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# *Air retarders, vapor retarders and attic ventilation*

**Mark S. Graham**
Vice President, Technical Services
National Roofing Contractors Association
Rosemont, Illinois

## My topics

- Principles/fundamentals (for roofing)
- Condensation control:
  - Low-slope roof assemblies
  - Steep-slope roof assemblies
- Air retarders

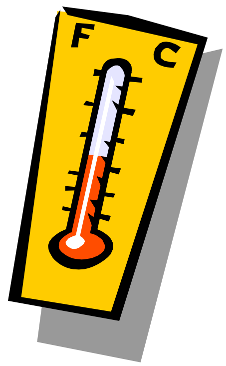
## Principles/fundamentals

## Moisture sources in buildings

- Construction moisture
- Building occupancy
- Building envelope infiltration
- Reflective roof coverings

## Phases of moisture

- **Gas phase** -- moisture vapor
  - Above 212 F
- **Liquid phase** -- water
  - 32 F to 212 F
- **Solid phase** -- frost or ice
  - Below 32 F

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## Humidity

The amount of water vapor in the air.

## Relative humidity

Relative humidity is defined as the ratio of the partial pressure of water vapor in a parcel of air to the saturated vapor pressure of water vapor at a prescribed temperature.

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## Condensation temperature

## ~~Dew point~~

The temperature at which the air can no longer hold all of its water vapor, and some of the water vapor must condense into liquid water.

*At 100% relative humidity, the dew point temperature and real temperature are the same, and condensation begins to form.*

## Comparing humidity & dew point

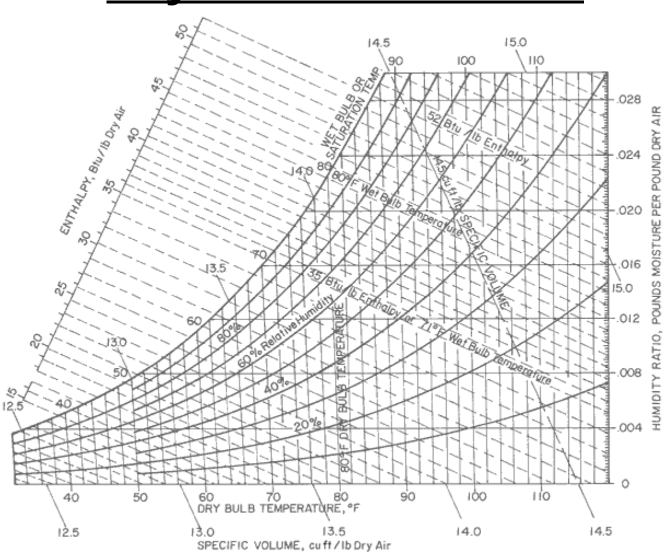
While relative humidity is a relative measure of how humid it is, the dew point temperature is an absolute measure of how much water vapor is in the air (how humid it is).

## Psychrometrics

The field of engineering concerned with the determination of physical and thermodynamic properties of gas-vapor mixtures.

Derived from the Greek *psuchron* meaning "cold" and *metron* meaning "means of measurement".

## Psychrometric chart



# Psychrometric chart "table"

| Dew-Point Temperature (°F) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Relative Humidity** | **Design Dry Bulb (Interior) Temperature (°F)** | | | | | | | | | | | | | | |
| | **32°F** | **35°F** | **40°F** | **45°F** | **50°F** | **55°F** | **60°F** | **65°F** | **70°F** | **75°F** | **80°F** | **85°F** | **90°F** | **95°F** | **100°F** |
| 100% | 32 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
| 90% | 30 | 33 | 37 | 42 | 47 | 52 | 57 | 62 | 67 | 72 | 77 | 82 | 87 | 92 | 97 |
| 80% | 27 | 30 | 34 | 39 | 44 | 49 | 54 | 58 | 64 | 68 | 73 | 78 | 83 | 88 | 93 |
| 70% | 24 | 27 | 31 | 36 | 40 | 45 | 50 | 55 | 60 | 64 | 69 | 74 | 79 | 84 | 88 |
| 60% | 20 | 24 | 28 | 32 | 36 | 41 | 46 | 51 | 55 | 60 | 65 | 69 | 74 | 79 | 83 |
| 50% | 16 | 20 | 24 | 28 | 33 | 36 | 41 | 46 | 50 | 55 | 60 | 64 | 69 | 73 | 78 |
| 40% | 12 | 15 | 18 | 23 | 27 | 31 | 35 | 40 | 45 | 49 | 53 | 58 | 62 | 67 | 71 |
| 30% | 8 | 10 | 14 | 16 | 21 | 25 | 29 | 33 | 37 | 42 | 46 | 50 | 54 | 59 | 62 |
| 20% | 6 | 7 | 8 | 9 | 13 | 16 | 20 | 24 | 28 | 31 | 35 | 40 | 43 | 48 | 52 |
| 10% | 4 | 4 | 5 | 5 | 6 | 8 | 9 | 10 | 13 | 17 | 20 | 24 | 27 | 30 | 34 |

