

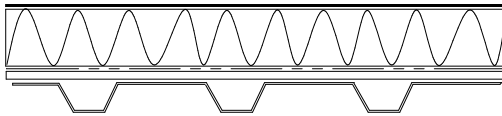
The Effects of Roof Membrane Color on Moisture Accumulation in Low-slope Commercial Roof Systems

Mike Ennis, Technical Director, SPRI
Manfred Kehrer, Senior Researcher,
ORNL

Agenda

- Background
- SPRI Field Study
- SPRI/ORNL Roof Drying Study
- WUFI Analysis
- Conclusions and Recommendations for Future Work

Background

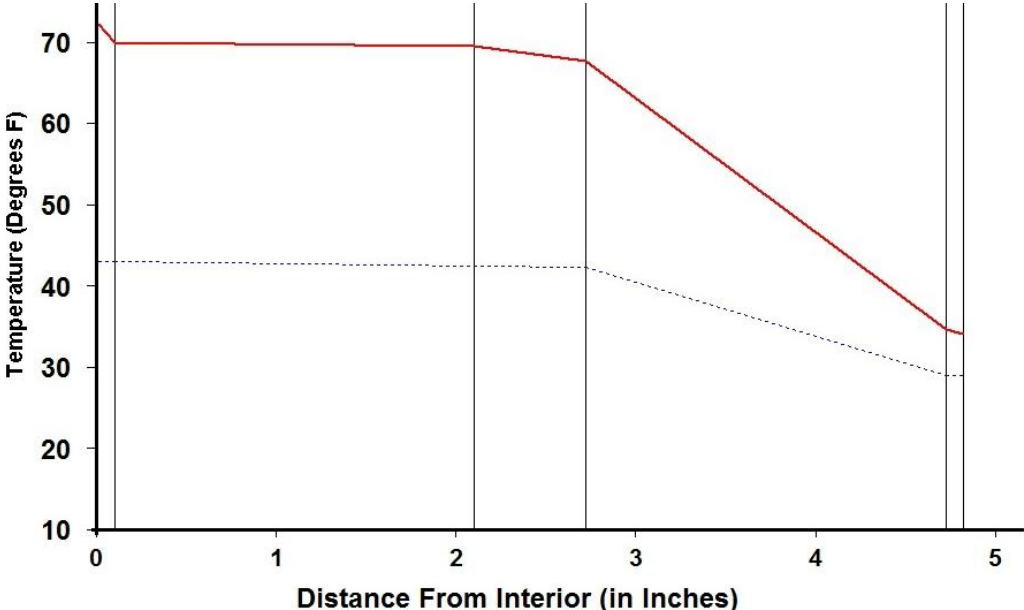


- Black membranes are typically 50F warmer than white membranes on a sunny day
- Theorized impact
 - Location/occurrence of dewpoint
 - Impact ability of system to dry out

Dewpoint calculation

- Must consider:
 - Interior and Exterior Temperature and RH
 - The R-value and water vapor permeability of the components of the roof assembly
 - Potential for direct air movement through the assembly
 - Compare dewpoint with actual conditions at each layer

Common dewpoint calculation



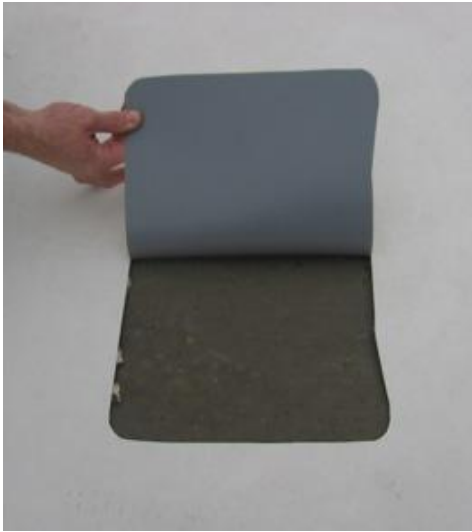
Legend	
—	Actual Temperature
- - -	Dewpoint Temperature

Dewpoint Theory predicts condensation in a system at any point where the actual and dewpoint temperature lines cross.

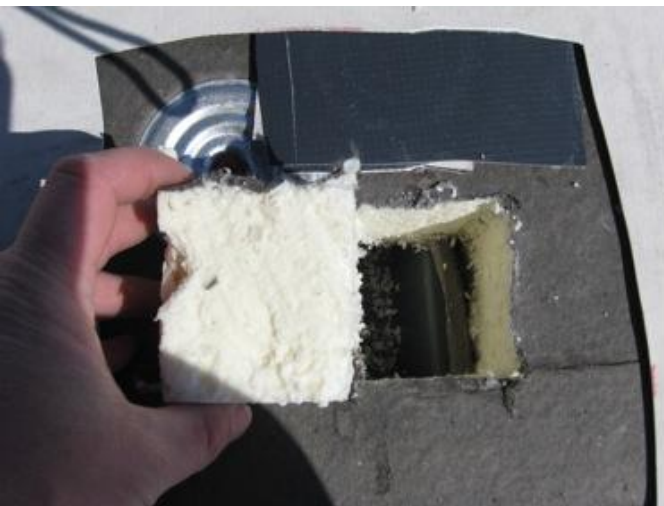
	Conditions:	
	Interior	Exterior
Temperature	72.0	34.0
Humidity	35	80

Component Name	Thickness	R-Value	Rep	Interface	Temperature		Accum (oz/day-sqft)
					Actual	Dewpnt	
A Interior Air Film	0.100	0.68	0.001	-A	72.00	42.88	0.000
B Metal Deck	2.000	0.10	0.100	AB	69.75	42.88	0.000
C GYPSUM.625in	0.625	0.56	0.023	BC	69.42	42.33	0.000
D DECKMATE Plus Insulatn	2.000	10.00	2.000	CD	67.58	42.20	0.000
E Out Air Film Winter	0.100	0.17	0.001	DE	34.56	28.91	0.000
F				EF	34.00	28.90	0.000
G				FG			
H				GH			
I				HI			
J				IJ			
K				JK			
L				KL			
TOTAL	4.825	11.51	2.125	L-			

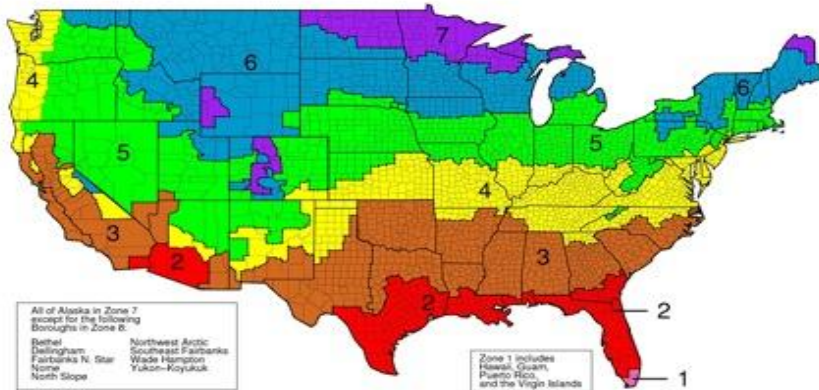
SPRI Field Study



- The objective was to examine roof systems using highly reflective roof membranes in heating climates by cutting into the roof systems and examining them for moisture accumulation.



