WUFI

hygrothermal simulation software

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importance of hygrothermal analysis

1. Increasingly complex assemblies
2. Decreased tolerance for moisture of materials
3. Decreased drying potential of assemblies

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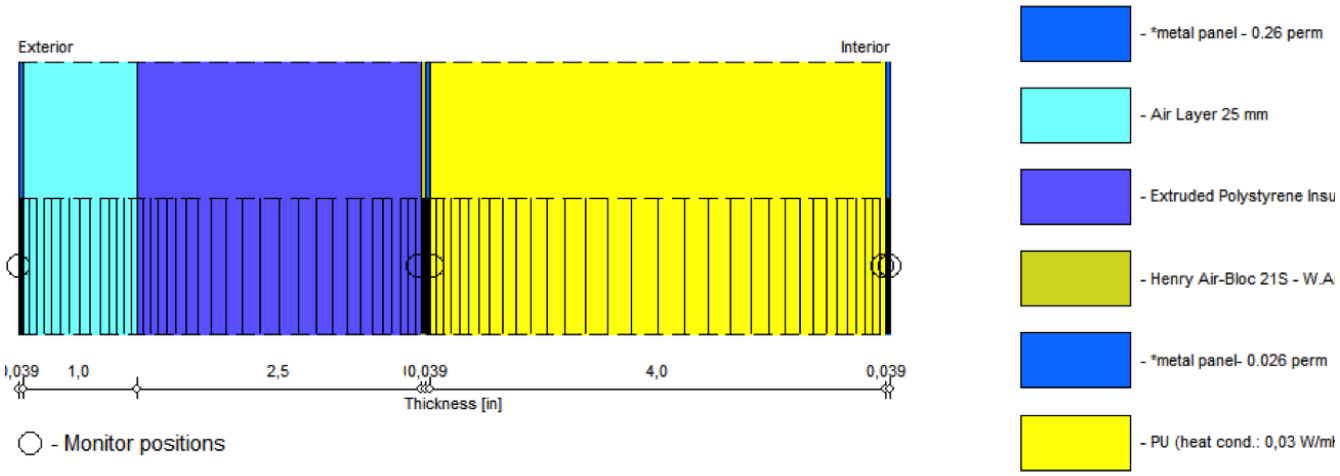
what does WUFI do?

User inputs the wall assembly, interior and exterior climate conditions and the computer plots temperature and relative humidity and moisture content of each component for each hour over a set period of time.*

