Moisture Risk Analysis & Assessment using WUFI

Version 1.1

Prepared for:

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Foreword

PHIUS+ is an energy performance standard for buildings. It is intended to guide designers towards high-performance building design, meaning buildings that provide all the amenity of a comfortable and healthy indoor environment without using a great deal of energy to do so. Passive building design is foundational to this high performance. The principles of passive design are:

- continuous insulation without thermal bridging and high-performance windows to limit heat transmission,
- a very airtight building envelope preventing infiltration of outside air and loss of conditioned air, balanced ventilation with heat recovery, and
- a minimal heating/cooling system.

Meeting the heating/cooling energy limits of PHIUS+ generally entails high levels of insulation. By itself this can increase moisture risk – “One of the key elements of energy efficient building enclosures is a high level of thermal insulation. However, as thermal insulation levels are increased, the rate of building enclosure drying decreases. This affects building durability as it affects the moisture balance.” (Lstiburek, 2006).

Accordingly, PHIUS+ has a number of requirements and provisions to limit moisture risk, including:

- The Energy Star Water Management Checklist
- Limits on the interior surface temperature at thermally-bridged construction details.
- Window Condensation Resistance requirement.
- Protocol for limiting moisture risk in assemblies.
- Attention to freeze-thaw risk for masonry walls.
- Special requirements on “fluffy floors”.

These provisions are spelled out in more detail in the PHIUS+ Certification Guidebook and Quality Assurance Workbooks.

This document concerns two of the points listed above – protocol for limiting moisture risk in assemblies, and special requirements for fluffy floors. As explained in the Guidebook, there are essentially three compliance paths for ensuring that that the moisture control strategy in the wall and roof assemblies keeps the moisture risk low enough:

1. Follow a set of prescriptive guidelines (see Certification Guidebook, Appendix B,)
2. Pass a performance test by calculation in WUFI, or
3. Present a moisture-engineered design by a qualified licensed professional engineer.

This document sets out the calculation protocol for the second option. Its purpose is therefore similar to that of ASHRAE 160, i.e., “specify performance-based design criteria for predicting, mitigating, or reducing moisture damage to the building envelope.” Inputs mostly follow ASHRAE 160; this document covers specifics of using WUFI software for the calculation, and the points where PHIUS protocol differs or supplements ASHRAE 160, such as in the stringency of the evaluation criteria. The structure of this document is aligned with the software user interface.

A few other points of context are noted below:

Bright line test
Because PHIUS+ is a pass-fail standard overall, the moisture design criteria must also come down to “do I have to change something or not” therefore, this protocol is designed to come to a yes or no decision, rather than to make relative comparisons.

Stress case for design
The idea here is of design for a stress case, not prediction of what will happen typically as in annual energy modeling. This particularly relates to the design weather data.

Early assessment
It is to be expected that this protocol will be used mainly early in design or pre-design as opposed to later in the project, for example as a forensics tool. The analyst might be working with vague materials callouts such as “sheathing per structural” rather than detailed product specifications. This protocol does not require detailed product specifications but does call for assumptions to be documented. The analyst should use engineering judgement to press for clarification or follow-up where it is likely to make a difference. In pre-design, additional cases may need to be run to determine the sensitivity to, e.g., the type of stone veneer cladding or air barrier material. In the context of an assessment being performed to fulfill PHIUS+ project certification requirements, updating to a specific assembly and materials will be required for pre-certification.

1 Purpose

The purpose of this protocol is to specify performance-based design criteria as to whether the risk of moisture damage to building wall, roof, and floor assemblies is below a threshold of risk to render a building project uncertifiable to PHIUS+. These include criteria for qualified software, for inputs, and for evaluation of outputs.

2 Scope

This protocol applies to all buildings within the scope of ASHRAE 160 or PHIUS+. A key aspect is that the buildings will be very well air-sealed. It does not address design to resist liquid water leakage from the outside (i.e. rain.)

3 Definitions, Abbreviations, Symbols

1D, 2D	One-dimensional, two-dimensional
ASHRAE	American Society of Heating, Refrigeration, and Air-conditioning Engineers
BSC	Building Science Corporation
EPDM	Ethylene propylene diene terpolymer
EPS	Expanded polystyrene insulation
EN	European Norm (Standard)
PHIUS	Passive House Institute U.S.
PU	Polyurethane Insulation
PVC	Polyvinylchloride
RH	Relative humidity
TPO	Thermoplastic Olefin
VTT	Finnish Research Institute
WUFI	Wärme Und Feuchte Instationär (Transient Heat and Moisture)

4 Qualified Software

Assemblies are to be modeled using one of the following:

- WUFI® Pro 5.3.4.1363 or later.
- WUFI Passive or Plus 3.1.1 or later.

