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Creating Energy Independence

New Construction Builders Challenge: Sealed Attic and High Efficiency HVAC in Central Florida: A Year in Review

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Monitored Prototypes - Springwater Homes

In 2010, the Florida Solar Energy Center (FSEC), with funding from the Building America program, was involved with a new Builders Challenge builder located in Rockledge, Florida -- Springwater Homes (see Figure 1). The home was constructed in March 2010 and features a sealed attic with R-27 open cell sprayed foam roof deck insulation (shown in Figure 2). Selection of the HVAC system, an important aspect to achieve high efficiency levels in buildings, ended with one of the highest residential equipment systems available in the U.S. – the Nutone IQ Drive (SEER 21). The house was confirmed with a HERS index of 53 using the EnergyGauge simulation program. By April 2010, FSEC researchers had installed a variety of sensors and a data logger to investigate the power consumption of the mechanical HVAC equipment and, most importantly, the humidity characteristics inside the sealed attic.



Figure 1: Builder’s Challenge home (2127 Sq. Ft.) construction with conventional hip roof and shingles in Rockledge, FL.



Figure 2: Roof deck insulation (R-27) featured on Builders Challenge Home in Rockledge, FL

Instrumentation and Measurements

A data logger at the site collected power measurements of the total building, power consumption of the high efficiency 3-ton (SEER 21) HVAC equipment and water heating energy consumption. The house was also equipped with a solar water heater; however no representative data was gathered since the house remains a model home.

In April 2010, FSEC completed installation of instrumentation wiring and sensors for temperature and relative humidity (RH) measurements in the conditioned space, attic and outdoors. The attic temperatures and RH sensors were positioned in the attic at mid and peak levels, as shown in Figure 3.



Figure 3: RH and temperatures were measured at peak and mid levels within the sealed attic.

The home is also outfitted with a Honeywell outside air damper control to provide fresh air intake. Instructions provided with this device recommend an outside air intake of 80 cfm for a 2,200 ft² home. The unit was setup as recommended by the manufacturer’s instructions. After setup, measurements were made by FSEC researchers to determine the outside airflow intake. Results of the outside fresh air intake can be seen in the table at right.

Fan speed	Outside fresh air intake
Medium	52 cfm
High	72 cfm

High Efficiency Air Conditioner (SEER 21) – Electricity Use

HVAC electricity used at the Builders Challenge home site, although it does not represent a typical family use pattern, was kept at a comfortable 73°F during the monitoring period (summer included). Average daily electricity consumption for the HVAC system can be observed in Figure 4. The months of June and July measured a daily electric consumption slightly above 15 kWh/day. The indoor air handler unit during cooling months (May-Oct 2010) represents 28% of the total air conditioner power consumption on average.

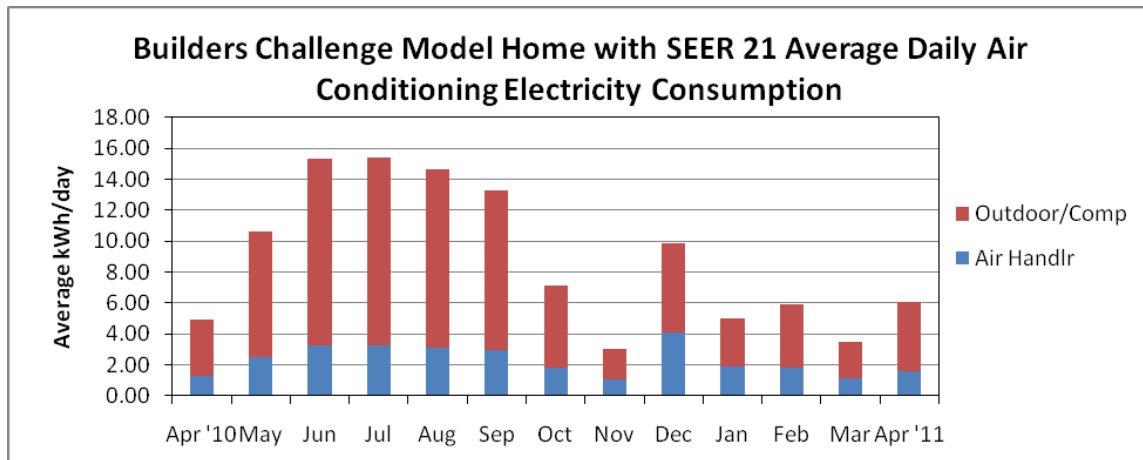


Figure 4 Average Daily electric consumption by month for the SEER 21 air conditioner on a 2,127 sq. ft. model home in Rockledge, FL.

At the end of September 2010, data also showed the standby power consumption characteristic of this unit. Surprisingly, the outdoor condenser and indoor air handler unit draws about 50 and 28 watts respectively (78 watt combined) when on standby.

