Long-Term Temperature and Relative Humidity [2005]

| Characterizing Crawl Spaces as Sources of Mold in the Home Environment |

PREPARED BY ADVANCED ENERGY

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Duke University Reports (Bioaerosol/Fungal Sampling)
Crawl Space Characterization, Advanced Energy
Long-Term Temperature and Relative Humidity Report, Advanced Energy

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Executive Summary

The overall purpose of this Duke University study was to evaluate the importance of typical wall-vented crawl spaces as sources of mold species in the livable parts of the home environment. Duke University conducted bioaerosol sampling in 187 homes in North Carolina. Duke contracted with Advanced Energy to conduct a building science evaluation to characterize the conditions of typical wall-vented crawl spaces in 45 homes in Durham, New Hanover, Wayne and Wilson counties, a subset of the homes studied by Duke. This is one of three reports written for this study. The other two reports capture Duke's bioaerosol sampling results and Advanced Energy's crawl space characterization results.

During the initial crawl space characterization sampling visit, researchers installed a data logger in the crawl space of each study home to measure and record temperature and relative humidity, and then calculate dew point temperature. Due to a staggered launch schedule, data analysis was based on data recorded between the dates of October 15, 2004 and September 5, 2005. This data was used to document the long-term moisture performance of wall-vented crawl spaces, focusing on the summer humid months of June, July and August, 2005.

Results showed that venting crawl spaces with outside air does not dry the crawl space nor does it have the potential to dry the crawl space during the summer months. Summer outdoor air was confirmed to be wetter than crawl space air and outdoor dew point temperatures frequently exceeded crawl space temperatures, potentially resulting in condensation. Not only did the liquid water from condensation create conditions that support mold growth but relative humidity levels alone were found to be at levels sufficient to support mold growth. Nearly 100 percent of crawl space relative humidity readings exceeded the threshold for mold growth during the summer seasons of June, July and August 2005.

In the crawl space characterization report, researchers documented that mold and water vapor present in crawl space air are entering livable parts of the house. The results show that typical wall-vented crawl spaces experience mold growth and moisture levels that could lead to indoor air quality problems in the home environment. The results imply that at a minimum, improved wall-vented crawl space construction techniques should be implemented. However, even improved wall-vented crawl spaces will still not control the airborne water vapor that causes the documented problems. To fully address the crawl space moisture problems identified in this study, outside air must be excluded from the crawl space by implementing closed crawl space construction techniques.

Introduction

The purpose of this study was to evaluate the importance of crawl spaces as sources of mold species in the livable part of the home environment. Duke University received a Housing and Urban Development (HUD) grant to perform this work and contracted with Advanced Energy to conduct deliverables associated with the building science/crawl space characterization and long-term temperature and relative humidity analysis. This report documents the results of the long-term crawl space temperature and relative humidity monitoring.

TABLE 1 Overall study goals and objectives of the research

Goal /Objective	Responsible Organization
▪ Conduct fungal sampling in 125 – 150 homes with crawl spaces in three study locations in North Carolina.	Duke University
▪ Conduct crawl space characterizations in 40 – 50 homes drawn from the Duke University fungal sample homes.	Advanced Energy
▪ Provide long-term monitoring data on the temperature and relative humidity conditions in the crawl space characterization homes.	Advanced Energy
▪ Provide study participants with a report on findings from their home.	Duke University and Advanced Energy
▪ Evaluate the relative contribution of crawl spaces to mold species in the livable part of the home	Duke University with support from Advanced Energy
▪ Evaluate the causes for transport of mold species from the crawl space to the livable part of the home environment.	Duke University with support from Advanced Energy

This project was divided into three tasks: orientation, fungal sampling and crawl space characterization. During the orientation task, Duke University and Advanced Energy researchers reviewed the research objectives, schedules and deliverables with HUD headquarters staff. Duke University conducted fungal and bioaerosol sampling in 125-150 homes (see Duke University reports). Advanced Energy conducted the crawl space characterizations which included building science characterization and long-term temperature and relative humidity data on 40-50 houses, a subset of the Duke University houses.

Objectives

The principal objectives of the crawl space characterization were to collect building science and crawl space information used in characterizing the conditions of typical wall-vented crawl spaces across at least three counties in North Carolina. As part of this characterization process, loggers were installed in each study home's crawl space. The data loggers recorded hourly temperature, relative humidity and dew point data for approximate intervals of three months to one year, depending on the staggered logger launch schedule. The objectives of this report were to document the temperature, relative humidity and dew point temperatures in a typical wall-vented crawl space throughout the monitoring period, focusing on the humid summer months.

Background

Researchers studying indoor air quality have increasingly focused on mold as a household pollutant. As a result of their periodic high levels of moisture, crawl spaces are a very likely building area to find visible molds and mold odors. However, it is unclear how much of a problem crawl space mold, transported from the crawl space to the house, presents to the occupants of these homes.

Effect of building dampness and mold

Mounting evidence suggests that exposure to mold in damp buildings is an important risk factor for childhood respiratory illness.[1] The strongest identifiable risk factor for the development of asthma

[1] Etzel, Ruth et al. 1999. "Indoor Mold and Children's Health." *Environmental Health Perspectives*. Vol. 107 (Supplement 3): 463-468.

appears to be exposure to environmental allergens, including indoor and outdoor pollutants.[2] Moreover, child allergies are closely associated with asthma expression. Children living in flood plains may experience increased risks for exposure to allergens and asthma triggers. The North Carolina coast and piedmont areas have been subjected to a number of flooding events during the past several years, including the effects of Hurricane Floyd.

Crawl spaces as sources of mold and building dampness

Crawl space foundations are cheap to build, functional in terms of providing a level foundation for flooring on sloping sites and popular as spaces to locate plumbing, duct work and heating systems. For more than a century, home builders in North America have built houses on crawl spaces with wall vents on the premise that these vents help dry crawl spaces. Builders have avoided building crawl spaces without these vents for fear of causing moisture problems.

While wall ventilation of crawl spaces may work in various climates during some times of the year, researchers have documented that many wall-vented crawl spaces experience serious moisture problems. Measurement of humidity in North Carolina shows that outside summer air has more water vapor than crawl space air. Therefore venting crawl spaces in the summer offers no potential for drying and can actually cause moisture problems such as standing water on top of plastic ground covers, water condensation on ductwork and pipes, wet insulation, and stained foundation walls due to moisture and visible mold. Crawl spaces in North Carolina and in regions with climate similar to North Carolina may be more prone to surface mold problems than crawl spaces in other states as a result of more humid weather. Wall-vented crawl spaces have been shown to stay damp with relative humidity above 70 percent for long periods of time.[3] When this happens, the excess moisture encourages mold to grow on wood and other organic material such as cardboard, dust and paper-faced drywall.

Papers presented at the ASHRAE symposium on moisture control in crawl spaces expressed a need to document and validate the poor performance factors that are reported in existing homes.[4] Building mold has emerged as a major issue for the entire home building industry. The issue stems from thousands of insurance claims and lawsuits, including successful multi-million dollar settlements that identify building mold as a health problem for tenants and homeowners.

The association between conditions in the crawl space and mold species in the home environment was previously identified during indoor air quality investigations in the homes of health-impacted patients being treated at Duke University Medical Center.[5] A subsequent pilot study undertaken jointly by Duke University and Advanced Energy expanded the mold contamination characterization and assessment protocol. This pilot study confirmed crawl spaces as potentially important reservoirs of mold species that may be transported into livable parts of the home environment. In addition, all pilot study homes were found to have significant air leakage pathways between the crawl space and the home through duct and floor holes. These results indicate that crawl spaces may represent a more important exposure source than previously anticipated.[6]

This study allowed for a more complete characterization of the relative risk associated with mold growth in crawl spaces. Understanding the scope of this problem, as well as the mechanism for transport of mold species, is critical to providing guidance on establishing healthier home environments.

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[2] National Institutes of Health. 1995. Global Initiatives for Asthma. National Heart and Blood Institute Publication Number 95-3659.
[3] Building Air Quality: A Guide for Building Owners and Facility Managers, Appendix C. EPA 402-F-91-102. http://www.epa.gov/iaq/largebldgs/graphics/iaq.pdf.
[4] ASHRAE Symposium Recommended Practices for Moisture Control in Crawl Spaces. 1994.
[5] W.R. Thomann, M.L. Miranda, M. Stiegel and M. Overstreet. "Shared Air: Examining the Contribution of Mold from Home Crawl Spaces to Home Interiors." Proceedings of the Fifth International Conference on Bioaerosols, Fungi, Bacteria, Mycotoxins and Human Health. December 2004.
[6] Davis, Bruce and William Warren. Characterization Study Final Report: A Field Study Comparison of the Energy and Moisture Performance Characteristics of Ventilated Versus Sealed Crawl Spaces in the South. Advanced Energy. June 22, 2005. www.crawlspaces.org.

Procedure and Methods

During the crawl space characterization sampling visit, data loggers were installed in each study house's crawl space. Hobo Pro data loggers were used to record hourly temperature and relative humidity data. The loggers used this data to calculate the dew point.[7] These loggers were designed to operate from -22°F to 122°F (-30°C to 50°C) and from 0 to 100 percent relative humidity (RH). The RH sensor was designed to withstand intermittent condensing environments up to 86°F (30°C) and non-condensing environments above 86°F (30°C). In the high resolution mode used for this study, temperature accuracy equaled ±0.33°F at 70°F (±0.2°C at 21°C). RH accuracy equaled ±3 percent from 32°F to 122°F (0°C to 50°C) and ±4 percent in condensing environments.[8]

Data loggers were installed near the crawl space access and recorded conditions for approximately three months to one year. The first data logger was installed on July 22, 2004 and the final logger on December 8, 2004. Table 2 displays which houses were monitored in each data logging interval. Comments about specific loggers are also found in this table. A number of houses were excluded from the data analysis for the reasons explained in the comments section. Most notably, despite their robust design, five loggers experienced sensor malfunctions which were most likely caused by the extremely humid conditions they experienced. All data loggers were stopped as of September 5, 2005. Due to the staggered launch dates, the core data analyzed for long-term trends was from October 15, 2004 to September 5, 2005. For the purposes of this analysis the "summer" humid season was defined as June through August 2005.

TABLE 2 **Data logging intervals and comments**

Study houses	Data logging intervals			Comments
	Oct. 15, 2004-Nov. 30, 2004	Dec. 1, 2004-May 31, 2005	June 1, 2005-Aug. 31, 2005	
	N = 19	N = 32	N = 33	
Durham County				
7				Logger failed due to setup error
9				Dehumidifier operated summer 2005
25	x	X	x	Logger inactive April-May, 2005
34		X	x	
33		X	x	
43		X	x	
24		X	x	
49				Dehumidifier operated summer 2005
53				Logger failed due to sensor malfunction
54				Logger failed due to sensor malfunction
55			x	
New Hanover County				
3	x	X	x	
4				Logger failed due to sensor malfunction

[7] Hobo Pro data loggers from Onset Computer Corp. were used for this study. Model number H08-032-08. http://www.onsetcomp.com/.
[8] Davis, Bruce and Cyrus Dastur. Moisture Performance of Crawl spaces and their Impact on Home Cooling and Heating Energy in the Southeastern United States ASHRAE technical paper. December 2004.

