

Kohta Ueno and Joseph Lstiburek

Unvented Roof Without Spray Foam: The Latest Building America Research



Background

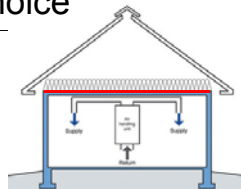


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Ventilated Attics—Best Choice

- Roof sheathing dries to ventilated attic-moisture safe
- Interior moisture (air leaks) ventilated away in winter
- Low-cost high-R roofs
- Air sealing at ceiling critical for best performance
 - (e.g., spray foam air barrier detail with sealant)



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Then Why Unvented Roofs?

- Living space built into roof
- Vented cathedral assemblies—often poor performance
- Complicated rooflines, hip geometries—how to vent?
- Unworkable air barrier at ceiling line
- HVAC in vented attic



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Why Unvented + Fibrous Risky?

- Different than walls?
- Moisture risks at sheathing
 - Interior-sourced air leakage
 - Vapor contributing too?
 - Zero-perm exterior (“wrong side perfect vapor barrier”)
 - Night sky radiation cooling
 - Stack effect in winter
- “Ridge rot” (thermal and moisture buoyancy)

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Spray Foam/Exterior Insulation Roofs

- 2006 IRC: § R806.4/5 Unvented attic assemblies
- Minimum R-value of “air impermeable insulation”
 - Actually ratio of R-values (BSI-100 Hybrid Assemblies)
- Nail base needed with rigid foam on roof deck

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Spray Foam/Exterior Insulation Roofs

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Why Fibrous Fill Unvented Roofs?

- Unvented roofs without spray/board foams could reduce costs and increase market penetration... IF moisture damage risks are addressed
- Retrofit opportunities (existing uninsulated living space at roof line, without removing finishes)

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Research Project Background




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Test Hut Experimental Approach

- Climate Zone 5A test hut
- Eight north-south roof bays
- ±R-50 (14-3/4" framing, 2012 IECC)
- Test variables:
 - Vapor retarder: variable perm vs. fixed perm
 - Diffusion vent at ridge vs. ~~no diffusion vent~~ "small" or "tight" DV
 - Fiberglass vs. cellulose
 - "Control" comparison § R806.4 spray foam + fibrous
- Varying interior boundary conditions
 - Winter 1: "Normal" interior conditions
 - Winter 2: Elevated RH (50% constant)
 - Winter 3: Air leakage into rafter bays

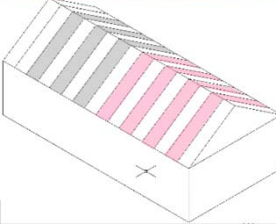


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Test Hut South Elevation



Test Hut Construction

- Roof bays 24" o.c.
- Guard bays between experimental bays ("flash and blow" ccSPF + cellulose)
- Fluid-applied air and vapor barrier at guard bays





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Test Hut Construction

- Flash and blow bays (ccSPF shown)
 - ccSPF completes air barrier between bays, wiring holes
- Insulation netted & blown




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Test Hut Construction

- Interior air barrier & vapor retarder membrane
- Double tape seal (double-sided tape + housewrap tape)


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Experimental Approach: Roof Section

- 4 fiberglass bays
- 3 cellulose bays
- 1 “flash and blow” control comparison


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Test Hut Construction

- Instrumentation completion


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Test Hut Construction

- ccSPF in guard bays and walls


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Test Hut Construction



- Fibrous insulation installed


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Test Hut Construction




- Interior air/vapor control installed


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Experimental Approach: Diffusion Vent




- ±6 in. opening (fits under typical ridge cap)
- Cosella-Dörken Delta-Foxx (214 perms dry cup, 550 perms wet cup)


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Test Roof IDs (Winter 1)

