Smart Vapor Barrier

CertainTeed DryRight – vs – Kraft-Faced Insulation

Objective

As a follow on to an evaluation of the MemBrain vapor retarder system in a CARB home built by Veridian Homes in Wisconsin, CertainTeed wanted to compare the hygrothermal performances of DryRight™ fiberglass batts and kraft-faced fiberglass batts in a south facing wall assembly with a moisture storage cladding material. DryRight is batt insulation faced with MemBrain®, the “smart” vapor retarder. MemBrain changes its ability to resist the flow of water vapor depending on the conditions within the construction assembly.

Monitoring Overview

Two adjacent bays in a second story, south facing wall of a new, modular home in Wilton, CT served as the field test section. Conventional 2x4 framing is used and both bays are insulated with CertainTeed R-21 fiberglass batts. Bay No. One uses CertainTeed’s DryRight system and bay No. Two uses kraft-faced batts. Twelve Humirel temperature/relative-humidity sensors (six in each bay) have been strategically placed to track moisture movement in each bay. Interior walls are finished with conventional drywall. The exterior wall is OSB over which Typar HouseWrap, a layer of 15 lb. felt and fiber-cement siding was applied.

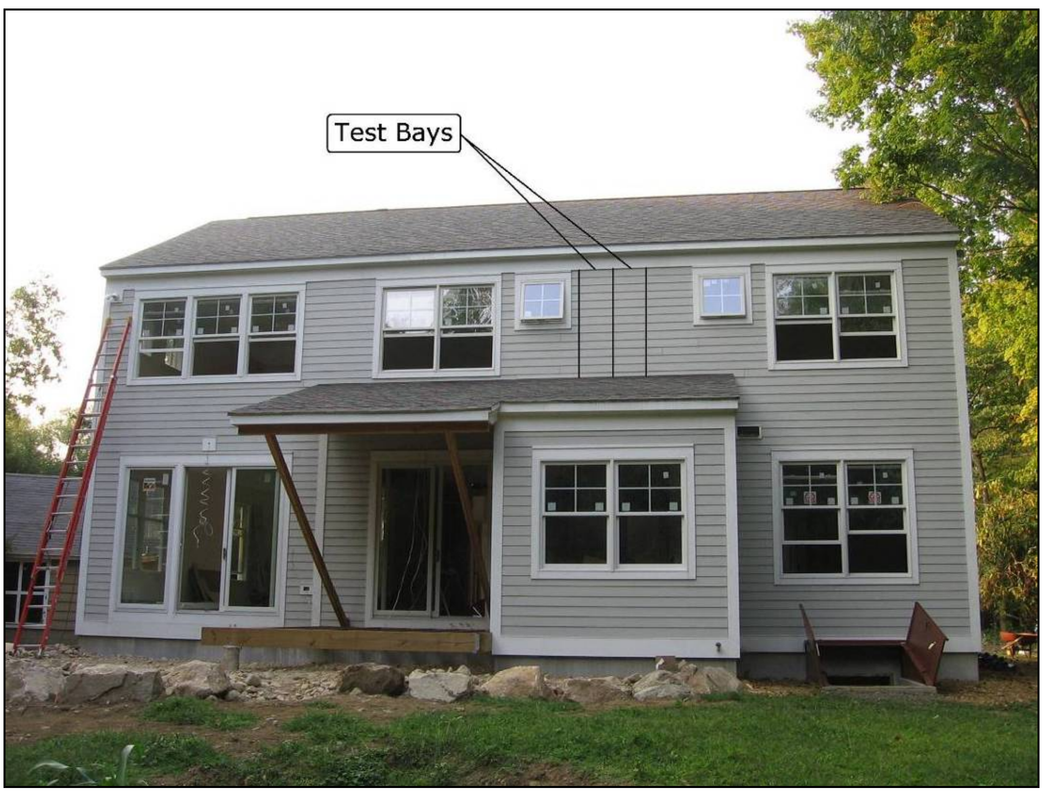

Figure 1: South side with test bays indicated.

Figure 2: South side prior to installing fiber cement siding.

Sensor Location and Installation

The Humirel HTM2500 sensor was selected to measure temperature and relative humidity at selected locations within the wall system. The specifications of this sensor are:

Testing range: -40~85ºC
Power Supply: 5V @ 0.4 mA
Accuracy: ±2 @ 55% RH
Response Time: 5 s
Output signal: DC 1~4V for 0~100% RH

Six temperature/relative-humidity sensors in each cavity are located as follows:

- Sensors #1 and #3: Between vapor barrier and insulation
- Sensor #2: On interior side of exterior sheathing
- Sensor #4: Between vapor barrier and drywall
- Sensor #5: Inboard on bottom plate
- Sensor #6: Outboard on bottom plate

Sensors #1 and #3 are friction fit between the fiberglass batt and its vapor barrier. Care was taken to avoid unnecessary air gaps in fiberglass batt during installation.

Figure 3: Installation of sensors #1 and #3.

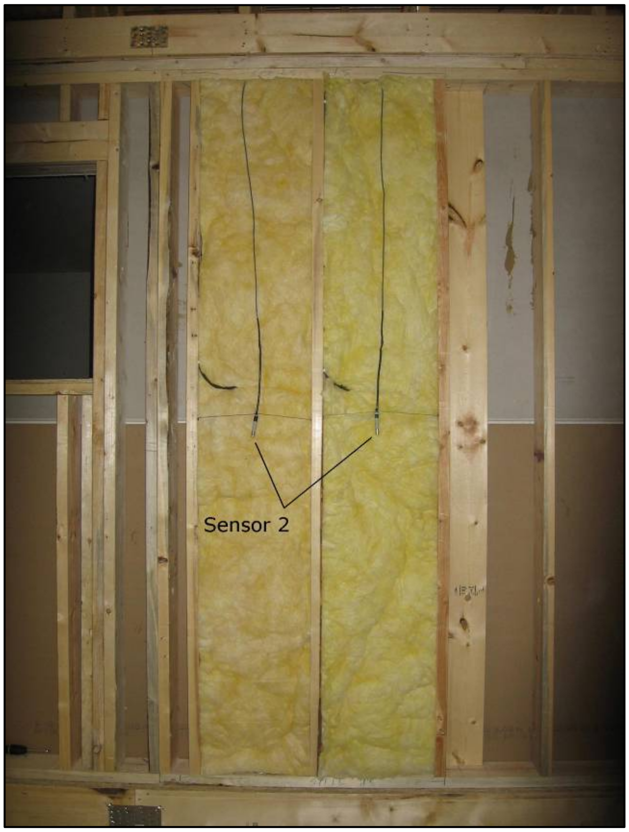

Figure 4: Sensor 2, both bays, prior to installing exterior sheathing.

Sensor #2 is located on the interior side of the exterior sheathing. It is centered both vertically and horizontally and is shown here tied in place awaiting the installation of exterior sheathing.

Sensor #2 located and awaiting the installation of the exterior OSB sheathing.

Figure 5: Close-up of sensor #2.

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Sensor #4, located between the insulation's vapor barrier and the drywall, are secured with metal tape.

Figure 6: Empty cavity showing location of sensors #4-6.

Sensors #5 and #6, located outboard and inboard respectively on the bottom plate, are secured with silicone and metal clip.

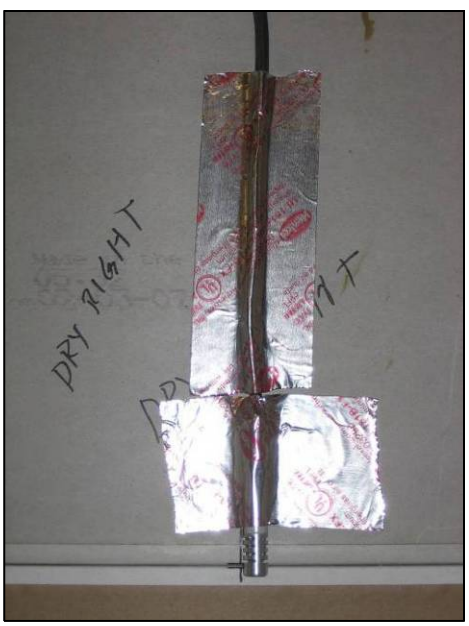

Figure 8: Close-up of sensor #4.

