Water Vapor Control Specification

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Managing buildings

HVAC, utilities

Occupancy, use

Envelopes

Structure

Light

Heat/energy

Air

Moisture

Bulk water

Assumption: no leakage
1. Roof
2. WRB in walls
3. Foundation waterproofing

Capillary

Capillary transfer is trivial in the absence of a bulk source

Water vapor

One aim: manage permeances and their arrangements
to avoid moisture problems
One problem: Mold growth within the envelope (not surface)
Tools: steady-state and transient hygrothermal analysis,
ASHRAE Standard 160, ISO 13788

Assumptions

- The walls and roofs comply with the thermal requirements found in the document.
- The walls and roofs are designed and constructed to be sufficiently airtight that the building can meet the airtightness requirements found in the document. For that reason, water vapor transport due to air movement through the building envelope assembly is ignored.
  - If water vapor transport due to air movement is to be included, the flows shall be calculated using the parallel permeance methods described in ASHRAE Handbook [ref].
- There is no leakage of liquid water into the assembly.
- The only damage to components in the building assembly that is considered in this section is mold growth on surfaces other than the exposed interior and exterior surfaces of the assembly.
  - Table below lists all common forms of damage to wall and roof assemblies, and explains why and how the form of damage is included or excluded from consideration in this section.
  - With the adoption of Addendum e, ASHRAE 160 has become a satisfactory method for estimating damage to assemblies due to mold growth on interior surfaces.
- The analysis used is one-dimensional. Two- and three dimensional effects are ignored.

Water vapor control specification

Walls and roofs of buildings must comply with ASHRAE Standard 160. Criteria for Moisture Design Analysis in Buildings.

In fact, most building assemblies already comply with Standard 160. Common building assemblies can be tested by the standard, requiring only desktop modeling, and limiting temperature differences and humidity differences inside and out can be calculated. Building assemblies in tables to follow are **deemed to comply** with ASHRAE Standard 160.

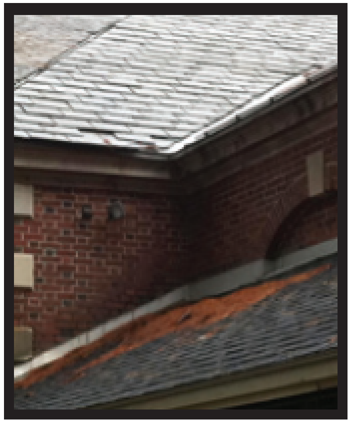
If at-risk assemblies are shown to comply at a set of conditions, then lower-risk assemblies can be presumed to comply as well at those conditions.

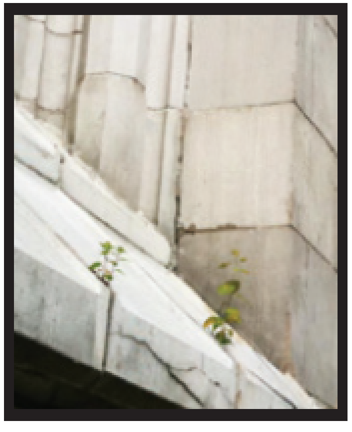
Variables for deemed-to-comply tables should include indoor climate (humidity) and outdoor climate (temperature).

Is “mold growth within the envelope (not surface)” the only problem within the scope of Water Vapor Control?

EPA United States Environmental Protection Agency

EPA 402-F-13053 | December 2013 | www.epa.gov/iaq/moisture





Moisture Control Guidance for Building Design, Construction and Maintenance

Figure 1-1 Mold growing on the surface of painted gypsum board and trim. Long-term high humidity is the source of the moisture that allowed the mold growth. All of the walls experienced similar near-condensation conditions. Consequently, the mold growth is widespread rather than concentrated in a single damp area.

1. Surface. High humidity

Figure 1-2 Mold growth on painted concrete masonry. The cool masonry wall separates a classroom from an ice rink. Humid air in the classroom provides moisture that condenses on the painted surface of the masonry. That moisture allows mold to grow on the paint film.

2. Cool wall. High humidity

Figure 1-3 Mold growth on vinyl floor tile. Long-term high humidity provided moisture that was absorbed into the cool vinyl tile and supported mold growth. Also note that the high humidity caused the adhesive attaching the tile to the floor to fail, allowing the tile to become loose.

3. High humidity. Loose tile

Figure 1-4 Corrosion of galvanized fluted steel floor deck. The floor is at grade level. The source of the water is rainwater seepage.

4. Corrosion. Capillary water

Figure 1-5 Corrosion of structural steel in a ceiling cavity in a cold climate. The steel extends into the exterior wall assembly. During cold weather, the steel near the wall is chilled by cold outdoor air. The building is humidified, and condensation from high indoor humidity provides the moisture that rusts the cold steel.

5. Thermal bridge. High humidity

Figure 1-6 Blistering paint on split face concrete block. Wind-driven rain is the source of moisture contributing to the damage. Water wicks into the concrete masonry unit (CMU) through pin holes in the paint. The sun drives water vapor through the CMU. The assembly cannot dry to the interior because low-vapor-permeability foam board, taped at the joints, insulates the interior surface of the wall. The wall remains saturated throughout the spring, summer and fall. The same paint on areas of the wall sheltered from sun and rain shows no damage.

6. Wind-driven rain. Exterior paint

Figure 1-7 Condensation behind vinyl wallpaper in a warm, humid climate. Condensation and mold growth occurs behind the vinyl wallpaper on both exterior and interior walls. Air leaks in the return plenum of the air handler depressurizes the interior and exterior wall cavities. Warm, humid exterior air is drawn from outside through air leaks in a heavy masonry wall.

7. Mold behind wall Covering. Air leakage In walls.

Figure 1-10 Further rain damage to interior plaster. At another location on an office window in the building shown in Figure 1-8, rain seepage turns gypsum board joint compound to a fluid, causing the gypsum to bubble and lift.