The following add-ons are also required:

- ORNL weather files from ASHRAE Research Project 1325.
- WUFI Mould Index VTT 2.1 or later.

  [Informative note: On the moisture design compliance path involving a qualified professional engineer, if calculation is involved it is also recommended to follow ASHRAE 160 and its software requirements, which are more inclusive.]

5 Inputs

5.1 Outdoor climate

For most cases, use the ASHRAE year 2 climate file nearest to the project location. In some cases, a station farther away might be appropriate if it is closer with regard to latitude and climate zone. If there is no file available for the project location, request guidance from PHIUS.

If there is no outdoor exposure for the assembly being analyzed, such as for interior partition walls, assign EN 15026 'normal moisture load' to the outdoor climate, unless there is a condition such as a swimming pool, sauna, steam room, in which case select 'high moisture load'.

5.1.1 *Below-ground climate*

In cases where the exterior is below ground, set up a User-defined sine curve for the exterior temperature according to ISO 13370[1]. The mean value and amplitude parameters can be obtained from a WUFI Passive model of the building using the "Passive house verification" scope. Set the time of maximum to noon on the 15th day of the warmest month.

For climates other than desert, set the RH to a constant 99%.

5.2 Indoor climate

First make sure the outdoor climate is assigned. Set the indoor climate according to section 5.2.1, 5.2.2, or 5.2.3 below.

5.2.1 *Residential*

Use ASHRAE 160 intermediate method for the indoor climate. For WUFI Passive/Plus this requires defining an optional climate as shown in Figure 1 below.

Choose (in WUFI Pro) or configure (in WUFI Passive) an air conditioning system type as planned for the building:

- Set the floating indoor temperature shift to 5 F [3 C].
- Enter the set point for heating at 68 F [20 C].
- Enter the set point for cooling at 77 F [25 C], if applicable.
- Enter the R.H. control set point at 60%, if applicable.

Set the Relative Humidity inputs to represent the most densely occupied dwelling unit (e.g. lowest floor area per person) or the zone that would be expected to be the most humid.

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[1] Monthly ground temperatures per ISO 13370 can be obtained from the foundation interface tab of a WUFI Passive model of the building.