SPRI Field Study Protocol



- Heating climate
- Test cuts during winter
- Test cuts before 10:30
- Single layer of insulation
- Mechanically attached system
- No vapor retarder
- Roof system in place for at least 5 years
- The building must be climate-controlled

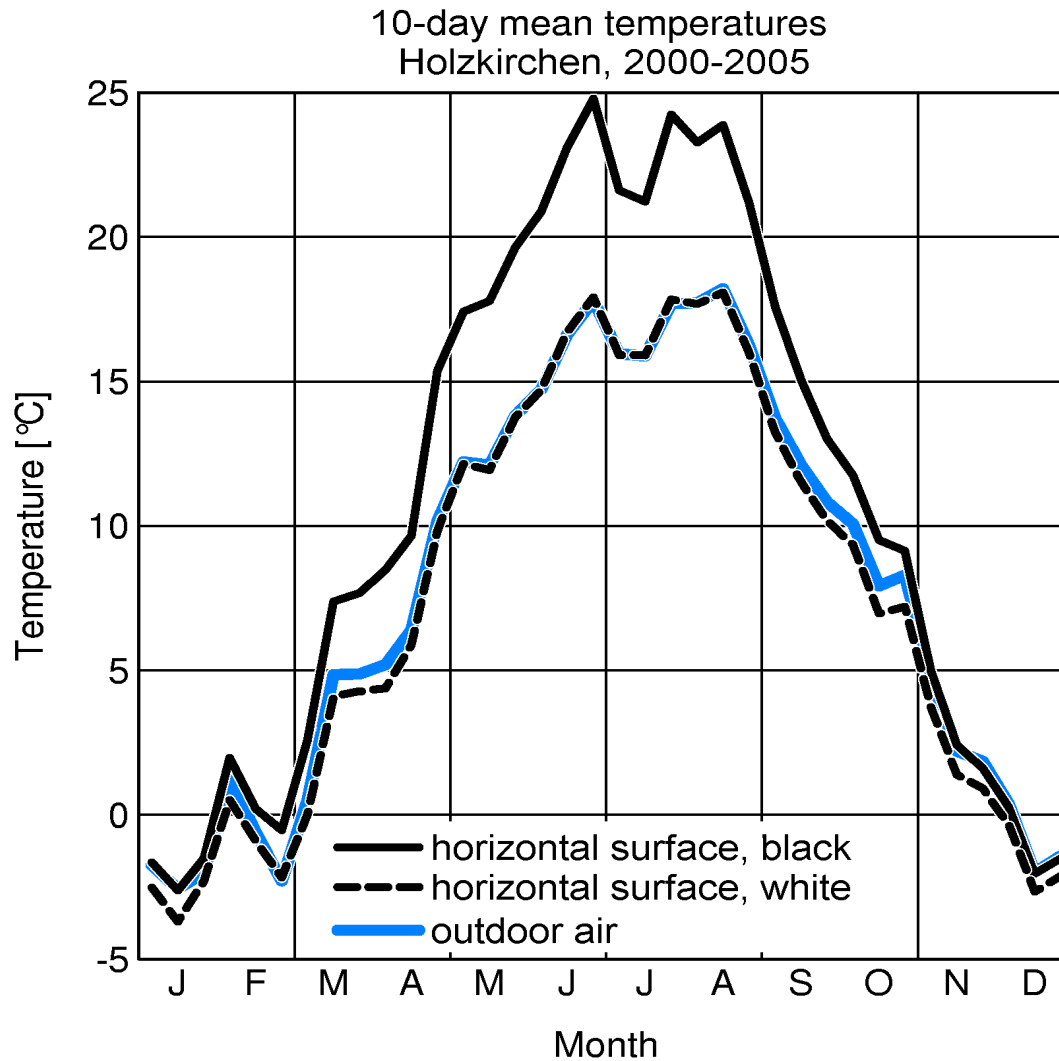
SPRI Field Study Results

- Ten roof systems were investigated.
- In seven of the cases, no moisture or damage to the polyisocyanurate foam insulation or facer was noted.
- In three of the cases, condensation was apparent on the back side of the highly reflective membrane.
 - The level of condensation as described by the observer was “damp” to “wet.”
 - Minimal damage had occurred to the polyisocyanurate foam insulation.
 - Consequential impact was limited on the facer of the product and described by the observer as “stained,” and in one case “wrinkled,” but still laminated to the insulation.
 - The foam itself was dry, with no rust on the steel roof deck.

SPRI Field Study Results

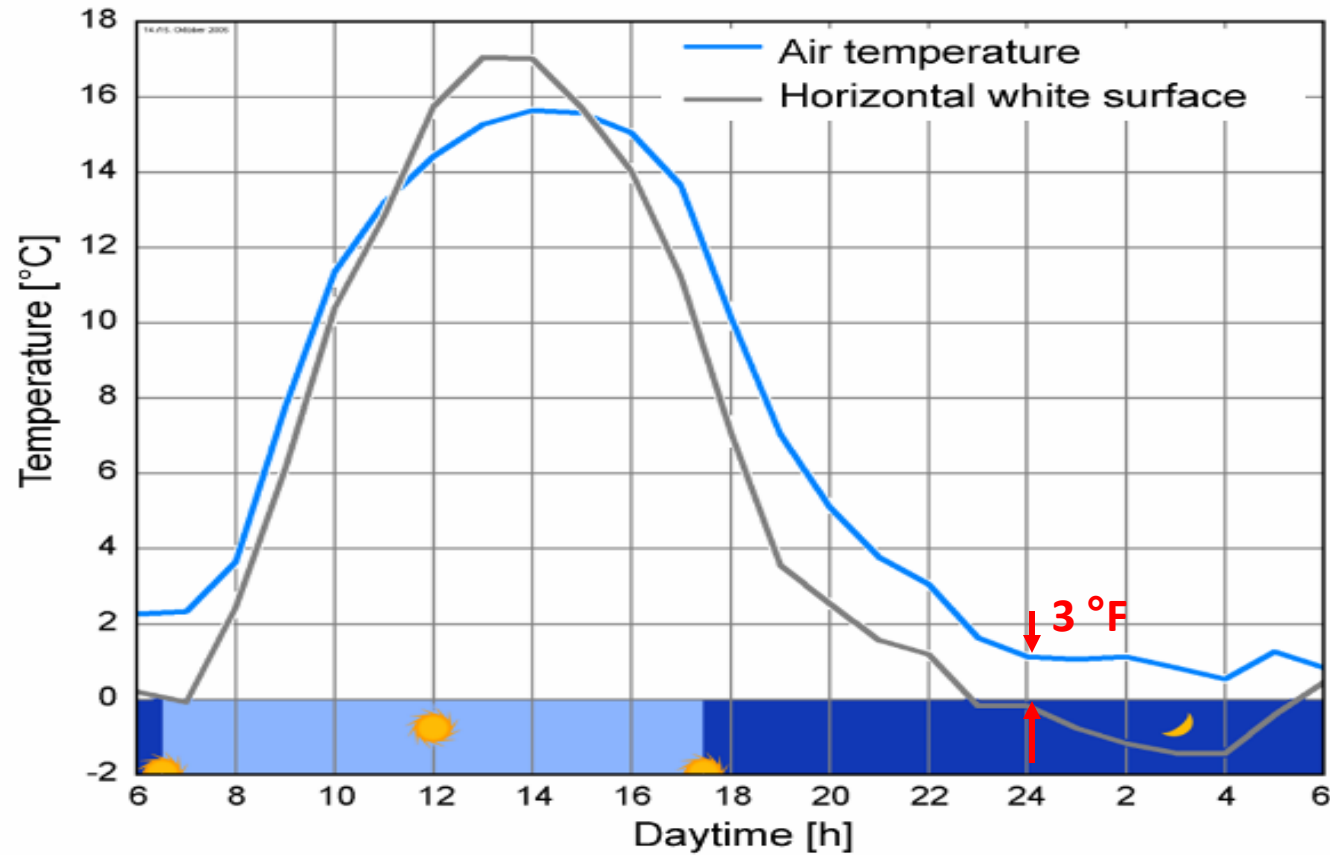
- The conclusion from this portion of the study is that although there were signs of moisture condensation in three of the 10 roofs observed, minimal effect had occurred to the roofing assembly that would affect its integrity, insulating value or performance. No detrimental effect to the roof system was noted.