Study houses	Data logging intervals			Comments
	Oct. 15, 2004-Nov. 30, 2004	Dec. 1, 2004-May 31, 2005	June 1, 2005-Aug. 31, 2005	
	N = 19	N = 32	N = 33	
10	x	X	x	
8				Dehumidifier operated summer 2005
15	x	X	x	
16	x	X	x	
20	x	X	x	
11	x	X	x	Logger inactive April-June, 2005
18	x	X	x	Logger inactive June, 2005
32	x	X	x	
22	x	X	x	
29	x	X	x	
26	x	X	x	
38				Logger failed due to sensor malfunction
42		X	x	
35		X	x	
46		X	x	
45				Logger failed due to sensor malfunction
47		X	x	
39		X	x	
56		X	x	
Wayne County				
19	x	X	x	
21	x	X	x	Logger inactive June, 2005
Wilson County				
2	x	X	x	
12	x	X	x	
23	x	X	x	
27	x	X		
37	x	X	x	
17			x	Logger inactive June, 2005
30		X	x	
14		X	x	
1				Logger failed due to setup error
52		X	x	

This analysis used outdoor temperature, relative humidity and dew point data from Weather Underground, which compiles data from National Oceanic and Atmospheric Administration (NOAA) monitoring stations. Researchers used BoxCar software to download the data loggers and export the data to Microsoft Excel for analysis.[9] Wayne County only had two study houses and was geographically close to Wilson County. Therefore, the two counties were combined for analysis.

[9] Box Car Pro 4.3 from Onset Computer Corp. was used to download the Hobo Pro data logger.

Results

The long-term temperature, relative humidity and dew point data was analyzed to understand the cycles of moisture in a typical wall-vented crawl space in North Carolina. This report focused more specifically on the conditions found during the hot and humid summer months. By evaluating outside conditions, crawl space temperatures, relative humidity and dew point temperatures, researchers were able to determine the potential for drying crawl spaces through ventilation with outside air. Additional comments about the use of dehumidifiers to control relative humidity levels and the role of relative humidity in indicating liquid water were included in this report.

Results are based on rolling averages of data recorded from October 2004 to September 2005. Summer months were considered to be June 2005 to August 2005.

Outside conditions

The outdoor temperature, relative humidity, and dew point conditions were similar across all counties. Figures A1 through A3 in the Appendix display the rolling 24-hour average of these conditions by county.

Crawl space temperatures

Crawl space temperatures for each county followed similar trends throughout the year. In the summer months, New Hanover, Wayne and Wilson counties ranged from around 70°F to 75°F. Durham County was slightly cooler, ranging on average approximately 68°F to 73°F. Figure A4 in the Appendix displays these county averages. During the winter, fall and spring months, the outside temperature generally remained below the crawl space temperature for all counties. During summer months, the outside temperature remained above the crawl space temperature. Crawl space temperatures fluctuate less than outside temperatures. Figure 1 illustrates the annual trends for Wayne and Wilson counties. Similar trends for Durham and New Hanover counties can be found in Appendix Figures A5 and A6. Figure 2 shows a more detailed look at Wayne and Wilson counties during summer months. Summer details for Durham and New Hanover counties are in Figures A7 and A8 in the Appendix.

FIGURE 1 **Outside temperature and crawl space temperature (°F) for Wayne and Wilson counties**

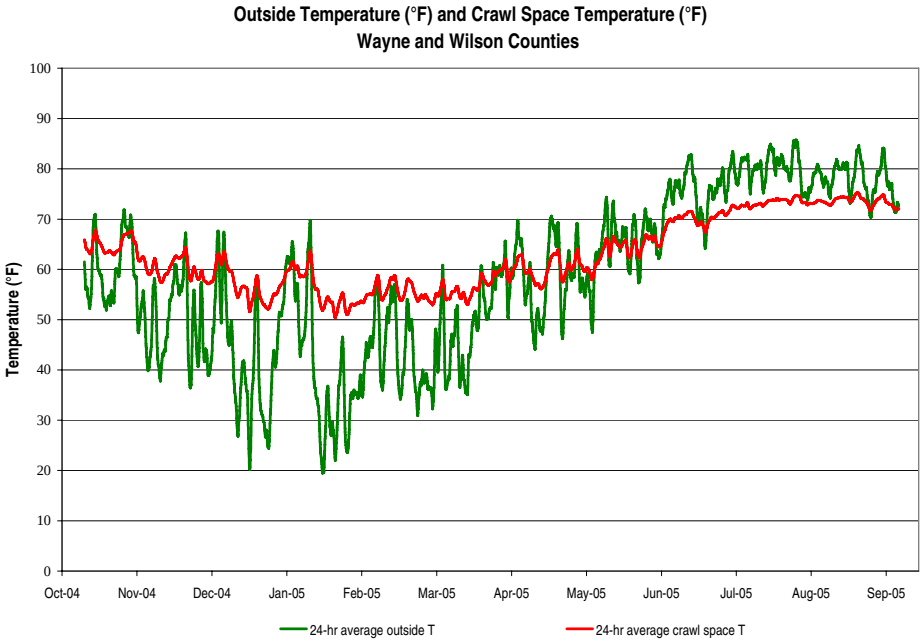
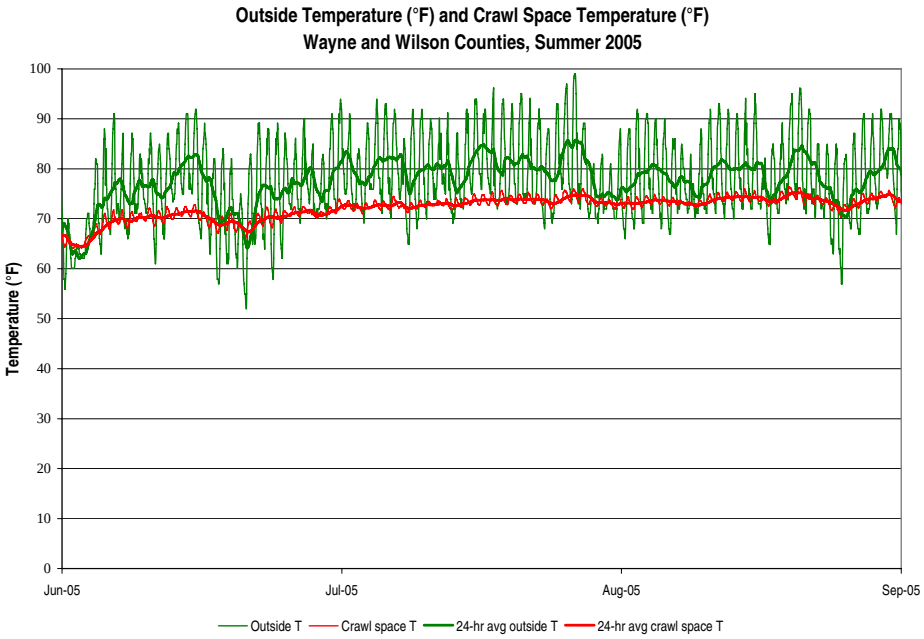


FIGURE 2 **Summer outside temperature and crawl space temperature (ºF) for Wayne and Wilson counties**



Crawl space relative humidity (RH)

One hundred percent of crawl space readings in June and July and 99 percent of readings in August were at or above 70 percent RH. Seventy percent RH is the commonly accepted threshold above which mold growth is supported.[10] Table 3 displays the percentages of readings exceeding 70 percent RH and 90 percent RH through the summer months of 2005. 80 percent RH is the critical relative humidity required for initiation of mold growth.[11] Long-term exposure to RH levels exceeding 90 percent can result in wood moisture content in exposed framing materials of 20 percent or more, which can also support surface mold growth.[12]

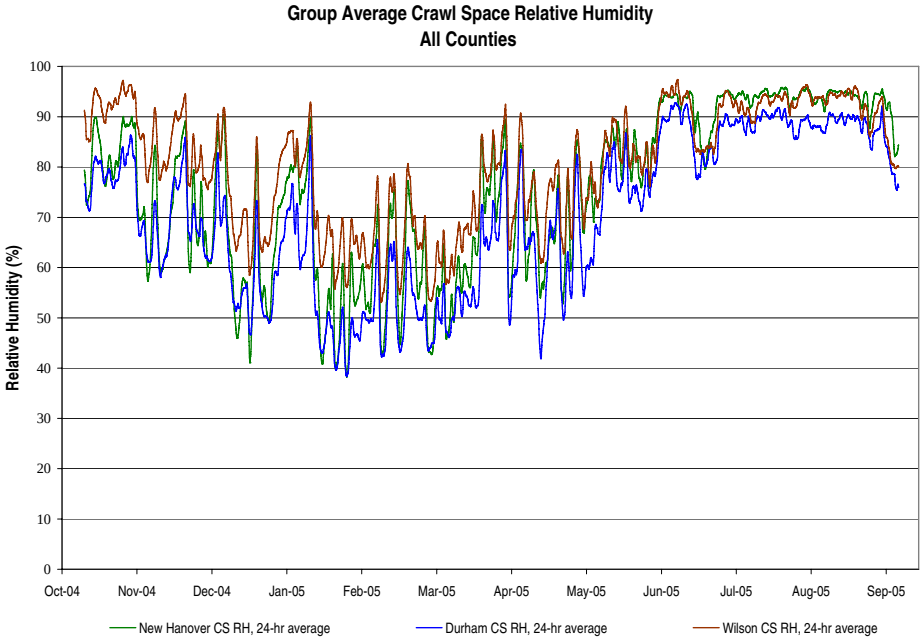
TABLE 3 **Percent of the crawl space readings that were ≥ 70 percent RH and ≥ 90 percent RH during the summer months of 2005**

RH	June	July	August
≥ 90%	56%	74%	72%
≥ 70%	100%	100%	99%

Comparing average crawl space humidity across all counties showed that during summer months, crawl spaces in all counties remained above levels supporting mold growth (70 percent RH). Figure 3 shows that all average summer RH levels exceeded 80 percent RH and most Wayne, Wilson and New Hanover readings exceeded 90 percent. These crawl spaces experienced dangerously high RH levels that are very supportive of mold growth.

[10] Building Air Quality: A Guide for Building Owners and Facility Managers, Appendix C. EPA 402-F-91-102. http://www.epa.gov/iaq/largebldgs/graphics/iaq.pdf.
[11] Hukka, A. and Viitanen H. 1999. A Mathematical Model of Mold Growth on Wooden Material. Wood Science and Technology 33(6) pp. 475-485.
[12] U.S. Forest Products Laboratory, Wood Handbook, Table 3-4.

FIGURE 3 **Average crawl space relative humidity**



Looking only at the summer months, the crawl space relative humidity was, on average, higher than the outside relative humidity. Figures 4 and 5 show this trend for Durham County. Similar data for Wayne, Wilson and New Hanover are in the Appendix (Figures A9–A12).