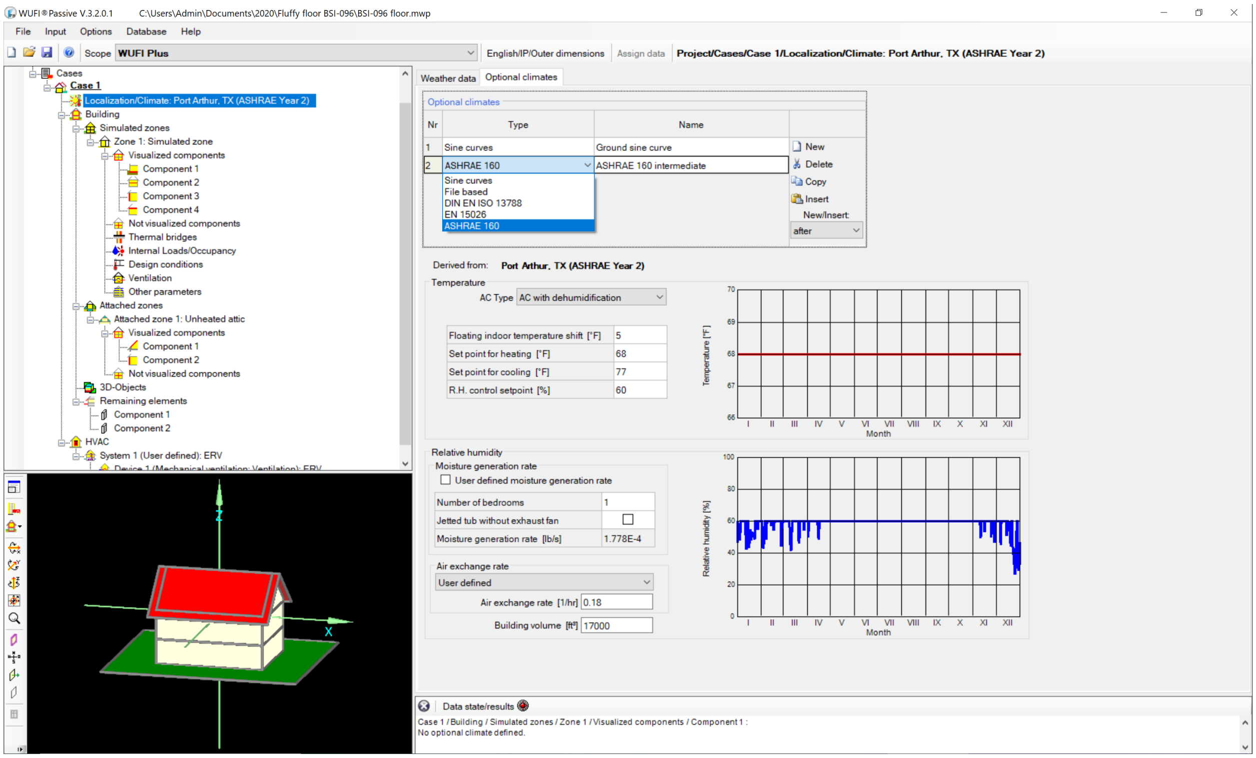

Figure 1. Setting up an indoor climate for ASHRAE 160 Intermediate Method in WUFI Passive/Plus.

Set the mode for Air exchange rate to “User defined”. Enter the designed rate of balanced ventilation and the volume of the chosen dwelling unit or zone.

Exception: If the balanced ventilation system includes latent recovery, modify the design ventilation rate to the “latently effective” ventilation rate by multiplying it by (1-LR), where LR is the latent recovery effectiveness (0≤LR≤1).

5.2.2 ***Nonresidential***

Use the EN 13788 method and set the humidity class appropriate to the building type (see Table 1 below.) WUFI Pro default is 3.

Table 1. Indoor humidity classes, per ISO 13788 Table A.1.

Class	description
1	Unoccupied buildings, storage of dry goods
2	Offices with normal occupancy and ventilation
3	Buildings with unknown occupancy
4	Sports halls, kitchens canteens
5	Especially humid, e.g. laundry, brewery, swimming pool

5.2.3 ***Full parametric method***

Section reserved for future expansion.

5.3 Assembly

An accompanying Assembly Notes document referencing the assembly cross-section(s) modeled is required. See Appendix A for examples.

Model the assembly as designed, including all construction layers and materials (see subsections below for exceptions, and protocol on certain kinds of materials.) Document and justify any simplifications or substitutions in the Assembly Notes. Focus the Notes on the interpretation of the documentation layer callouts into modeled layers.

Exceptions:

- For uninsulated pitched roofs over vented attics with insulation flat on the attic floor (non-compact roofs): model with the insulation as the outermost layer, turn off the rain absorption, and set the solar radiation absorption to 0.5 times the short wave absorptivity of the roofing material.
- For flat roofs with pavers over pedestals over membrane, model with the membrane as the outermost layer, and set the solar radiation absorption to 0.5 times the short wave absorptivity based on the color of the pavers.
- For roofs with solar panels on racks, do not model the panels as a material layer, but set the solar radiation absorption to 0.5 * (1-H), where H is the DC-rated efficiency of the modules (typically 0.15).

User-defined materials

Material properties should be obtained from manufacturers' data. Clearly note cases when this isn't possible.

Minimum material data required is:

- Thermal conductivity based on aged R-value; this should match what is modeled in the corresponding WUFI Passive energy model for building project certification. (As a function of temperature when appropriate.)
- Permeability of materials as function of RH when appropriate

If manufacturers data is not available, copy the bulk density, porosity, and specific heat capacity from a similar material in the WUFI materials database.

In particular, if the density of a cellulose insulation material in the assembly differs by more than 20% from the density listed in one of the built-in options, create a custom User-defined material having the density of the specified material.

Note that the cellulose fiber density in the North America library is 1.87 lb/ft3 [30 kg/m3] and the one in the Fraunhofer library is 4.37 lb/ft3 [70 kg/m3].

Density correction is also recommended for fiberglass insulation. Note that there are two densities available in the North American library: Low Density Glass Fibre Batt Insulation at 0.55 lb/ft3 [8.8 kg/m3], and Fibre Glass at 1.87 lb/ft3 [30 kg/m3].

When creating a custom material in the WUFI database, on the Info tab, enter notes as to:

- The database & material on which the User-defined material is based.
- The properties modified.
- Your initials and the current month and year.

If using WUFI Plus, add initials, month and year to the end of the material name, e.g. LMW 04-2020.

