

## Measured Crawlspace Conditions Under Manufactured Homes

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### ABSTRACT

The Florida Solar Energy Center conducted research utilizing two unconditioned, old, singlewide side-by-side manufactured homes, one with a ground cover and one with exposed dirt under it. Three different skirting options were tested, open or no skirting, perforated skirting, and solid skirting.

Ambient and crawlspace dewpoints were averaged over a fifteen minute interval and recorded. The data is summarized in the table below. The skirting configurations tested are in Column 1, Column 2 lists the average ambient dewpoint, 3 the ground cover crawlspace, 4 the exposed dirt crawlspace dewpoint.

Successfully sealing HUD code home crawlspaces is the last piece of the puzzle of floor failures plaguing homes in hot, humid climates. Merely curing the duct leakage is not always enough to keep the floors of the house intact.

<b>Dewpoint Temperatures °F</b>			
	<b>Ambient</b>	<b>Covered</b>	<b>Exposed</b>
<b>Open</b>	73.3 <sup>0</sup>	73.3 <sup>0</sup>	73.3 <sup>0</sup>
<b>Perforated</b>	73.5 <sup>0</sup>	73.7 <sup>0</sup> (+0.2)	75.4 <sup>0</sup> (+0.9)
<b>Solid</b>	74.3 <sup>0</sup>	76.3 <sup>0</sup> (+2.0)	78.6 <sup>0</sup> (+4.3)

### INTRODUCTION

After working with HUD-code manufactures for years to promote leak-free ductwork (McIlvaine, et al, 2004 and Moyer et al, 2001) the word has been heard and the majority of HUD-code builders do a respectable job on their duct system integrity. While this is a laudable achievement, the motivator for the factories to pursue leak-free ductwork was a reduction in warranty claims caused by leaky duct systems. A leaky duct system usually causes the home to run at a negative pressure, which in turn can cause warm, moist outside air to infiltrate into the house, leading to moisture induced building failure. In most homes and factories visited recently by the Florida Solar Energy Center's (FSEC) Building America Industrialized Housing Partnership (BAIHP) personnel, ductwork is acceptably tight, but there are still nagging moisture induced floor failures found in the field in homes with tight ducts. The source of the

moisture for these failures appears to be the crawlspace.

What is going on in these crawlspaces? Are there factors raising the dewpoint in them above ambient? Although the ambient dewpoint is often high enough to cause problems in houses where the A/C is used to cool the house well below the ambient dewpoint, there have been cases of floor failure in homes that were not "overcooled" well below the ambient dewpoint.

Some manufactures' installation instructions suggest the use of a ground cover under the house, but then go on to say that if the site is not prepared properly do not use a ground cover. Further, in an effort to mimic site built housing, many installations run the home's siding all the way to the ground, producing an un-vented crawl space, or a poorly vented one.

BAIHP is in a unique position to examine the conditions found in a "typical" manufactured home. BAIHP has equipment and the experience to monitor temperature and relative humidity in a crawl space, and FSEC has a test site with three singlewide manufactured homes located on it, and a well instrumented double wide manufactured home on our main campus.

### PROCEDURE

The three singlewide homes are sited side-by-side at the site (Figure 1). Two of the homes are virtually identical 14' by 60' units, and the third is a 12' by 60' unit. One of the homes had to be moved into place for the three homes to be side-by-side, so when this was done a ground cover of 6-mil polyethylene was installed under the house (Figure 2). All houses were in poor condition, with badly breached rodent barrier (an air barrier installed under the home's floor insulation, isolating the home from the crawl space) and rotten spots in all three floors. For the sake of uniformity between the houses, it was decided to remove the floor's rodent barrier and insulation from all homes and remove all interior walls from the homes. When this was done the bad spots in the floor were repaired, and new vinyl flooring was installed on all three homes, creating a

moisture impermeable barrier between the home's interior and crawlspace (Figure 3).



**Figure 1** The Three experimental houses



**Figure 2** Ground Cover installed



**Figure 3** Typical interior

This configuration provides a control home and two experimental homes, all subjected to the

same environmental conditions. One of the experimental homes has a vapor retarder (ground cover) installed over the ground in the crawl space, and the remaining experimental home and the control home do not.

Before installing a ground cover, site preparation is critical. The ground beneath the house must be above grade to avoid flooding issues leading to standing water under the house. To facilitate this during this test a truckload of dirt was brought in. After the site work was done the dirt level under the house was only an inch or two above grade, when six to twelve inches is ideal.

The insufficient dirt under the house was not a problem after skirting was installed; the windbreak at the skirting did not allow water to penetrate under the house and the ground was fairly level at the site. This was observed immediately after a heavy rain accompanied by a stiff breeze (not a hurricane). However, it is better to err on the side of caution, and it would be best to have more dirt under the house, six to twelve inches above grade to allow for other site drainage problems. Prior to the installation of the skirting wind driven rain did puddle under the house.