FIGURE 4 **Outside and crawl space relative humidity for Durham County**

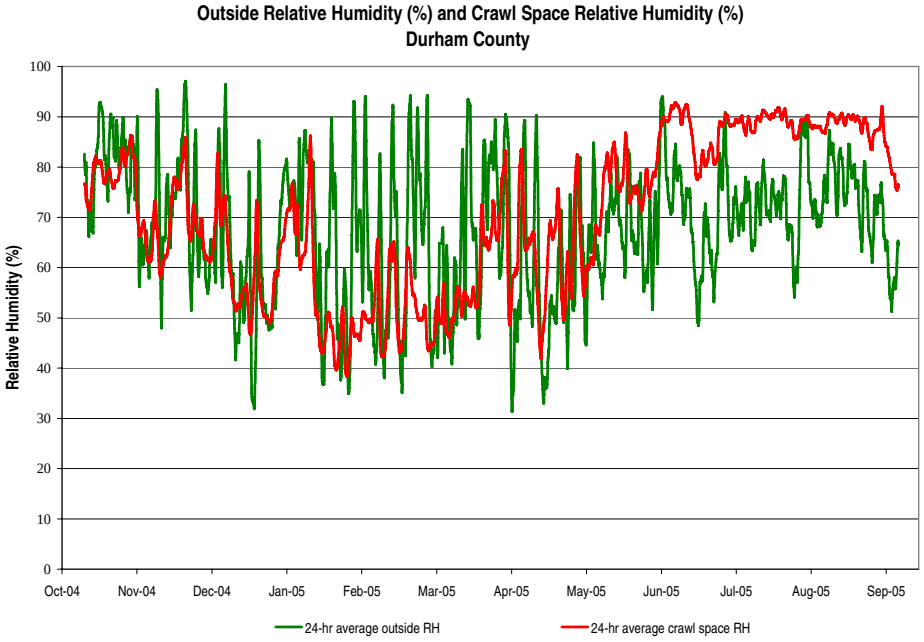
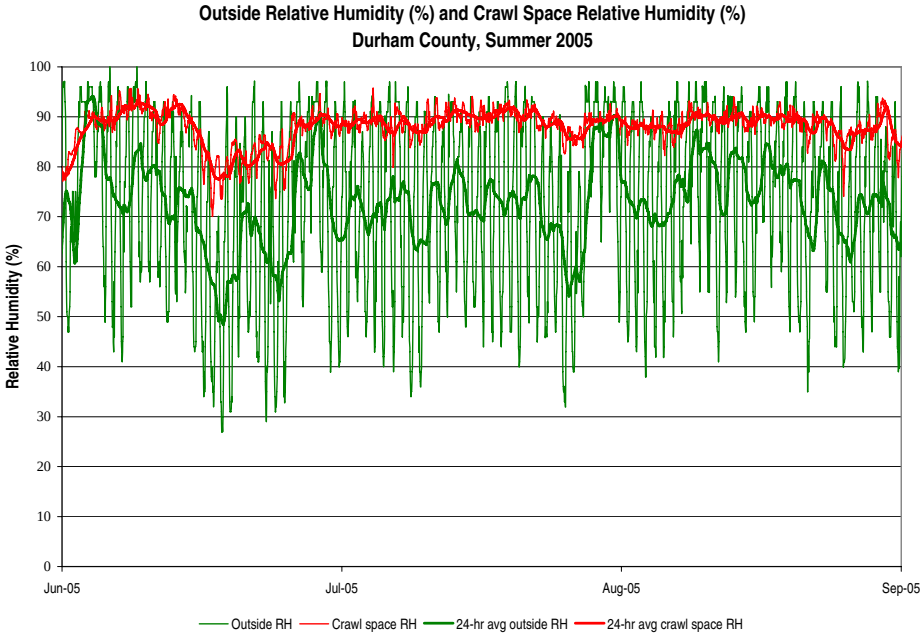


FIGURE 5 **Summer outside and crawl space relative humidity for Durham County**



Crawl space dew point

Those that advocate for ventilation of crawl spaces with outdoor air believe that introducing the lower RH outside air to the higher RH crawl space air will dry out the crawl space. What this assumption lacks is consideration of dew point temperature that takes both temperature and RH into account. Dew point gives an accurate measure of the absolute amount of moisture in the crawl space and outside air and indicates crawl space condensation potential.

Dew point results showed that Wayne, Wilson and New Hanover county crawl spaces, on average, were slightly wetter than Durham County crawl spaces (Figure 6). Figures 7 and 8 show that during the New Hanover summer months, the outside dew point temperature was higher than the crawl space dew point temperature, meaning the outside air was wetter than the crawl space air. Figures A13–A16 in the Appendix show that Durham, Wayne and Wilson counties have the same pattern of wetter outside air than crawl space air.

FIGURE 6 **Average crawl space dew points**

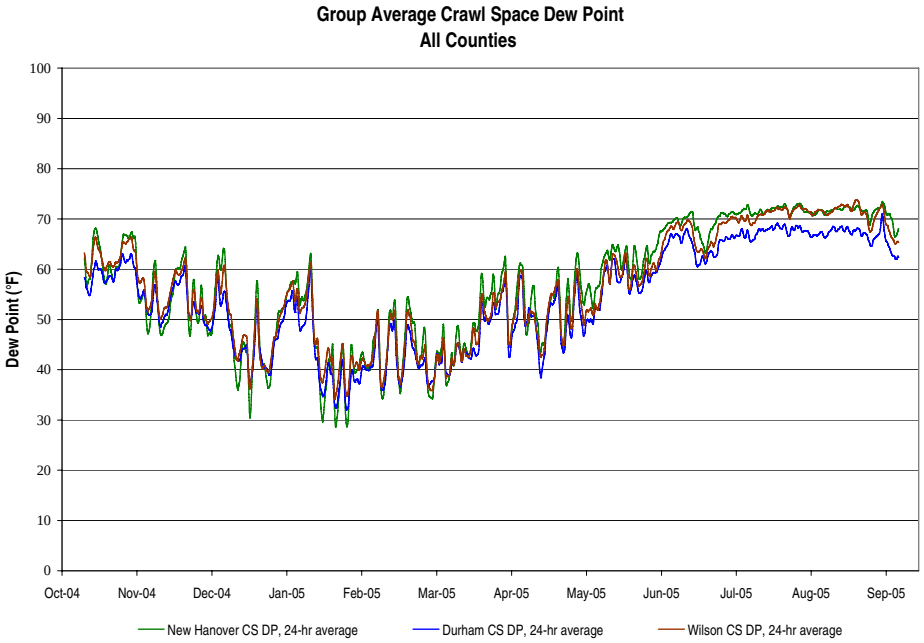


FIGURE 7 **Outside and crawl space dew point for New Hanover County**

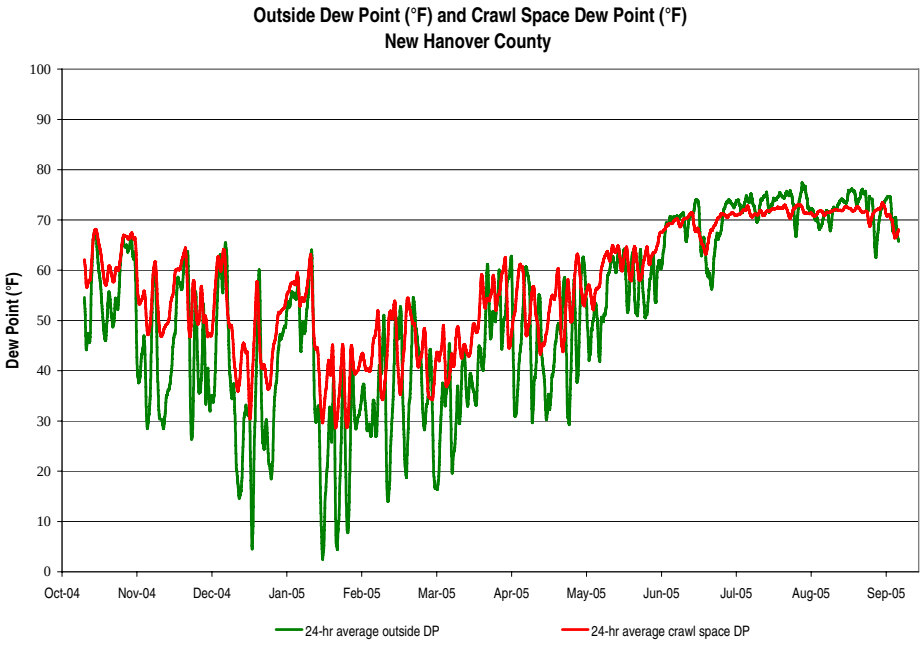
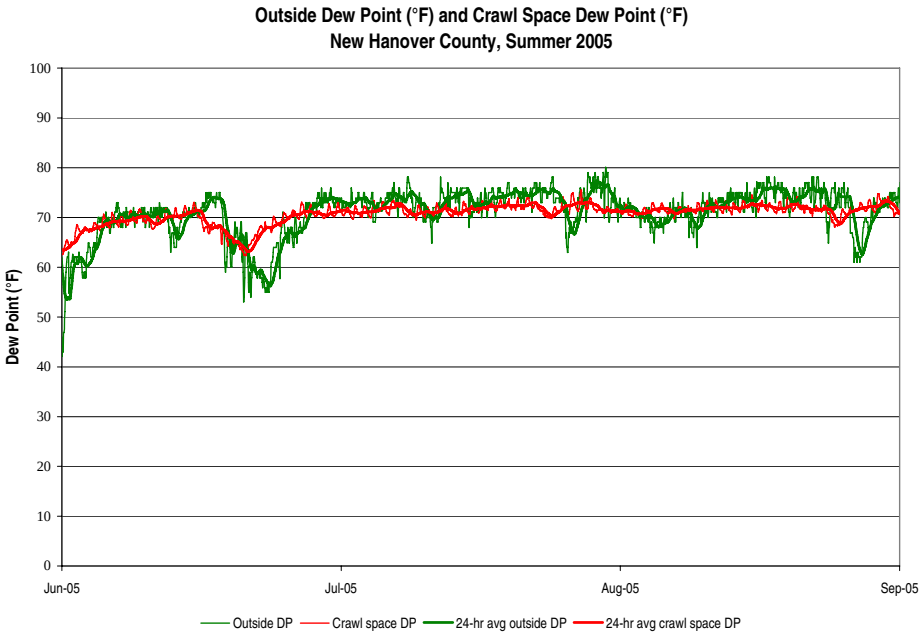


FIGURE 8 **Summer outside and crawl space dew point for New Hanover County**



The outside and crawl space dew points determined that the summer outside air was wetter than crawl space air, offering no potential for drying. Comparing the outside dew point and the crawl space temperature determines the possibility of condensation. Figure 9 shows this comparison in Durham County over the full data collection period. During the summer months, the outside dew point exceeded the crawl space temperature at numerous points. If the outside air enters the crawl space and contacts surfaces that have a temperature lower than its dew point, the water vapor in the outside air will condense on that surface. Figure 10 focuses on the summer months, displaying that during much of the summer, condensation is possible in these crawl spaces. The same trends were found in the other studied counties (Appendix Figures A17-A20).