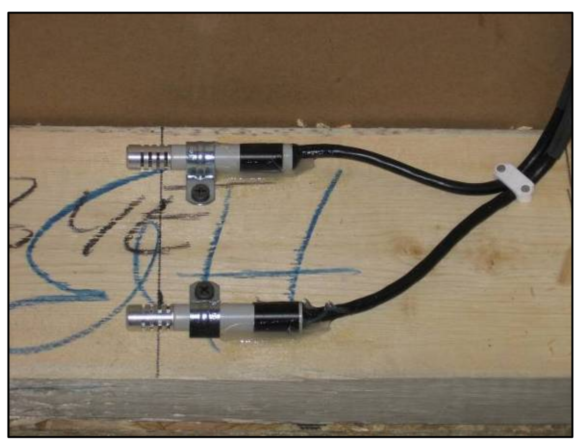

Figure 7: Close-up of sensors #5 and #6.

In order to measure the indoor temperature and relative humidity, a less intrusive HOBO U12 logger was placed inside to monitor and record conditions during the test period.

Testing range: -20~70ºC
Accuracy: ± 0.35°C from 0° to 50°C / ±2.5% from 10% to 90% RH

Outdoor weather conditions were monitored using the same Humirel temperature/relative-humidity sensor that is used in the wall cavities. For exterior use, it was mounted in an R. M. Young radiation shield and mounted on the upper east corner of the home's south-facing side.

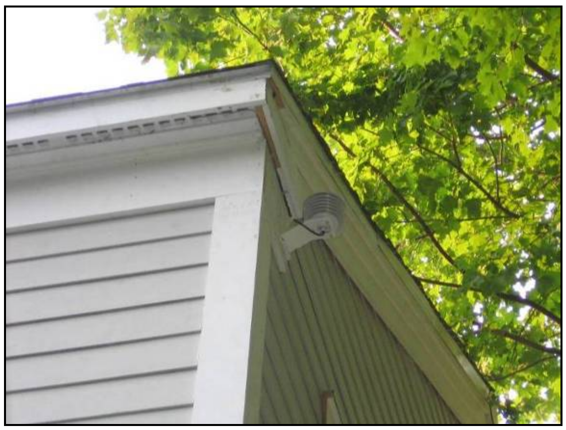

Figure 9: Exterior Temp/RH Sensor housed in radiation shield.

To measure the amount of sunlight available on a given day, (sunny versus overcast), a Li-Cor LI-200SA pyranometer was installed on the ridge cap of the home. The pyranometer is not tilted. The specifications of the pyranometer are:

Error: <5%
Sensitivity: 90 μA/ 1000Wm-2
Response time: 10 μS
Operation Temperature: -40~65 ºC
Operation Relative humidity: 0~100%

Figure 10: Pyranometer on ridge cap.

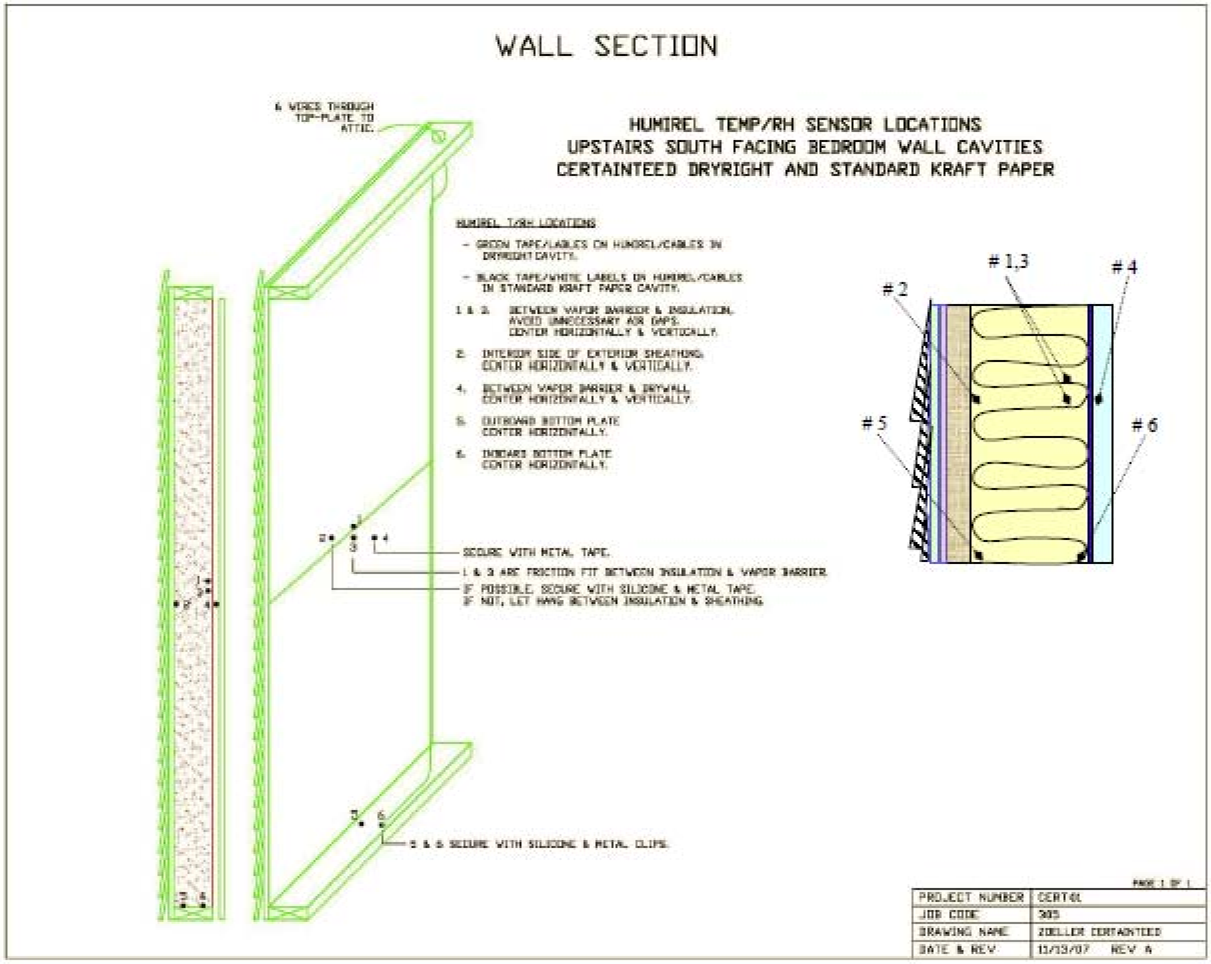

Figure 11: Wall section drawing.

Testing Methodology:

In order to compare the moisture performance of CertainTeed Dry Right with kraft-paper, an identical surface wetting condition is required as the initial condition to start the test. This condition was manually generated by spraying the outside surface on a sunny day so as to stimulate a solar-driven moisture incursion.

Data was collected for nearly two months. The monitoring period can be summarized in three different stages:

1. Initial manual surface wetting with solar-driven moisture incursion (Aug 26^{th}, 2008 to Sep 5^{th}, 2008)
2. Natural tropical storm (Sep 6^{th}, 2008 to Sep 25^{th}, 2008)
3. Rainy days (Sep 26^{th}, 2008 to Oct 13^{th}, 2008).