Radiation Effects

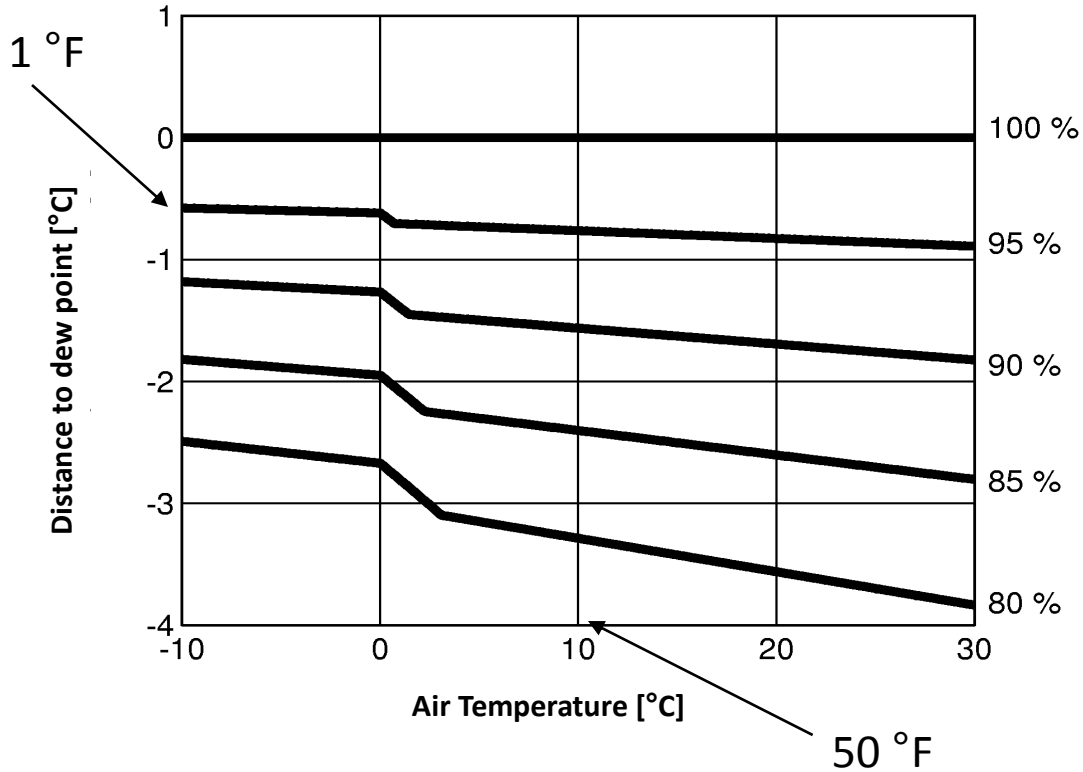


Radiation Effects

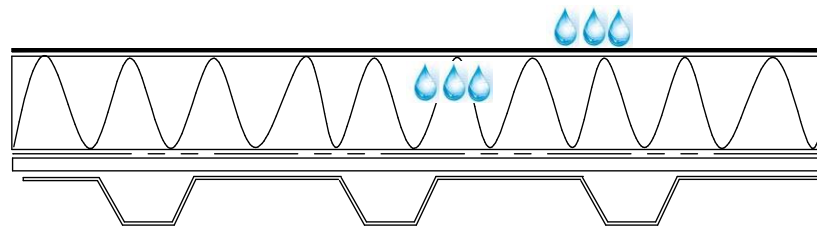
Holzkirchen: clear day in Oct. 2006



Distance: dew point temperature – air temperature

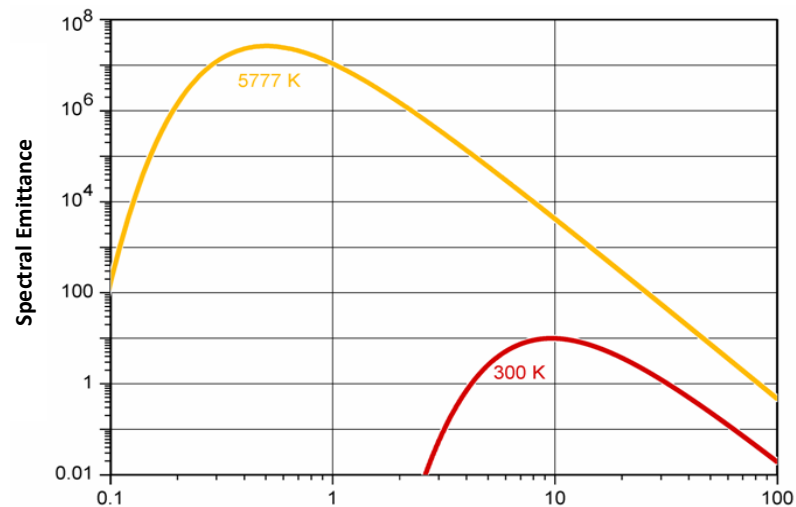


**Consequence:
Minor overcooling of
exterior surfaces
yields condensation.**

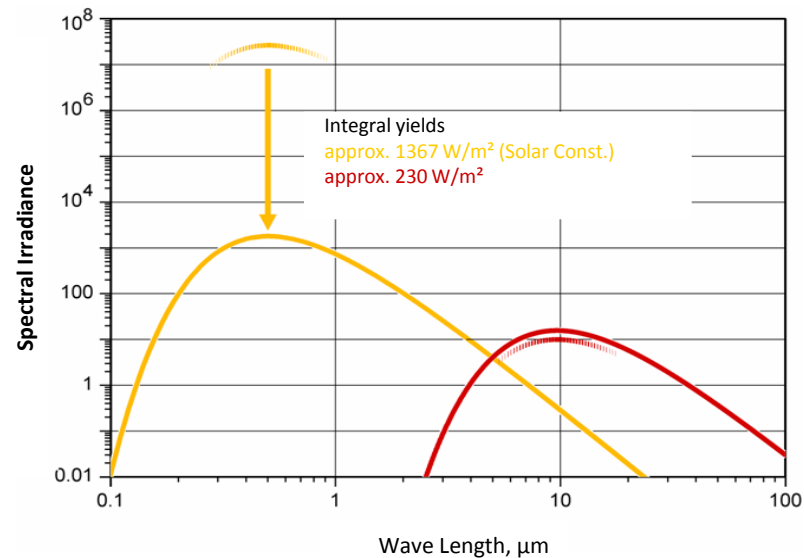
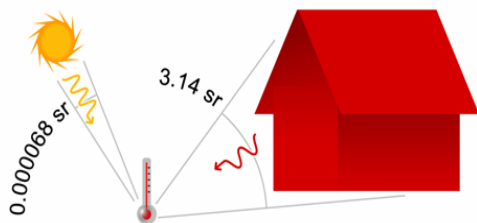


Radiation Physics