Adapted from ASHRAE Psychrometric Chart, *1993 ASHRAE Fundamentals Handbook*.

*Warm air can hold more moisture than cold air*

## Thermodynamics

In physics, the study of energy conversion between heat and mechanical work, and subsequently the macroscopic variables such as temperature, volume and pressure.

Derived from the Greek *therme* meaning "heat" and *dynamis* meaning "power".

## First law of thermodynamics

Energy can be transformed (changed from one form to another), but cannot be created or destroyed.

*Law of conservation of energy*

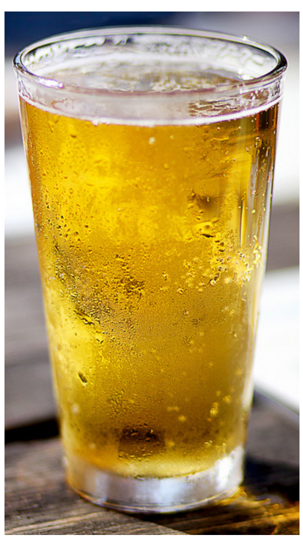
*Solid → Liquid → Gas → Liquid → Solid…*

## Second law of thermodynamics

The entropy of an isolated system which is not in equilibrium will tend to increase over time, approaching a maximum value at equilibrium.

*Heat → Cold*

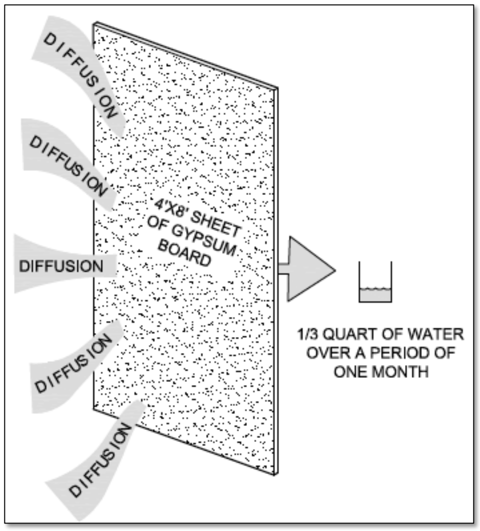
## A practical application…



Is the glass "leaking"?

No!  We're just studying thermodynamics

## Diffusion




## Diffusion terminology

**Permeability:** the time rate of vapor transmission through a flat material of a unit thickness induced by vapor pressure difference between two specific surfaces under specified temperature and humidity.

Expressed as "perm-inch" units

## Diffusion terminology

**Permeance:** the time rate of vapor transmission through a flat material or construction assembly induced by vapor pressure difference between two specific surfaces under specified temperature and humidity.