10. Water leakage. Lifting of gypsum.

Figure 1-8 Rainwater leaks in a rooftop parapet wall result in damaged plaster and peeling paint. Rainwater is drawn into this brick assembly by capillary action, and the moisture is aided in its downward migration by gravity. The peeling paint contains lead and results in an environmental hazard as well as physical damage to the plaster.

8. Rainwater. Peeling paint

Figure 1-11 Gypsum board on the lower edge of a basement wall dissolved by seasonal flood waters. The water table is just below the basement floor during dry weather and rises several inches above the floor during heavy spring rains.

11. Flood water. Gypsum damage.

Figure 1-9 Interior plaster damaged by rain seeping around a window in a brick building. The inside of the exterior wall is insulated with closed-cell spray foam. Consequently, the wall cannot dry to the interior, so it retains excessive amounts of moisture. At the point where the plaster on the window return meets the brick wall, rainwater wicks into the plaster causing the damage seen in this photo.

9. Seepage

Figure 1-12 Hardwood gymnasium floor warped by moisture in the cavity below it. Water rises through the concrete sub-floor. The source of the moisture is rainwater that has not been drained away from the foundation of the building.

12. Water beneath slab.

Figure 1-13 Tile adhesive that failed to cure because of water in the concrete and high pH. The tile can be removed by hand. The floor is a concrete slab-on-grade. The water visible in the photo evaporates into the room after several minutes. Its source may be liquid water wicking up from the sub-slab fill or water vapor migrating through the slab.

13. Water beneath slab. Lifting floor tile.

Figure 1-14 Damage to bricks caused by the migration of soluble salt through them. Salts in the brick or mortar dissolve in rainwater that wicks through the brick. The water evaporates in the building's interior, and the salt left behind crystalizes and splits the surface layer off the brick, exposing its interior. This process is called sub-fluorescence.

14. Salts in masonry. Spalling and efflorescence.

Moisture Problems are Expensive

How Water Causes Problems in Buildings

	Addressed?	Explain.
Mold on inside of wall sheathing	Yes. Standard 160	Standard 160 was designed specifically for this purpose.
Mold on interior surface	No, not vapor control	Will be associated with thermal bridges, diffuser throw, HVAC design/operation, or a combination, not with arrangement of permeances.
Freeze-thaw in masonry	No, not vapor control	Freeze thaw effects are associated with outdoor exposure, as possibly worsened by temperature of exterior materials. Insulation requirements that exterior elements will be cold in cold weather. No arrangement of permeances at the interior will impact freeze-thaw.
Exterior or interior coating failure	Vapor control plays minor and undefinable role	Industry must specify coatings, substrates, and appropriate substrate preparation using baseline (mothball) conditions, i.e. conditions with no indoor climate conditioning.
Mold on back of vinyl wallcovering	No.	Occurs under conditions of airflow in the assembly, precluded under the airtightness requirement.
Foundation walls (leaking spotting, mold growth, etc.)	No. Outside of scope	Usually damaged by water leakage, thus outside this specification.
Corrosion	No.	Corrosion resistance of metal elements must be specified for design conditions.
Construction moisture effects	Yes.	Accounted for in Standard 160 and WUFI.
Loss of shingle service life.	No.	Product quality issue.
Full attic sheathing darkening, winter	No. Airtightness issue.	With relatively airtight ceiling, the full range of ventilation ratios is permissible. (To discuss: ratio of ceiling airtightness to roof plane airtightness.)
Full attic sheathing darkening, summer	No. Not a vapor control issue	Associated with powered ventilation and cooling loss into the attic.
Water spotting at flashing and details	No. Not a vapor control issue.	Water penetration exclusion.
Mold in “vented” cathedral ceiling	Yes.	It is impossible to estimate or anticipate airflow in cathedral vents. Therefore, the assembly should be modeled using the roof assumptions in the specification.
Spalling or coating failure in protruding elements	No. Two- or 3-D effects.	Protruding elements have highest exposure, and are least likely to be affected by flows from the interior.

No water leakage in the building?

Roof must work, like a roof

Walls must have a Weather-Resistive Barrier

- ASHRAE Standard 160 allows 1% leakage across the WRB

Foundations must have a water barrier

- Basement walls must have dampproofing membrane and water management system
- Crawl spaces must have a ground cover
- Slabs must have a low-permeance membrane beneath the concrete
- Basement water problems are almost always associated with failure of the water management system.

Foundation water management system

Water management in foundations consists almost entirely of liquid water management and capillary water management. Vapor management plays a minor role. Liquid water management rarely relies on a single element, but instead includes several elements in series, each of which may be expected to be less than perfect. Liquid water management may occur at several levels:

- Gutter and downspout configuration to keep water away from the foundation,
- Sloping of soil surface away from the building
- ''Flashing" the building into the soil so that surface water close to the building is directed away from the soil in contact with the foundation
- Drainage of surface water downward so it cannot apply a head of liquid water to the foundation walls,
- Collection tiles at the base of the building, leading to daylight, to storm drains or to sump pumps,
- **Waterproofing** (membrane, coating, expansive clays) applied to walls.
- Coatings to resist capillary flow applied to the footing/wall joint, or to the insides of foundation materials
- Collection methods for rising ground water, together with discharge of collected water.
- Ground covers (ideally sealed against water leakage and evaporation) in crawl spaces.
- Low permeance membranes beneath slabs.
- Isolation of the building from the foundation space