WUFI Wall Assembly - Sample



* simplified description

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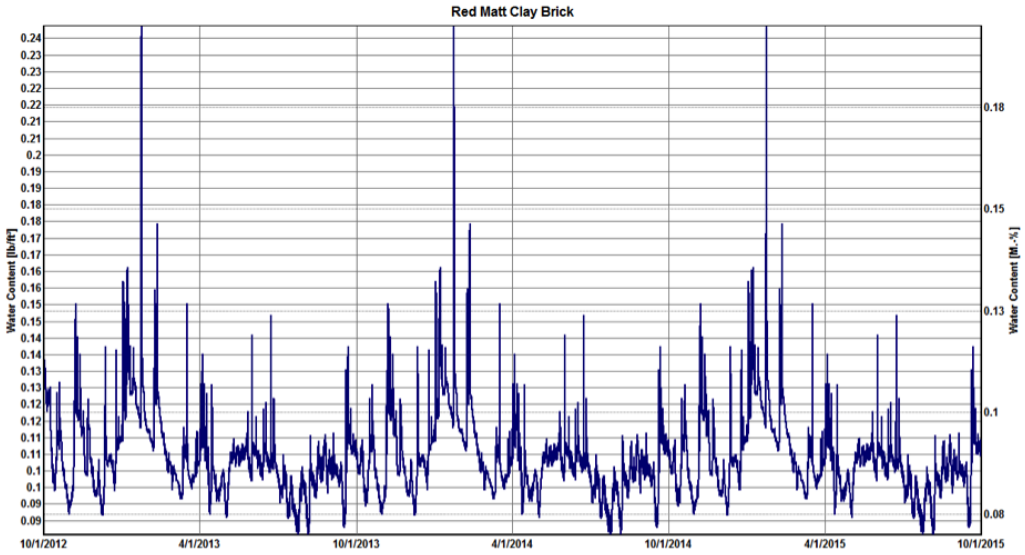
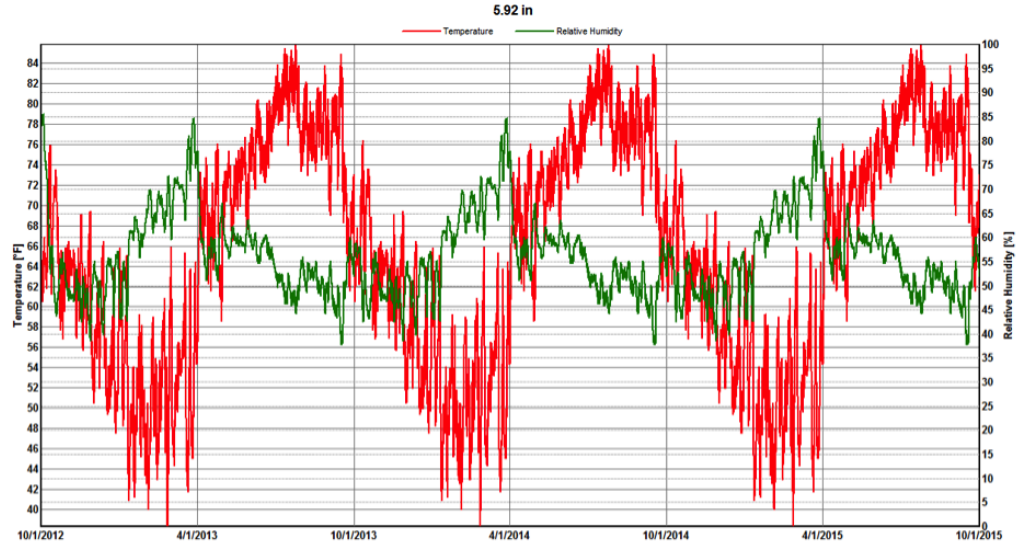
WUFI outputs



Water Content



Temperature
& Relative Humidity

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mechanisms of heat transfer

1. Convection

   bulk movement of fluid (liquid or gas)

2. Conduction

   direct contact of solid, liquid or gas

3. Radiation

   flow of electromagnetic waves through a gas, vacuum or porous materials

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mechanisms of moisture transfer*

1. Liquid transport
   - Movement of clusters of water molecules
   - Direction of flow is dependent on gravity, wind, momentum, etc.
   - Examples: rain, groundwater, capillarity
2. Vapor diffusion
   - Movement of water molecules through materials
   - Direction of flow is dependent on a concentration gradient (more to less) and a thermal gradient (hot to cold)
3. Air transport
   - Movement of air carrying water molecules
   - Requires a path and a pressure difference
   - Direction of flow is from more to less pressure

* There are other mechanisms of moisture transfer (ex: surface diffusion, liquid diffusion), however for the purposes of analyzing moisture transfer in buildings the three listed above are most significant.

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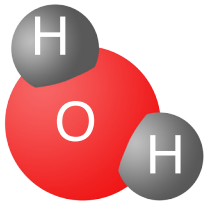
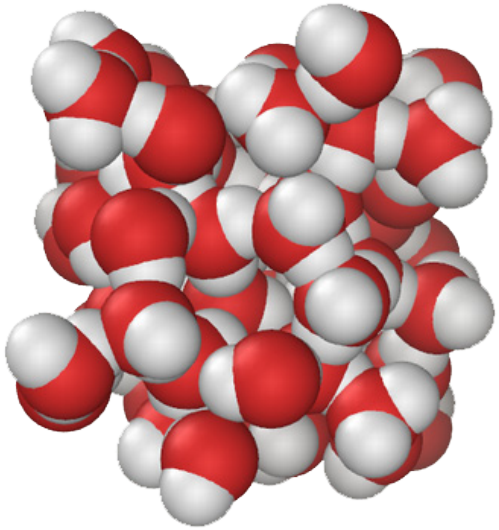
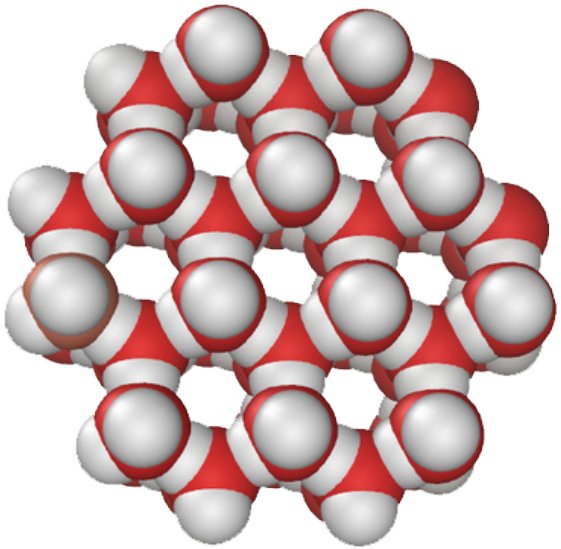
states of water