Emittance of a solid surface according to Max Planck

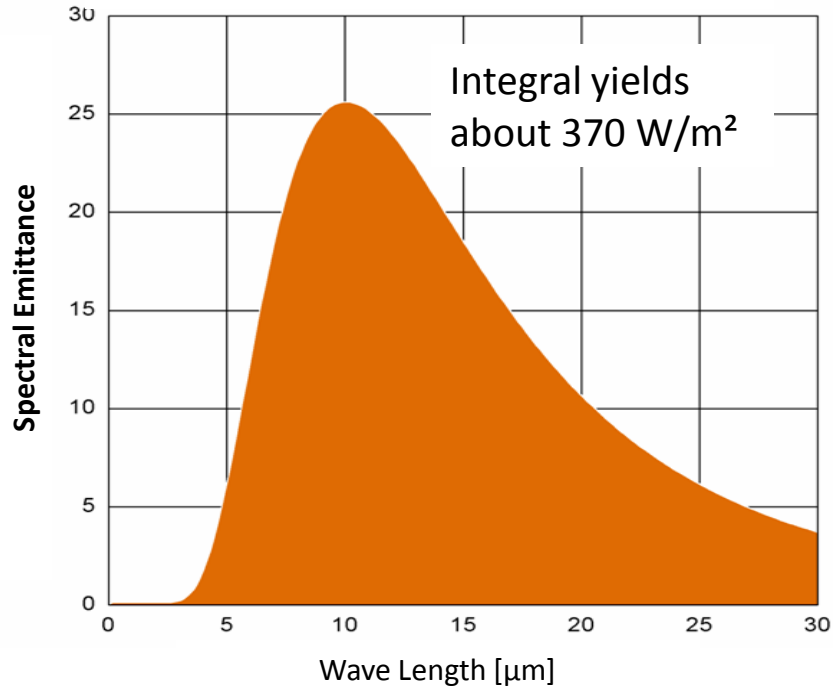


Radiation to a recipient surface (irradiance)

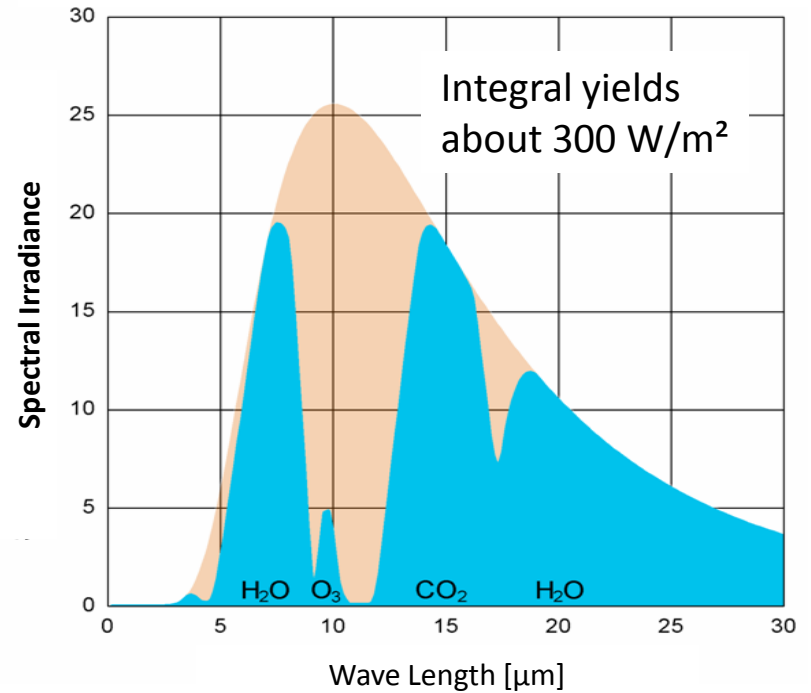


Radiation Physics

Emittance of the flat roof at 15°C (60°F)

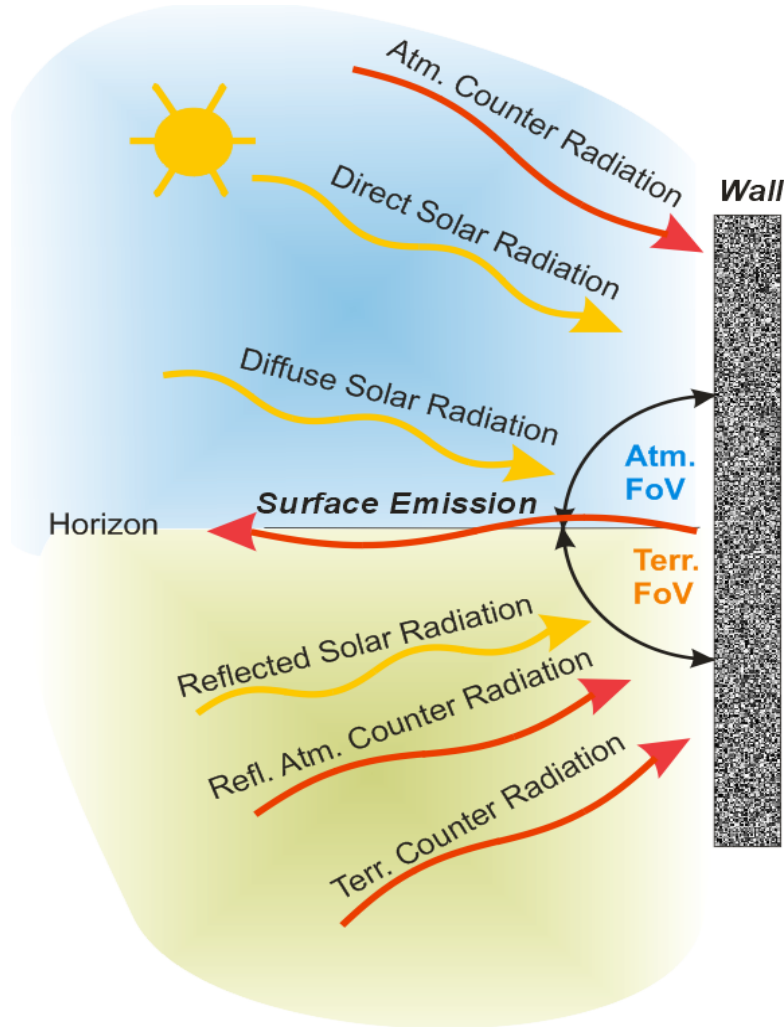


Irradiance from the Atmosphere at 15°C (60°F)



Difference, about. 70 W/m² (12 Btu/h ft²) is the reason for night-time overcooling.