Water control for foundations

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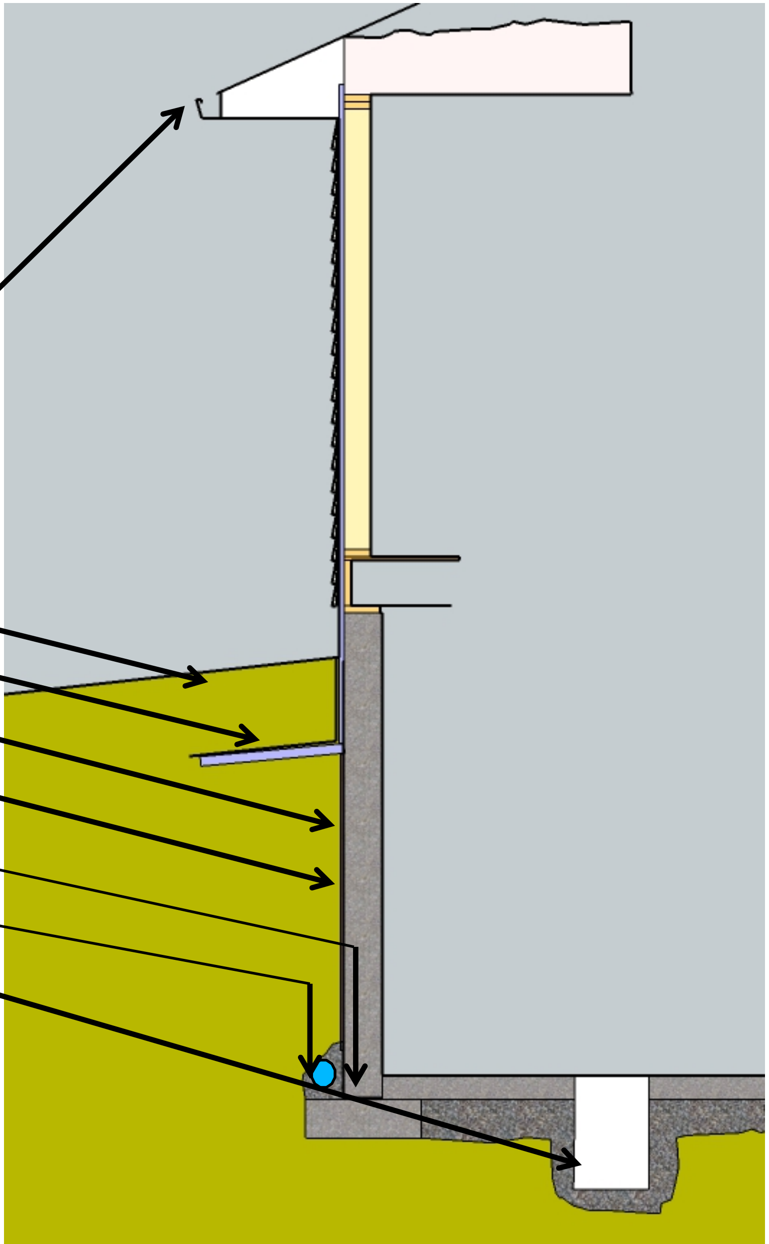
11.