SEM image of semi-permeable membrane
(vapor open, liquid & air closed)







Vapor
H_2O

Liquid
$H_{150}O_{75}$

Solid

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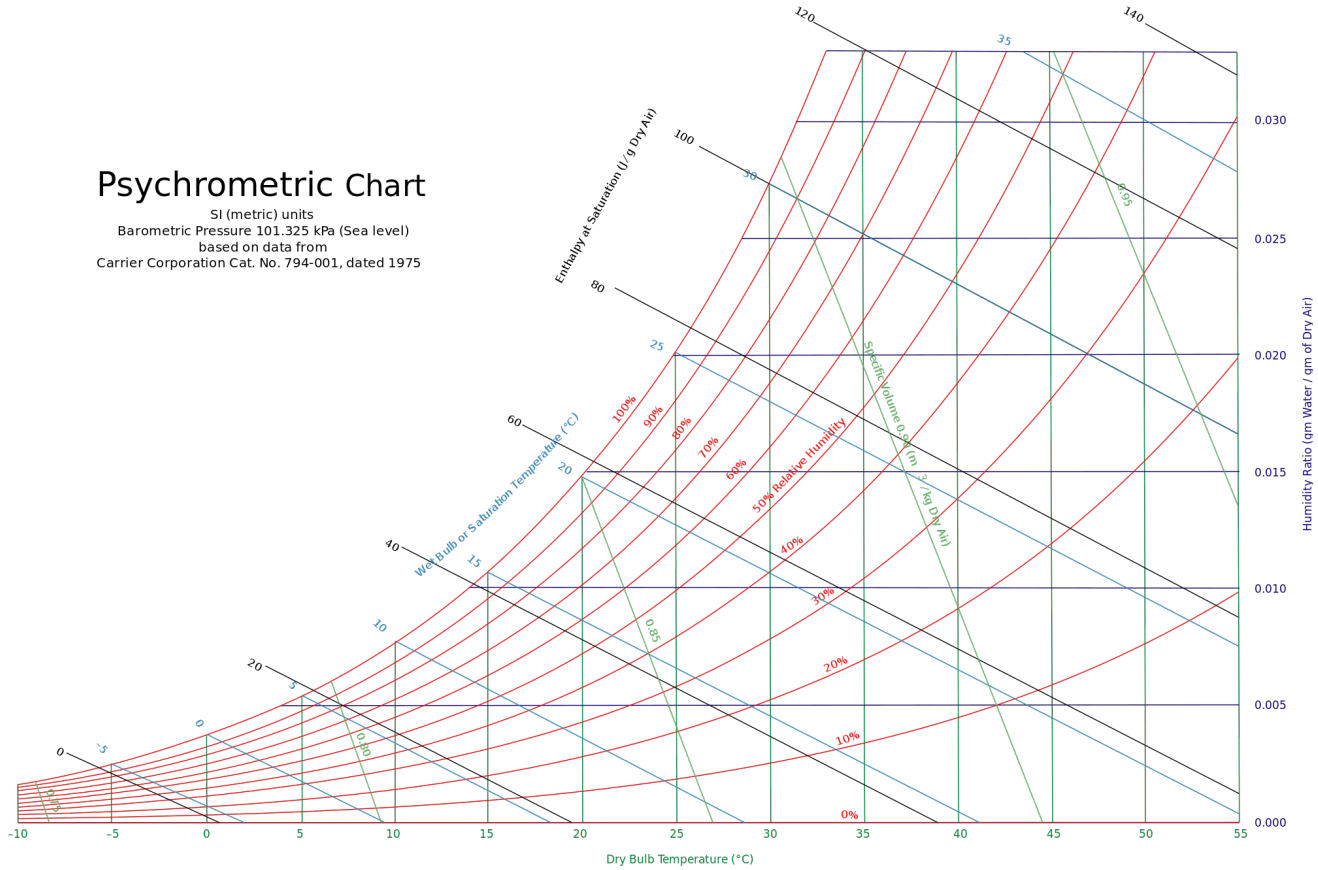
thermodynamic potential of water