Roof #	Insulation	Interior VB	Diffusion Vent
1	Fiberglass	Fixed perm (OC 1 perm)	Yes
2	Fiberglass	Variable perm (MemBrain)	Yes
3	Fiberglass	Fixed perm (OC 1 perm)	No
4	Fiberglass	Variable perm (MemBrain)	No
5	Dense pack cellulose	Fixed perm (DuPont 1 perm)	No
6	Dense pack cellulose	Variable perm (DuPont Variable)	No
7	Dense pack cellulose	Variable perm (DuPont Variable)	Yes
8	ccSPF + cellulose "flash and blow"	None	No

- 4 fiberglass bays
- 3 cellulose bays
- 1 "flash and blow" control comparison


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Winter 1 Conclusions

- Roofs with diffusion vent & variable-perm vapor consistently safest; ridge RHs and MCs controlled
- No diffusion vent → worst performance
- Year 1 of 3-year project; interior conditions:
 - Winter 1: “Normal” interior conditions
 - Winter 2: Elevated RH (50% constant)
 - Winter 3: Air leakage into rafter bays
- Modifications to existing assemblies
 - Winter 1 to Winter 2

Winter 1-Winter 2 Roof Modifications

Roof #	Insulation	Interior VB	Diffusion Vent	Short Name
1	Fiberglass	Fixed perm (OC 1 perm)	6"/±300 perm (Yes)	FG-VB-DV
2	Fiberglass	Variable perm (MemBrain)	6"/±300 perm (Yes)	FG-SVR-DV
3	Fiberglass	Variable perm (MemBrain) Fixed perm (OC 1 perm)	2"/±25 perm No	FG-SVR-tDV FG-VB-nDV
4	Fiberglass	Variable perm (MemBrain)	2"/±300 perm No	FG-SVR-sDV FG-SVR-nDV
5	Dense pack cellulose	Variable perm (DuPont Variable) Fixed perm (DuPont 1 perm)	2"/±25 perm No	Cell-SVR-tDV Cell-VB-nDV
6	Dense pack cellulose	Variable perm (DuPont Variable)	2"/±300 perm No	Cell-SVR-sDV Cell-SVR-nDV
7	Dense pack cellulose	Variable perm (DuPont Variable)	6"/300 perm (Yes)	Cell-SVR-DV
8	ccSPF + cellulose “flash and blow”	None	No	ccSPF-Cell

Results: Fiberglass Roofs

Warning on Presentation of Results

- Limited “soda straw” view of selected data
- 30 minute window to present
 - Too many roofs (mental gear-shifting)
 - Too many sensors (which one is that one?)
 - Too many sub-experiments

Fiberglass Roofs: Color Codes

Roof #	Insulation	Interior VB	Diffusion Vent
1	Fiberglass	Fixed perm (OC 1 perm)	6"±300 perm (Yes)
2	Fiberglass	Variable perm (MemBrain)	6"±300 perm (Yes)
3	Fiberglass	Variable perm (MemBrain)	2"±25 perm
4	Fiberglass	Variable perm (MemBrain)	2"±300 perm
5	Dense pack cellulose	Variable perm (DuPont Variable)	2"±25 perm
6	Dense pack cellulose	Variable perm (DuPont)	
7	Dense pack cellulose	Variable perm (DuPont)	
8	ccSPF + cellulose "flash and blow"	None	

Roof	Short Name
1	FG-VB-DV
2	FG-SVR-DV
3	FG-SVR-tDV
4	FG-SVR-sDV

- DV = Diffusion Vent
- nDV = no Diffusion Vent
- sDV = "small" Diffusion Vent (±300 perm, 2" wide)
- tDV = "tight" Diffusion Vent (±25 perm, 2" wide)

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Fiberglass Roofs: Ridge RH

Difficult to resolve-variations
 Roof 3 (tDV) > 95% RH most of Winter
 Roof 2, stays wettest into summer
 Roof 4 (sDV) next highest RHs