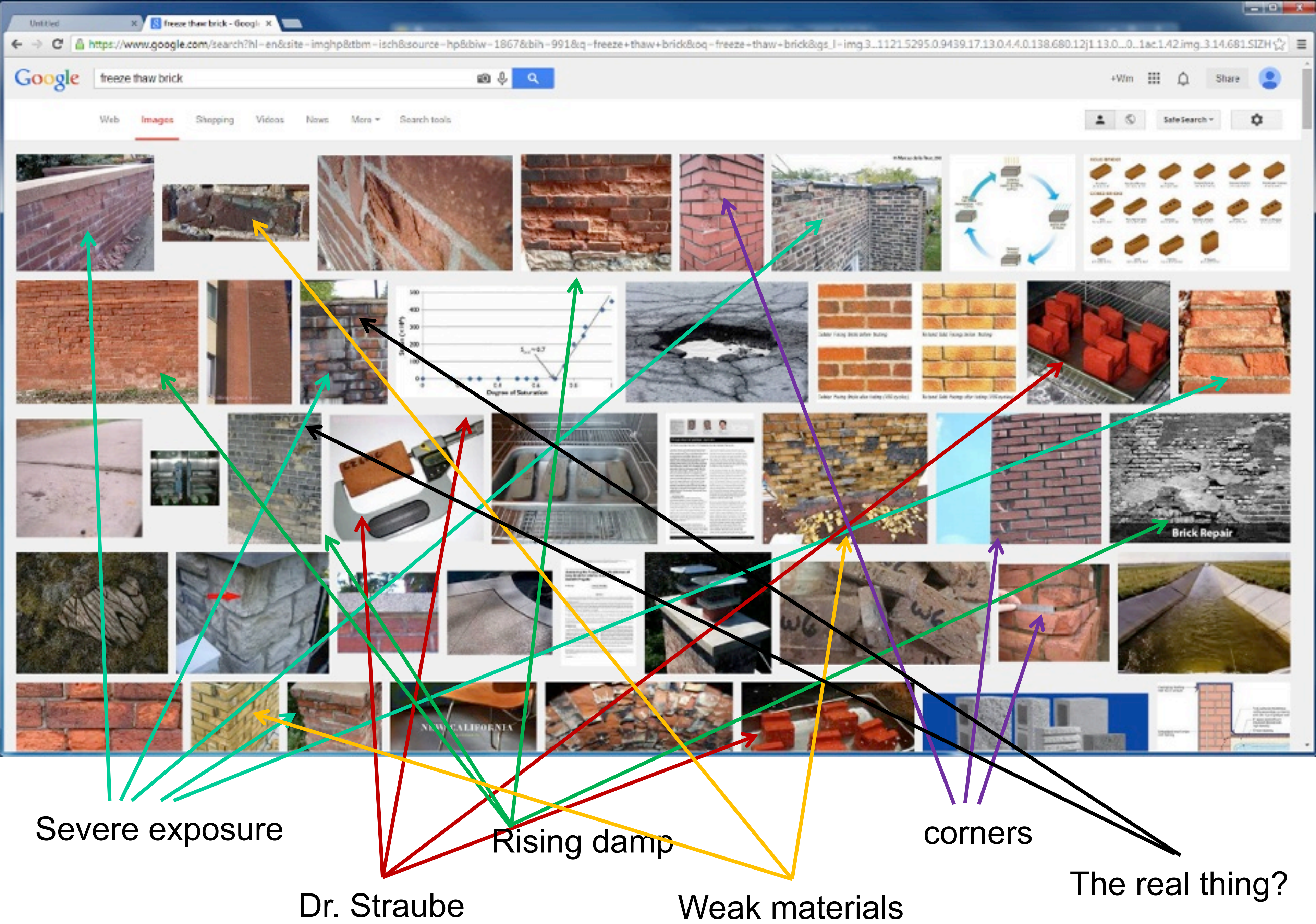
Attic ventilation

- In sloped roof construction, the insulation may be placed at the ceiling plane or at the roof plane. In either case, the air barrier should be located contingent to or integral with the thermal barrier.

  - For ceiling-insulated thermal barriers, with high levels of insulation and with low-airflow ceilings, the presence or absence of attic ventilation makes little difference in water vapor control. Attic ventilation carries an energy penalty and a resilience (wind and fire storm resistance) penalty.
  - Low-slope roofs which comply with Standard 160 typically use high moisture-resistance materials in the assembly. They are not vented.
  - Sloped roofs with the thermal barrier placed within the roof assembly should be designed to comply with Standard 160 without reliance on ventilation. Achieving useful ventilation is difficult in simple roofs, and is practically impossible in roofs with other than simple geometry: hips, valleys, sloped and low-slope adjacencies, long lengths.

Freeze-thaw?

1. Is there a stand-alone freeze-thaw problem?
   - A freeze-thaw problem where all water comes from the inside and none comes from the outside?
   - Answer: no. The water in freeze-thaw comes from exposure, not flow.
2. Will permeances and their arrangements make a difference?
   - No.
3. If it’s 100% exposure, how do we solve the problem?
   - Manage exposures.
4. Doesn’t low temperature, thanks to interior insulation, make it worse?
   - Yes.
   - But imagine consigning a building to perpetual fuel consumption, based on your professional opinion that, in the absence of that consumption, the building will collapse. Can’t you imagine alternatives?


freeze thaw brick
Web
Images
Shopping
Videos
News
More
Search tools
SafeSearch
Brick Repair
Severe exposure
Rising damp
corners
The real thing?
Dr. Straube
Weak materials

Field Monitoring and Simulation of a Historic Mass Masonry Building Retrofitted with Interior Insulation

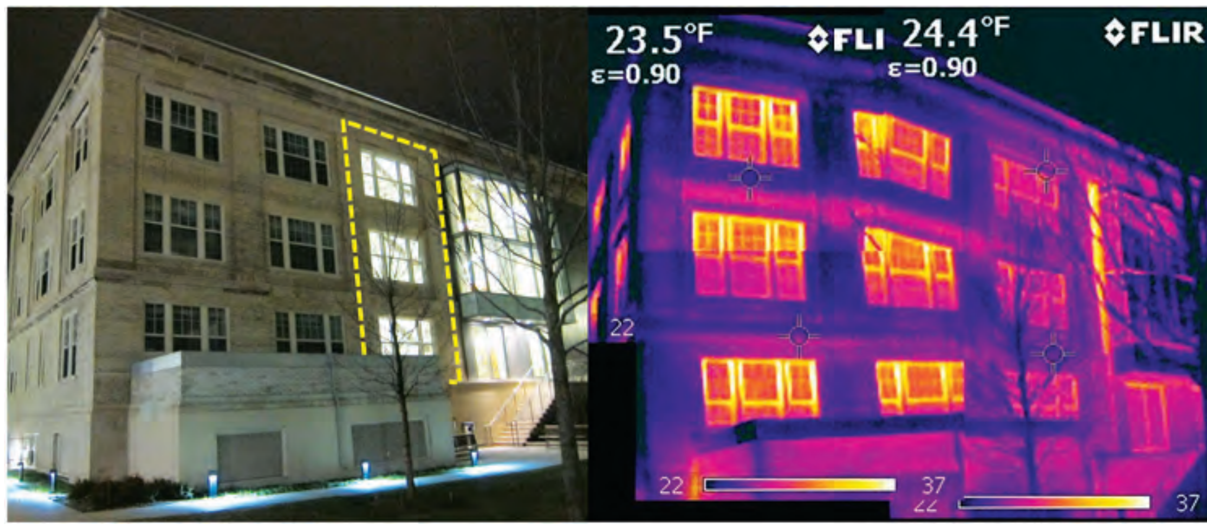
Kohta Ueno
Associate Member ASHRAE

John Straube, PhD, PEng
Associate Member ASHRAE

Randy Van Straaten
Student Member ASHRAE

ABSTRACT

Load-bearing masonry buildings are a significant portion of the existing building stock, and there is a great deal of interest in adding thermal insulation to the walls of these structures. Exterior insulation provides the ideal conditions for building durability; however, many buildings cannot be retrofitted with insulation on the exterior for reasons such as historic preservation,



The measured data from this mass masonry building retrofitted with interior insulation indicates that the masonry wall **experiences colder temperatures than uninsulated walls**, as would be expected. Monitoring also indicates that the insulated wall experiences **higher moisture contents**; however, this might reflect both the insulation retrofit and rain exposure at the sensor location. In addition, the **moisture measurements in the walls varied** in nominally identical wall sections: some sensors measured seasonally steady moisture levels, while others measured wetting responses consistent with driving rain events, followed by drying in warmer/drier conditions.