For each User-defined material, include the following information in the Assembly Notes:

- Which default WUFI database material was used as the basis for the custom material.
- Which properties were modified from the basis material.
- A description of any assumptions / calculations used to modify the material properties, and the documentation used to create the custom materials.

Wood-based structural sheathing layers, e.g. oriented strand board and plywood, must be subdivided into three adjacent layers, with a 1/8 inch [3mm] thick slice on the inboard and outboard of the overall material layer. (Percent moisture content in such layers is a key result that must remain below a threshold to avoid rot and decay, and because moisture is driven into the layer from one side or the other, the near-surface conditions in the layer will need to be analyzed.)

In framed cavities, the primary material should be modeled, in most cases, the insulation. (Separate consideration of the cross section at the framing members is not required for wood framing, but may be required for metal studs or concrete ribs. In such cases, instead of a 1D WUFI analysis, a 2D static thermal analysis at a design condition may be requested.)

Do not add additional assembly layers for interior paint or wallpaper. These will be addressed as surface film coefficients.

Optional - for WUFI Pro, place Monitors at the outboard and inboard faces of all air-permeable insulation layers, and any other locations of interest. The time-series plots that these generate can also be obtained post-calculation from the Animation window.

5.3.1 ***General treatment of claddings***

Represent the cladding as a solid sheet of the given material, and use a surface permeance to represent any paint. Exception: elastomeric type coatings, see below.

Specific claddings

- Vinyl or Cellular PVC – North America vapor retarder 0.1 perm
- Brick, new construction, North America – Use Red Clay Brick or Buff Matt Clay Brick, rather than Brick, Old
- Membrane roofing (EPDM, TPO) – Generic Roof Membrane V13
- Standing seam steel roofing, metal siding – Generic Roof Membrane V13.
    - For air gaps adjacent to metal surfaces, use Air layer 10mm; metallic. See also section 6.1 Numerical Quality, below.
- Elastomeric coatings – model as a material layer, using manufacturer data on permeability (and liquid transport diffusivity if available), otherwise, create a material based on the Generic Roof Membrane V13 and modify the permeability.

For walls, model a 0.04 inch [1mm] layer of 'Brick, old' (from the North American material database) on the exterior surface of the first construction layer that behaves as a weather resistive barrier or drainage plane. (Walls with thin exterior insulation might be designed to drain on the inboard side of the insulation, while walls with thick exterior insulation might be designed to drain on the outboard face of the insulation.)

5.3.2 ***Claddings back-ventilated by design***

For walls with vented, ventilated or rain screen cladding, and for pitched roofs with vented "cold roofs" or over-roofs, represent the vent gap using the air layer without additional moisture capacity that is closest in thickness to the assembly's design. Do NOT change the thickness of the air layer; do not use more than one air layer in succession.

5.3.3 ***Claddings with drained gaps***

For walls with unvented drainage gaps or grooves (e.g. drained EIFS), or claddings that touch the weather resistive barrier only in some places, as with lapped boards, model an air layer without additional moisture capacity, inboard of the cladding layer, at a thickness of 5mm, or the thickness of the mat/mesh, whichever is larger.

5.3.4 ***Sources and sinks***

The addition of a 1% driving rain moisture source must be made to all exposed wall assemblies. This moisture source is applied to the entire 0.04 inch [1 mm] fictitious layer of 'old brick'.

For traditional stucco walls add 3% driving rain on the inboard 0.1-0.2 inch [3-5 mm] of the stucco.

The addition of air and heat sources within the assembly is not necessary, with the exception of the following:

- For vented cladding per section 5.3.2, add an air source to the 'air layer without additional moisture content'. The suggested default value is 25 ACH. It may be either a constant air change rate, or an intermittent air change rate, if for example the project is in a location with established high wind patterns during a certain part of the day. For guidance on air change rates of various claddings, please refer to figure 5 in Finch & Straube (2007). Values above 100 ACH constant airflow require special justification.
- For drained cladding per section 5.3.3, add an air source to the air layer. Set the air change rate to a constant as follows[2]:
    - Vinyl siding – 25 ACH
    - Unpainted wood siding – 20 ACH
    - All other claddings – 5 ACH
- For floor assemblies that include high-power radiant heating (>~ 10 Btu/h.ft2), add a heat source, read from an external file set up so that it operates only during the heating season.
- For green roofs, living walls, or water feature walls, add an intermittent moisture source to the appropriate layers, according to irrigation or operation schedule.