Expressed as "perm" units

| Material | Permeance (perm)[1] | Permeability (perm•inch)[1] |
| --- | --- | --- |
| **Construction materials:** | | |
| Concrete (1:2:4 mix) | | 3.2 |
| Brick masonry (4 in. thick) | 0.8 | |
| Concrete block (8 in. thick, cored) | 2.4 | |
| Plaster on metal lath (¾ in. thick) | 15 | |
| Plaster on wood lath | 11 | |
| Gypsum wall board (⅜ in. thick, plain) | 50 | |
| Hardboard (⅛ in. thick, standard) | 11 | |
| Built-up roof membrane (hot applied) | 0.0 | |
| Plywood (¼ in. thick, Douglas fir, exterior glue) | 0.7 | |
| Plywood (¼ in. thick, Douglas fir, interior glue) | 1.9 | |
| **Thermal insulation materials:** | | |
| Air (still) | | 120 |
| Cellular glass | | 0 |
| Expanded polystyrene | | 2.0-5.8 |
| Extruded polystyrene | | 1.2 |
| Mineral wool (unprotected) | | 116 |
| **Plastic and metal foils and films:** | | |
| Aluminum foil (0.001 in. thick) | 0.0 | |
| Polyethylene (0.004 in. thick) | 0.08 | |
| Polyethylene (0.006 in. thick) | 0.06 | |
| **Building paper, felts, roofing papers:** | | |
| Saturated and coated roll roofing (65 lbs./100 ft.$^2$) | 0.05 | |
| Kraft paper and asphalt laminated, reinforced (6.8 lbs./100 ft.$^2$) | 0.3 | |
| 15-lb. asphalt felt | 1.0 | |
| 15-lb. tar felt | 4.0 | |
| Asphalt (2 oz./ft.$^2$) | 0.5 | |
| Asphalt (3.5 oz./ft.$^2$) | 0.1 | |
| Self-adhering polymer-modified bitumen membrane (0.040 in. thick) | 0.1[2] | |

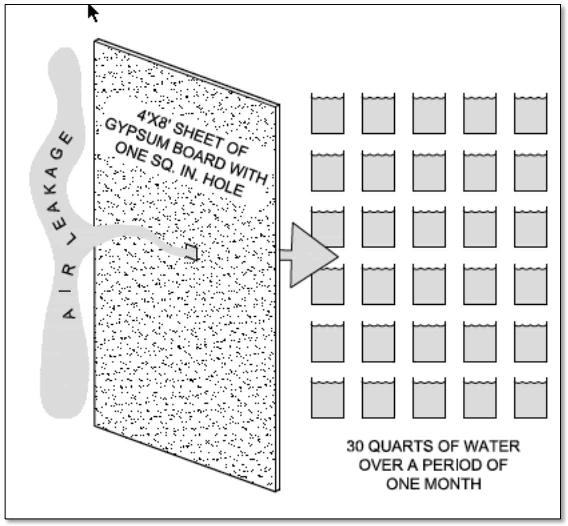
## Vapor retarders

| Classification | Permeance |
|---|---|
| Class I vapor retarder | 0.1 per or less |
| Class II vapor retarder | 1.0 perm or less, and greater than 0.1 perm |
| Class III vapor retarder | 10 perm or less, and greater than 1.0 perm |
| Permeance determined according to ASTM E96, Test Method A (desiccant method or dry cup method) | |

*NRCA recommends effective vapor retarders have perm-ratings of 0.5 or less*

*Vapor retarder continuity is critical.*

## Air leakage



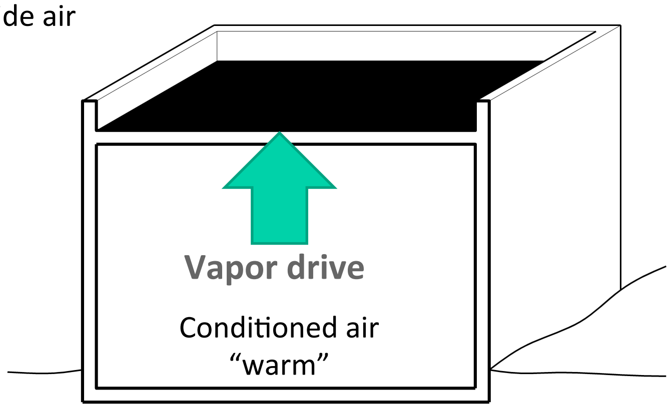

Note: Compared to ⅓ quarter by diffusion (~100 X)

*Air leakage, not vapor diffusion, can and does cause most of the moisture problems building envelopes suffer.*

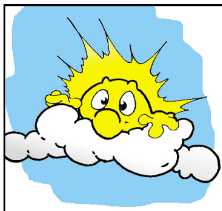
*Now, pulling all these principles and fundamentals together into a roofing-specific example….*