FIGURE 9 **Outside dew point and crawl space temperature for Durham County**

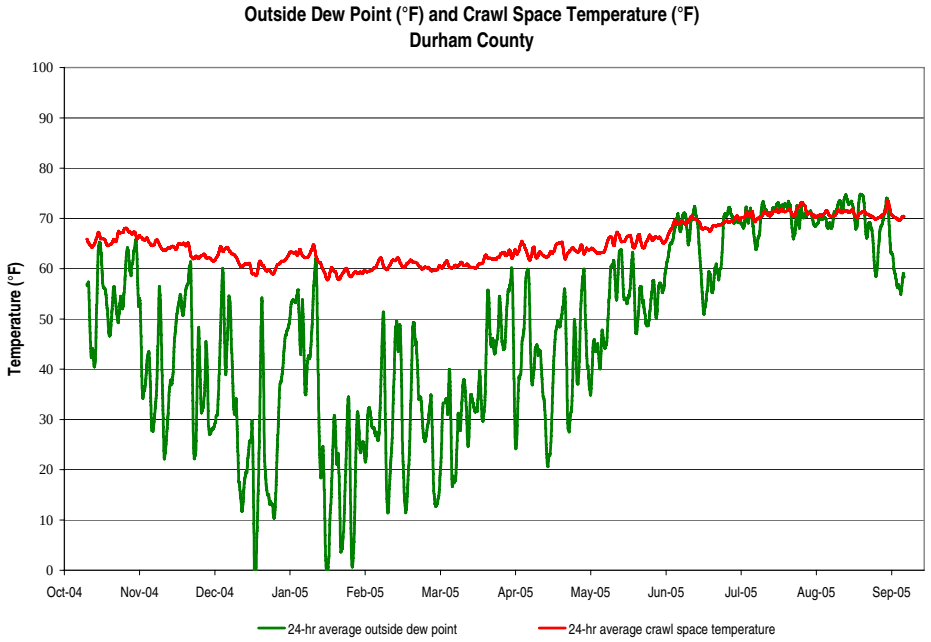
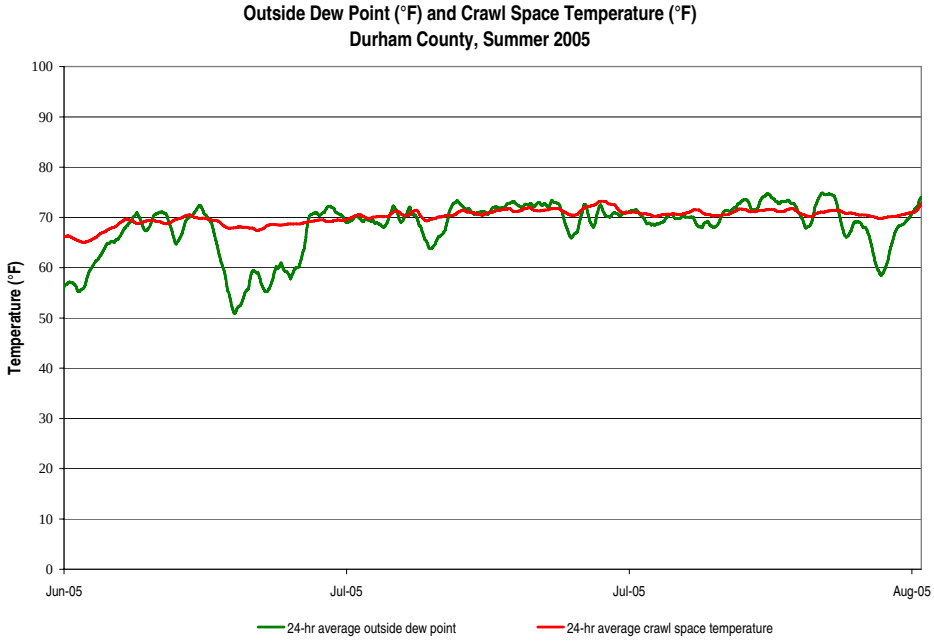


FIGURE 10 **Summer outside dew point and crawl space temperature for Durham County**



Effects of crawl space dehumidifiers on RH

A few homeowners added dehumidifiers to their crawl spaces to control humidity levels. Figures 11 and 12 display the effect dehumidifiers can have on crawl space RH levels. The crawl space in house 8 remained well below the New Hanover group average (Figure 11). In Durham, the addition of a dehumidifier also lowered RH levels. The owner of house 9 filled the wall vents with cement blocks, improved coverage of the crawl space floor with a ground vapor retarder, and added a dehumidifier. The owner of house 49 also installed a dehumidifier but the extent of other improvements is unknown. The RH of house 9 is below the county average but higher than house 49 (Figure 12). The RH of house 9 remains around the 70 percent mold growth threshold even with

a dehumidifier. Among many factors, operation and settings of the dehumidifier could affect its impact on crawl space RH. Operating a dehumidifier is one way to reduce RH levels, but alone, does not guarantee that the crawl space will be out of the danger zone for mold growth.

FIGURE 11 **Relative humidity county average and dehumidified crawl space for House 8, New Hanover County**

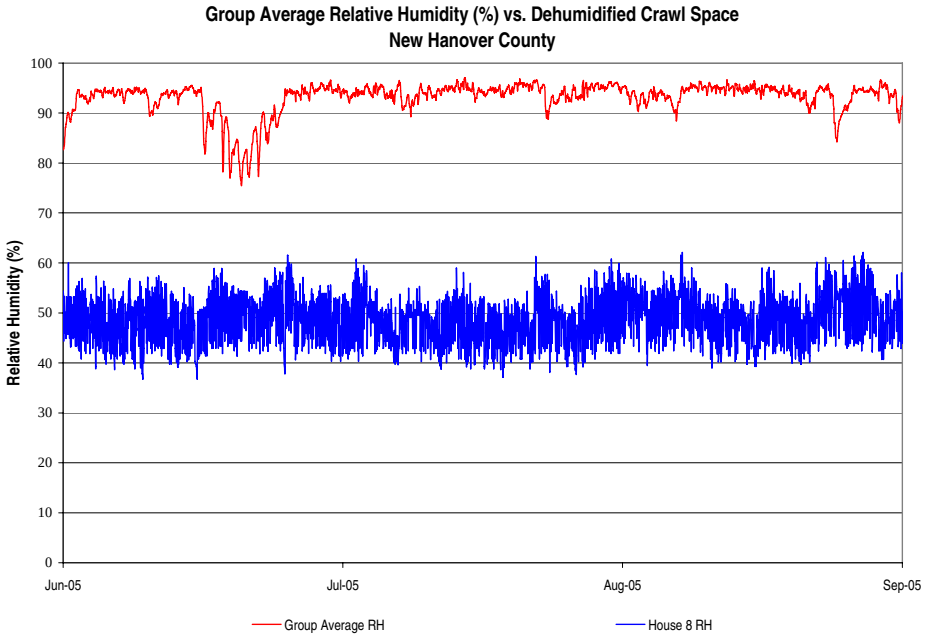
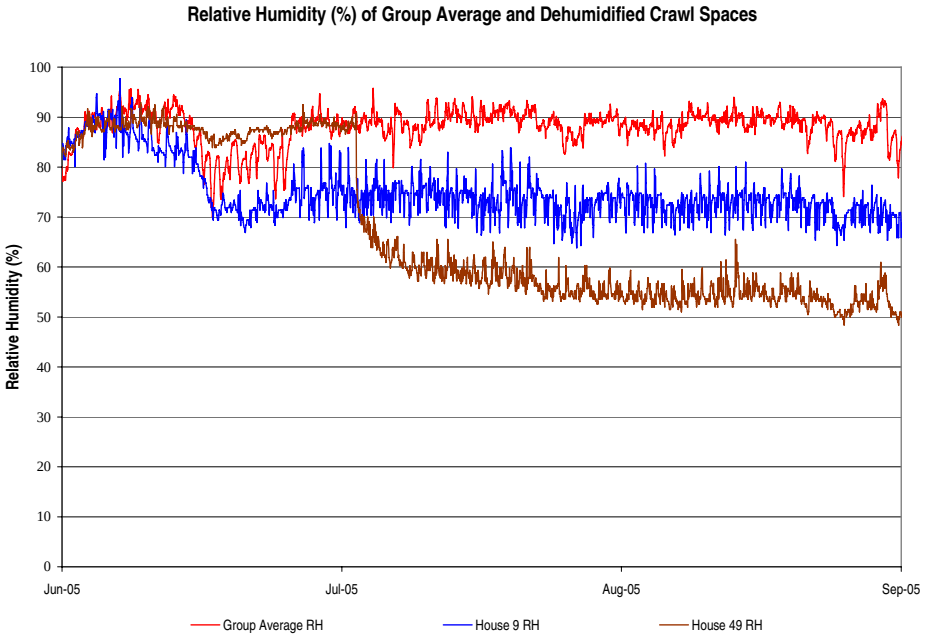


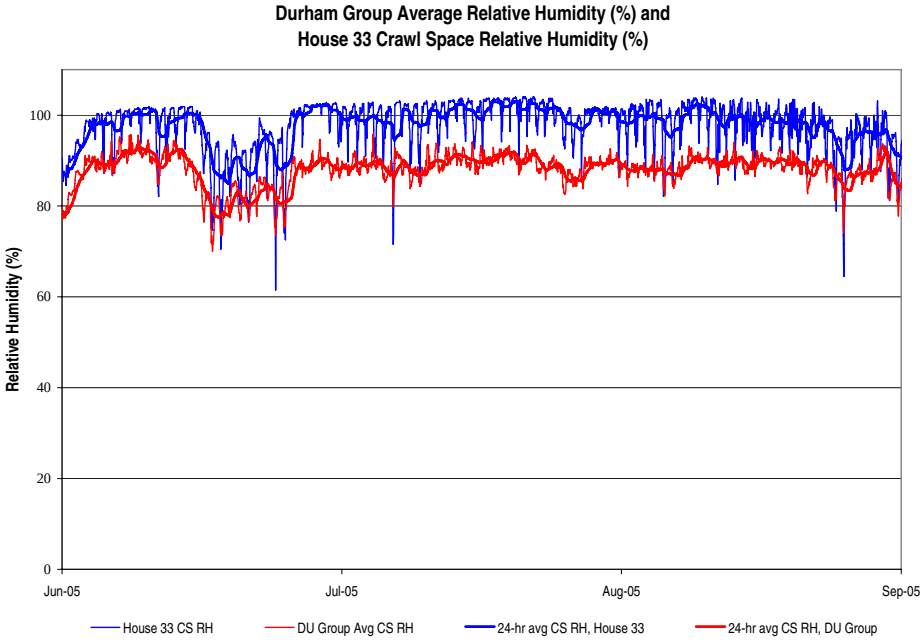
FIGURE 12 **Relative humidity county average and dehumidified crawl space for Houses 9 and 49, Durham County**



Relative humidity as an indicator of crawl space wetness

This study's crawl space characterization report documented observed crawl space moisture conditions. A comparison of relative humidity to selected, observed, "wet" crawl spaces should give insight into the use of RH as an indicator of wetness. "Wet" crawl spaces had significant liquid water present. Figures 13-15 display three "wet" crawl spaces' RH and county average RH. Figure 13 shows house 33 had notably higher RH than the county average. Figure 14 showed similar trends. The RH averages in Figure 15 were not significantly different, giving mixed results on the use of RH to detect liquid water problems.[13]

FIGURE 13 House 33 (wet crawl space) and county average relative humidity



[13] Figures 13-15 display readings above 100 percent RH. According to the logger manufacturer, this reading indicates condensation on the logger.