Interior and Sealed Attic Conditions

Interior Conditions

Indoor temperature and relative (RH) humidity sensors were installed above (and offset) to the IQ drive thermostat on a hallway wall of the house to measure comfort levels. During the initial months of data collection, analysis revealed that the high efficiency air conditioner kept interior temperatures at a comfortable average of 73°F with relative humidity (RH) levels below 58% on

average. The trend of relative humidity throughout the following months is shown in Figure 5 along with the interior temperatures. The relative humidity trend indicates that the HVAC equipment slowly brings interior conditions of the new constructed house slowly towards the target of 50%. High humidity content is typically found in new construction due to moisture in building materials. Furthermore, the Manual on Moisture Analysis in Buildings states that a newly constructed house can release an estimated 5,730 lb of water from concrete foundation and construction lumber. Thus, moisture from construction materials can be a serious source of humidity in the first year and second year.

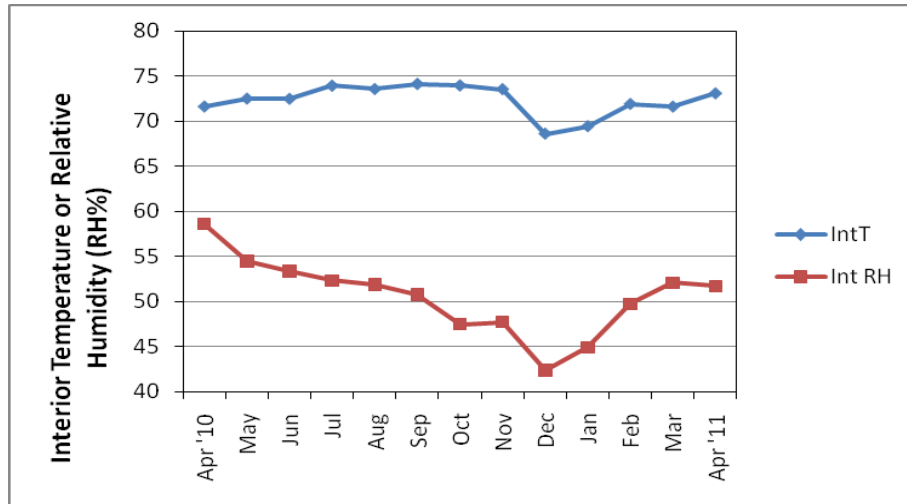


Figure 5: Average monthly interior temperatures and progressive downward trend of relative humidity.

Sealed Attic Conditions

In Florida, as recommended by code, it may be standard practice to apply a vapor barrier underlayment on a shingle roof constructed with sealed attic. Averaged hourly data collected during May 2010 clearly indicates high relative humidity measurements appearing at 4:00 PM at the peak of the attic. This measurement is being taken at 6 inches below the sprayed roof deck insulation. Relative humidity levels reached as high as 83% in May 2010 and 78.3% during April 2011 as indicated from 15-minute data interval. The relative humidity levels almost seem inversely proportional with respect to the outdoors, as shown in Figure 6.

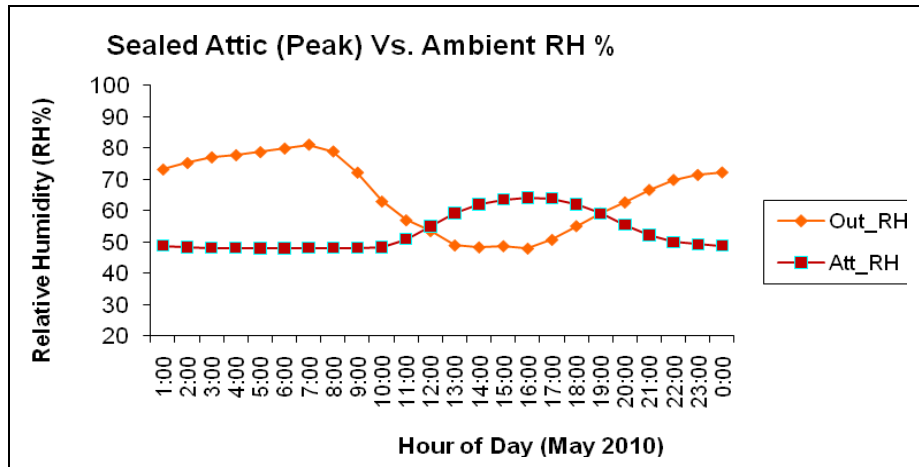


Figure 6: Sealed attic (peak) and outdoor relative humidity averaged daily by hour for May 2010.