Cold outside air

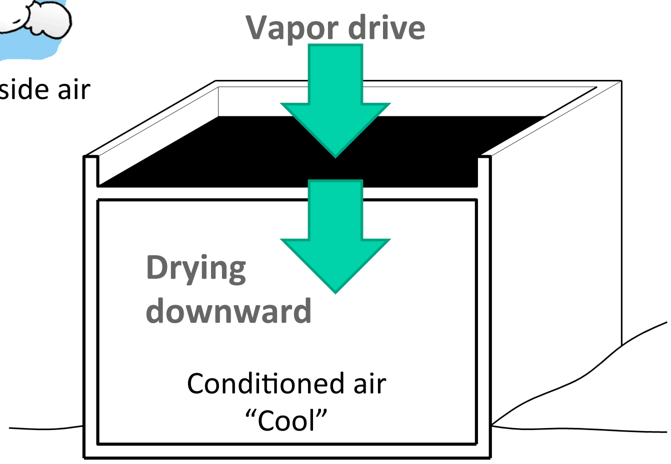
**Winter conditions**



## Summer conditions



Warm outside air




*"Self-drying" roof assembly*

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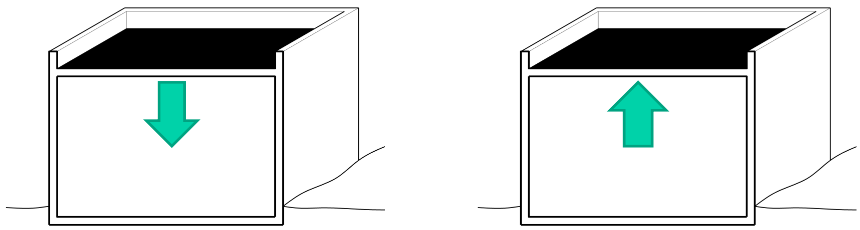
*Historically, most roof systems have effectively performed as "self-drying roofs"…*

*Self-drying roofs function properly if…*

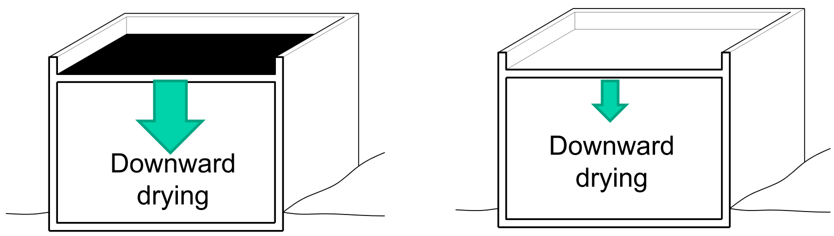


**Downward drying ≥ Moisture pick-up**

## <u>Unintended consequences</u>

Unintended consequences are outcomes that are not the results originally intended by a particular action.

*The unintended results may be foreseen or unforeseen, but they should be the logical or likely results of the action*




**"Non-cool" roof**

**"Cool" roof**

*Cool roofs do not dry-down as efficiently as "non-cool" roofs*

## Recommendations

Self-drying "cool" roofs

- Adhered roof covering (membrane)
- 2 or more layers of insulation
- Off-set board joints on insulation

--or--

- Don't rely on the "self-drying" concept:
  - Consider providing for a properly-placed vapor retarder

