raleigh, N.C.: Advanced Energy.

Fallah, Payam and Kamash Ramanathan. 2004. "Fungi of the Month (II): Lumberyard molds – Ceratocystis/Ophiostoma (C/O) group." The Environmental Reporter Volume 2, Issue 5. Environmental Microbiology Laboratory, Inc.

Hill, William W. 1998. "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.

Rose, W. B. 1994. "A Review of the Regulatory and Technical Literature Related to Crawl Space Moisture Control." In *ASHRAE Transactions*, Vol. 100 Pt. 1. Atlanta, Ga. American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Rose, W. B. and A. TenWolde. 1994. Issues in crawl space design and construction – a symposium summary. *Recommended Practices for Controlling Moisture in Crawl Spaces*, ASHRAE Technical Data Bulletin volume 10, number 3. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Ga.

Other Resources

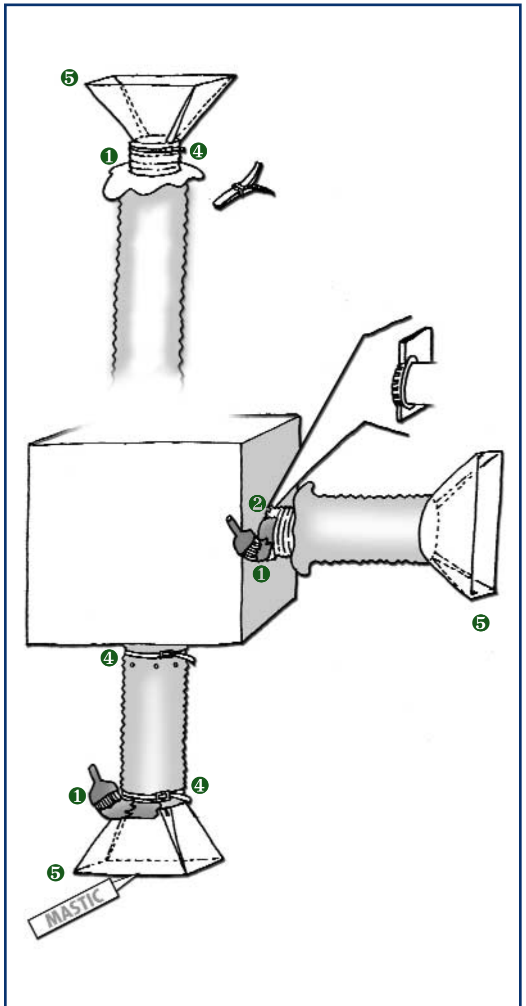
IICRC. 2003. *Standard and Reference Guide for Professional Mold Remediation S520*. Institute of Inspection, Cleaning and Restoration Certification, Vancouver, Wash.

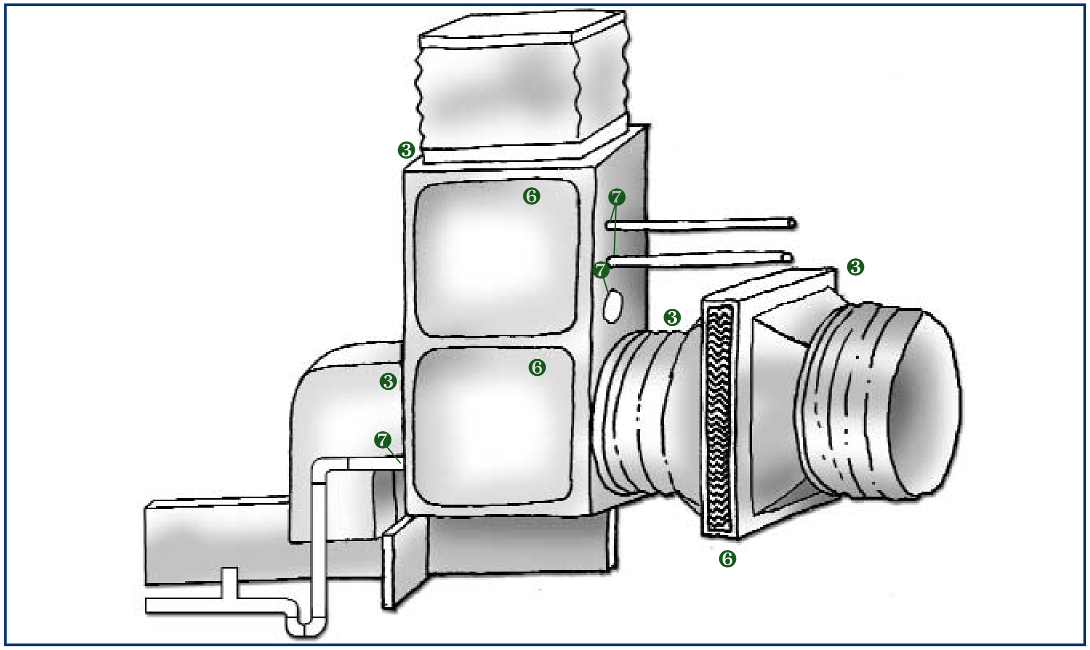
Institute of Medicine, 2004. *Damp Indoor Spaces and Health*. Committee on Damp Indoor Spaces and Health; Institute of Medicine, National Academies Press.