FIGURE 14 House 3 (wet crawl space) versus county average relative humidity

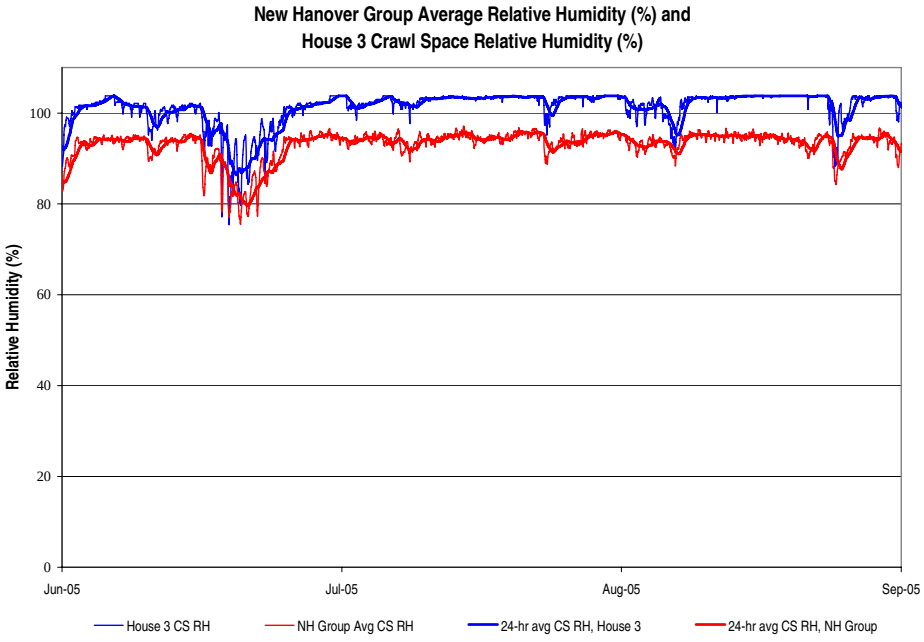
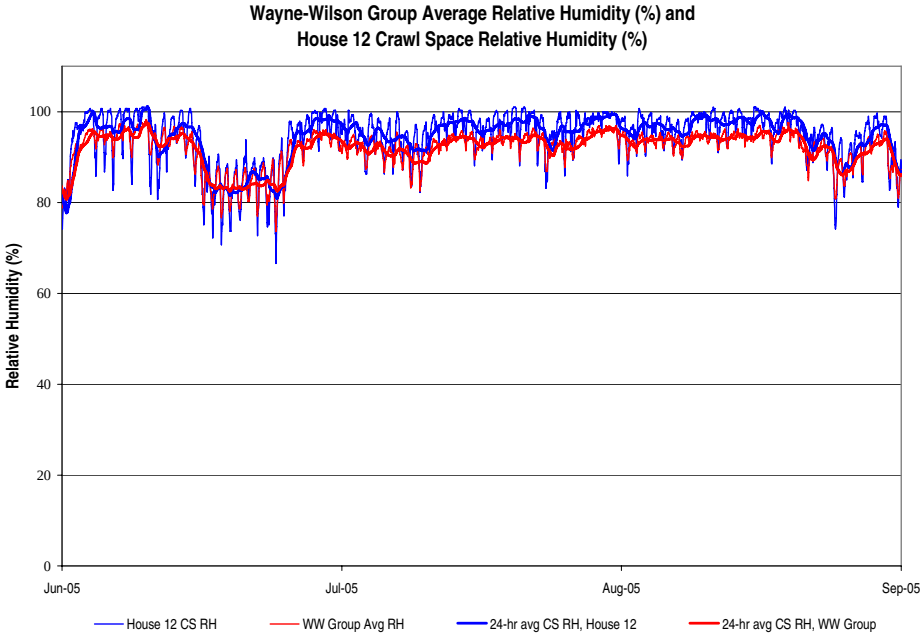


FIGURE 15 House 12 (wet crawl space) and county average relative humidity



Discussion

Builders have been constructing crawl spaces under the assumption that during humid months, drier outside air is entering through vents and drying the crawl spaces. Data analyzed in the study shows that in summer months, this is not an accurate assumption.

Although the relative humidity of outside air is less than crawl space air, this condition alone does not indicate the outside air is drier. The appropriate indicator of absolute moisture, dew point temperature, is calculated based on temperature and relative humidity. Dew point measurements from this study documented that outdoor air dew point temperatures exceed crawl space dew point temperatures, confirming summer outdoor air was actually wetter than crawl space air. Introducing this wetter outside air into the crawl space offers no drying potential. In fact, during summer months, outside dew points were frequently greater than the crawl space temperature, leading to condensation of the outside air on surfaces inside the crawl spaces.

This condensation creates liquid water that could fuel mold growth. Condensation aside, nearly 100 percent of the summer crawl space RH readings were at levels that could support mold growth (70 percent). Table 4 shows that high percentages of readings were above 90 percent, well in the danger zone for mold growth. Prolonged exposure to humidity levels exceeding 90 percent also results in wood moisture content of exposed framing material at mold supporting levels. This study's crawl space characterization report documented that contaminants in crawl space air (bioaerosols and water vapor) are able to enter livable parts of the home.

TABLE 4 **Percent of the crawl space readings that were ≥ 70 percent RH and ≥ 90 percent RH during the summer months**

RH	June	July	August
≥ 90%	56%	74%	72%
≥ 70%	100%	100%	99%

Some homeowners elected to install dehumidifiers in the crawl space to reduce RH levels. Results from three crawl spaces showed that the dehumidifier did decrease the RH levels. However, the dehumidifier alone might not be sufficient to reduce RH levels below mold-forming thresholds. The impact of dehumidification relies on a number of factors such as dehumidifier size and removal capacity, crawl space size and air leakage to outside, to control the balance of water vapor entering and leaving the crawl space. Additionally, analysis showed that relative humidity might not be a consistent way to detect liquid water in a crawl space. A comparison of three observed wet crawl spaces and relative humidity levels showed that in at least one crawl space there was not a significant difference in crawl space RH compared to the county averages. Further study is needed to verify whether liquid water sources (e.g. plumbing leaks or intermittent flooding) cause elevated RH levels in moisture-managed crawl spaces, such as closed crawl spaces, sufficient to indicate the problem.

Conclusion

This study was intended to characterize moisture problems with typical wall-vented crawl spaces as well as their importance as sources of mold in the living space. By documenting the failures of these crawl spaces in the North Carolina summer season, this report as well as this study's crawl space characterization report, confirmed that crawl spaces experience moisture and mold problems. This long-term temperature and relative humidity report goes on further to determine that outside air does not have the potential to dry typical wall-vented crawl spaces during the summer months. This failure to control moisture in the crawl space supports mold growth and can lead to indoor air quality problems.

Venting crawl spaces with outside air did not dry the crawl spaces because summer outdoor air had comparable or higher dew point temperatures, and therefore was wetter than the air in the crawl space. During the same months, outside dew point temperatures exceeded crawl space temperatures which could result in condensation. Not only does the liquid water from condensation create conditions that support mold growth, but relative humidity levels alone were found to be at mold-supporting levels. Nearly 100 percent of crawl space relative humidity readings exceeded the threshold for mold growth during the summer seasons of June, July and August 2005. From 56-74 percent of the summer month readings were more than 90 percent RH, putting these crawl spaces well into the danger zone for mold growth.

In the crawl space characterization report, researchers documented that mold and water vapor present in crawl space air are entering livable parts of the house. The results show that typical wall-vented crawl spaces experience mold growth and moisture levels that could lead to indoor air quality problems in the home environment. The results imply that at a minimum, improved wall-vented crawl space construction techniques should be implemented. However, even improved wall-vented crawl spaces will still not control the airborne water vapor that causes the documented problems. To fully address the crawl space moisture problems identified in this study, outside air must be excluded from the crawl space by implementing closed crawl space construction techniques.