The detailed outdoor weather conditions are listed in the following tables:

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Table 1: Stage 1 - Initial Manual Wetting

Date	Weather	Day time Max T (°F)	Day time average RH	Wetting Method
26-Aug	Fair/Sunny	70.8	40%	Sprinkler - Manual
27-Aug	Fair/Cloudy	67.9	52%	
28-Aug	Cloudy	70.0	57%	
29-Aug	Cloudy	68.8	69%	
30-Aug	Cloudy	65.7	79%	
31-Aug	Fair	73.8	51%	
1-Sep	Fair	72.1	54%	
2-Sep	Fair	76.6	56%	
3-Sep	Partly Cloudy	74.7	67%	
4-Sep	Fair	79.8	60%	
5-Sep	Fair/Partly Cloudy	79.0	64%	

Table 2: Stage 2 - Natural Wetting by Wind-Driven Rain (Tropical Storm)

Date	Weather	Day time Max T (°F)	Day time average RH	Wetting Method
6-Sep	Rain (Tropical Storm)	75.9	88%	Wind-driven Rain
7-Sep	Rain/Fair	72.5	60%	Wind-driven Rain
8-Sep	Fair	70.2	56%	
9-Sep	Rain	67.4	89%	Wind-driven Rain
10-Sep	Fair	63.6	57%	
11-Sep	Cloudy	63.0	67%	
12-Sep	Cloudy/Rain	63.8	80%	
13-Sep	Cloudy	71.1	81%	
14-Sep	Cloudy	78.2	84%	
15-Sep	Cloudy	76.6	52%	
16-Sep	Cloudy	62.6	75%	
17-Sep	Fair	63.3	66%	
18-Sep	Fair	63.8	61%	
19-Sep	Fair	56.7	61%	
20-Sep	Fair	57.8	66%	
21-Sep	Fair	65.8	65%	
22-Sep	Partly Cloudy	63.3	73%	
23-Sep	Fair	60.6	64%	
24-Sep	Fair	60.7	71%	
25-Sep	Cloudy	56.6	71%	

Table 3: Stage 3-Natural wetting by rain

Date	Weather	Day time Max T (°F)	Day time average RH	Wetting Method
26-Sep	Heavy Rain	60.2	99%	Rain
27-Sep	Light Rain	64.9	99%	Rain
28-Sep	Light Rain	69.3	91%	Rain
29-Sep	Cloudy	65.8	78%	
30-Sep	Cloudy	62.8	76%	
1-Oct	Mostly Cloudy	65.2	73%	
2-Oct	Cloudy	55.3	65%	
3-Oct	Cloudy	53.8	66%	
4-Oct	Sunny	51.3	67%	
5-Oct	Light Rain	51.3	96%	Rain
6-Oct	Cloudy	52.3	71%	
7-Oct	Sunny	50.8	55%	
8-Oct	Partly Cloudy	54.8	62%	
9-Oct	Partly Cloudy	66.2	77%	
10-Oct	Sunny	60.9	56%	
11-Oct	Sunny	58.6	62%	
12-Oct	Sunny	58.8	64%	
13-Oct	Cloudy	61.4	75%	

Prior to the field test, a laboratory test was performed to determine how to evaluate the uniformity of moisture (water) content on the wall assembly's fiber-cement siding. The procedure was as follows:

1. Calibrate the moisture content meter. A moisture content meter (Delmhorst BD-2100) was used to measure the uniformity of the moisture content on the exterior siding after wetting, and the average moisture content on the siding. A sample of fiber-cement siding collected from the field site (Specimen A) was placed in a water bath. A digital weight scale was used to measure the weight change of the specimen A. It showed after soaking for approximately two and a half days, specimen A had reached equilibrium, its weight was not changing. A saturated weight (equivalent to 100% moisture content) was recorded. Then specimen A endured a drying process so as to calibrate the moisture content meter: Specimen A was exposed to normal indoor air conditions for a certain time, then it was put in a sealed can for moisture re-distribution for at least a couple of days (so as to eliminate the moisture gradient within the specimen), then the moisture content meter was used to measure the moisture content as it dries. Finally, specimen A was put in an oven for a 24-hr period at 212ºF, which would produce the absolute "dry" base weight for specimen A. This base weight could be used to compute the real

moisture content (RMC) for the specimen, and then it could be used to generate the calibration curve so as to translate the reading into real moisture content. This would be used to determine the initial moisture content at the start of the field test. The result for the calibration is summarized in Table 4.

Table 4: Moisture Meter Calibration - drying process for the soaked specimen

Specimen A	Weight (g)	Procedure	Time	Moisture content	RMC	Delmhorst
Wetting	674	Soaking	2.5 days	0.212	100%	98.8
Drying	640	Drying	1 day	0.151	71%	82.5
	635	Drying	1 day	0.142	67%	82.0
	602	Drying	1day	0.083	39%	78.3
	595	Drying	1 day	0.070	33%	73.6
	585	Drying	1 day	0.052	25%	53.3
	576	Drying	4 day	0.036	17%	45.1
	571	Drying	4 day	0.027	13%	36.6
Oven Drying	556	Drying	1 day	0.0	0%	/

2. <u>Determine the length of time for the initial water-spray wetting.</u> A wetting process was performed on another specimen (Specimen B). Before the wetting test, specimen B (from equilibrium with normal indoor condition) had been dried in an oven to record its "dry" base, then a water spray was applied to track its weight change with time, as shown in Table 5. It is estimated that after about 90 minutes spray, the siding would reach about 80% moisture content.

Table 5: Wetting process for the specimen

Specimen B	Weight (g)	Procedure	Time	Moisture content	RMC	Delmhorst
Oven Drying	329	Drying	1 day	0.0	0%	/
Wetting	366	Spraying	21 minutes	0.112		/
	371	Spraying	40 minutes	0.128		/
	379	Spraying	65 minutes	0.152		/
	385	Spraying	90 minutes	0.170	80%	83.5

The field test was initiated at noon on Aug 26th, 2008, a sunny day. The siding of the test wall sections was sprayed to simulate a "wind-driven-rain" effect. The spraying time was about 105 minutes.

In order to ensure that the fiber cement siding was uniformly wet; the Delmhorst hand-held moisture content meter was used. Overall there are 12 pieces of siding from the top to the bottom of the test wall assemblies which have been assigned Siding 1 (on the top) to Siding 12 (on the bottom). The test section is about 7.5 feet wide, which was evenly divided into 3 zones;

A, B, and C. The arrangement can be demonstrated in the following Fig. 13. Uniformity measurements were taken immediately after the spray wetting and the results are depicted in Fig. 15. Good moisture content uniformity for the fiber cement siding was found across the test area, with an average reading of 81.4 (Delmhorst Reading), which can be translated to about 60% soaked condition.