Roof	Short Name
1	FG-VB-DV
2	FG-SVR-DV
3	FG-SVR-tDV
4	FG-SVR-sDV

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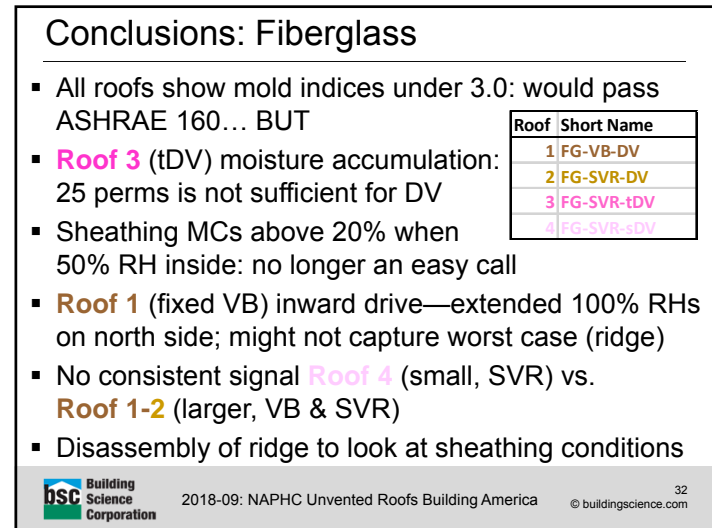
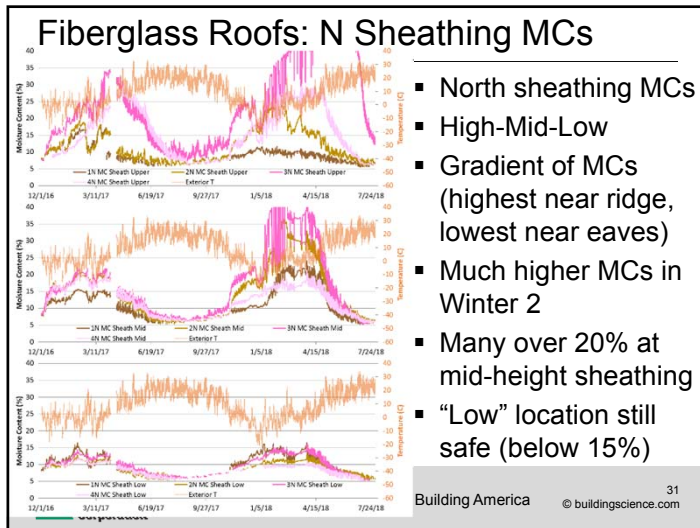
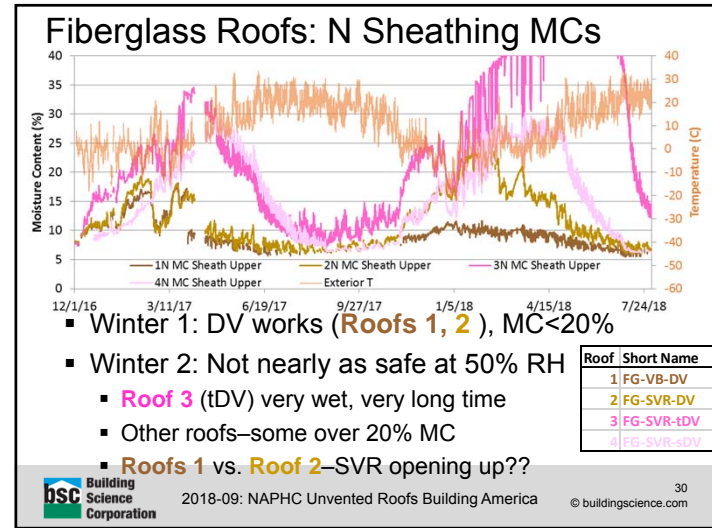
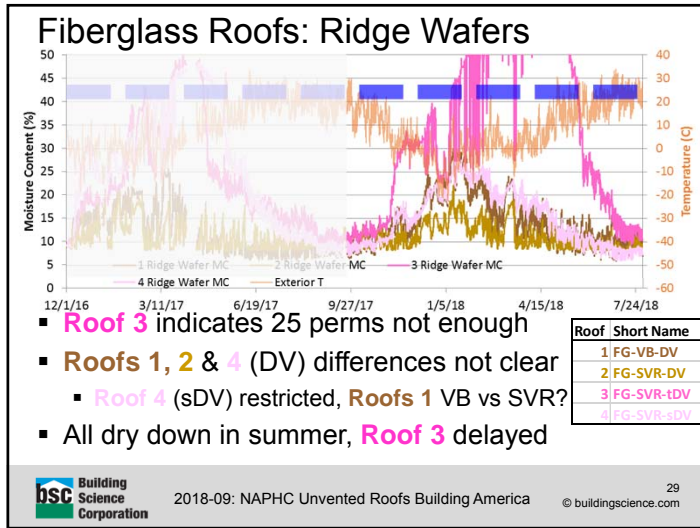
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Fiberglass Roofs: Ridge Wafers