NYCDOH, 2000. *Guidelines on Assessment and Remediation of Fungi in Indoor Environments*. New York City Department of Health.

Appendix A

A Quick Overview of Duct Sealing





Sealing ductwork for forced-air heating and cooling systems is one of the most effective ways to improve energy efficiency and indoor air quality in a home. If you have any gas-fired or other fuel-burning appliances in the home, you should contact a building performance professional to assess whether duct sealing will cause a combustion safety problem. It is ideal to contact a building performance professional in any case, so that any necessary changes to the duct system can be implemented before sealing, and so that the duct tightness improvement and combustion safety can be verified after the sealing work is complete. Sealing ducts involves the following steps:

1. Seal all permanent connections or seams in the duct system with duct mastic
2. Embed fiberglass mesh tape in the mastic at connections or seams with gaps larger than 1/8 inch.
3. Embed fiberglass mesh tape in the mastic at connections or seams within ten feet of an air handler unit.
4. Mechanically fasten the inner liners of flexible ducts to register boots and seal the joint with mastic. Mechanically fasten the outer liner to the register boot. Zip-tie connectors are typically used for the mechanically attachments.
5. Seal duct register boots with mastic to the subfloor, drywall or other paneling they penetrate. Seal joints or gaps in the boot itself with mastic.
6. Gasket or tape access panels for the air handler or filtering systems.
7. Seal permanent panels, electrical, refrigerant and condensate line penetrations, and any unused holes in the air handler permanently.

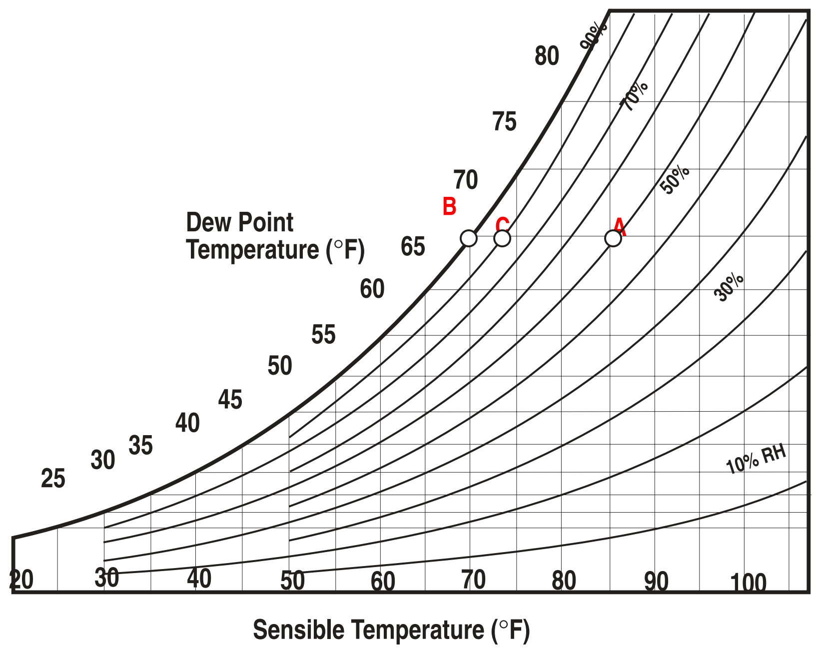
Appendix B

SIMPLIFIED PSYCHROMETRIC CHART

This chart is a simplified version of the complex psychrometric charts typically used in the refrigeration and air-conditioning industries. It is included as a tool for calculating the dew point temperature of air when temperature and relative humidity are known, and for predicting changes to dew point temperature or relative humidity when the air temperature changes.

Sensible temperature (also referred to as "dry bulb" temperature) is read on the bottom scale of the chart and is the temperature reading you would get from a standard thermometer. Relative humidity is plotted on the curved lines in the center of the chart. Dew point temperature is read along the curved left side of the chart.