Appendix

FIGURE A1 Outside temperature by county

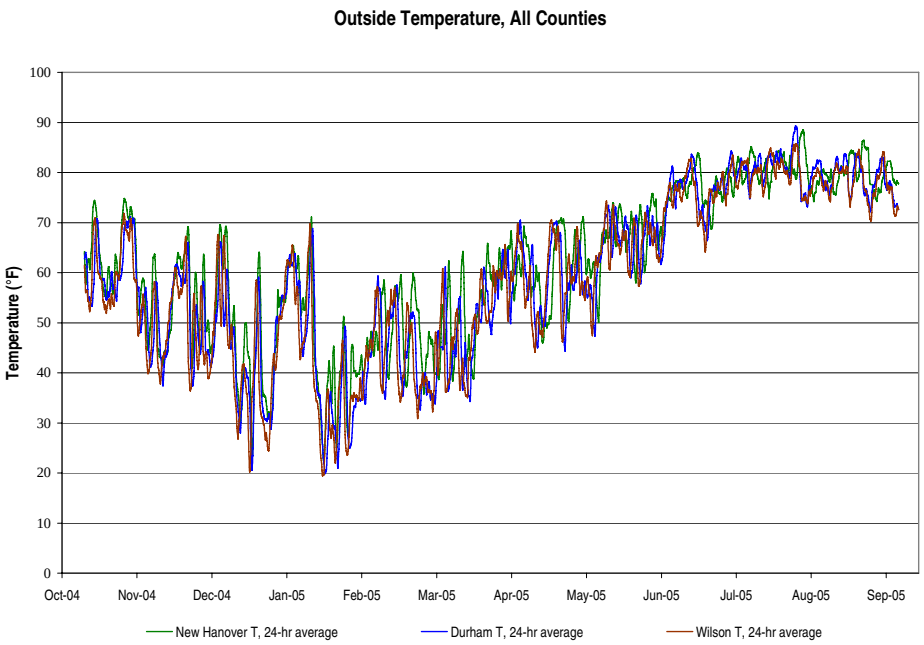


FIGURE A2 Outside relative humidity by county

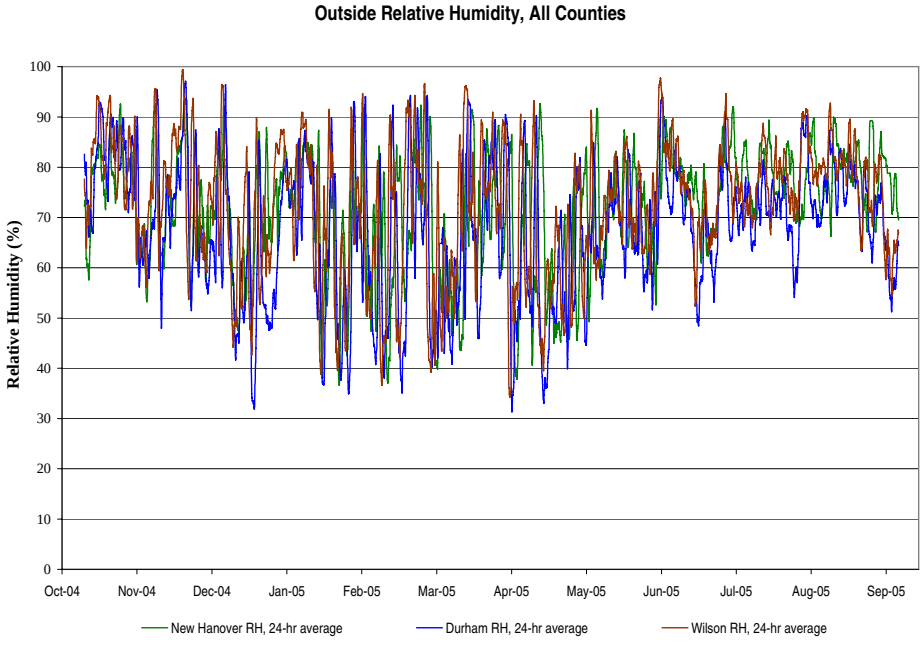


FIGURE A3 **Outside dew point by county**

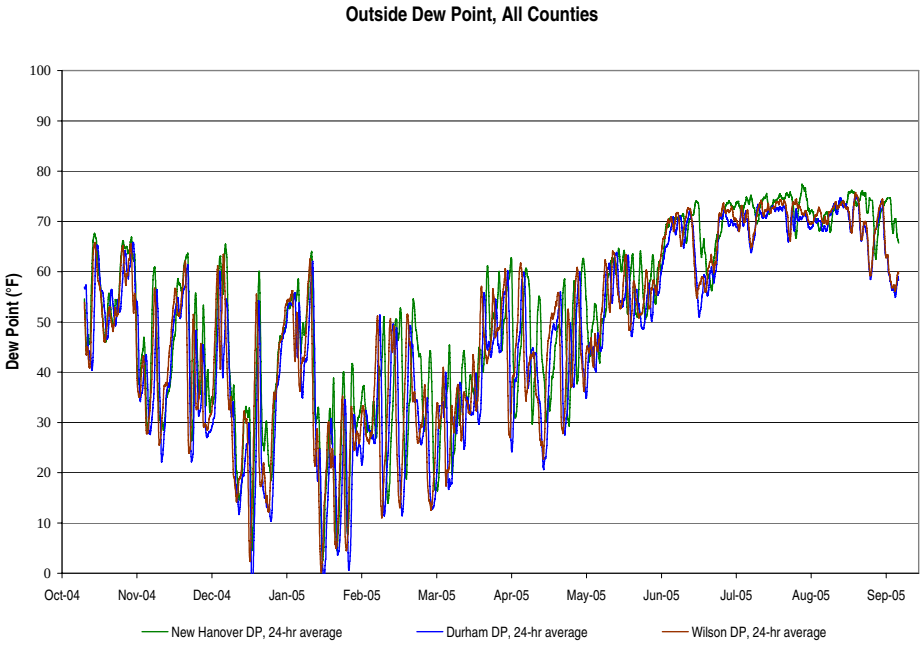


FIGURE A4 **Average crawl space temperature by county**

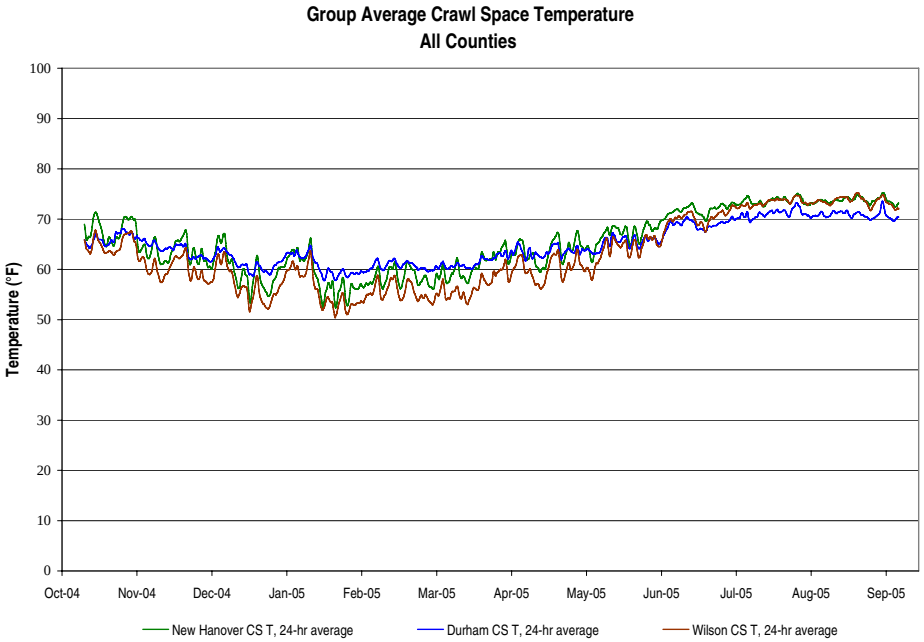


FIGURE A5 **Outside temperature and crawl space temperature (ºF) for Durham County**

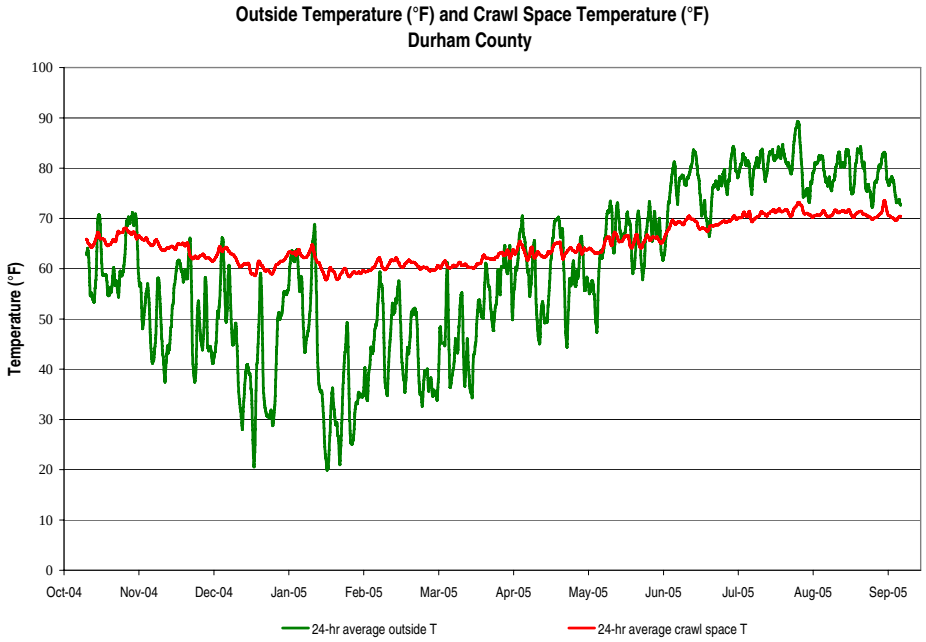


FIGURE A6 **Outside temperature and crawl space temperature (ºF) for New Hanover County**

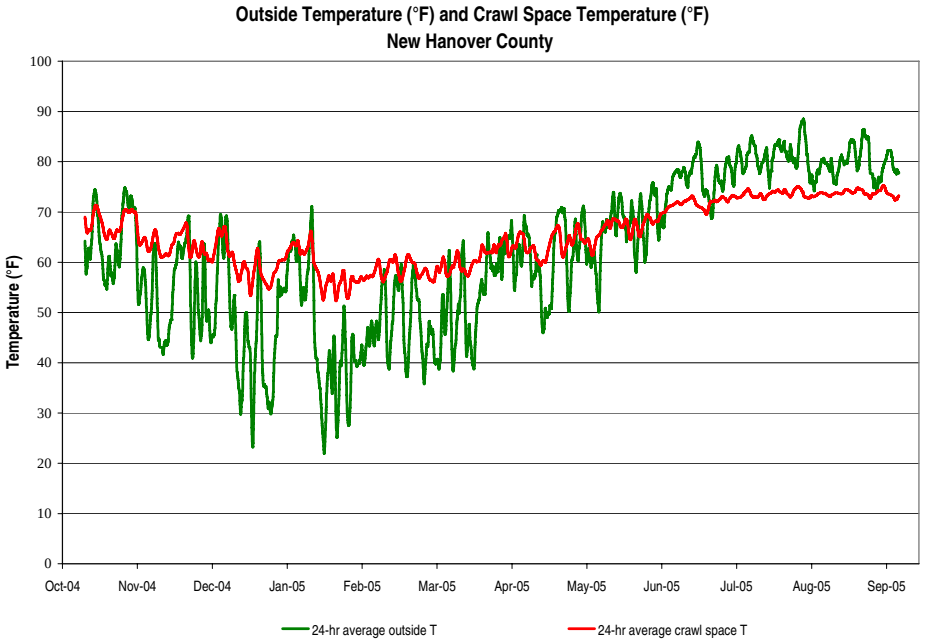


FIGURE A7 **Summer outside temperature and crawl space temperature (°F) for Durham County**

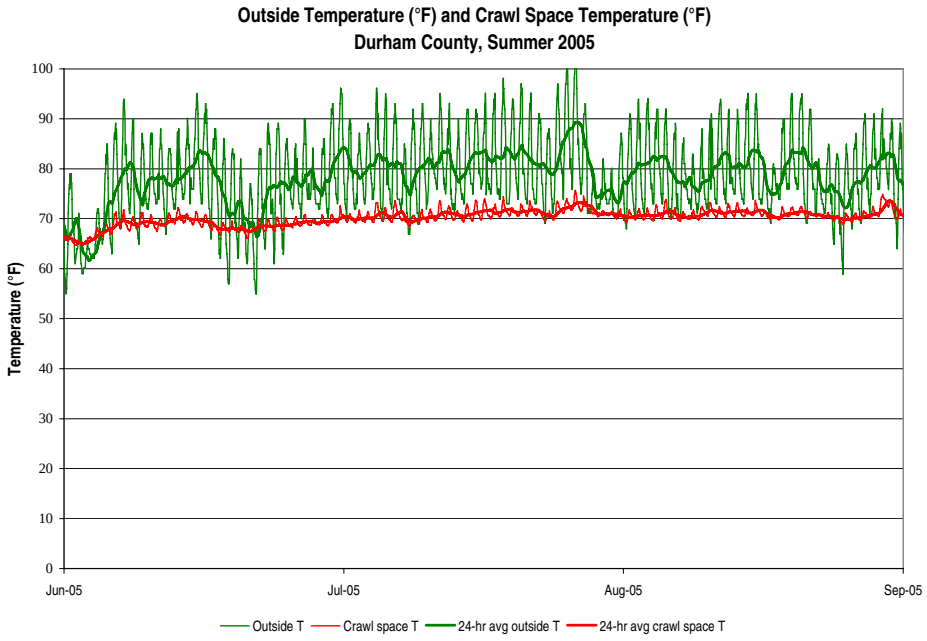


FIGURE A8 **Summer outside temperature and crawl space temperature (°F) for New Hanover County**

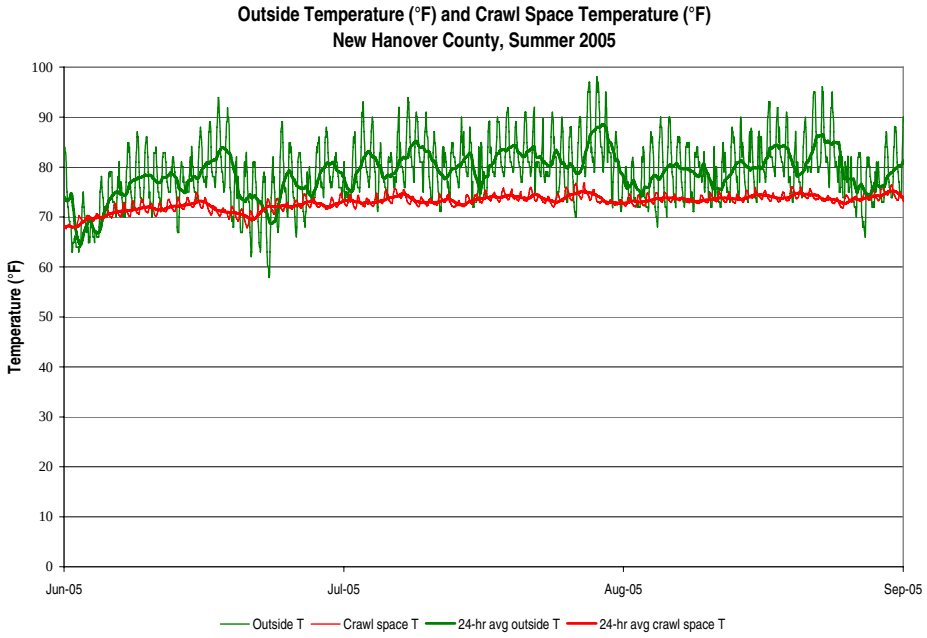


FIGURE A9 **Outside and crawl space relative humidity for Wayne and Wilson counties**