Hygrothermal **simulations** of the wall assemblies show good correlation to temperature measurements; however, there were significant differences in the **moisture** responses. These differences may be due to sensor response, driving rain exposure, or anomalies within the mass masonry wall assembly (redistribution of moisture due to voids and cracks).

The hygrothermal simulations indicate a **low risk of freezethaw damage**, based on predicted brick moisture content levels and insulation levels. The installed **sensors cannot resolve moisture contents** in the high range (critical degree of saturation or *Scrit*) at which freeze-thaw damage occurs. However, these instruments indicate seasonal trends of wetting and drying.

Although the measured moisture levels were highly variable, and did not have high correlation with modeled results, it still may be useful to install instrumentation in other mass masonry buildings retrofitted with interior insulation to gain understanding of the variables that affect the results. Direct measurement of driving rain on the instrumented wall surface may reduce the uncertainty.

In future work on insulated mass masonry buildings, the **assessment of water shedding and water concentrations on the exterior face and improving the water shedding details are the key requirements before considering interior insulation**. Material property testing and hygrothermal simulations are useful for assessing the risk in a more rigorous manner, based on localized climate and assembly type. Site load monitoring (driving rain, climate conditions) and building assembly monitoring are also useful tools—albeit more costly, intrusive, and time consuming—to consider in critical cases.

Condensation

"Condensation" is not listed as form of moisture damage to walls and roofs. This is because:

The building materials considered here (almost entirely) are sorptive. That is, the building materials here do not show the formation of droplets condensed from adjacent air cavities containing water vapor.

- Instead, sorptive materials will absorb or adsorb water, they will become heavier or lighter with daily and other cycling, and this weight change or moisture uptake is natural, not a cause for concern.
- Moisture uptake in sorptive materials becomes a concern when the wetness of the materials, together with the temperature of the surface, permits mold to grow. Mold growth is precisely the focus of ASHRAE 160, which serves as the basis for this specification.

Condensation 2

Student:

“No, no, no. Condensation is when two lines cross on a dewpoint chart.”

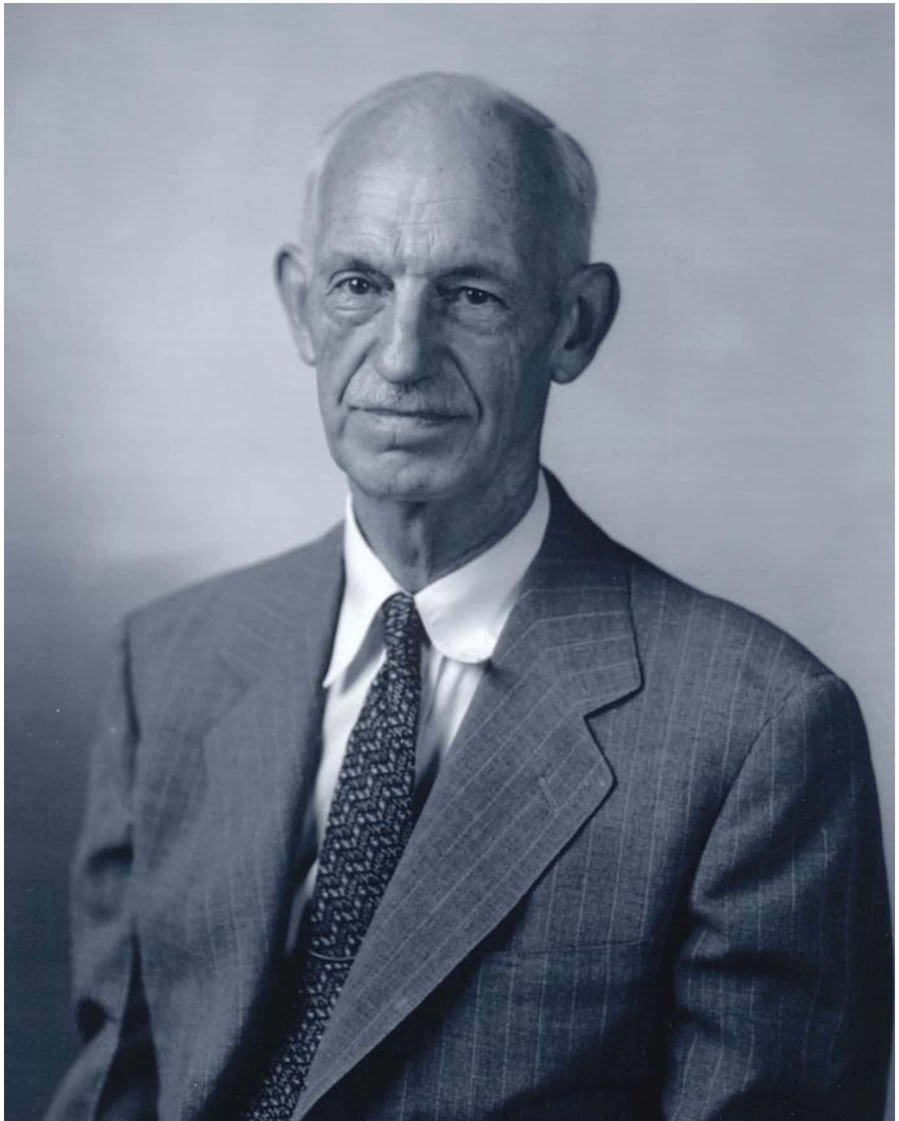
Professor (me):

“Lines never cross on a dewpoint chart.”