As a quick example, say that you have air conditions of 85° F and 60% relative humidity. Find 85° F on the sensible temperature scale at the bottom of the chart, then go up vertically until you reach the intersection with the 60% relative humidity curve, at point A. To determine the corresponding dew point temperature, go left horizontally until you reach the dew point temperature scale on the left side of the chart at point B, which indicates that the dew point temperature is 70° F. To find out the relative humidity of this air at different temperatures, go right horizontally until you line up vertically with the desired sensible temperature. For example, going right to point C indicates that at 73° F sensible temperature, the relative humidity of this air would be 90%.



Appendix C

Wood Moisture Content at Different Temperatures and Relative Humidities

Taking a single-point measurement of either wood moisture content or relative humidity in a crawl space may not provide a complete picture of the long-term moisture conditions inside the crawl space. Relative humidity can vary much more quickly than wood moisture content, and wood moisture content readings can be dramatically increased by the presence of intermittent condensation on the surface of the wood.

The table below relates wood moisture content and ambient temperature to long-term conditions of relative humidity. If you can measure wood moisture content and ambient temperature, you can use this table to then estimate the long-term relative humidity that the wood has been exposed to. Note that wood moisture content varies only slightly (0.5% to 1.2%) at a particular relative humidity over the range of temperature from 40° F to 90° F.

For example, if you were to measure wood moisture content of 18% in a 70° F crawl space, then you can estimate that the wood has been exposed to relative humidity of approximately 85% over recent days or weeks, even if the relative humidity at the time of your measurement is much lower due to drier outside conditions.

Note that when the crawl space is vented with outside air, relative humidity inside the crawl space can change significantly over short periods of time. In some situations, measurements of relative humidity and wood moisture content may still appear to be contradictory even when using the equilibrium data from the table. The more controlled conditions in a closed crawl space generally make it easier to interpret measurements.

Moisture content of wood in equilibrium with stated temperature and relative humidity

(Source: U.S. Forest Products Laboratory, Wood Handbook, Table 3-4.)

Temperature		**Moisture content (%) at various relative humidity values**											
°C	**°F**	**40%**	**45%**	**50%**	**55%**	**60%**	**65%**	**70%**	**75%**	**80%**	**85%**	**90%**	**95%**
4.4	40	7.9	8.7	9.5	10.4	11.3	12.3	13.5	14.9	16.5	18.5	21	24.3
10	50	7.9	8.7	9.5	10.3	11.2	12.3	13.4	14.8	16.4	18.4	20.9	24.3
15.6	60	7.8	8.6	9.4	10.2	11.1	12.1	13.3	14.6	16.2	18.2	20.7	24.1
21.1	70	7.7	8.5	9.2	10.1	11	12	13.1	14.4	16	17.9	20.5	23.9
26.7	80	7.6	8.3	9.1	9.9	10.8	11.7	12.9	14.2	15.7	17.7	20.2	23.6
32.2	90	7.4	8.1	8.9	9.7	10.5	11.5	12.6	13.9	15.4	17.3	19.8	23.3

Appendix D

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ACCA – Air Conditioning Contractors of America

ACGIH – American Conference of Governmental Industrial Hygienists

AE – Advanced Energy

ARI – Air Conditioning and Refrigeration Institute

ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers

ASTM – American Society for Testing and Materials

BTU – British thermal unit

CAR – constant airflow regulator

CDC – Centers for Disease Control and Prevention

CMU – concrete masonry unit

CO – carbon monoxide

DOE – U.S. Department of Energy

EPA – U.S. Environmental Protection Agency

EPDM – Ethylene propylene diene terpolymer

FEMA – Federal Emergency Management Agency

FHA – Federal Housing Administration

FSEC – Florida Solar Energy Center

HEPA – High-Efficiency Particulate Arrestance

HSPF – Heating System Performance Factor

HVAC – Heating, Ventilation and Air Conditioning

ICC NER – International Code Council National Evaluation Report

IECC – International Energy Conservation Code

IRC – International Residential Code

MADD – Mold Amplification and Delivery Device

NAHB – National Association of Home Builders

NBS – National Bureau of Standards

NFIP – National Flood Insurance Program

ORNL – Oak Ridge National Laboratory

OSHA – Occupational Safety and Health Administration

SEER – Seasonal Energy Efficiency Ratio

SFHA – Special Flood Hazard Area

TIF – Thermal Industries of Florida, Inc.

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