Figure 12: Spray wetting of the siding outside the test bay

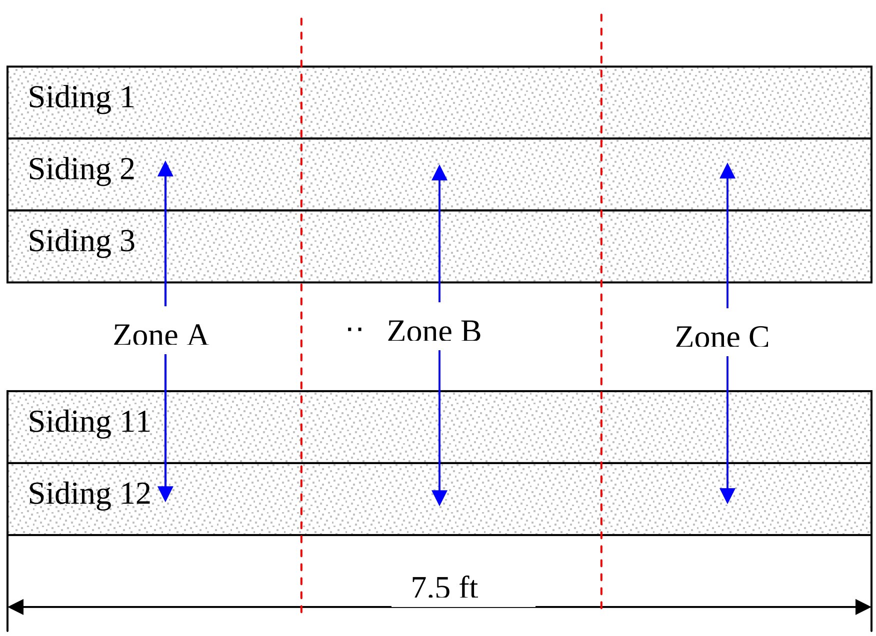


Fig. 13 The geometry arrangement for the siding

Figure 14 Testing the uniformity on the siding outside the test bay

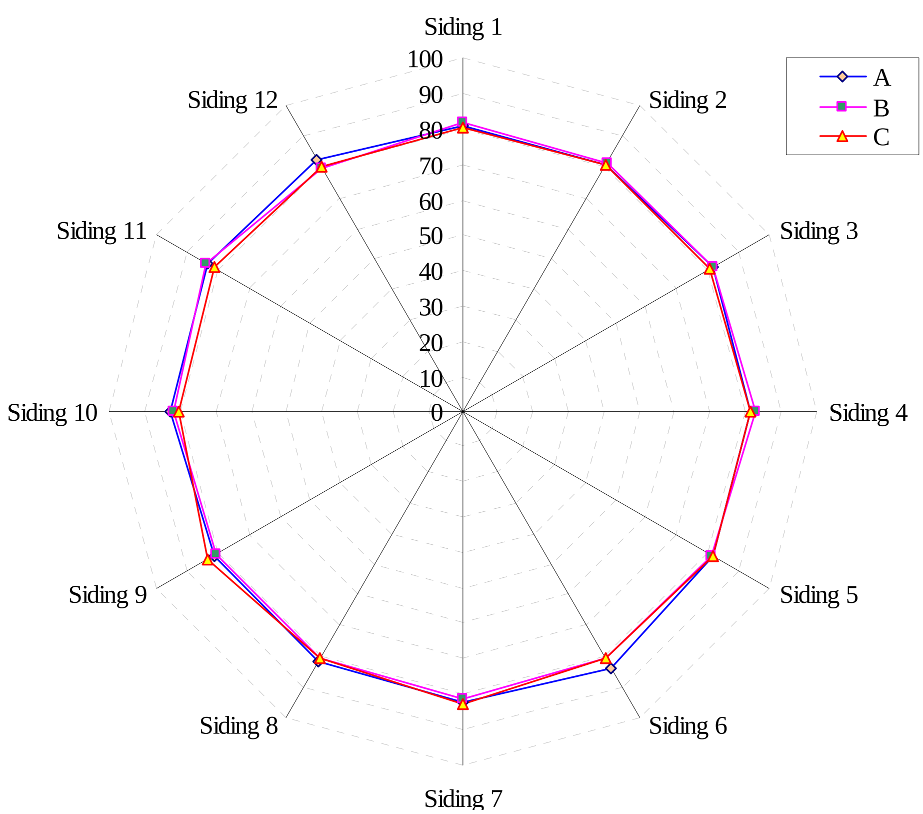
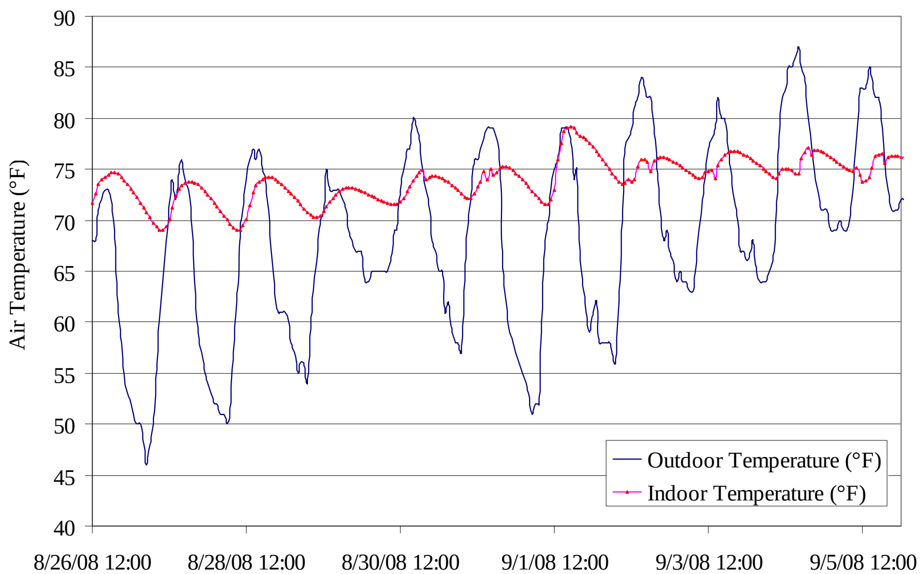


Figure 15 Uniformity test for the siding

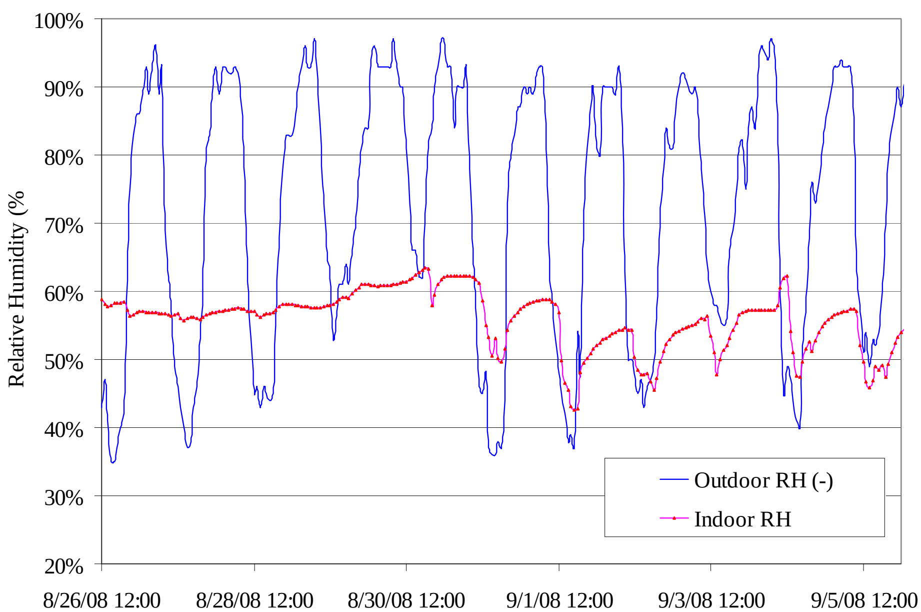
Testing Results and Analysis

Stage 1 - Manual wetting by water spray

The outdoor and indoor air temperature and relative humidity during test stage 1 is shown in Fig. 16. The daily high temperatures kept rising during this test period and the relative humidity usually swung from 50%-90% daily, which was good for the test. For indoor conditions, the temperature varied within the 68-78°F range, and the relative humidity stayed below 65%.



Temperature Conditions



Relative Humidity Conditions

Figure 16 Outdoor/Indoor air temperature and RH during testing stage 1

The relative humidity within the insulation of the test bay sections indicate that the insulation within CertainTeed MemBrain™ vapor retarder section was at a lower relative humidity compared to the kraft paper section, as Figure 17 shows.