- Winter 1 Roof 3 & 4 (nDV) > 40% MC
 - Immersed wafer calibrated ~40-45% MC
 - Diffusion Vent Roofs 1 & 2 stay drier <25%
- Winter 2 Roof 3 (tDV) soaking wet ridge
 - Roofs 1, 2 & 4 (DV) 20-30% MC

Roof	Short Name
1	FG-VB-DV
2	FG-SVR-DV
3	FG-SVR-tDV
4	FG-SVR-sDV

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Results: Cellulose Roofs




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Cellulose Roofs: Color Codes

Roof #	Insulation	Interior VB	Roof Short Name
1	Fiberglass	Fixed perm (OC 1 perm)	5 Cell-SVR-tDV
2	Fiberglass	Variable perm (MemBrain)	6 Cell-SVR-sDV
3	Fiberglass	Variable perm (MemBrain)	7 Cell-SVR-DV
4	Fiberglass	Variable perm (MemBrain)	8 ccSPF-Cell
5	Dense pack cellulose	Variable perm (DuPont Variable)	2"±25 perm
6	Dense pack cellulose	Variable perm (DuPont Variable)	2"±300 perm
7	Dense pack cellulose	Variable perm (DuPont Variable)	6"±300 perm (Yes)
8	ccSPF + cellulose "flash and blow"	None	No

- DV = Diffusion Vent
- nDV = no Diffusion Vent
- sDV = "small" Diffusion Vent (±300 perm, 2" wide)
- tDV = "tight" Diffusion Vent (±25 perm, 2" wide)




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Cellulose Roofs: Ridge RH

- Difficult to differentiate
- RH sensor failures: **Roof 6** (2017), **Roof 5** (unrealistic data 2018), **Roof 7** (2018)

Roof	Short Name
5	Cell-SVR-tDV
6	Cell-SVR-sDV
7	Cell-SVR-DV
8	ccSPF-Cell




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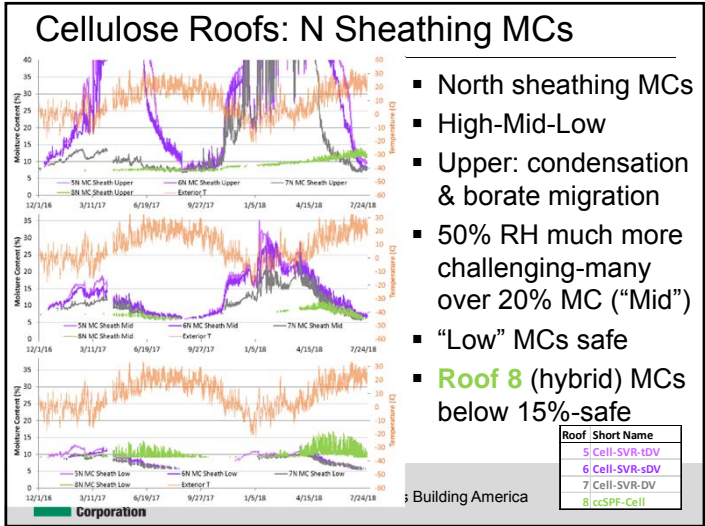
Cellulose Roofs: Ridge Wafer