Radiation Physics



Enhanced Radiation Modell has been incorporated into WUFI in 2007

For details please refer to:

Kehrer, M., (2008), Radiation Effects on Exterior Surfaces, Nordic Symposium on Building Physics, Copenhagen.

WUFI Modelling

Outdoor Conditions

Boston, Albany, Chicago, Cleveland, Detroit

Solar Absorptivity

White Roof: 30%

Black Roof: 90%

Indoor Conditions

ASHRAE 160; Simplified Method

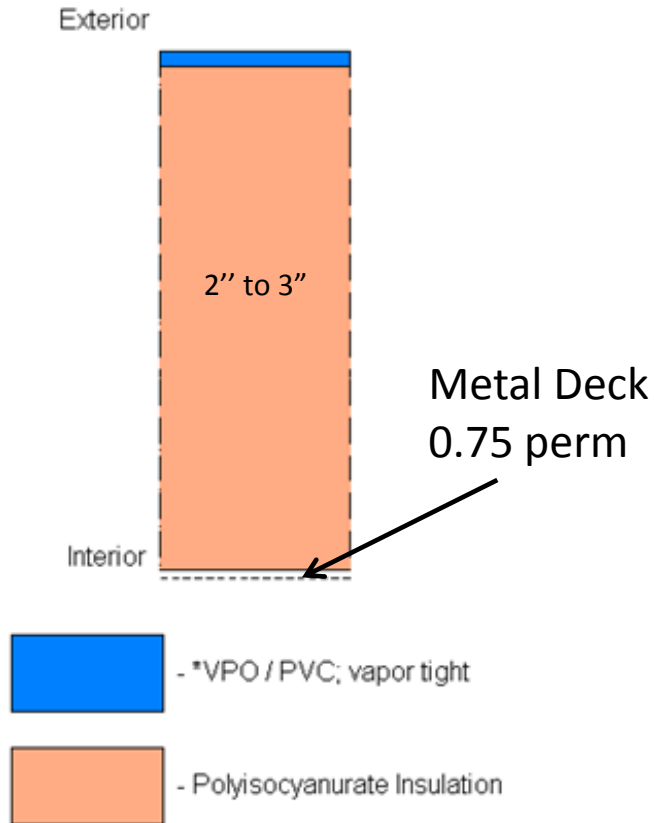
Initial Conditions

80% Equilibrium Moisture Content