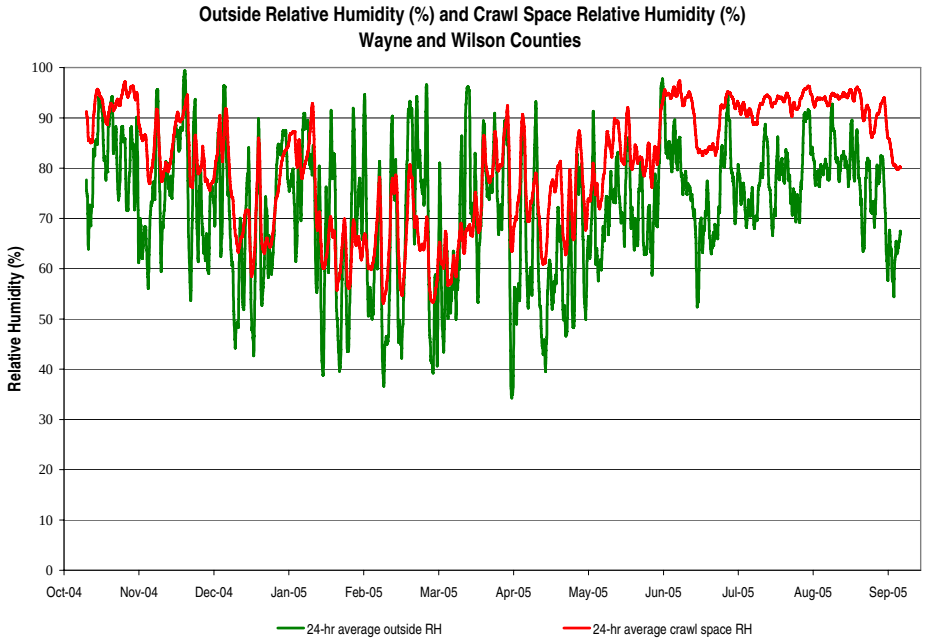


FIGURE A10 **Outside and crawl space relative humidity for New Hanover County**

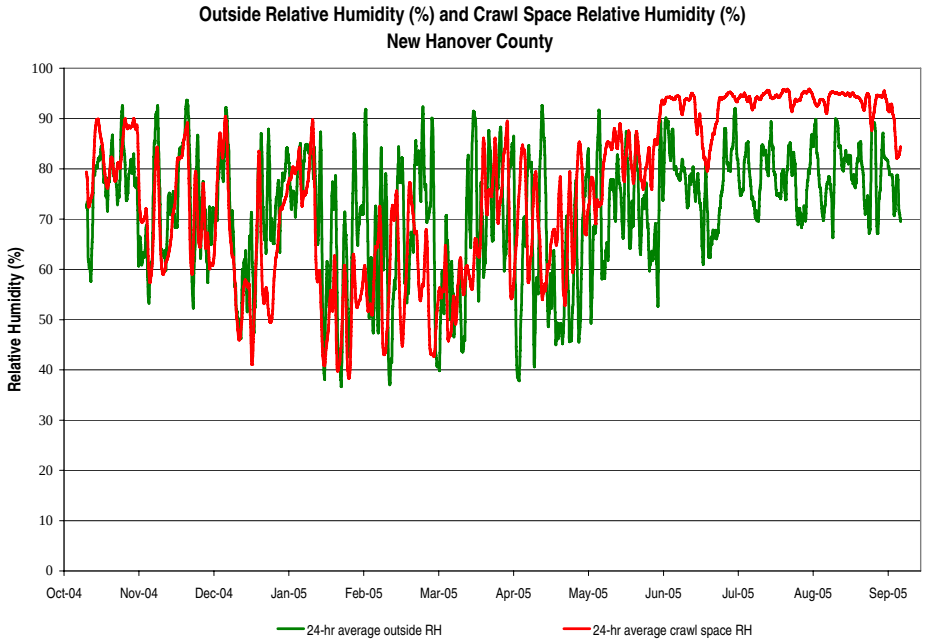


FIGURE A11 **Summer outside and crawl space relative humidity for Wayne and Wilson counties**

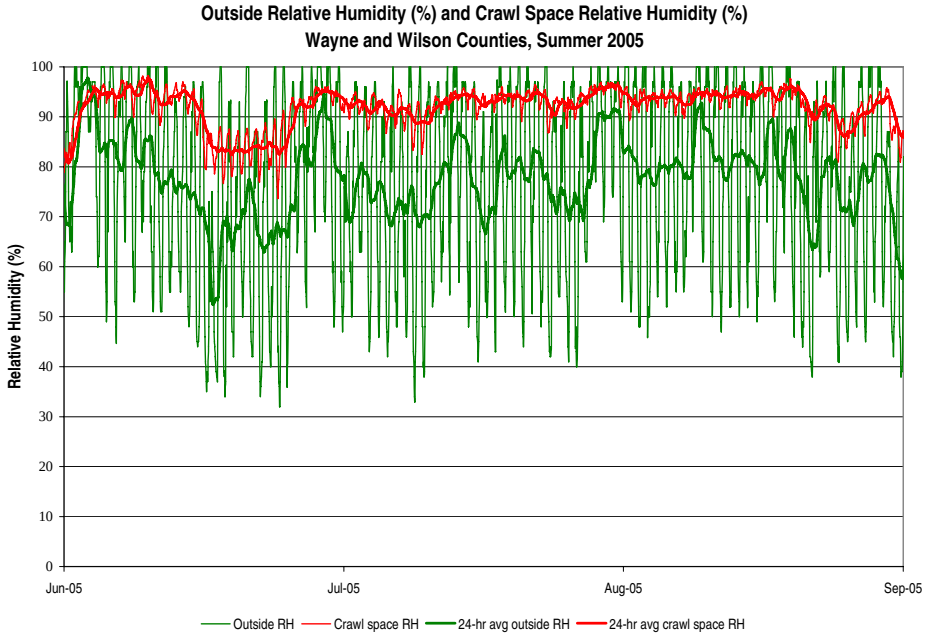


FIGURE A12 **Summer outside and crawl space relative humidity for New Hanover County**