## Vapor retarder guidelines for condensation control

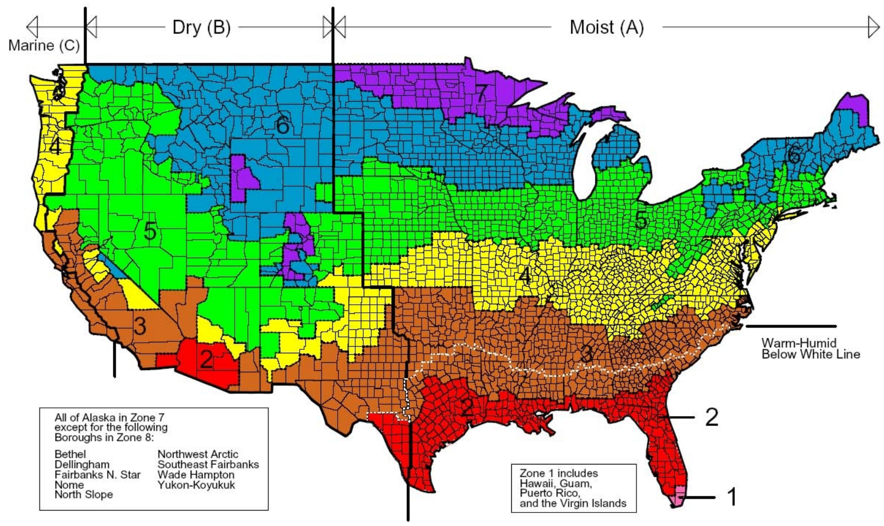
Low-slope roof assemblies

## Vapor retarders should be considered

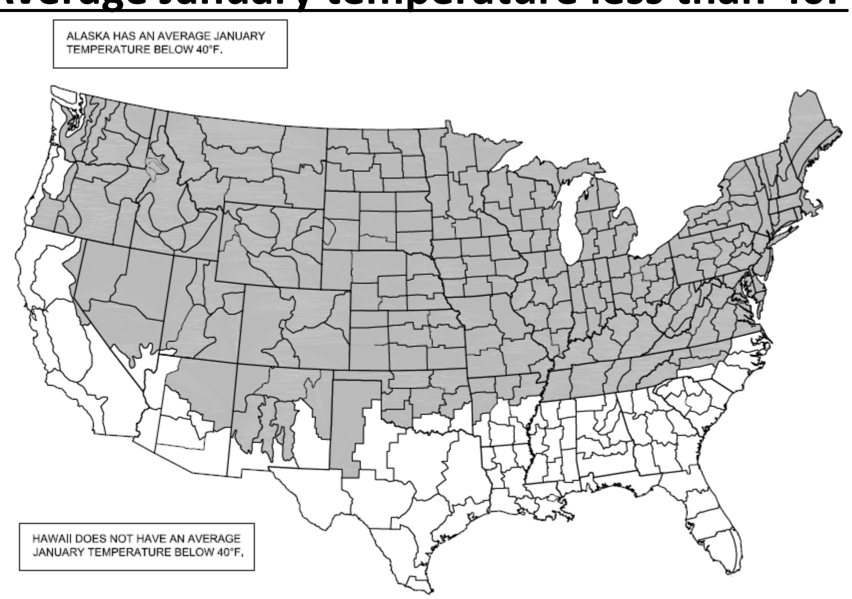
Low-slope roof assemblies

- Climate Zones 6A, 7 or 8
- High interior humidity occupancies (swimming pools)
- Coldest month < 40 F, interior RH ≥ 45%
  - US Army CRREL method enhancement
- Cold storage/freezer buildings (vapor retarder will function as an air barrier)

## Climate zone map




## Average January temperature less than 40F



## US Army CRREL method

Vapor retarder determination
(CRREL: Cold Regions Research and Engineering Laboratory)

Enhances the "Coldest month < 40 F, interior RH ≥ 45%" guideline:

- Applies to adhered roof coverings (only)
- Provides interior RH thresholds for throughout the U.S. (68 F design interior temperature)
- Provides RH threshold corrections for design interior temperatures other than 68 F

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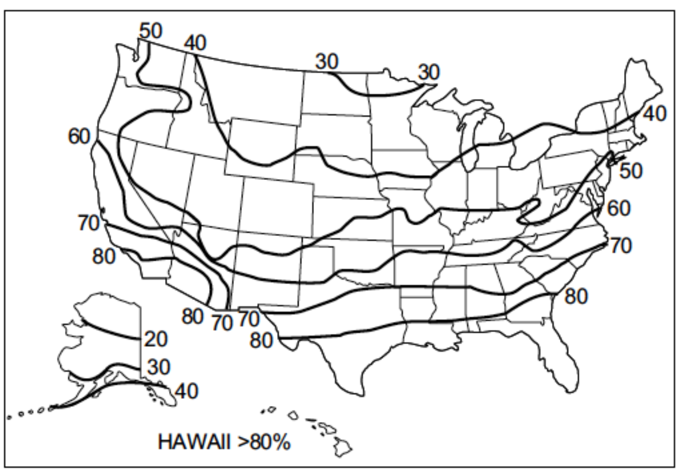
## US Army CRREL method

Vapor retarder determination




Maximum allowable design interior humidity
(before use of a vapor retarder is suggested)