5.4 Orientation, Inclination, and Height

Set the orientation to the primary direction of the driving rain, or oriented north, whichever retains more moisture, that is, if the driving rain direction is not north, evaluate the baseline case in two orientations to determine which is more stressful.

For the case of "reservoir claddings" such as brick, it is recommended also to check the south (equator) facing direction to capture any sun-driven moisture effects.

Set the Inclination according to design; 90 degrees for typical walls, <90 degrees for roofs and 0 degrees for floors and flat roofs/ceilings.

Set the building height and associated driving rain coefficients to "Rain load calculation according to ASHRAE Standard 160."

Select the Rain exposure factor (FE) range corresponding to the project's design height.

Select the Rain exposure category as defined by ASHRAE 160:

- Severe: hilltops, coastal areas, funneled wind
- Sheltered: trees, nearby buildings, valley

[2] The scientific literature is somewhat lacking here. It is suggested to model the assembly also with an air change rate of zero in the drained gap to get a sense of its robustness or dependence on air exchange.

- Medium: conditions neither ‘severe’ nor ‘sheltered’, but somewhere between

Rain depositions factor (FD) should be selected according to design. ‘Walls subject to rain runoff’ is the most conservative and should be used for roofs. For slab assemblies, below grade or interior assemblies and party walls with no outdoor exposure, or the rain deposition factor is 0.

5.5 Surface transfer coefficients

5.5.1 *Exterior*

Assign the Exterior surface coefficient based on the design, i.e, External wall, roof, basement (for any below-grade assemblies) or partition wall (for assemblies which have no outdoor exposure.)

Wind-dependent should be selected for all except for assemblies which have no outdoor exposure.

Permeance of any additional coating (e.g. paint) applied to the outermost material of your modeled assembly. Select from the dropdown or choose user-defined.

Short-wave and ground short-wave radiation absorptivity should be selected from dropdown menus based on the assembly design. For floors, and assemblies with no outdoor sun exposure, select ‘no absorption/emission’ and ‘no reflection’. Note: lighter colors are generally more stressful and roofs are particularly sensitive to the short-wave absorptivity. See also section 5.3.

Use “explicit radiation balance” for roofs.

Evaluate unvented compact roofs at their specified color and with a short-wave radiation absorptivity of 0.3 (if the specified roofing has higher absorptivity).

Adhering fraction of rain should be dependent on inclination of component and does not apply to assemblies that are below grade or with no outdoor rain exposure. Turn off the rain for floors.

5.5.2 *Interior*

Set the Permeance of any additional coating applied to the innermost material of the modeled assembly. Choose ‘user defined’ and enter 5 perm [Sd=0.65m] for standard latex paint (2 layers), or select from the dropdown options.

5.6 Initial Conditions

Follow ASHRAE 160 protocol on initial conditions:

If the construction is protected from rain:

> Set “Initial moisture in component” to ‘constant across component’ at 0.8 initial RH for assemblies that do not contain concrete.

For assemblies that contain concrete, set initial RH to 0.9, note the water content for any concrete layers, then set RH back to 0.8. Next select 'in each layer' and manually change the water content for concrete layers to reflect 0.9 RH levels.

If the construction is not protected from rain, use twice the 90% water content for concrete and twice the 80% water content for other materials.

Set initial temperature to 'constant across component' at 68 F [20 C].

5.6.1 Initial conditions for *'fluffy floors'*

Floors that are subject to bulk water events[3] from above due to the plumbing plan, are evaluated with an initial condition representing a post-water-leak condition as follows:

If the floor assembly contains a water-resistive layer such as a vapor open housewrap weather barrier or outright waterproofing, set the initial water content of layers above the water-resistive layer to twice the equilibrium water content at 90% RH.

If there is no water-resistive layer, set the initial condition of the whole floor assembly to twice the equilibrium water content at 90% RH.

5.7 Control

Set the Calculation period to at least 5 years.

Start the calculation at the beginning of the cold or rainy season for the project location (WUFI Pro default is October 1).

Set Time steps to 1 hour, for the first attempt.

Under Numerics settings, enable 'adaptive time step control' with the default 3 steps and 5 stages max, for the first attempt.

For structures that are radially symmetric (i.e. geodesic dome), select that setting.

6 Post-processing and Evaluation

6.1 Numerical quality check

Problems in the convergence are pointed out by a slow calculation and convergence failures and balances. After the calculation, check the numerical quality, mainly the balances:

[3] Bulk water event sources here includes: water heater failure; floods from dishwashers, clothes washers; sink/tub/toilet overflows; wet-pipe or dry-pipe sprinkler systems; but not incidental beverage spills or water lines to residential freezer ice-makers.