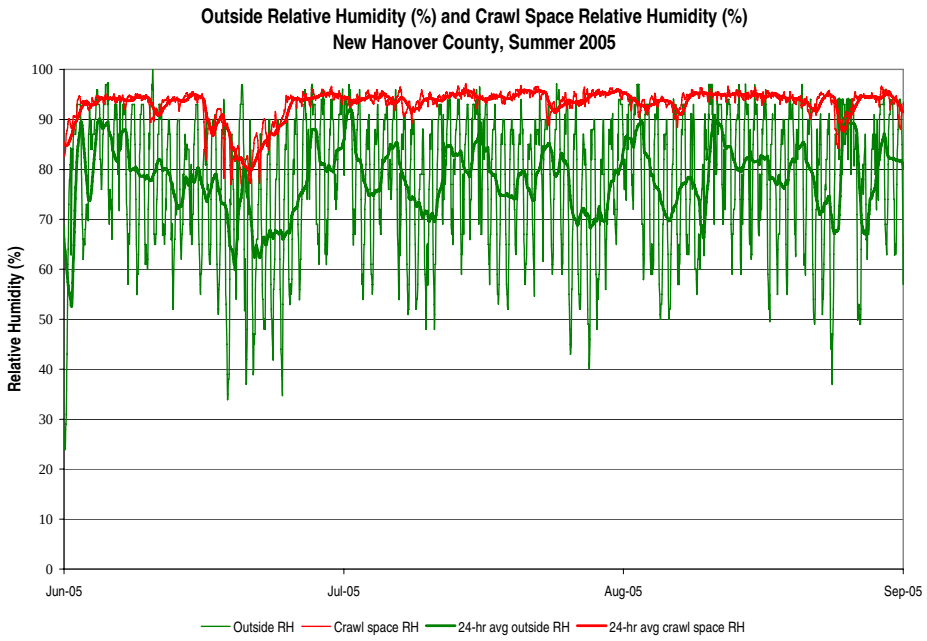


FIGURE A13 **Outside and crawl space dew point for Durham County**

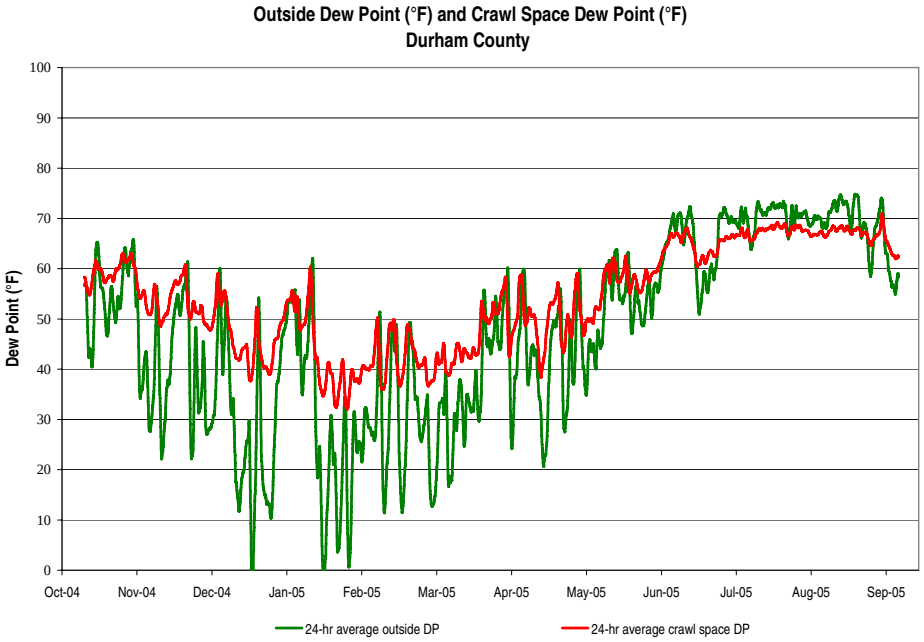


FIGURE A14 **Outside and crawl space dew point for Wayne and Wilson counties**

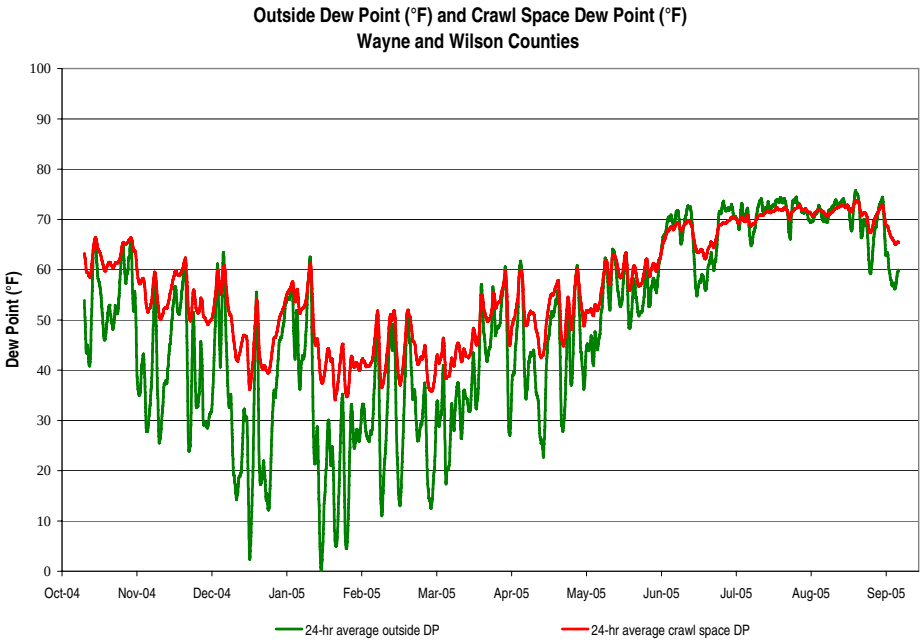


FIGURE A15 **Summer outside and crawl space dew point for Durham County**

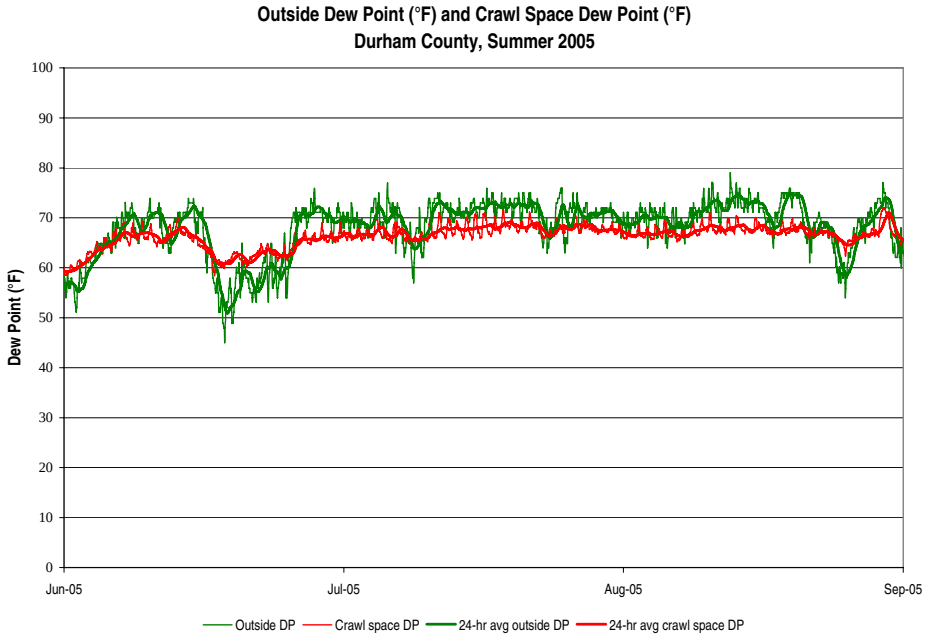


FIGURE A16 **Summer outside and crawl space dew point for Wayne and Wilson counties**

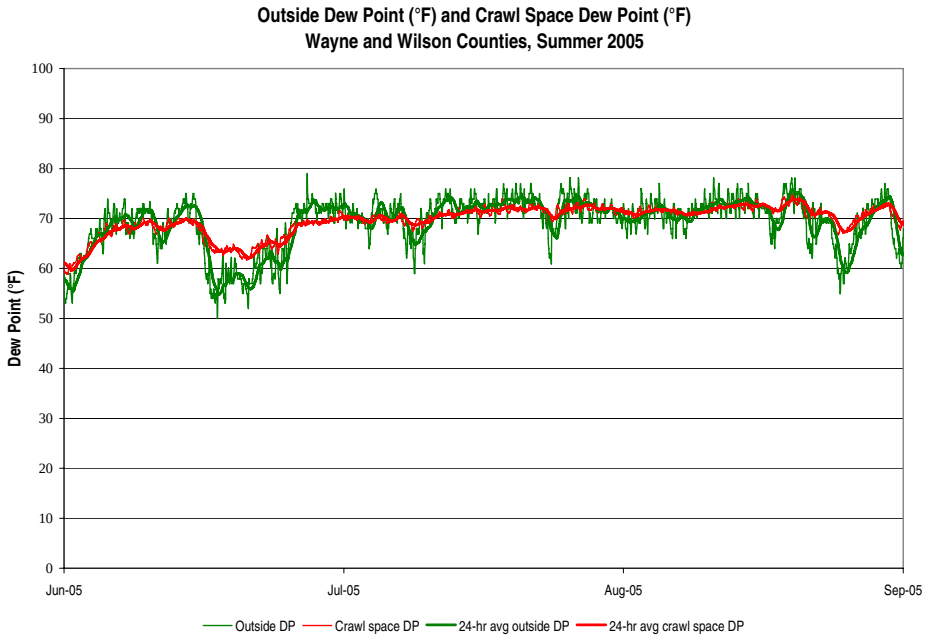


FIGURE A17 **Outside dew point and crawl space temperature for Wayne and Wilson counties**

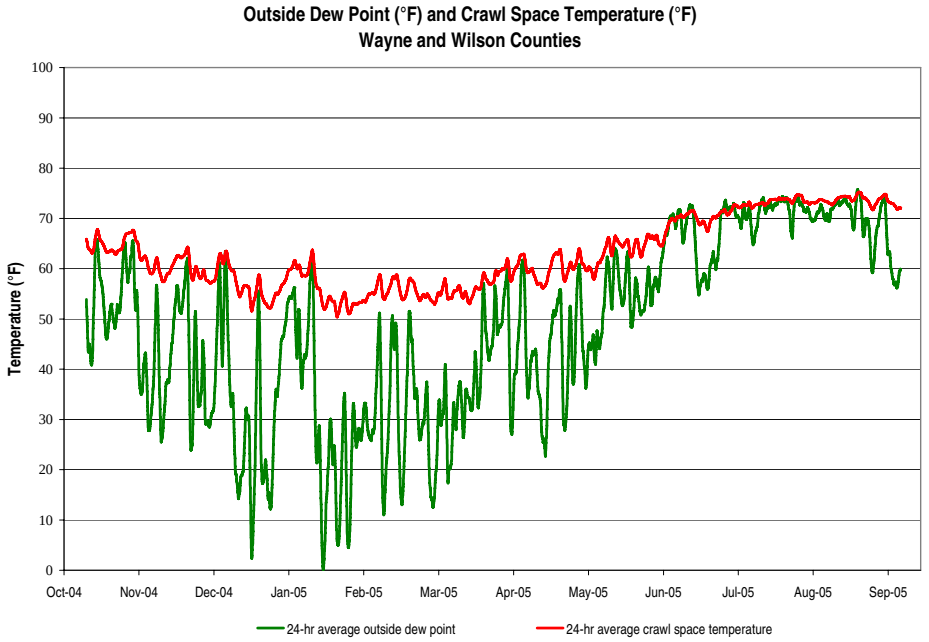


FIGURE A18 **Outside dew point and crawl space temperature for New Hanover County**

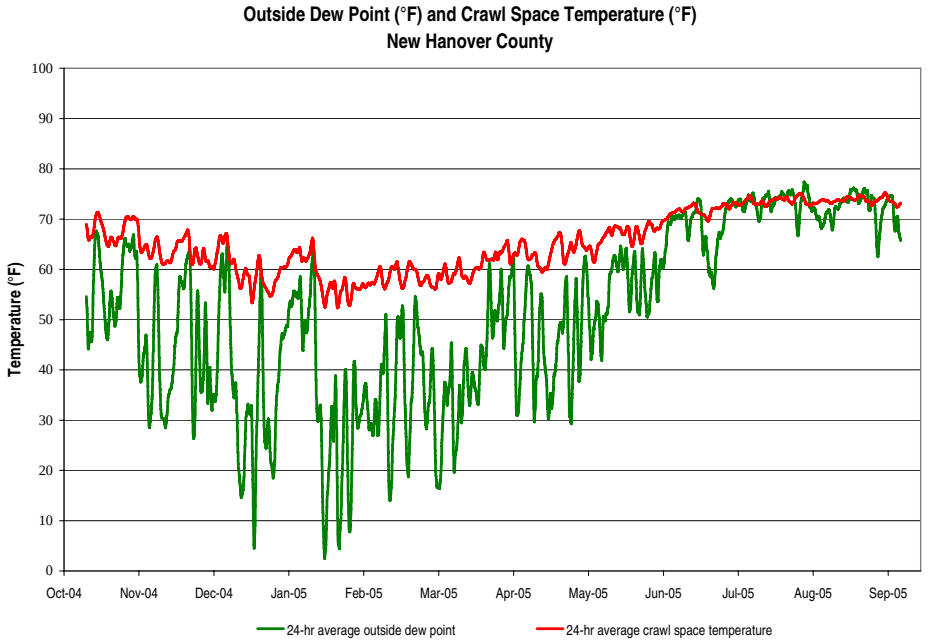


FIGURE A19 **Summer outside dew point and crawl space temperature for Wayne and Wilson counties**

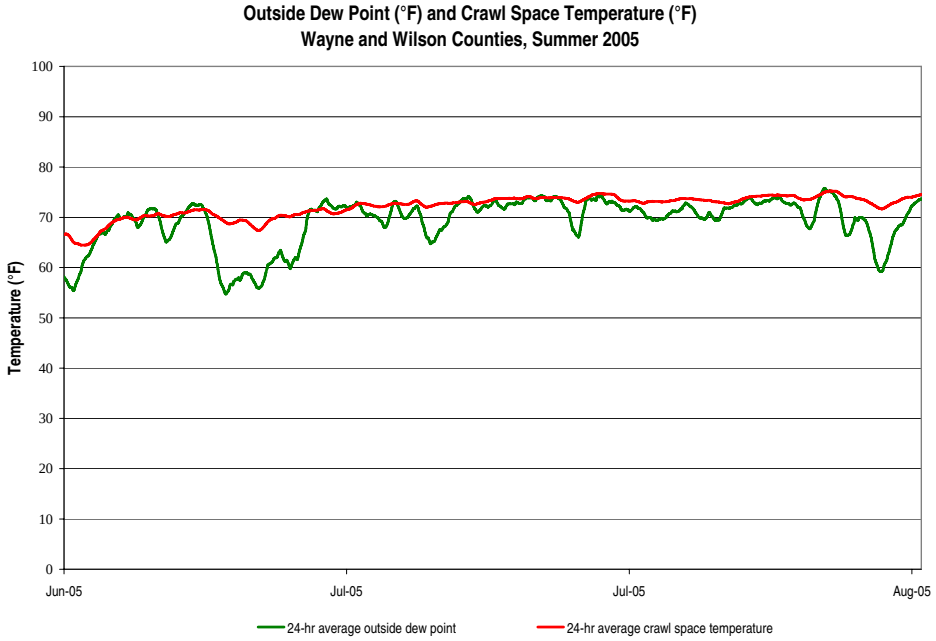


FIGURE A20 **Summer outside dew point and crawl space temperature for New Hanover County**