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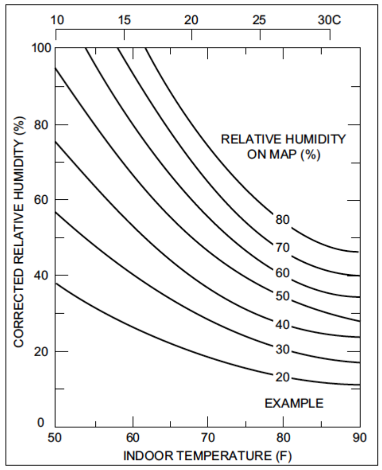
## US Army CRREL method

Vapor retarder determination




Temperature correction
(other than 68 F)

## Vapor retarder fundamentals

- Evaluate the dew point temperature during winter design conditions (in North America)
- To prevent the formation of condensation on the interior side of a vapor retarder, the temperature at the vapor retarder level must be warmer than the dew point temperature.

*Position the vapor retarder as close to the "warm side" as possible.*

## Determining necessary R-value above a vapor retarder layer

Fundamental equation:

$$R_o = \frac{R_i\,(T_{dp} - T_o)}{(T_i - T_o) - (T_{dp} - T_o)}$$

where:

$R_o$ = R-value on the exterior side of the vapor retarder

$R_i$ = R-value on the interior side of the vapor retarder

$T_{dp}$ = Design dew point temperature

$T_o$ = Design outside temperature

$T_i$ = Design inside temperature

## Determining necessary R-value above a vapor retarder layer

Steps:

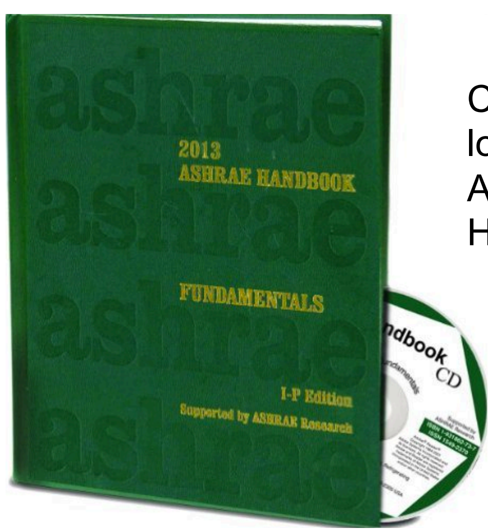
1. Determine $T_o$ using the winter design dry bulb
2. Determine $T_{dp}$ using $T_i$ and the design RH
3. Determine $R_o$ and $R_i$, and solve for $R_{INSUL}$

## An example

Scenario:

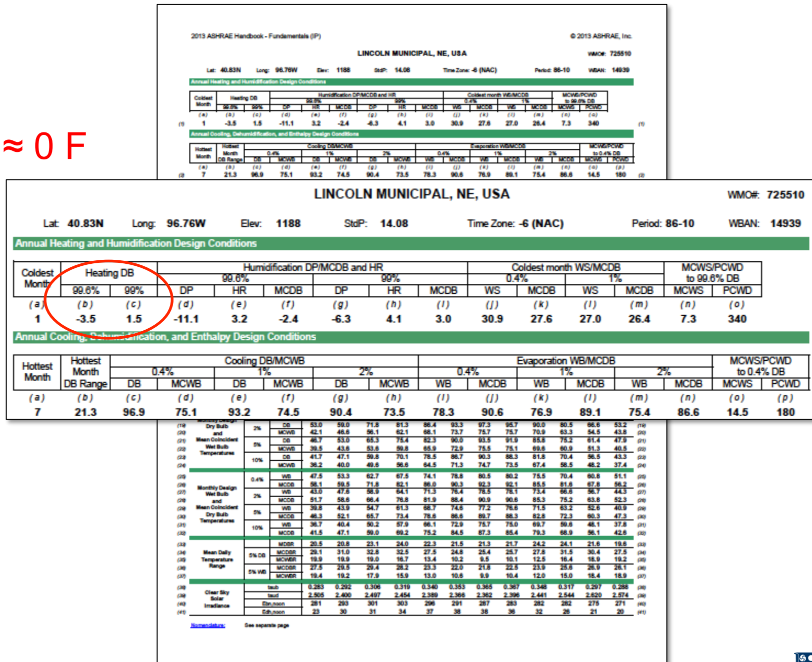
- Lincoln, NE ($T_o$ = 0 F)
- Interior design conditions: 75 F and 60% RH
- Roof assembly:
  - Single-ply roof membrane
  - Rigid board insulation ($R_{INSUL}$)
  - Kraft paper vapor retarder
  - 2½-inch-thick wood plank deck