Audience (you):

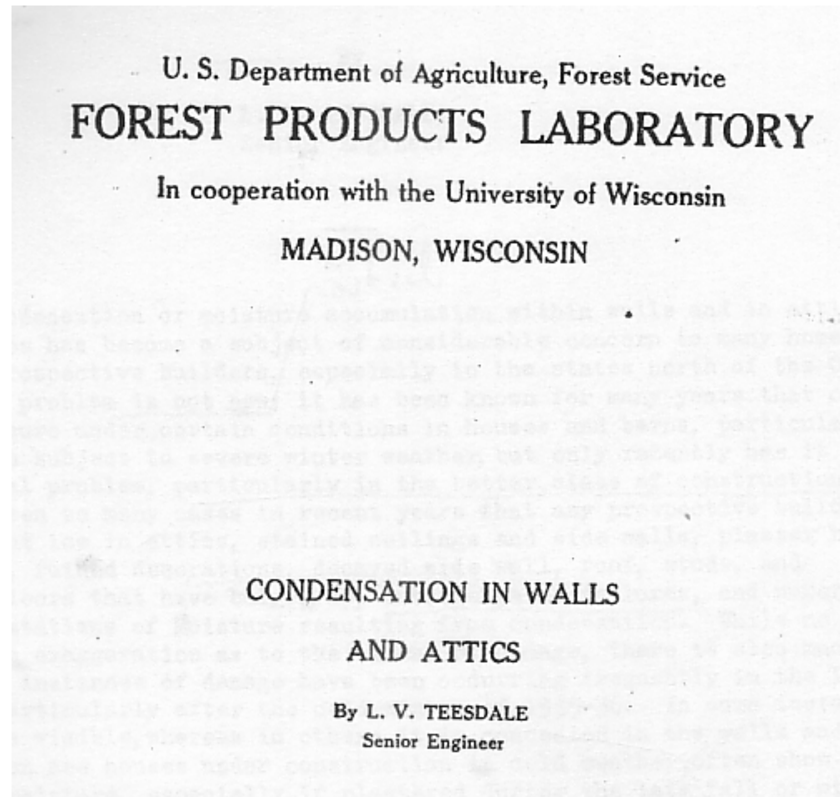
“huh?”

Larry V. Teesdale



Senior research engineer at US Forest Products Laboratory, Madison WI.

Smart guy.