There were several differences between these units and what is typically found in the field. First, the condition of the bellies of the test units was so poor, that for the sake of similarity between test units, the belly board / rodent barrier and insulation in the floor was removed. Continuing with the theme of similarity between units, all of the floors were covered with roll goods / vinyl flooring. Due to a lack of electricity at the test site, the units were left unconditioned (no air conditioning / cooling). A typical unit found in the field will not have 100% vinyl flooring; a majority of the floor would be carpeted, with vinyl found only in wet areas. In addition, the lack of floor insulation and rodent barrier is extreme, in the field the barrier is often torn and ripped, but not gone, as is also seen with the insulation. Cooling equipment is typically found in the field; often cooling is found to be at an extreme level, BAIHP researchers have observed set points of 65 °F, well below the South's summertime ambient dewpoint.

As the main intent of this experiment was to measure crawl space conditions and not floor conditions, it was felt by the researchers that these differences would not profoundly affect the results. The 100% vinyl flooring might tend to trap more moisture in the crawl space as the flooring could not "breathe" and let crawl space moisture penetrate into

the home. If cooling had been provided, the floor would have been colder, possibly causing more moisture to enter the crawl space.

The homes were instrumented with temperature and relative humidity sensors in two locations in the crawl space, 15 feet from each end and one foot above the ground, and on the central interior of the building, four feet above the floor. The test site has a weather station providing ambient conditions.

An ambitious test schedule was designed, but nature, in the form of three hurricanes, severely curtailed the test schedule. Only three different configurations of skirting were tested, open (no skirting), perforated skirting, and solid skirting. Data reported here are from the two identical homes, one with a ground cover, and one without. The third house's data is available as a control, but was not used in this paper.

## RESULTS

The results of these tests are presented below (Figures 6-8); three different crawlspace configurations chosen as representative of what is found in the field. The first test conducted was of open crawlspaces (Figure 2 and 6) with no skirting. As many local codes and park regulations prohibit un-skirted homes, the other tests used skirting. First tested was "standard" perforated skirting (Figure 4 and 7). Trends observed in the field are revealing more and more homes with the siding run all the way down to the grade level, or a solid faux rock skirting used. The result of these practices is a poorly vented crawlspace, simulated for these tests with solid skirting (Figure 5 and 8).

All data is an hourly average of data collected at 15-minute increments. Crawlspace data is the average of the two measurements made at each end of the crawlspaces. The plots represent all available data during the period indicated by the dates at the bottom of the plot. The titles of the plots tell what skirting configuration is described, and the legends show which crawlspace is shown by the data. The data is presented as an "average" day; all the readings from 8 AM for the test period are averaged, all the 9 AM, etc.

Test three (Figure 5 and 8) employed solid, un-perforated skirting. We were unable to measure how airtight the crawl space was or whether the ground cover completely covered the ground. Hurricane Jeanne destroyed the test configuration before air tightness measurements could be taken.

However, we believe these crawlspaces were typical of poorly vented crawls one might find under a manufactured home.



**Figure 4** Perforated skirting

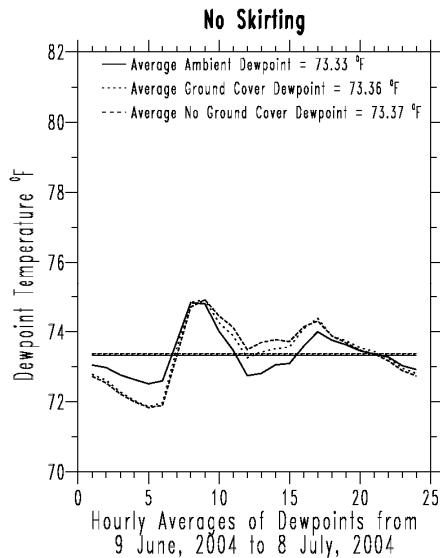


**Figure 5** Solid skirting

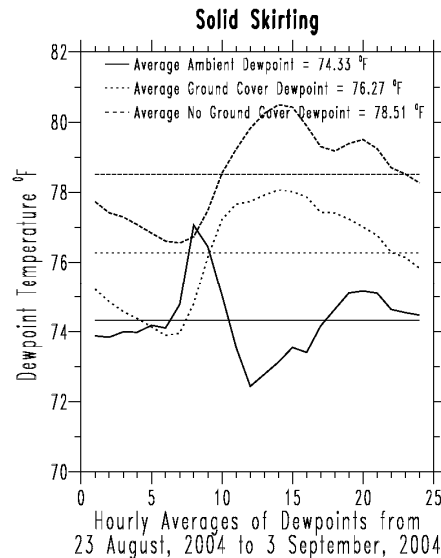
## CONCLUSIONS

As can be seen from the graphs, skirting installations increase the dewpoint under manufactured homes. Solid skirting (Figure 8) installed on a home without a ground cover increases the dewpoint under homes above the ambient dewpoint on average 7°F or more from 12 noon until 15:00. Installation of a ground cover mitigates this dewpoint increase, but crawlspace dewpoints are still increased over 5 °F during the same time period.