www.carrier.com

Willis Carrier



www.wikipedia.com

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✓ Reasonably reliable estimate possible

? Difficult to estimate

confidence in WUFI estimate / user estimate

sources of heat and moisture

? 1. Initial Conditions

initial temperature and moisture content of materials

✓ 2. Environmental conditions

a. External environment (climate): temperature, relative humidity, rainfall (below grade: groundwater)

b. Interior environment: temperature, relative humidity dependent on occupant behavior: breathing, cooking, showering, using appliances, etc.

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factors influencing how assembly responds to heat & moisture

✓ 1. Material properties of each component

thermal conductivity (moisture & temperature dependent), water storage capacity, liquid transport redistribution, liquid transport suction, permeability (moisture dependent),

✓ 2. Organization within the assembly

exposure to climate conditions and other layers within the assembly

✓ 3. Exposure of assembly

orientation (north, south, east, west; wall or roof)

factors influencing how assembly responds to heat & moisture

4. Mechanisms of heat transfer within component & assembly
   - ? a. convection (air flow)
   - ✓ b. conduction
   - ✓ c. radiation
5. Mechanisms of moisture transfer within component & assembly
   - a. liquid transport
     - ? i. rain
     - ? ii. groundwater
     - ✓ iii. capillarity
   - ✓ b. vapor diffusion
   - ? c. air transport

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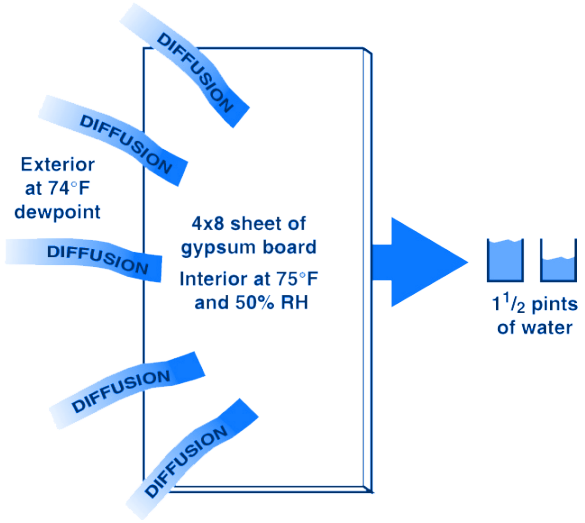
vapor diffusion