Balance 1: Change in the total water content during the calculation period (negative: drying, positive: moisture accumulation)

Balance 2: Sum of moisture fluxes through the surfaces and released by sources

The balances should normally be small or zero. Numerical errors or inaccuracies can cause water to “appear” or to “disappear” in the assembly (longer periods cause higher differences in balances). IF the differences in the balances are small relative to the total amount of water taken up or dried out, or relative to the total water content, this may be harmless (depends also on the type of construction). High relative and absolute differences in the balances indicate unreliable results.

If there are more than 100 convergence errors in a 5 year simulation, increase the number of steps under Numerics settings ‘adaptive time step control’ or decrease the main step interval on the Calculation Period tab, or increase the fineness of the grid on the Assembly tab, and re-run the calculation.

Assemblies with “metal” cladding may be prone to convergence/balance problems due to condensation that wants to form on one side of the air layer. In that case, try the following – split the air layer in the cavity as follows for e.g., a 20 mm air gap:

0.04 in [1mm] “air layer 20 mm”

0.79 in [18mm] “air layer 20 mm without additional moisture capacity”

0.04 in [1mm] “air layer 20 mm”

6.2 Evaluation procedure

For air-permeable insulation layers in the assembly, examine the graphs of the mass % of water content over time. (Criteria are given below in Section 6.3).

For wood-based layers in the assembly, examine the graphs of the mass % of water content in the 1/8-inch surface layers over time.

Open the assembly in the WUFI Animation 1D and run the animation to determine the location(s) of high RH in the air-permeable insulation materials, e.g the inboard or outboard faces of those layers. (In heating-dominated climates this is typically just inboard of the sheathing.)

For each high-RH point that is also inboard of the water control layer, select each point in turn for VTT analysis. (Select the VTT plug-in in the Animation player, and click on the assembly location at the point to be analyzed. This must be done separately for each location.)

Set VTT inputs:

- Set the Occupant Exposure class to “ASHRAE 160 Requirements.”
- Set the sensitivity class based on the properties of the air-permeable material or the adjacent solid material, whichever is more sensitive.

Table 1. Mold sensitivity classes for various materials

Sensitivity Class	ASHRAE 160 Table 6.1.1 general description	WUFI VTT data
Sensitive	Planed wood, paper-coated products, wood-based boards	Moisture-resistant particle board, OSB, paper-backed gypsum board, typical plywood, PU insulation uncoated, resistant natural fiber materials, untreated pine or spruce heartwood, wall paints for indoor use
Medium resistant	Cement or plastic based materials, mineral fibers	Aerated concrete, concrete, glass wool, lightweight concrete, polyester wool, brick, cement-based materials, mineral fibers, plastic surfaces (smooth), plastic wool, gypsum or lime render, silicate wall paint, coated wooden materials for outdoor use, oak, larch, red cedar
Resistant	Glass and metal products, materials with efficient protective compound treatments	EPS, glass, metal, metal coated surface, foil-faced PU insulation

6.3 Evaluation criteria

As indicated by the graphs of water content in the air-permeable and wood-based layers, the initial dry-out transient must not take too long: the assembly must settle into a regular seasonal cycle by the third year, otherwise vapor drive is not effectively managed. This criterion applies only to light construction and not to e.g., structural masonry/concrete walls with interior wood framing.

The mass % of water content in the 1/8-inch [3 mm] facial subdivisions of wood-based layers (per section 5.3) must remain less than 20%, on a month average basis, after the initial dry-out transient has passed and the assembly has settled into a regular seasonal cycle.

The WUFI VTT “traffic light” must be Green or Yellow. This corresponds to a mold index ≤ 2 throughout the simulation period. (Viitanen et al, 2015).

7 Reporting

Assemble the following documentation:

- The Assembly Notes.