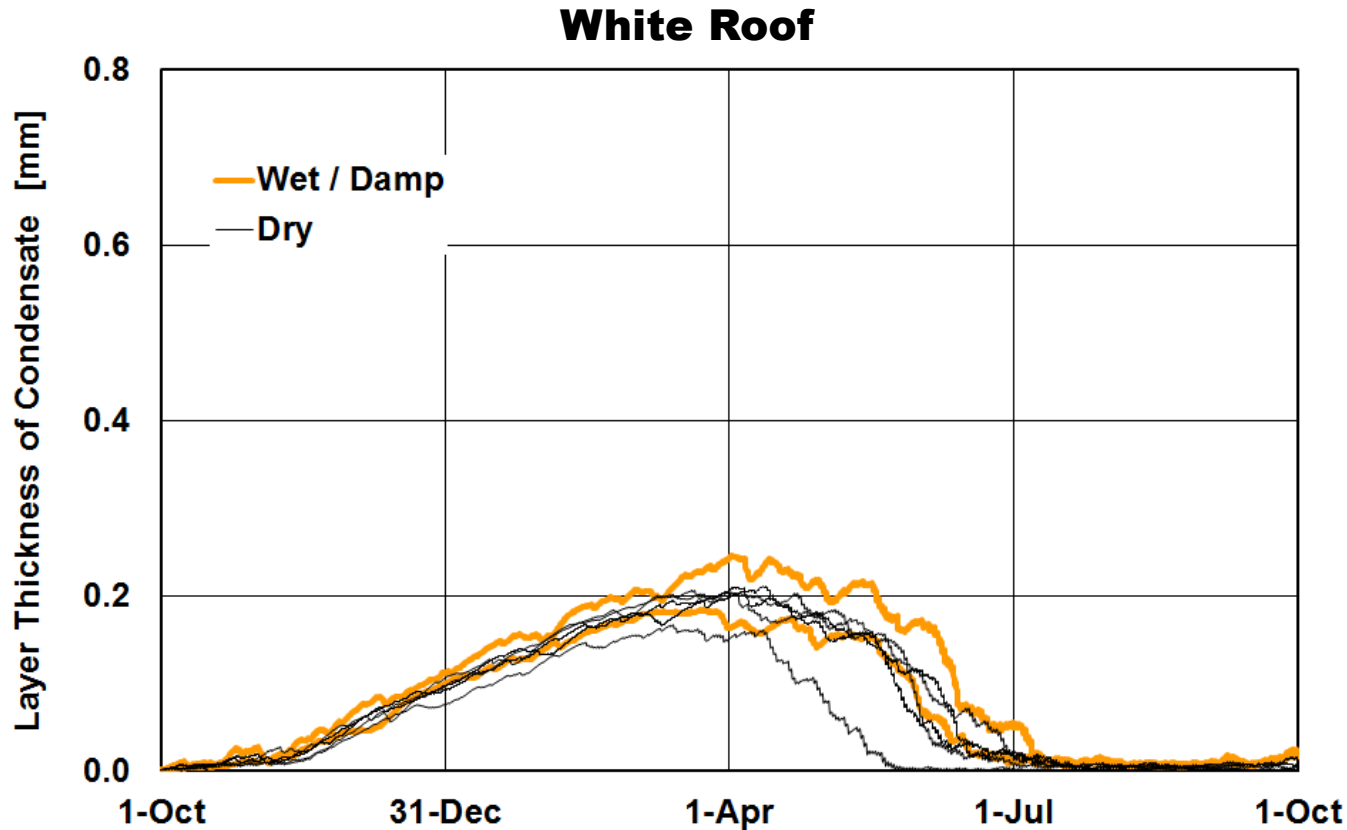
1 year calculation; starting in October

Evaluation

Condensate of most exterior 2 mm of Polyisocyanurate

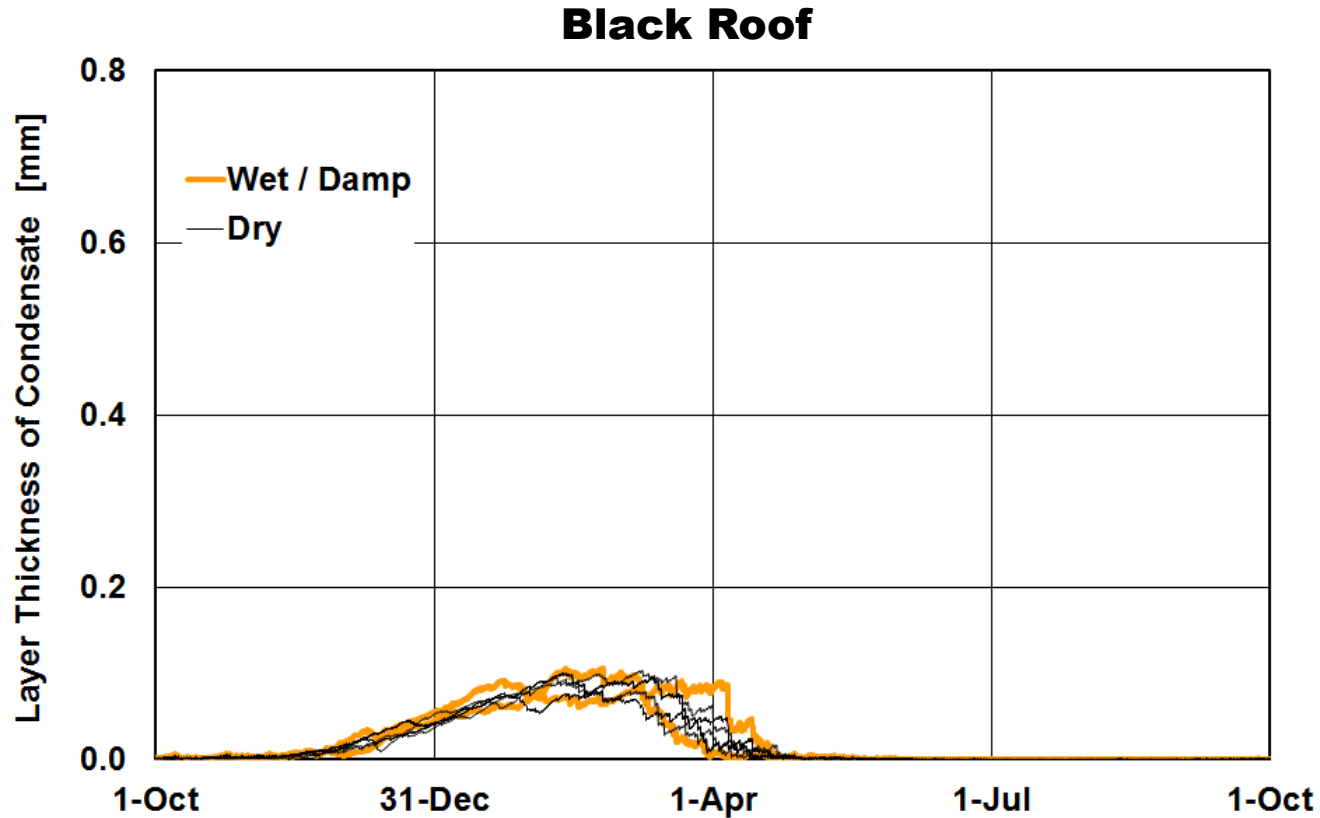


WUFI Results



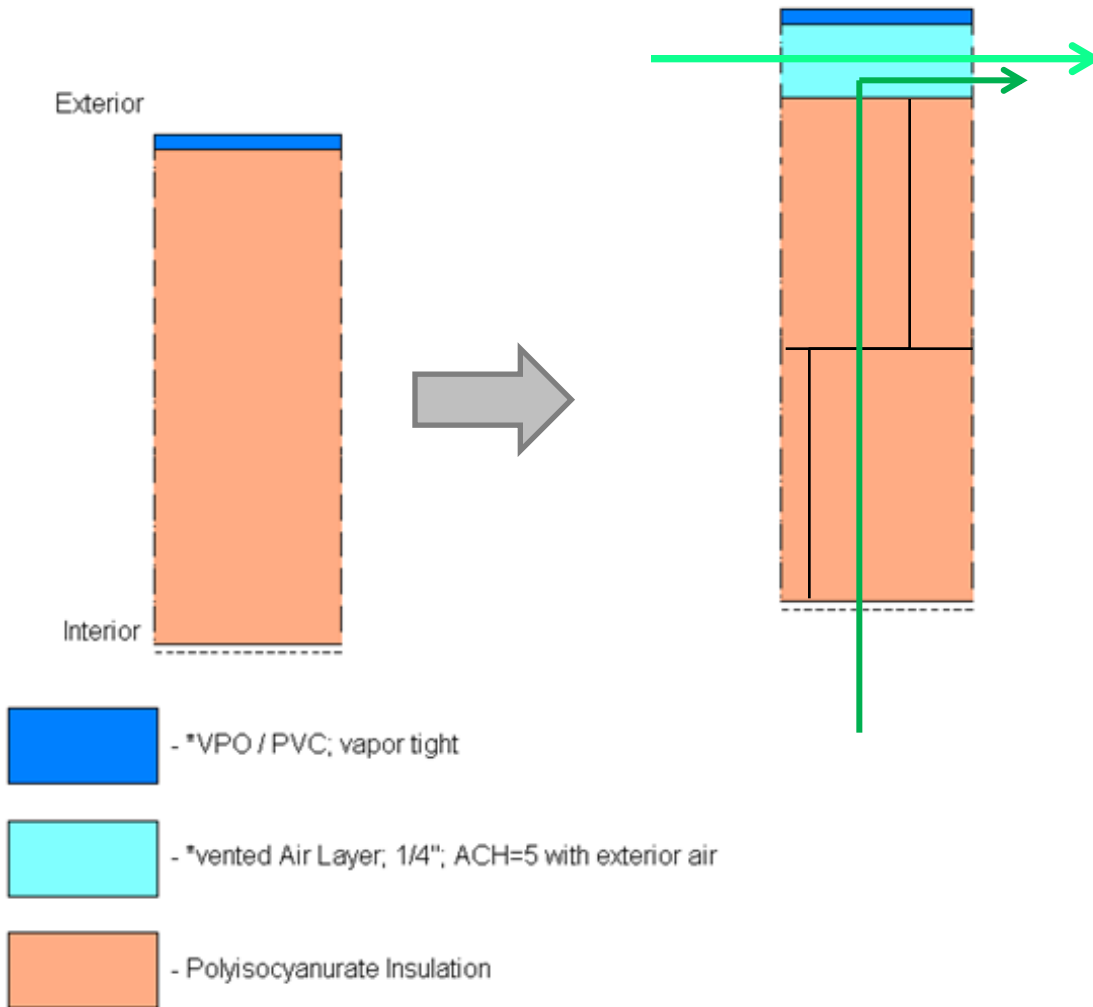
- All roofs accumulate water during the winter and dry out completely in summer.
- Layer thickness about 0.2 mm (8 mil) in maximum.
- Minor Impact of the climate location/exact insulation thickness.
- Minor correlation between the simulation results and the observations