U. S. Department of Agriculture, Forest Service

FOREST PRODUCTS LABORATORY

In cooperation with the University of Wisconsin

MADISON, WISCONSIN

CONDENSATION IN WALLS AND ATTICS

By L. V. TEESDALE
Senior Engineer

Teesdale, “Condensation in walls and attics”, US FPL Report 1937

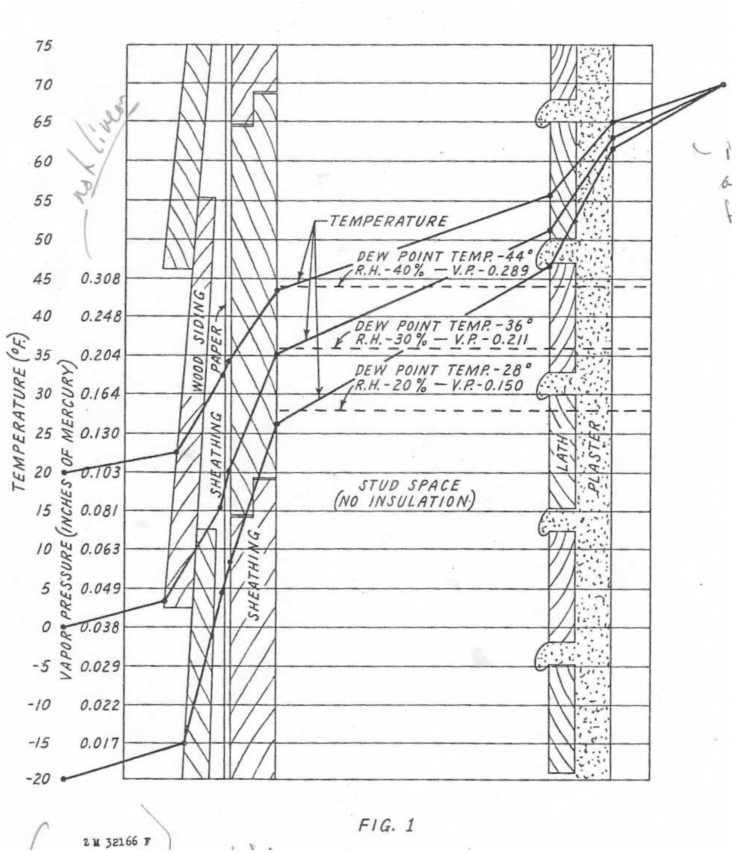


FIG. 1

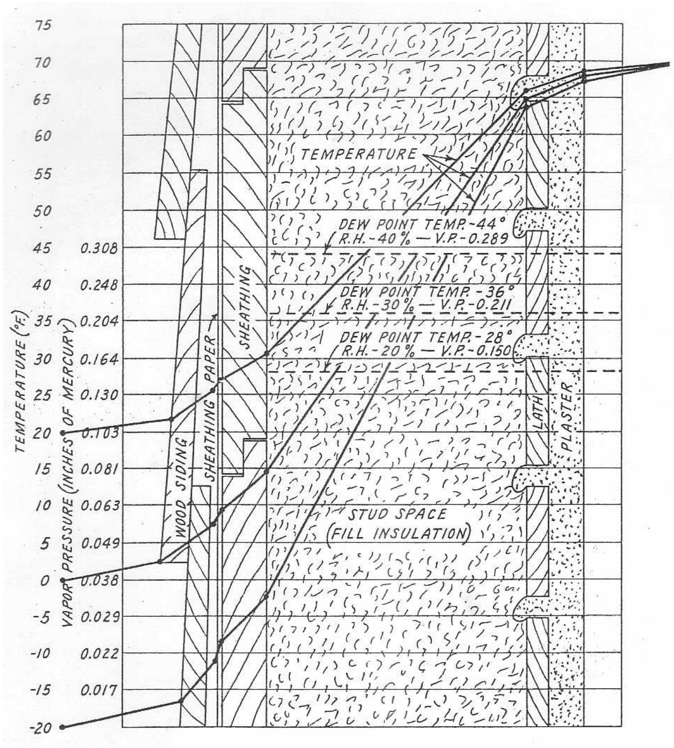
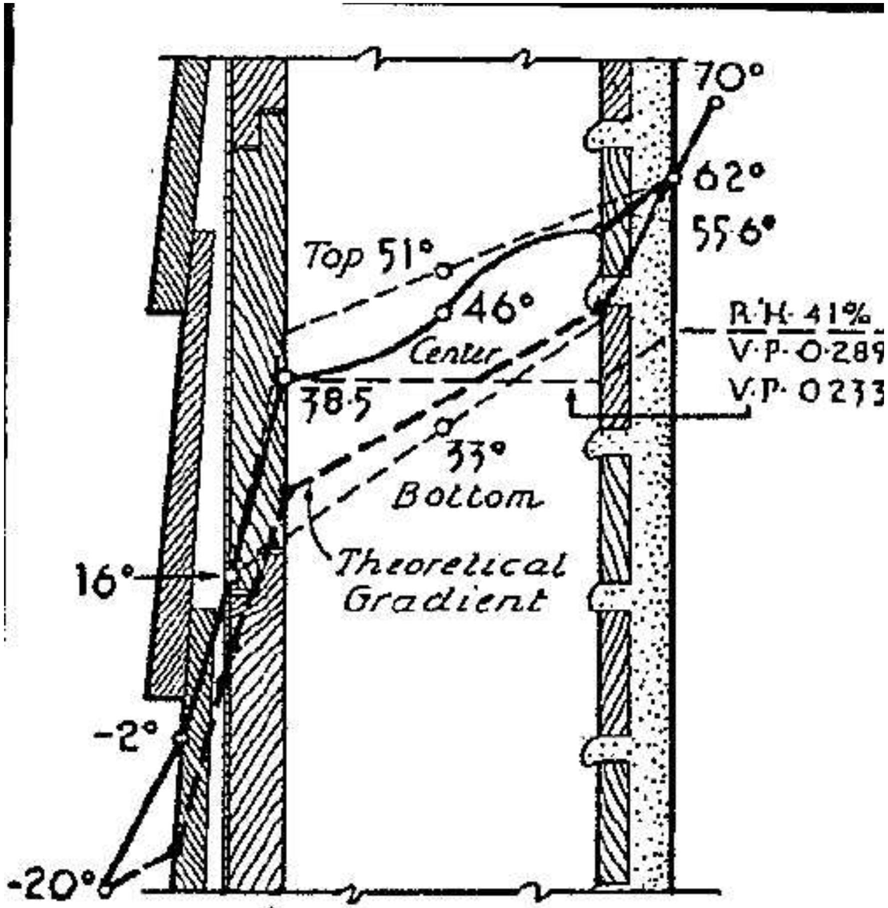
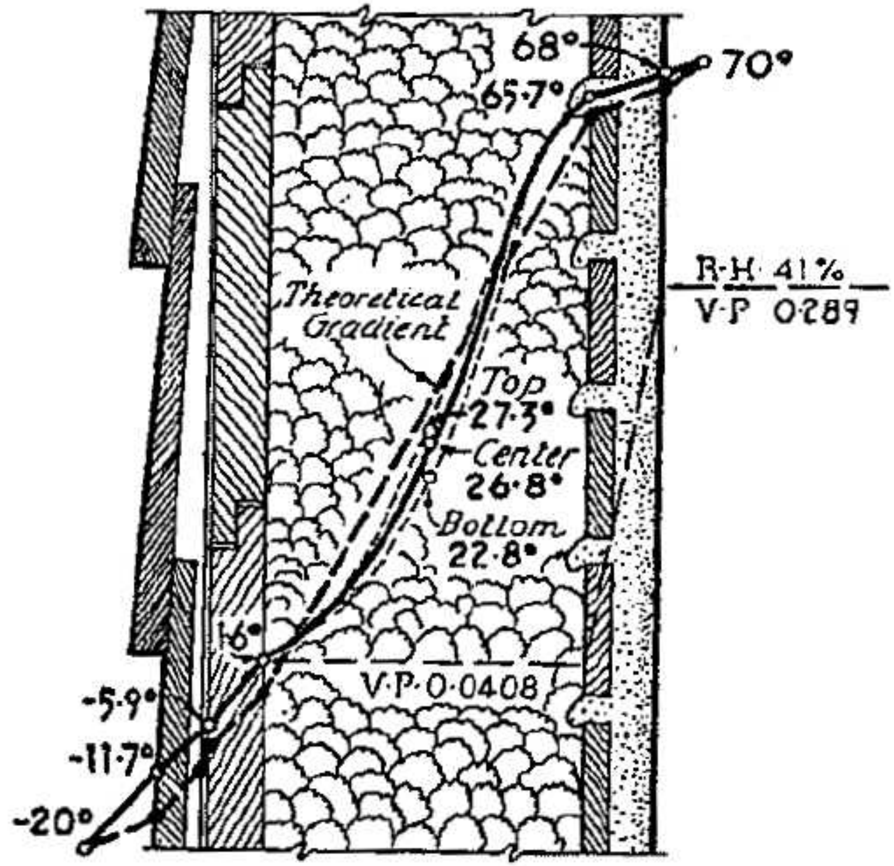