diffusion

✓

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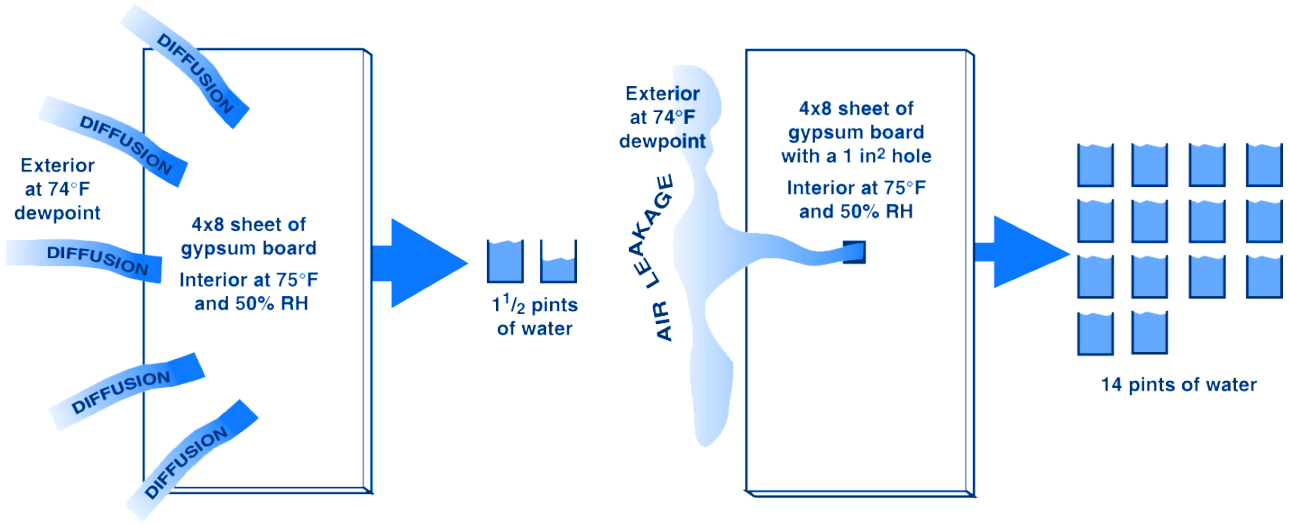
vapor diffusion vs air leakage



diffusion ✓

air leakage ?

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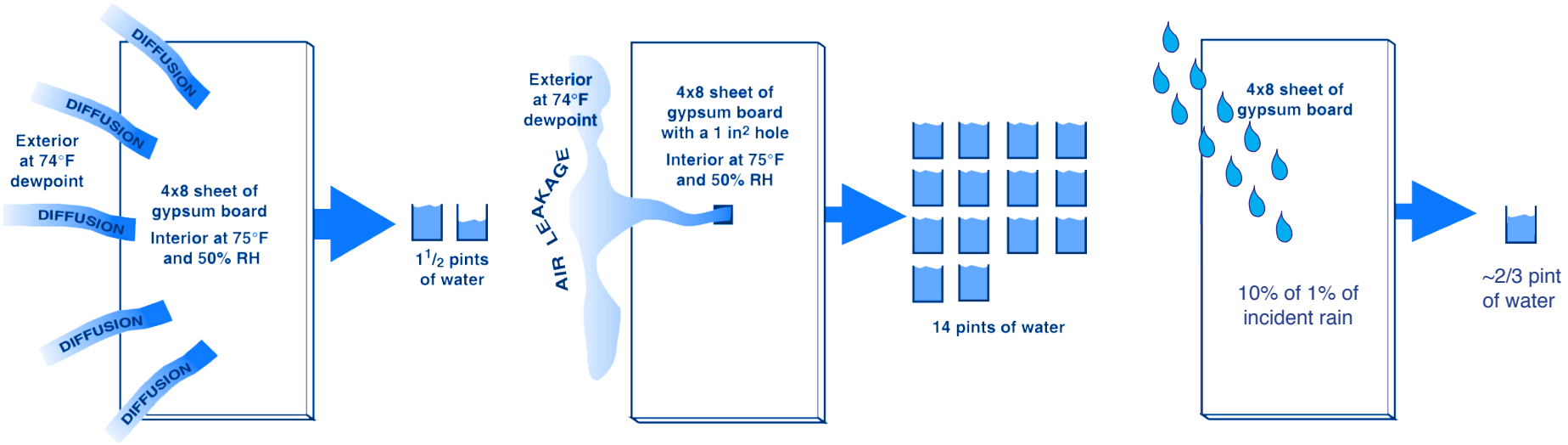
vapor diffusion vs air leakage vs bulk transport*



diffusion ✓

air leakage ?

bulk transport ?

*Diffusion & air leakage graphic courtesy of Lstiburek, "Builder's Guide to Hot Humid Climates" (2006); bulk transport graphic from C. Cronin, approximation based on 1% incident rain penetrating cladding (ASHRAE 160P) and10% of that entering the wall cavity. Calculations (all cases) based on climate data for Atlanta, GA.