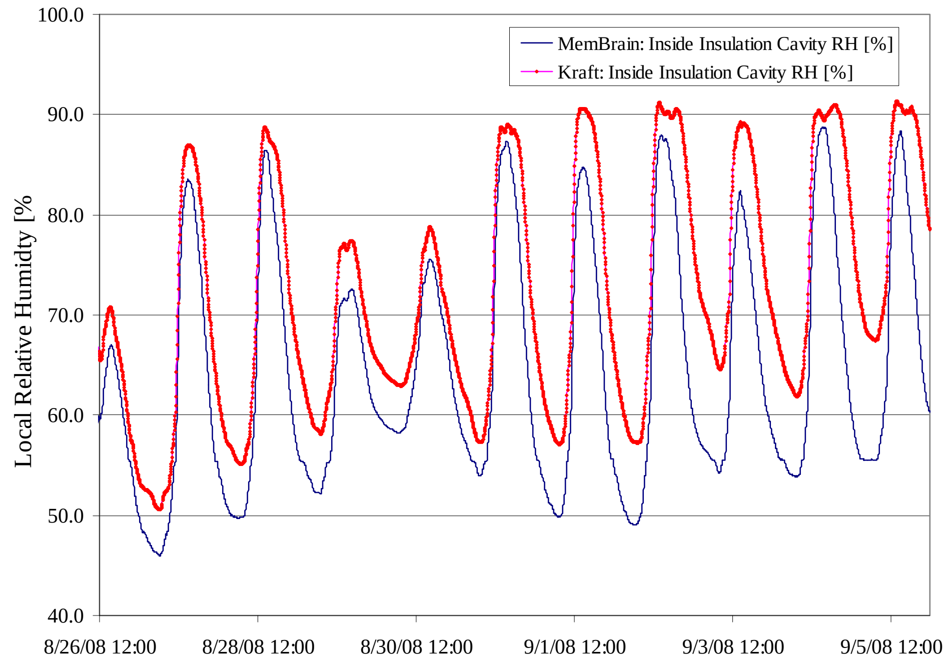


Figure 17 Comparison for RH within insulation cavity during testing stage 1

There is another potential benefit from the CertainTeed MemBrain™ vapor retarder's ability to keep the wall assembly dry. This can mean lower local moisture content for the building material that translates into a lower local air RH within the porous building material, as shown in Fig. 19 (the MemBrain bay has lower RH compared to the same position in the kraft bay). Higher moisture content will increase the thermal conductivity of porous building material, which will result in higher local temperature, which is shown in Fig. 18 (compared to the MemBrain, the kraft had higher local temperature on the corresponding position at any time).

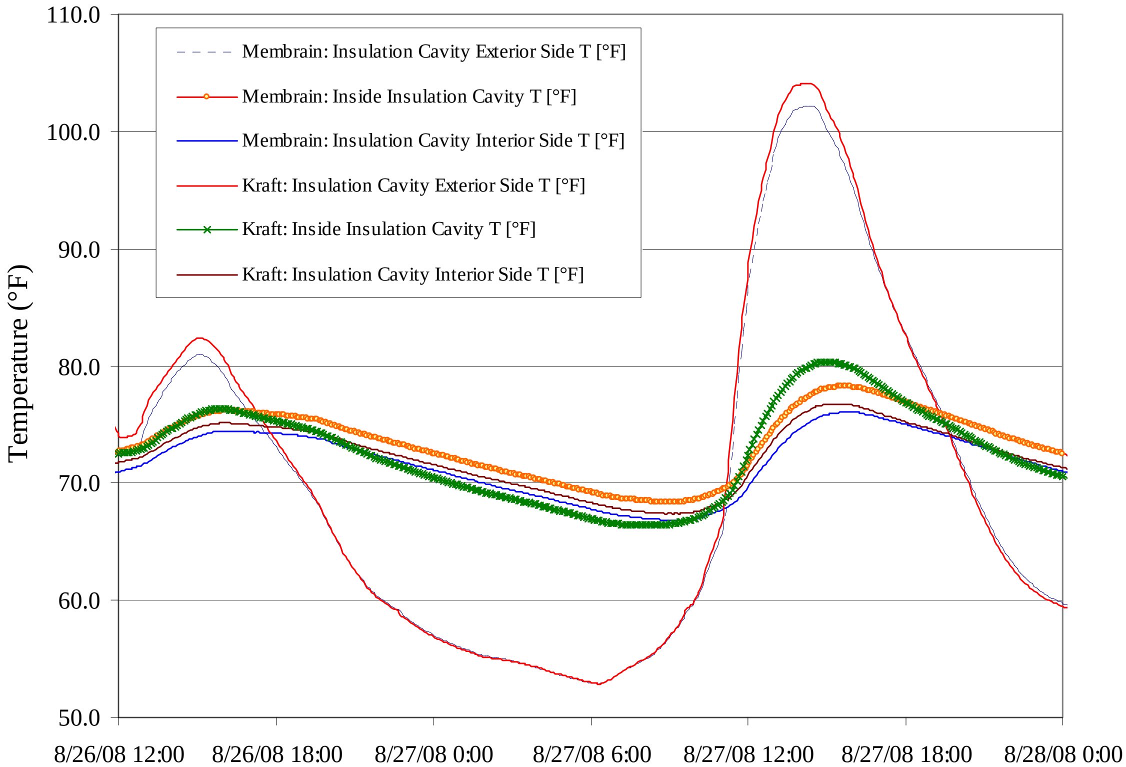


Figure 18 Comparison of Temperatures within the test bays

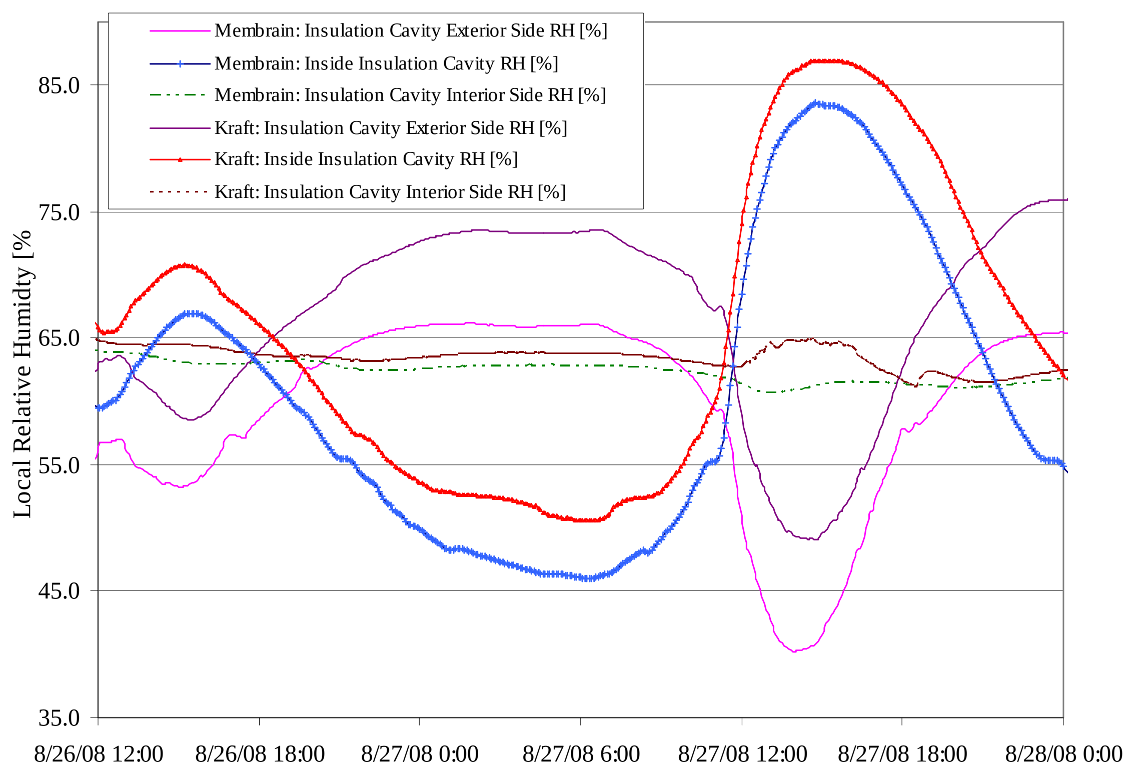
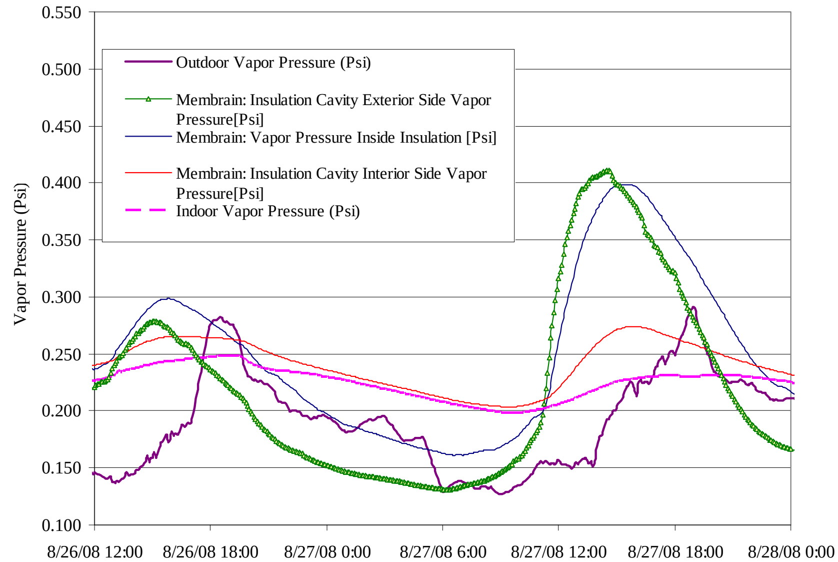
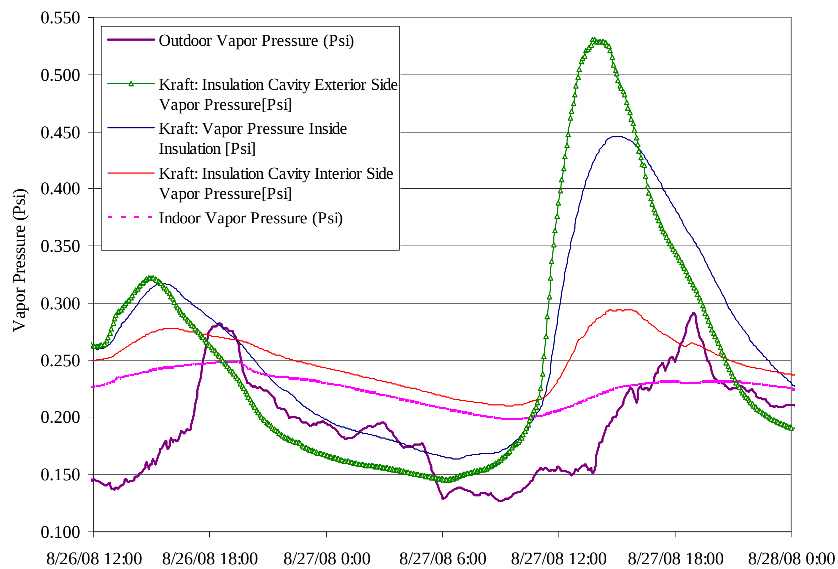