FIG. 2

Teesdale, *Architectural Forum*, 1938



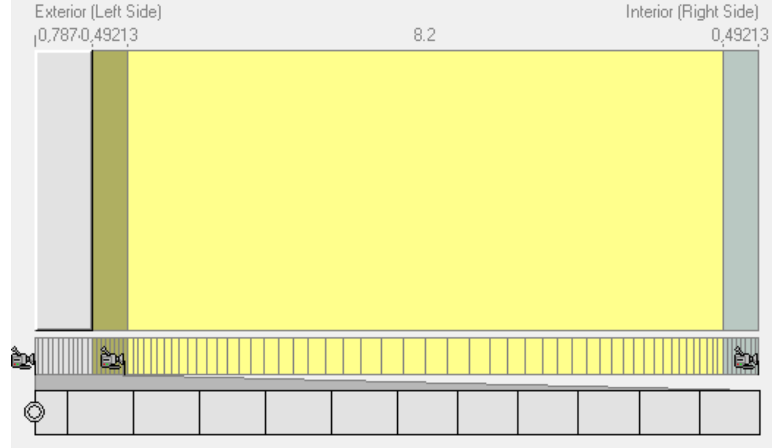


Test results. Note: the cavity vapor pressure is DETERMINED by the sheathing temperature.

Common wisdom: “If the lines cross, you have condensation.” Actual fact: The lines don’t cross.

This is exactly consistent with ASHRAE *Handbook Fundamentals*, Glaser method.

Deemed-to-comply calculations: fg only



Four material sensitivity classes, 1, 2, 3, 4
"O" mold index < 3, otherwise "X"

R-30

City/indoor humidity class	**1**	**2**	**3**	**4**
Anchorage	O, O, O, O	X, X, O, O	X, X, X, O	X, X, X, O
Minneapolis	O, O, O, O	X, O, O, O	X, X, O, O	X, X, O, O
Seattle	O, O, O, O	X, O, O, O	X, X, O, O	X, X, O, O
Chicago	O, O, O, O	X, O, O, O	X, X, O, O	X, X, O, O

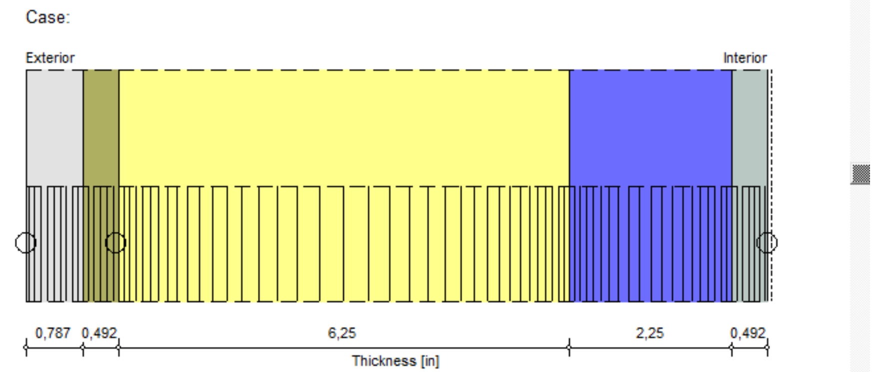
R-40

City/indoor humidity class	**1**	**2**	**3**	**4**
Anchorage	X, O, O, O	X, X, O, O	X, X, O, O	X, X, X, O
Minneapolis	O, O, O, O	X, O, O, O	X, X, O, O	X, X, O, O
Seattle	O, O, O, O	O, O, O, O	X, X, O, O	X, X, O, O
Chicago	X, O, O, O	X, O, O, O	X, X, O, O	X, X, O, O

R-50

City/indoor humidity class	**1**	**2**	**3**	**4**
Anchorage	O, O, O, O	X, X, O, O	X, X, O, O	X, X, X, O
Minneapolis	O, O, O, O	X, O, O, O	X, X, O, O	X, X, O, O
Seattle	O, O, O, O	O, O, O, O	X, X, O, O	X, X, O, O
Chicago	O, O, O, O	X, O, O, O	X, X, O, O	X, X, O, O

Deemed-to-comply calculations: fg + foam



Four material sensitivity classes, 1, 2, 3, 4
"O" mold index < 3, otherwise "X"

R-30

City/indoor humidity class	1	2	3	4
Anchorage	O, O, O, O	O, O, O, O	O, O, O, O	O, O, O, O
Minneapolis	O, O, O, O	O, O, O, O	O, O, O, O	O, O, O, O
Seattle	O, O, O, O	O, O, O, O	O, O, O, O	O, O, O, O
Chicago	O, O, O, O	O, O, O, O	O, O, O, O	O, O, O, O

R-40

City/indoor humidity class	1	2	3	4
Anchorage	O, O, O, O	O, O, O, O	O, O, O, O	O, O, O, O
Minneapolis	O, O, O, O	O, O, O, O	O, O, O, O	O, O, O, O
Seattle	O, O, O, O	O, O, O, O	O, O, O, O	O, O, O, O
Chicago	O, O, O, O	O, O, O, O	O, O, O, O	O, O, O, O

R-50

City/indoor humidity class	1	2	3	4
Anchorage	O, O, O, O	O, O, O, O	O, O, O, O	O, O, O, O
Minneapolis	O, O, O, O	O, O, O, O	O, O, O, O	O, O, O, O
Seattle	O, O, O, O	O, O, O, O	O, O, O, O	O, O, O, O
Chicago	O, O, O, O	O, O, O, O	O, O, O, O	O, O, O, O

Summary

1. With assumptions regarding insulation, airtightness and water tightness,…
2. Single specification: compliance with ASHRAE 160
3. Deemed-to-comply tables for simplicity
4. Discussed:
    1. Moisture problem types and dependence on water vapor control
    2. “Condensation”
    3. Foundations
    4. Freeze-thaw
    5. Attic ventilation

To-do list

1. Number of years for d-t-c tables? 3 yrs? 10 yrs?
2. Maps or tables or formulas for d-t-c?
3. Critical plane identification
4. Cooling season problems?
5. Coordinate with ISO 13788