WUFI Results



- Generally similar behavior compared to white roofs.
- Maximum Condensation layer thickness only at half; 0.08 mm (3 mil)

WUFI Modelling



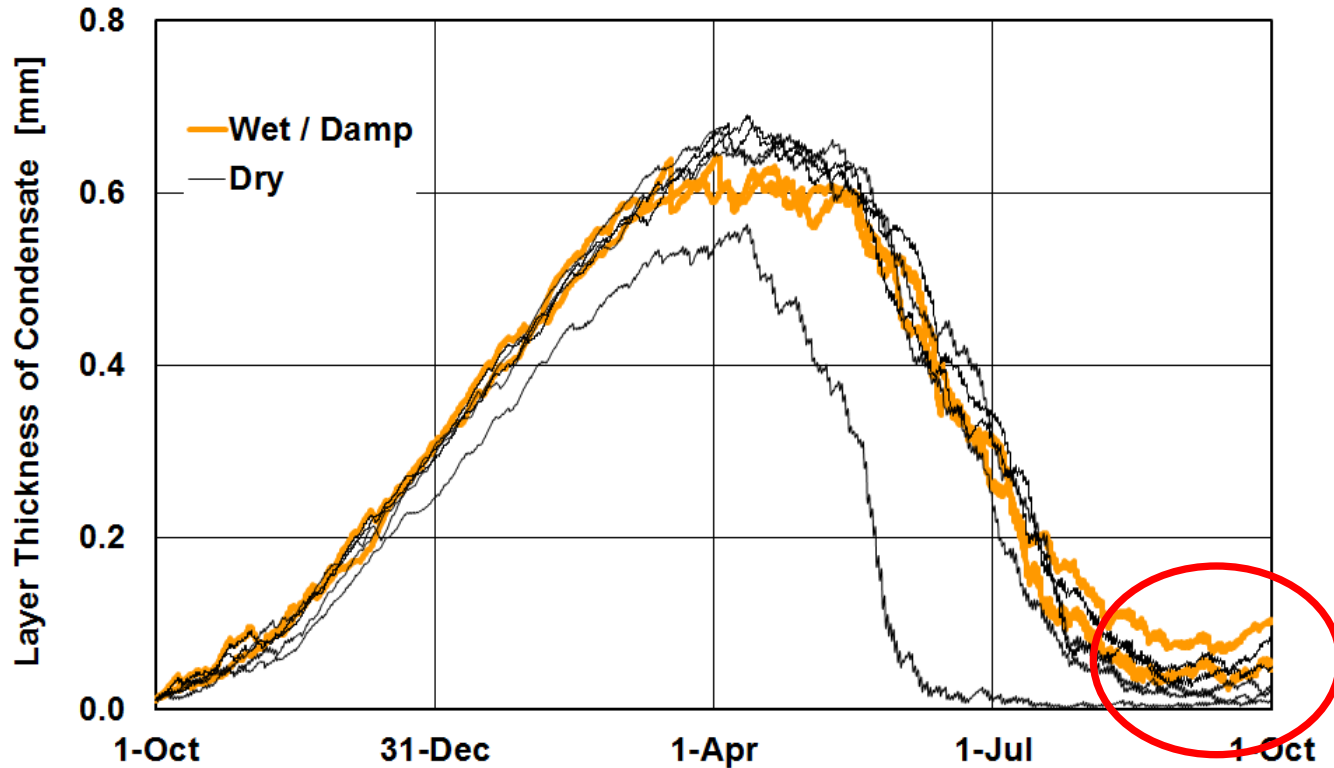
Uplift of the exterior membrane, due to wind pressure.

Hence, air infiltration from indoor trough joints, nail holes.

Estimated air change rate of 5 [1/h].

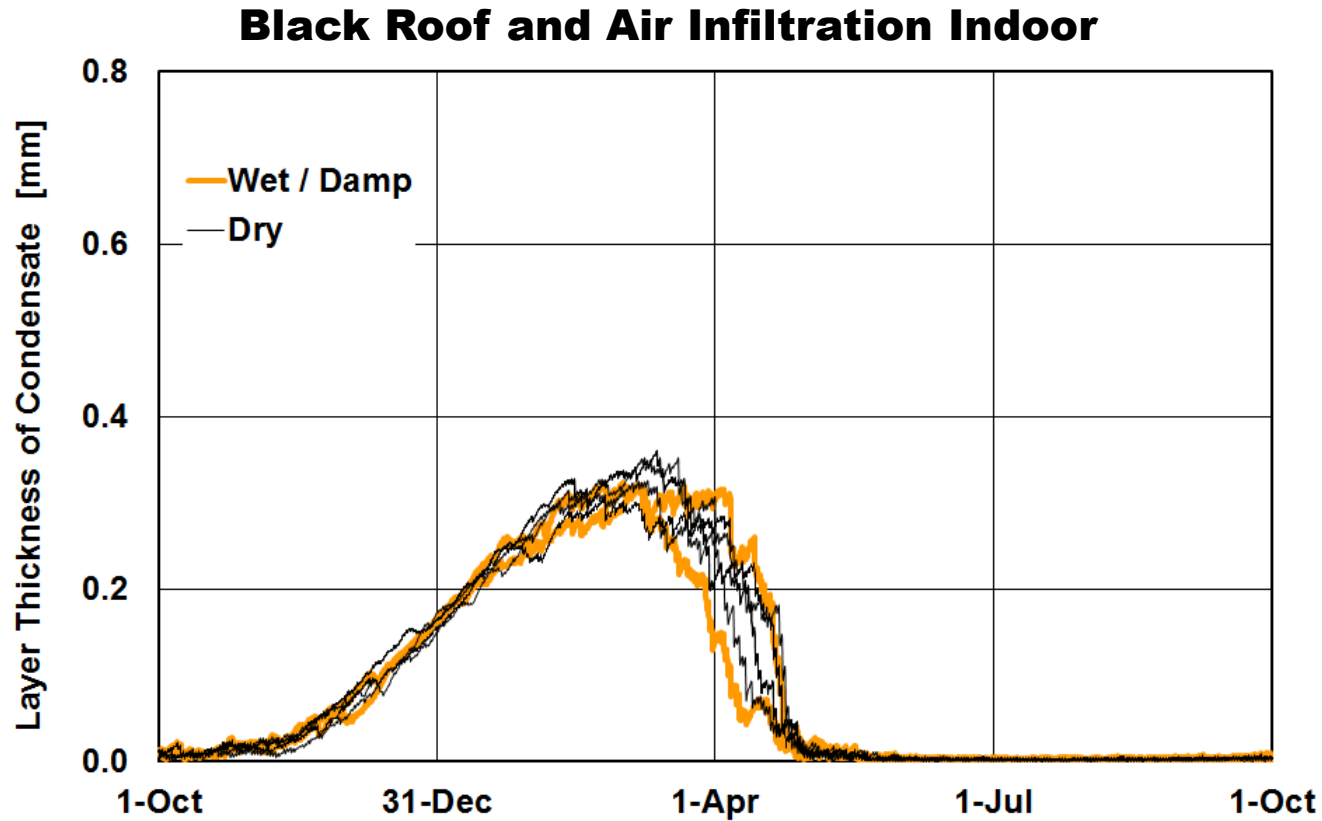
WUFI Results

White Roof and Air Infiltration Indoor



- 3 times more condensate 0.6 mm (24 mil) in maximum.
- Accumulating condensate.