Figure 19 Comparison of Relative Humidity within the test bays

It is of interest to focus on the early stage of the drying, right after the wetting of each vapor retarder system. As Figure 20 depicts, in each of these systems it is clear that from morning until a couple of hours after the peak afternoon spike, the outside of the sheathing has the potential to dry to both the relatively drier inside and outside of the house. However, while the MemBrain material allows moisture to diffuse from the insulation cavity to the inside in response to this potential (as the water vapor pressure is much higher than the indoor side sheathing, the MemBrain allows the sheathing to dry out more rapidly than the kraft and does not result in any moisture build-up behind the vapor retarder). Therefore, both the outdoor sheathing and the insulation cavity can maintain a lower moisture level, resulting in lower local vapor pressure compared to that of the kraft system.



a. MemBrain System

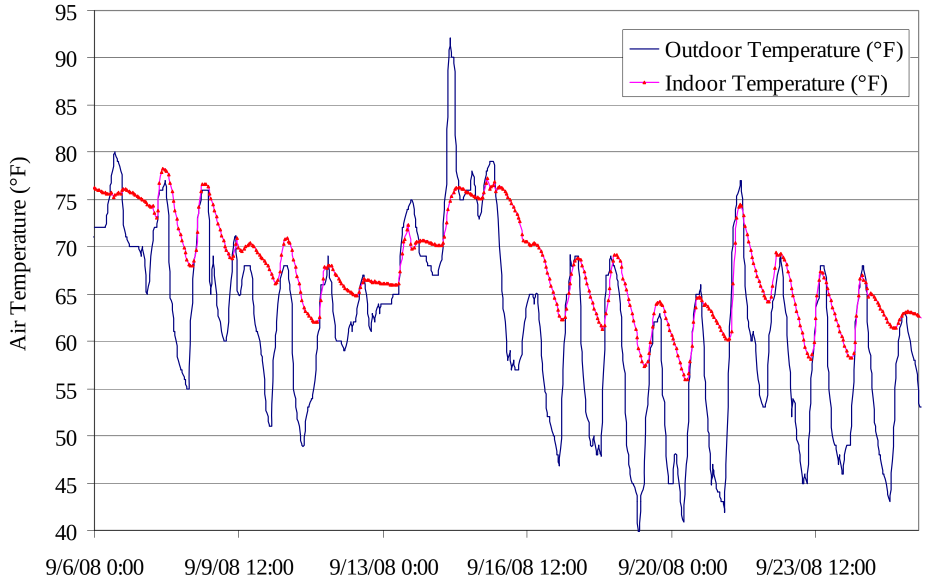


b. Kraft System

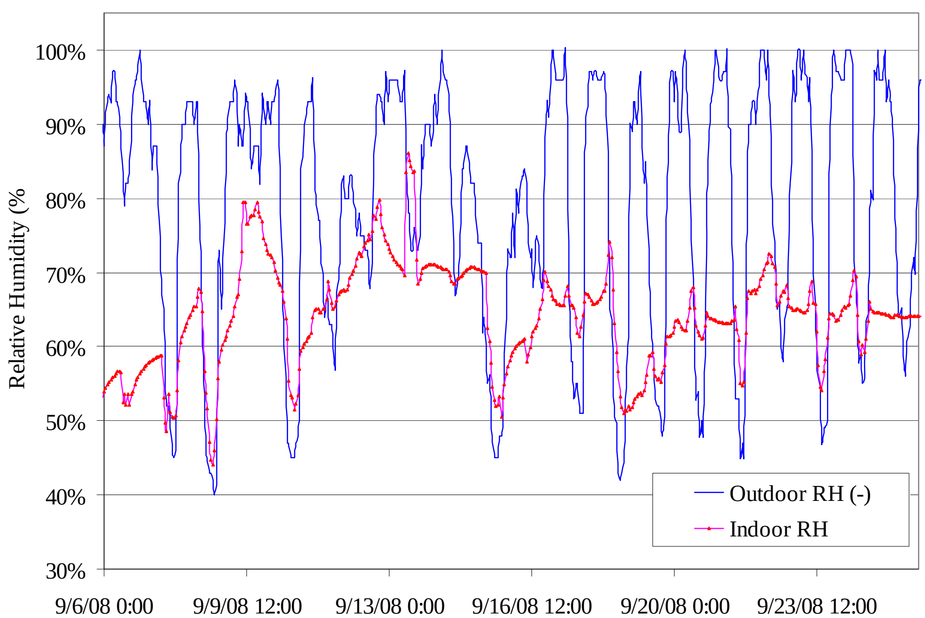
Figure 20 Comparison of local vapor pressure for both vapor retarder systems

Stage 2 - Natural wetting by tropical storm

A 2-day tropical storm began on September 6th with heavy rain. Figure 21 shows the outdoor and indoor temperature and RH.



a. Temperature



b. RH

Figure 21 Outdoor/Indoor air temperature and RH during testing stage 2

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The results indicate that the MemBrain system did help keep the wall dryer, especially for the insulation cavity within the wall assembly, as shown in Figure 22.