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The most influential factors affecting the hygrothermal performance of the wall are:

(1) the hardest to estimate and,
(2) at the discretion of the modeler

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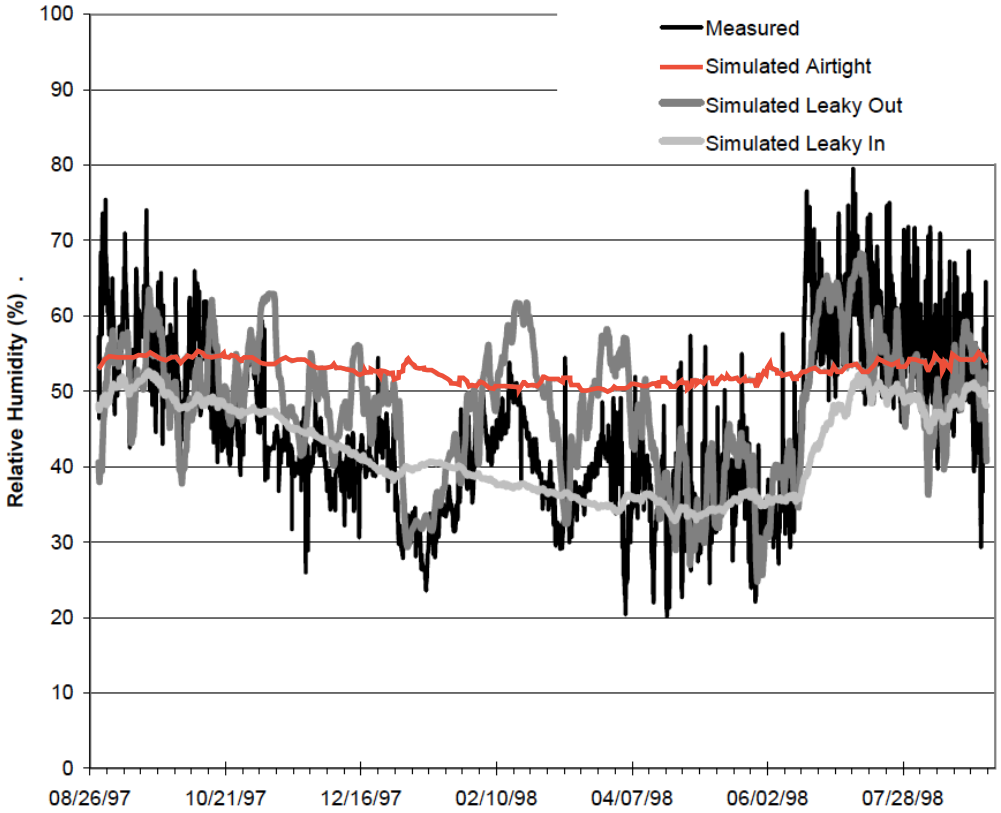
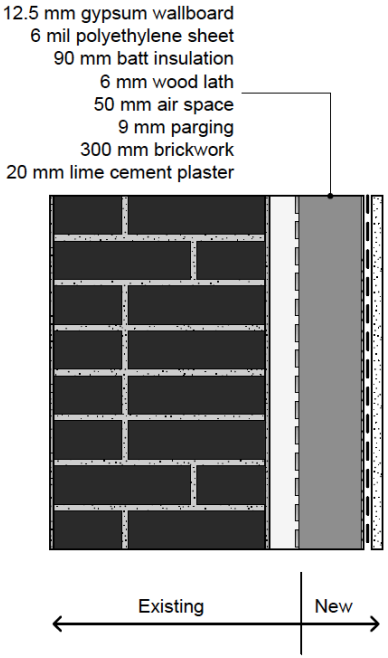
modeled results vs measured data



Comparison of measured and simulated RH behind masonry for various leakage scenarios

CMHC Study: Prince Albert Masonry Retrofit



Straube & Schumacher, "Comparison of Modeled and Monitored Performance of a Wall Insulation Retrofit in a Solid Masonry Building" (2003), http://cmhc.gc.ca/

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challenges and limitations

- Accounting for liquid transport of water
- Accounting for air leakage
- Limited knowledge of material properties
- Limited knowledge of boundary conditions
- Limited knowledge of material tolerances

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