- For WUFI Pro, save a pdf of the Report for each case (this documents most of the input data reporting called for by ASHRAE 160.)
- Save a version of the WUFI file with the inputs only (not the film or time series results) as e.g. "filename_inputs".
- Capture the following time series plots for each case:
    - Water content in the 1/8-inch [3 mm] wood layers examined for wood rot risk in the evaluation.
    - WUFI VTT results for the critical interstitial locations examined for mold growth risk in the evaluation.
    - RH and Temperature plots at same locations evaluated with VTT.
- Write a narrative. This should at least contain a statement of whether the assembly passed or failed, e.g. "The above grade wall 04 is ok."
    - If the assembly or some proposed variant failed, indicate where the trouble was.
    - If the analysis is of an unvented roof, and if it indicates that the roof would not pass if it became a lighter, cooler color, it is recommended to include the following admonishment:

      "It is recommended to affix a plaque to the roof bearing a statement such as the following:

      The roof assembly of this building depends on absorbing heat from the sun in order to stay dry and to avoid problems of moisture accumulation and mold. Therefore when replacing this roofing, do not use white / cool-colored material. Rather, use a material which is at least as dark in color. (Absorption coefficient 0.85 or more, or Solar reflectance index 0.15 or less.)

      El montaje de la azotea de este edificio depende de absorber el calor del sol para mantenerse seco y para evitar problemas de acumulación de humedad y moho. Por lo tanto, al sustituir este material para techos, no utilice el material blanco / color fresco. Más bien, utilizar un material que es al menos tan oscura en color. (Coeficiente de absorción 0,85 o más, o un índice de reflectancia solar de 0,15 o menos.) "

References

ASHRAE. 2016. ANSI/ASHRAE Standard 160-2016, Criteria for Moisture-Control Design Analysis in Buildings.

Lstiburek, J. 2006. BSD-144: Increasing the Durability of Building Constructions. Building Science Corp., December 20, 2006.

PHIUS. 2019. PHIUS+ 2018 Passive Building Standard Certification Guidebook. June 2019.

Viitanen, H.; Krus, M.; Ojanen, T.; Eitner, V.; Zirkelbach, D. 2015. "Mold Risk Classification Based on Comparative Evaluation of Two Established Growth Models." Energy Procedia 78, pp. 1425-1430, 2015.

Finch G, Straube J. 2007. Ventilated Wall Claddings: Review, Field Performance, and Hygrothermal Modeling.Thermal Performance of the Exterior Envelopes of Whole Buildings X International Conference [accessed 2020 Mar 26]; paper 51. https://web.ornl.gov/sci/buildings/conf-archive/2007%20B10%20papers/051_Finch.pdf

Appendix A – Assembly Notes documentation examples

Project: Second floor double-stud wall

Case(s): #1 exposed wall, #2 wall to attic

Documentation file(s): 2nd Floor Double Stud Wall Drawing.jpg

Layer documentation callout (outside to inside)	Modeled as [DB/material]	Note. If used-defined, basis DB/material & modification	Supporting documents
L.P. Smartsiding	NA / Oriented Strand Board		https://www.bobvila.com/articles/525-everything-you-need-to-know-about-engineered-siding/
1x3 furring strips 16" oc create 3/4" rainscreen behind siding	Gnrc / Air Layer 20 mm; w/o add'l m.c.		
5/8 plywood covered with Henry Blueskin vapor permeable weather barrier	IBP / weather resistive barrier (sd=0,1m)	Assumed Blueskin VP100	HE100GUSA_techdata.pdf
	NA / Plywood (USA)		
6" rigid insulation	NA / Expanded Polystyrene Insulation		
¾" plywood	NA / Plywood (USA)		
2x6 wd studs 16" oc with Roxul mineral wool insulation between studs	NA / Roxul CavityRock		CAVITYROCK-Cavity-Wall-and-Rainscreen-Applications-Techdata.pdf
3 ½" space between stud walls with Roxul mineral wool batts laid horizontal	NA / Roxul ComfortBatt		COMFORTBATT-Exterior-Wood-and-Steel-Stud-Thermal-Batt-Insulation-Techdata-US.pdf
2x4 wd studs 16" oc with no insulation	Gnrc / Air Layer 90 mm; w/o add'l m.c.		
½" gyp board	NA / Interior Gypsum Board		

Project: Pitched compact roof

Case(s): 1

Documentation file(s): details_200108_detail5.pdf, catalog sheet_roofing metal color_200109.pdf

Layer documentation callout (outside to inside)	Modeled as [DB/material]	Notes. If used-defined, basis DB/material & modification	Supporting documents
Standing seam metal roofing	Gnrc / Roof Membrane V13		
High temp roof underlayment			
Roof sheathing per structural	NA / Plywood (USA)		
Mineral wool insulation	IBP / Mineral Wool (heat cond.: 0,04 W/mK)		
Nonstructural sheathing (air barrier)	NA / Plywood (USA)		
Rafters per structural, cellulose insulation	IBP / Cellulose Fiber (heat cond.: 0.04 W/mK)		
GWB ceiling	NA / Interior Gypsum Board		
Structural beams beyond	Not modeled		