Initially, during May 2010, humidity levels in the attic appeared high, but consecutive months showed a steady downward trend in magnitude, as seen on the top plot in Figure 7, for the first eight months ending on December 2010. However the latest data analysis clearly shows a reverse trend with increasing relative humidity levels beginning in January of 2011 (Figure 7, bottom plot). Relative humidity levels in the attic during April 2011 appear to exceed those high levels measured almost a year before during May 2010. These monthly averaged measurements of relative humidity conditions have prompted further investigation of the humidity in this particular sealed attic configuration. Relative humidity and attic temperature measurements were used to calculate the amount of moisture content in the air, also known as humidity ratio (W).

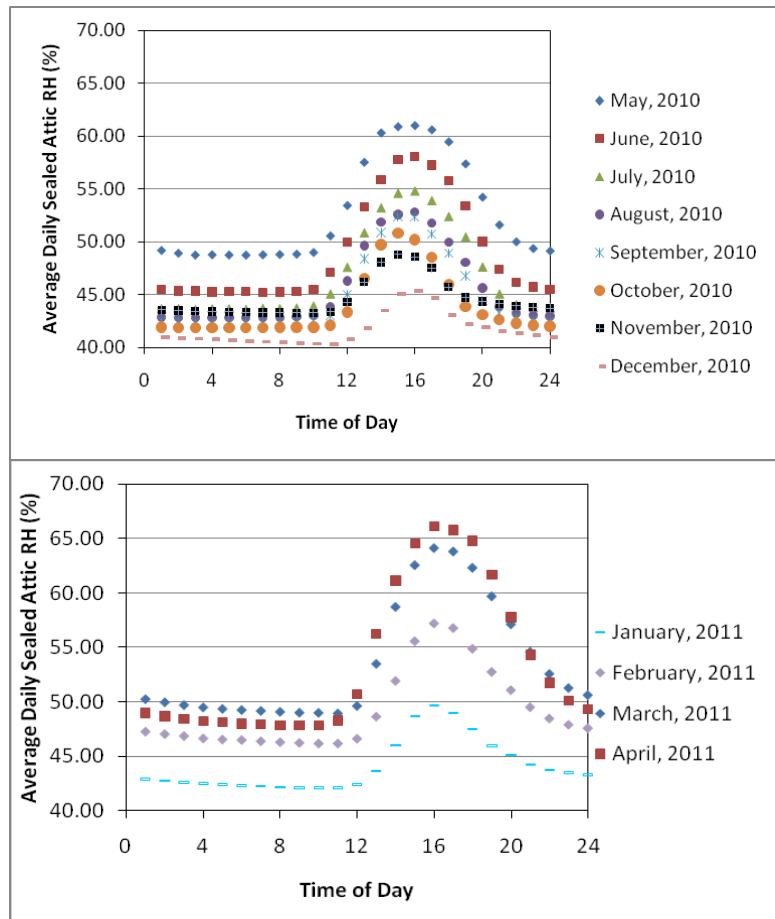


Figure 7: Monthly trend of relative humidity levels in sealed attics for 2010 and 2011.

The humidity ratio (W), as defined in the ASHRAE handbook of fundamentals, is the ratio of the mass water vapor to the mass of dry air. The humidity ratio is expressed as pounds of moisture per pound of dry air in the British (IP) system. Analysis of sealed attic humidity content may be easier to analyze by looking at the calculated W values of the sealed attic air and adjacent air spaces. In this manner, the source of moisture can be easier to identify on a 24-hour day period, for example. Figure 8 shows the calculated moisture content (W) found in the attic plotted along with the W ratios found for outdoor air on April 1, 2011. Air temperature measured at the sealed attic peak level is also shown in degrees Fahrenheit (F). The temperature data is helpful to identify trends of moisture. As indicated previously, this model home does not have the typical moisture generation of an occupied residence (i.e., showers, cooking, occupants). The plot on Figure 8 may indicate that a year after the home was built, wood truss components exposed in the sealed attic are prone to sorption and desorption trends throughout the day.