WUFI Results



➤ Apparently no problem

Simulation Conclusion

- **White Surfaces on flat roofs increase moisture content**
- **In Combination with Indoor Air Infiltration moisture accumulation/damage are more likely**

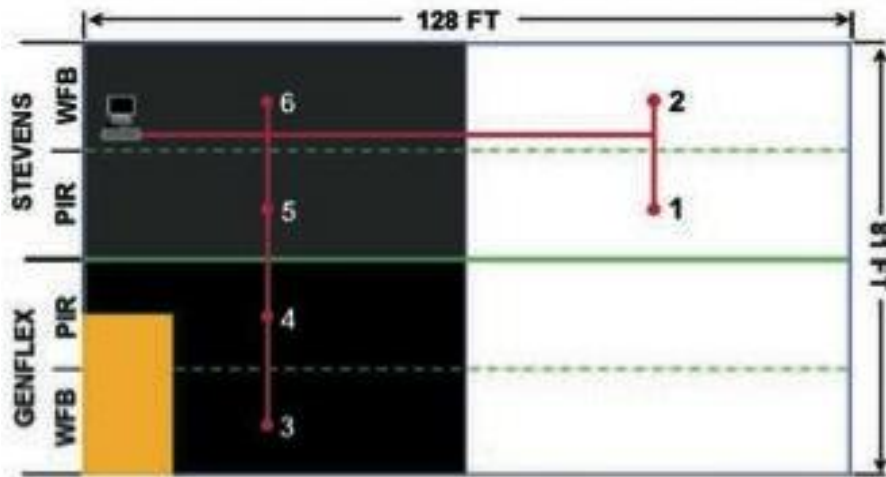
Further Investigation required

- **For Climate Zones 6, 7 and 8**
- **About the amount of Indoor Air Infiltration**

SPRI/ORNL Roof Recover Drying Rate Study

- The size of the building was large enough to represent a typical building but small enough to control the cost. (between 3,000 and 10,000 square feet)
- The building was located in a northern climate (CZ5) and had a conditioned interior.
- The roof system was contaminated with an appreciable amount of water.
- The roof system had the potential to dry downwardly (no vapor retarder).
- The roof system was “typical” —i.e., had a metal deck, some insulation and a traditional membrane.
- The deck was structurally sound.

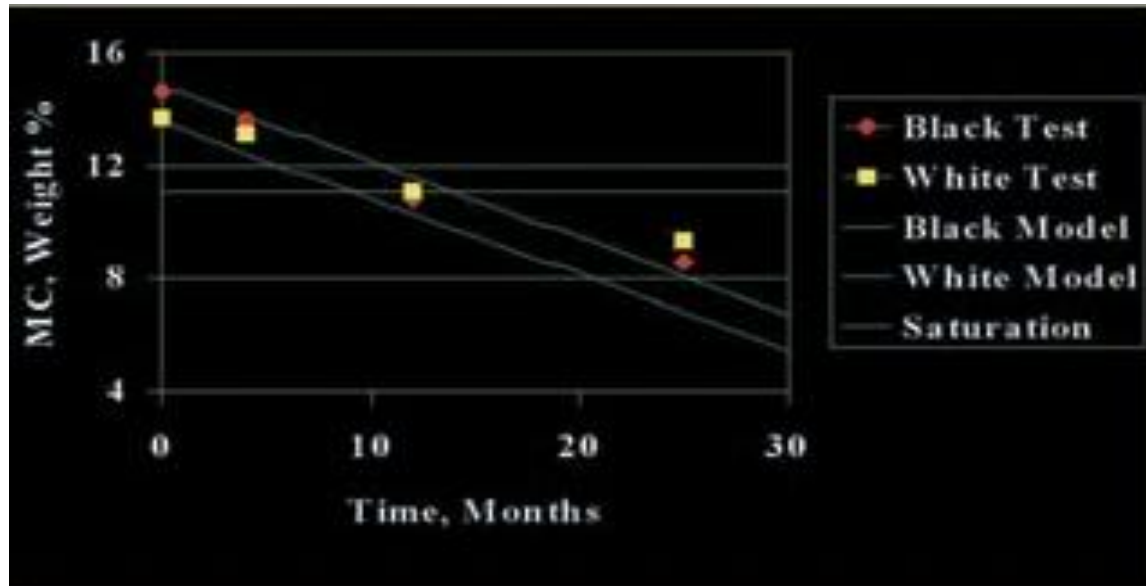
Test layout



- About half the roof area was covered with a black or white mechanically attached TPO single-ply membrane.
- Instrumentation was installed in the roof system during the reroofing. Six temperature sensors were installed directly under the membrane and two sets of temperature and relative humidity sensors were installed inside the building.

Drying rate

- A major goal of this project was to determine how rapidly the existing roof system would dry after it had been re-covered.
- To assess the roof system's drying rate, it was essential to accurately determine the initial concentration and distribution of moisture in the existing roof system.
- To accomplish this, a nuclear densometer moisture survey of the entire roof on a grid with nodes 5 feet (1.5 m) apart was completed.
- Seven core samples were taken at the same time and were used to calibrate the output of the nuclear densometer.



Drying rate results

The black membrane side dried at a slightly greater rate. (6 percent by weight vs. 4.4 percent by weight.)

This difference in drying rate did not affect the performance of the fasteners or insulation over the two-year period of the study.

Overall conclusions and future work

- Situations where moisture accumulation occurs are design issues.
- When designing a roof system membrane color, in addition to other variables such as building conditions, insulation levels and local weather conditions must be considered in order to prevent moisture condensation and subsequent accumulation within the assembly.
- Within the parameters used in this study, roof systems with white membranes and those with black membranes both went through wetting and drying periods throughout the year, with both systems returning to a dry state during the course of the year.
- Modeling using transient moisture models such as WUFI can and should be used by design professionals to assess the tendency of various roof designs to allow for.
- It is recommended that further investigation should be conducted in climate zones 6, 7 and 8.
- It is also recommended that the effect of possible ventilation effects due to wind pressure and hence uplift of the exterior membrane be investigated