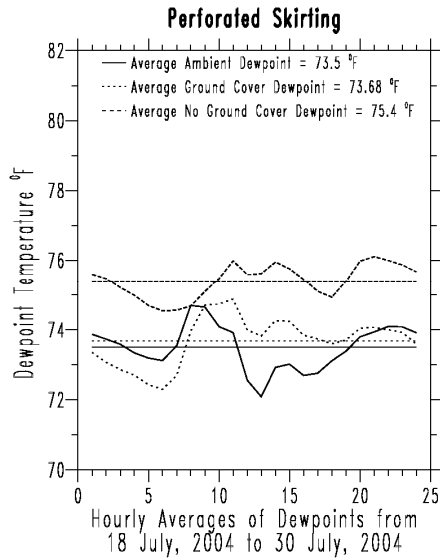
Elevated dewpoints in crawl spaces contribute to, or cause, floor failures. Most manufactured homes in hot, humid climates have overhead duct systems with registers blowing cold air onto the floor of the home.



**Figure 6** Dewpoints without skirting



**Figure 8** Dewpoints with solid skirting



**Figure 7** Dewpoints with perforated skirting

This causes a cold spot on the floor, which is almost guaranteed to be below the dewpoint of the crawlspace. If crawlspace air can get to the floor, condensation will occur there. The intended air and moisture barrier on HUD-code homes is typically the rodent barrier. Most rodent barriers on the market today are intentionally made with perm ratings below 1, defined as a moisture retarder. It is not unheard of for the home's rodent barrier to be breached, ripped, or just gone even if the home left the factory with the rodent barrier intact.

Installation procedures typically involve lagging the two halves of the home together, usually right through the rodent barrier. Other opportunities to damage the rodent barrier during installation occur during the plumbing and A/C installation. Perhaps the biggest offenders observed in the field are the trade people that appear after installation and set-up, such as telephone, cable, and alarm installers. Often these installers cut large holes in the belly to facilitate the installation of their equipment. These trades are rarely equipped to make suitable repairs to the rodent barrier.

Another culprit often observed in the field is factory field repairpersons. Homeowners call and complain about floor problems from squeaks to soft spots. The service center sends out a repairperson that then proceeds to open a huge hole in the rodent barrier to find and repair the problem. Although it

shouldn't happen, these holes are often not repaired, poorly repaired, or repaired in a fashion that soon fails. BAIHP researchers often observe rodent barriers repaired with black duct tape. These repairs are almost impossible to perform in a lasting fashion, and most observed in the field had failed (Davis, 2003).

Why are these problems of any concern? In hot, humid climates with outside dewpoints over 70°F the dewpoint in the crawlspace can easily exceed the temperature of the floor (temperature, not dewpoint, of the floor). If the outside dewpoint is 72°F, and the crawlspace dewpoint is elevated 10°F, then any surface at a temperature of 82°F or under will be subject to condensation. Crawlspace dewpoints 10°F higher than outside may be rare, but an outside dewpoint over 72°F is fairly common in the hot, humid south.

Homes have been built over poorly vented uncovered crawlspaces for years, and it is often not a problem. However, construction practices can make a home more susceptible to damage from humid crawlspaces. Often, manufactured homes have a lot of vinyl floor covering, as well as vinyl wall covering and a vapor barrier in the ceiling. When water vapor condenses on a surface that will not allow the water to penetrate towards a dry area (water on the underside of a wet floor will not move through the vinyl to the house) it will be trapped. This trapped water can cause mold and fungal growth, building material degradation, and possibly lead to building failure.

If a home has a well vented crawlspace it will not see crawlspace dewpoints significantly higher than the outside dewpoint. However, surfaces can still reach temperatures below the outdoor dewpoint in the crawlspaces, which can lead to condensation problems.

One sure way to avoid water damage to floors of homes is to have breathable finish, like carpet or tile over the entire surface of the home's floor. This allows the moisture to come through the floor into the dryer house air, and be removed by the home's air conditioning system. Site built housing has reported problems with hardwood floors installed over poorly vented crawlspaces, as the moisture causes cupping or warping of the flooring. The installation of a ground cover is definitely beneficial; in this experiment reducing the dewpoint in skirted installations by 2 or 3 °F in the crawlspace. Manufactures should consider changing the language

of their installation manuals to require proper site grading and the installation of a ground cover,

Some site builders and building scientists have been advocating totally un-vented crawlspaces that are sealed from any outside influence (Davis et al 2004). Such crawlspaces can work but they do require higher standards of construction resulting in totally sealed crawlspaces and with some conditioned supply air or a dehumidifier. There are added concerns; how to deal with termite inspection, and what to do when a flood occurs (plumbing or rain related). Solutions to these problems add to the complexity and cost of a true sealed crawlspace for the HUD-code industry.

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