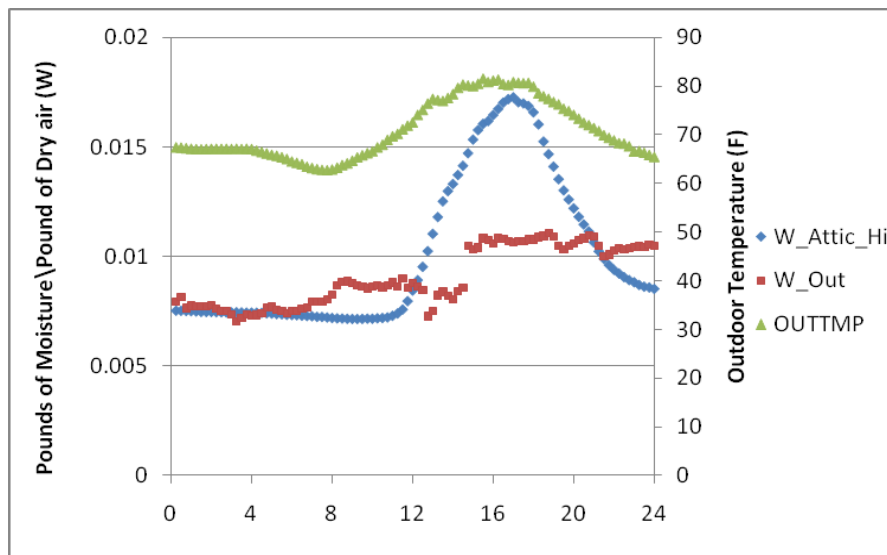


Figure 8: Humidity content plot for sealed attic and outside air on April 1, 2011.

Furthermore, the same plot was enhanced to examine humidity content in the sealed attic at mid-level (Figure 9). Data points representing indoor relative humidity conditions are also shown to represent interior conditions. Although the air conditioner did not operate until late afternoon this day, relative humidity in the conditioned space did not vary much from 50% throughout the day. The interior temperature that day (April 1, 2011) was kept by the air conditioner at or below 73.1°F, and relative humidity reached 52.7% at its highest. A small reduction in moisture content can be seen due to the operation of the variable speed HVAC unit between 4:45 PM and 6:00 PM.

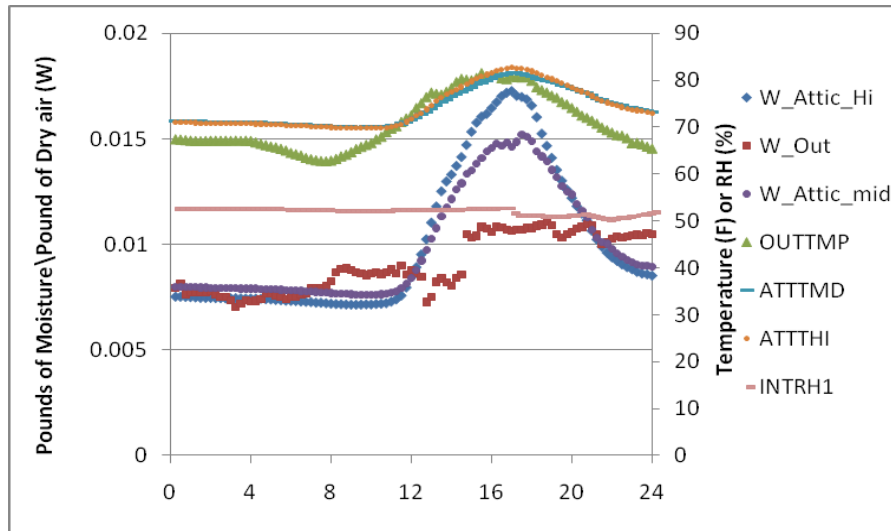


Figure 9: Enhanced plot showing humidity content at two levels in attic and temperatures along with interior home conditions

Lessons Learned

The moisture content absorbed (sorption) and moisture released (desorption) by the pine trusses appears to explain the time-varying moisture content in the sealed attic. Pine trusses in this particular sealed attic configuration undergo the sorption process during cooler attic temperatures and desorption at higher attic temperatures. This indicates that changes in temperature in a sealed attic with the substantial mass of pine wood can be considered the driving force for humidity content in the unvented space. As a reference to demonstrate the dynamic amount of moisture content in pine wood, properties for pine published by the IEA in Canada reported during a sorption test (68°F [20°C]), the moisture content in pine at relative humidity levels of 43.5% is 0.094 kg/kg.¹ Also during sorption under the same 68°F temperature conditions and relative humidity of 85.8%, the moisture content of pine is 0.177 kg/kg. This data indicates the ability of pine wood to act as a variable moisture storage medium.

At this point, it is unknown whether the high levels of moisture will have a degrading effect on the longevity of roof materials. The fact that peak humidity content is detectable and that it reverses on a daily cycle could mean that humidity may not fully transfer through the open-cell sprayed insulation core. Placement of the RH sensor itself may be leading to false indication of high peak humidity levels. Another sensor positioned away from the wood truss may be needed to verify RH levels at the peak attic space.

The overall concern here is that moisture or water content in this sealed attic configuration may not leave the attic envelope as quickly as in standard vented attics. More analysis is underway to investigate the moisture content in this particular sealed attic. More investigation is also needed

¹ M, Kumar Kumaran, Heat Air and Moisture Transfer in Insulated Envelope Parts, Final Report Volume 3, Task 3: Materials Properties, International Energy Agency (IEA).

to verify conditions in sealed attics where the sorption and desorption point process is reversed. Data for this particular site is collected, reported and archived on a daily basis at FSEC's Infomonitors website. (<http://infomonitors.com/spw/>).