- Unrealistic MCs: condensation, borate migration
- **Roof 5** no data Winter 2 (unspicable)
- **Roof 6** drier than **Roof 7**?
- **Roof 7** dries down faster (larger DV)

Roof	Short Name
5	Cell-SVR-tDV
6	Cell-SVR-sDV
7	Cell-SVR-DV
8	ccSPF-Cell



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Conclusions: Cellulose

- Roof 8 (hybrid) safe through Winter 2
- Roof 5-Roof 6-Roof 7:
 - High RHs at sheathing (90-95% common)—not necessarily a problem, but paying attention
 - Wafers & MCs high but inconclusive (borate spreading)
 - Sheathing MCs high (uncertainty-borate migration)
 - Roof 7 consistently fastest to dry (largest DV)
- Inward drive sensors non-issue in cellulose roofs, even after 50% RH winter (storage)
- All roofs show mold indices under 3.0: would pass ASHRAE 160... BUT

Roof	Short Name
5	Cell-SVR-IDV
6	Cell-SVR-sDV
7	Cell-SVR-DV
8	ccSPF-Cell

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Ridge Disassembly

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Summer 2 Ridge Disassembly Work

- Fiberglass: staining, rundown, some mold spotting

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Summer 2 Ridge Disassembly Work

- Cellulose: worst mold, settling (greater at north)

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Conclusions and Further Work

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Conclusions

- Interior at 50% RH creates much more challenging conditions: many pushing edge of risk
- Mold Index #s remain below 3.0
- BUT we grew mold in several roofs
- Many MCs over 20% to 30%, sustained high RH
- “Tight” diffusion vent (~25 perms vs. ~300 perms) did not work acceptably
- “Small” diffusion vent: smaller → less drying
- 50% RH pushes limits of “flash and blow” ratios—safe storage saves cellulose roof

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Conclusions

- At 50% RH interior, these are assemblies we “might get away with” without failure
- Consider requirements for interior conditions?
 - Control interior RH to maximum %?
 - Difficult to implement or enforce
 - 50% RH interior increasingly likely (tighter, multifamily)
- Takeaways from the research:
 - Diffusion vent good; bigger is better
 - Variable perm inward drying: every chance we can get
 - Hybrid roof is indisputably safest

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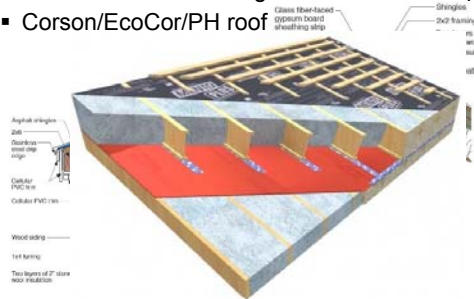
Further Work

- Winter 3 Operation (Proposed)
 - Start at 50% RH, no air leakage
 - Introduce air leakage in later winter (possible on/off)
- “Tight” diffusion vent (Roof 3 & Roof 5): replacement?
 - Full-size 300 perm diffusion vent (like others)
 - Different variable-perm interior air barrier/vapor retarder

Recommendations

Recommendations

- Code-compliant (IRC § R806.5) still safest (spray foam or exterior rigid insulation)
 - Mineral fiber exterior rigid insulation is an option
 - Corson/EcoCor/PH roof



Recommendations

- Fibrous-only insulation (no exterior insulation) roof assemblies are “off-label” (against code)
- Diffusion vent + variable-perm vapor retarder best
- Test airtightness of interior membrane
 - Workmanship sensitive: project type? (e.g., public bid)
- Control interior RH—for life of building
 - 20-30% RH maximum in worst of winter?
- Complete cavity fills safer
- Cellulose moisture storage capacity
- Retrofit/remediation applications?

Recommendations

- Possible application to retrofitting “short slope” of kneewall attic geometry
- Eliminates “chute,” possible to retrofit longer runs
- Higher R-value in limited cavity
- Not proven by this research, but this is “lower half of roof” geometry (low risk portion)
- Rafter bay has “full-size diffusion vent” to vented attic above



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Questions?

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