Project: 7261

Case(s): 12in wall South, 12in wall North

Documentation file(s): email Mar 16.pdf, 2020.02.12_Zzzzz Residence_Full Set for PHIUS (A4.11)

Layer documentation callout (outside to inside)	Modeled as [DB/material]	Note. If user-defined, basis DB/material & modification	Supporting documents
Painted 2x3 tight knot cedar vertical bats	-		
1x12 tight knot cedar boards	NA / Western red cedar		
10mm rainscreen	Gnrc / Air layer 10mm; w/o add'l moisture capacity		
-	NA / Brick, old	0.04 in., for 1% driving rain	
Water resistant barrier	IBP / weather resistive barrier (sd=0.5m)		
¾ in LP Flameblock Fire-Rated OSB sheathing	NA/ Oriented strand board		
BIBs insulation	NA/ Fibre glass		CertainteedOptima.pdf
1/8 in thermo-ply	NA/ Oriented strand board low	Thickness adjusted to 0.173 in. for 0.63 perms. Assumed no foil facing.	Thermo-Ply-Installation-Instructions.pdf
BIBs insulation	NA / Fibre glass		CertainteedOptima.pdf
-	NA / Interior gypsum board		

Project: 4071			
Case(s): at Pavers base case, at Solar panels base case			
Documentation file(s): email Mar 11.pdf, 00 Z St - Passive House Set (2019 11 15)-1.pdf A503(4), A303			
Layer documentation callout (outside to inside)	**Modeled as [DB/material]**	**Note. If user-defined, basis DB/material & modification**	**Supporting documents**
2'x2' concrete pavers on adjustable pedestal deck supports, or Solar Panels	-	Exterior color difference only	
60 mil TPO roofing membrane	Gnrc / Roof Membrane V13		
Rockwool Toprock DD	NA / Roxul Toprock DD		
5/8" roof sheathing	NA / Plywood (USA)		
Blown-in dense pack cellulose	IBP / Cellulose Fiber		
Smart vapor retarder, Intello Plus or similar	IBP / Intello Plus		
-	Gnrc / Air layer 40 mm; w/o add'l moisture capacity		
5/8" gypsum wall board	NA / Interior gypsum board		

Project: 4071

Case(s): Northeast wall, Northeast wall +Intello

Documentation file(s): email Mar 11.pdf, 00 Z St - Passive House Set (2019 11 15)-1.pdf, A501(1)

Layer documentation callout (outside to inside)	Modeled as [DB/material]	Note. If user-defined, basis DB/material & modification	Supporting documents
Existing 3-wythe brick exterior wall	NA / Brick, old		
Sto Coat Gold or similar	IBP / weather resistive barrier (sd=0.2m)	Sto Gold 19 perm wet cup. Sd ~ 3.28/19 perm = 0.17 m	PB_81636_Sto_Gold Coat_EN.pdf
Two (2) layers 2" Rockwool Comfortboard 80	Roxul FacadeRock	Closest match to 8 lb/ft3 density, thickness increased 5% to match R-value	COMFORTBOARD-80-Non-Structural-Sheathing-Continuous-Insulation-Techdata.pdf
Blown-in cellulose fill insulation	NA / Cellulose Fibre Insulation		
Smart membrane	IBP / Intello		
5/8" gypsum wall board	NA/ Interior gypsum board		

Project: 7261			
Case(s): Bright East, Bright West, Dark East, Dark West			
Documentation file(s): 2020.02.12_Zzzzz Residence_Full Set for PHIUS (A4.02, A4.11)			
Layer documentation callout (outside to inside)	**Modeled as [DB/material]**	**Note. If user-defined, basis DB/material & modification**	**Supporting documents**
Mtl. roof	-		
Grace Ice & Water HT	Gnrc / Roof Membrane V13		
2" Rmax Thermasheath-R Deck (R10.2)	NA / Polyisocyanurate Insulation	Thickness adjusted to 1.7 in to match specified R-value	Not a current product?
Plywood sheathing S.S.D.	NA / Plywood (USA)		
Min. 11 ¼" dense pack Optima BIBS insulation R4.2/in (R-47.25)	NA/ Fibre Glass		CertainteedOptima.pdf
-	Gnrc / Air layer 150 mm; w/o add'l moisture capacity	Actual air gap ~ 220 mm (8.75in)	
¾" T&G wood finish	NA/ Hardwood		