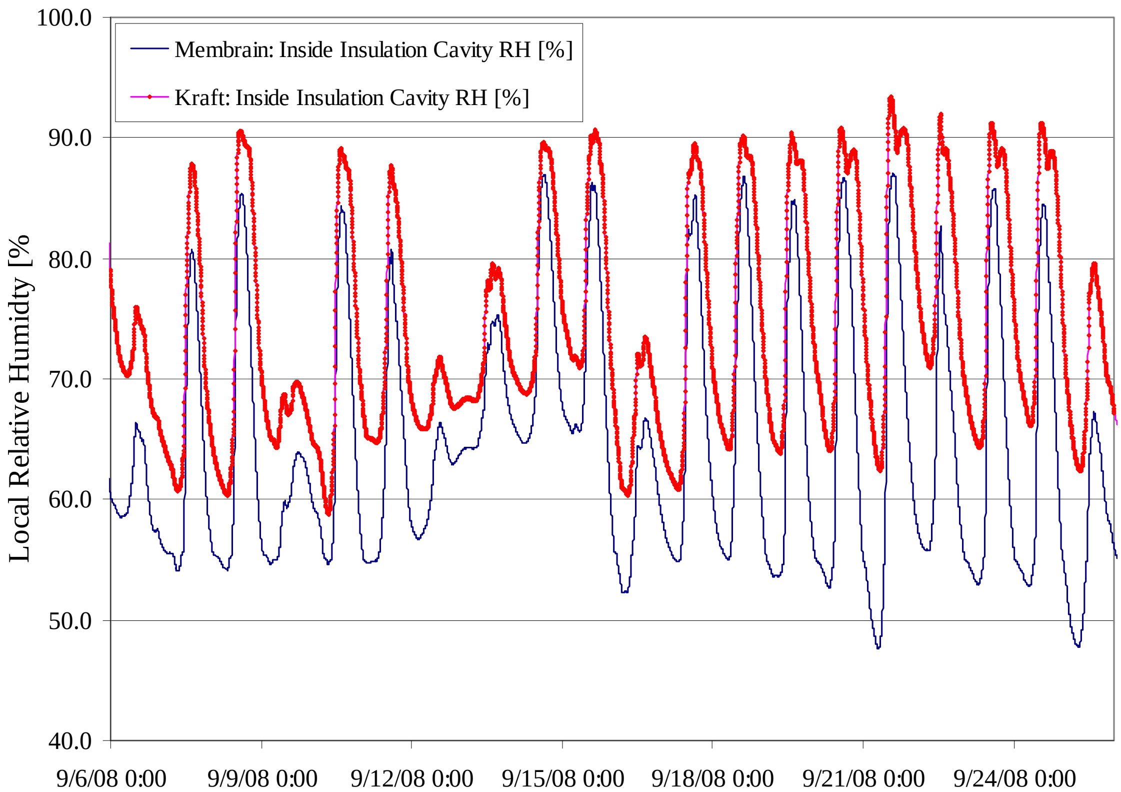

Figure 22 Local RH within insulation cavity during testing stage 2

Stage 3-Natural wetting by continuous rain

Three continuous days of rain began on September 26th, 2008. The test continued to evaluate the moisture performance for both vapor retarder systems under this condition. Figure 23 shows the outdoor and indoor temperature and RH.

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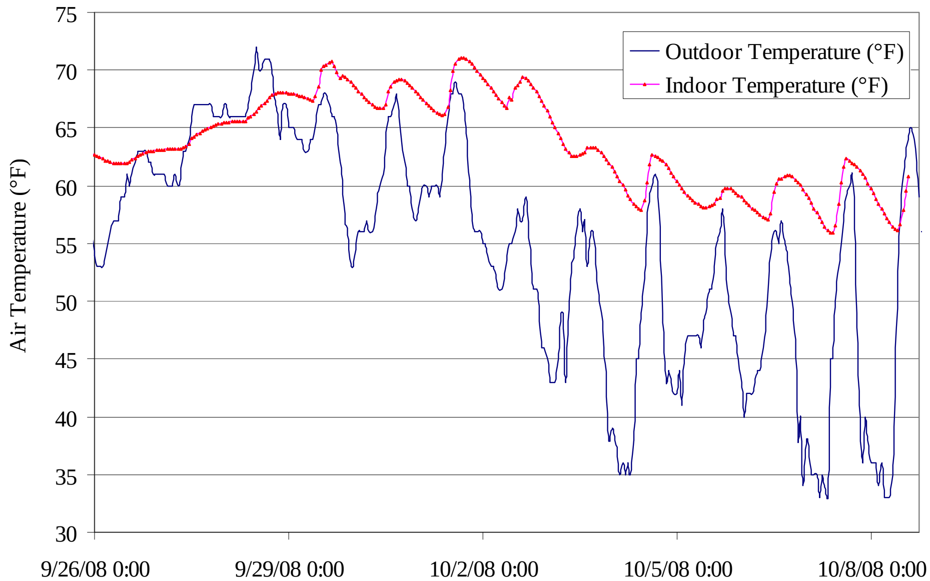
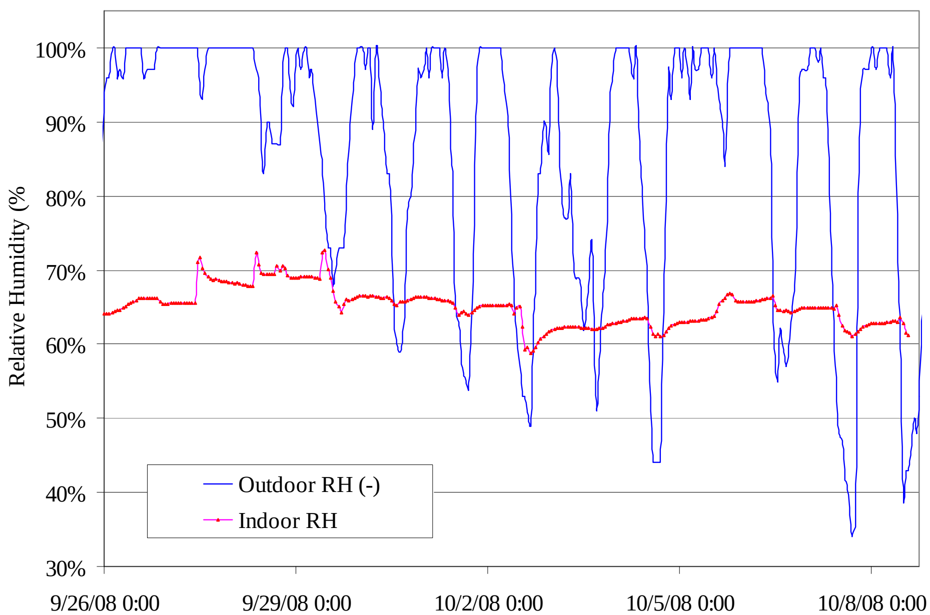


a. Temperature



b. RH

Figure 23 Outdoor/Indoor air temperature and RH during testing stage 3

Again, the MemBrain system kept the wall at more favorable conditions as shown in Figure 24. In most instances, the MemBrain system kept the insulation cavity well below 80% local RH, and successfully reduced the number of hours the local RH >80% (80% RH is a threshold that is adopted by ASHRAE to evaluate the potential danger of mold growth due to favorable air temperature and relative humidity). Relative humidity over 80% with air temperatures from 40~100°F for a continuous 30 day time span is suggested by the ASHRAE Handbook of Fundamentals to have the potential for mold growth (ASHRAE Handbook - Fundamentals, 2005).

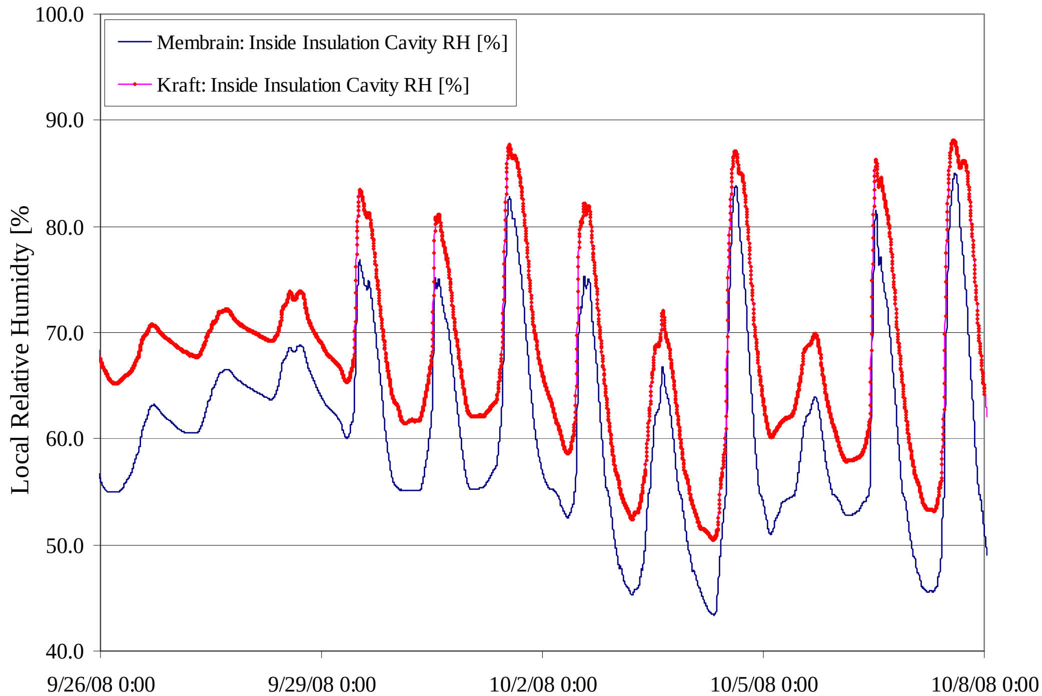


Figure 24 Local RH within insulation cavity during testing stage 3

It is noticeable in Figure 25 that in the early stage of the rain wetting, the RH levels within the insulation cavity for both vapor retarder bays did not swing as sharply as usual because the ambient condition of rain showers with continuous high RH (>95% for three days). The benefits of MemBrain are most apparent in this situation. Since the ambient condition is wet, the outdoor sheathing is wet and the only path to avoid moisture build-up is the penetration through the vapor retarder to indoor air, allowing drying to the interior. Figure 25 demonstrates this result showing that the vapor pressure at the outside sheathing and the insulation cavity of the MemBrain system is much lower than the kraft system. This indicates that the MemBrain system will perform better in humid and rainy areas since it provides the “narrow escape” for moisture to the indoor side.

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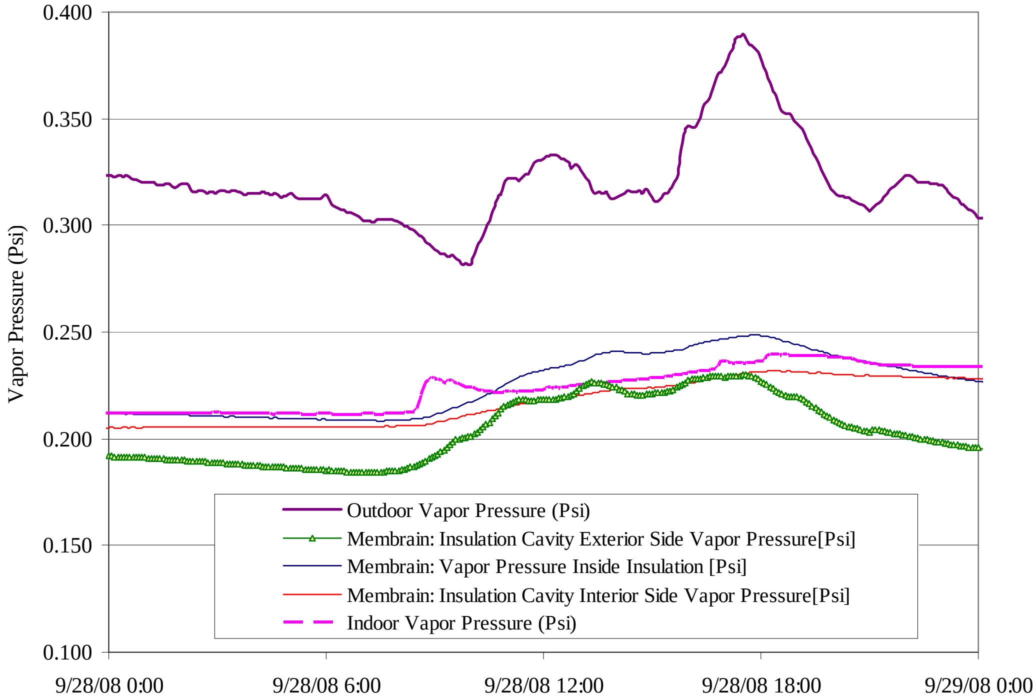
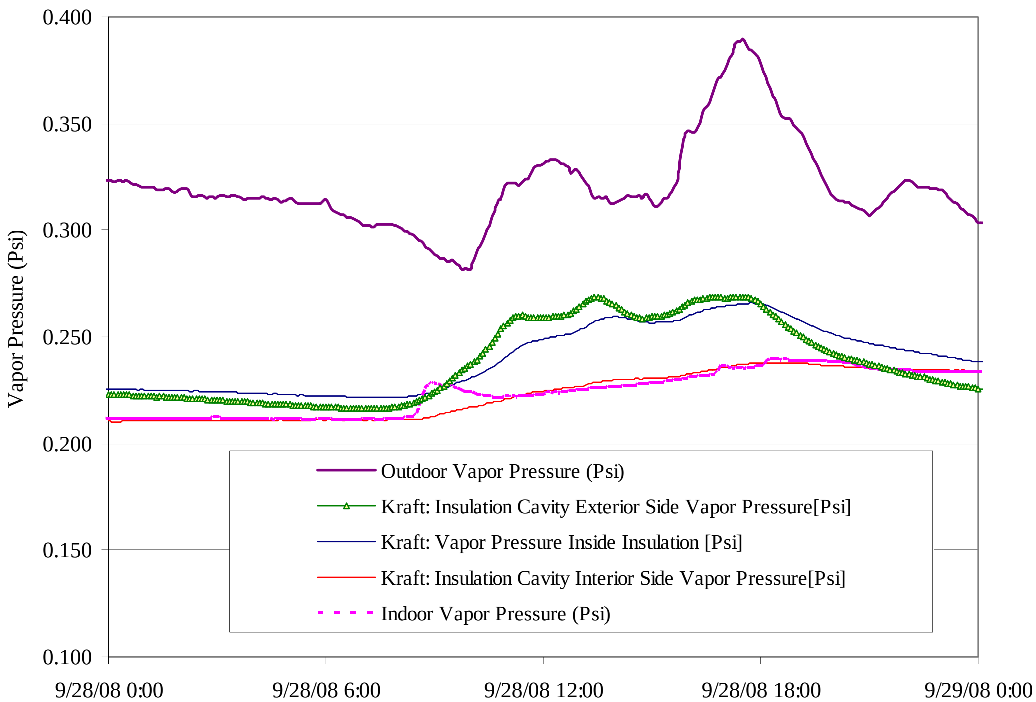


a. MemBrain System



b. Kraft System

Figure 25 Comparison of local vapor pressure for both vapor retarder systems

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Conclusions

A comparison field test was performed to evaluate the moisture performance of the CertainTeed DryRight system which uses the MemBrain vapor retarder versus conventional kraft-faced batts. The results indicate that:

1. The relative humidity within the insulation of the test bay with the MemBrain vapor retarder was lower than the test bay with kraft paper facing.

2. When the ambient conditions are very wet for a relatively long time span (several rainy days) with significant wetting to cladding and sheathing assemblies, the MemBrain system can provide a moisture escape path by its variable open-pore structure allowing higher levels of drying to the interior than does standard kraft-faced batts.

For more information or comments, contact Zhipeng Zhong at Zhong@swinter.com.