## Determine $T_o$ using the winter design dry bulb




Climatic data for 1,445 locations is provided in ASHRAE's Fundamentals Handbook

$T_o \approx 0$ F



LINCOLN MUNICIPAL, NE, USA — WMO#: 725510

Lat: 40.83N — Long: 96.76W — Elev: 1188 — StdP: 14.08 — Time Zone: -6 (NAC) — Period: 86-10 — WBAN: 14939

**Annual Heating and Humidification Design Conditions**

| Coldest Month | Heating DB | | Humidification DP/MCDB and HR | | | | | | Coldest month WS/MCDB | | | | MCWS/PCWD to 99.6% DB | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 99.6% | | | 99% | | | 0.4% | | 1% | | | |
| | 99.6% | 99% | DP | HR | MCDB | DP | HR | MCDB | WS | MCDB | WS | MCDB | MCWS | PCWD |
| (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) | (j) | (k) | (l) | (m) | (n) | (o) |
| 1 | -3.5 | 1.5 | -11.1 | 3.2 | -2.4 | -6.3 | 4.1 | 3.0 | 30.9 | 27.6 | 27.0 | 26.4 | 7.3 | 340 |

**Annual Cooling, Dehumidification, and Enthalpy Design Conditions**

| Hottest Month | Hottest Month DB Range | Cooling DB/MCWB | | | | | | Evaporation WB/MCDB | | | | | | MCWS/PCWD to 0.4% DB | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.4% | | 1% | | 2% | | 0.4% | | 1% | | 2% | | | |
| | | DB | MCWB | DB | MCWB | DB | MCWB | WB | MCDB | WB | MCDB | WB | MCDB | MCWS | PCWD |
| (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) | (j) | (k) | (l) | (m) | (n) | (o) | (p) |
| 7 | 21.3 | 96.9 | 75.1 | 93.2 | 74.5 | 90.4 | 73.5 | 78.3 | 90.6 | 76.9 | 89.1 | 75.4 | 86.6 | 14.5 | 180 |

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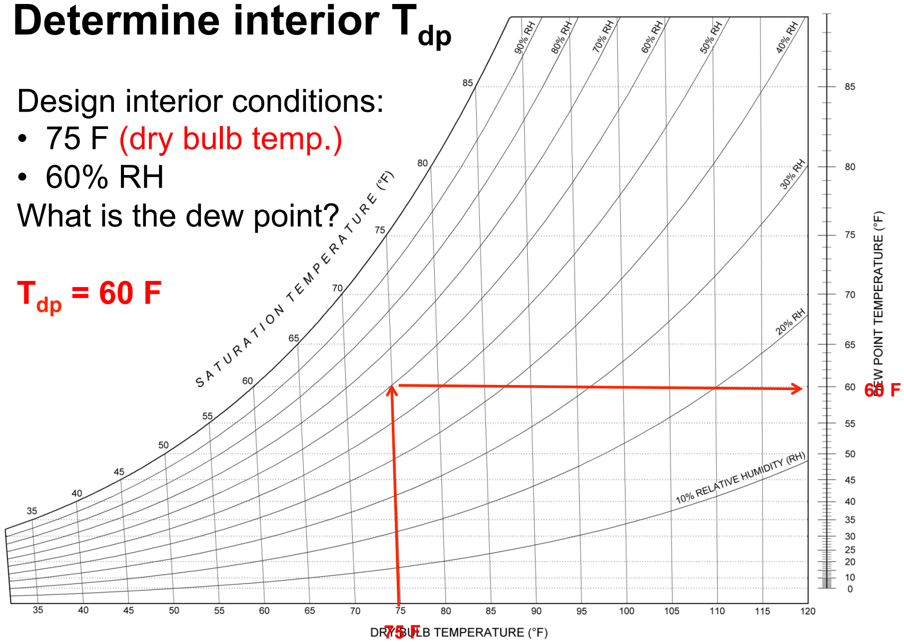
# Determine interior $T_{dp}$

Design interior conditions:

- 75 F (dry bulb temp.)
- 60% RH

What is the dew point?

$T_{dp} = 60$ F



## Determine $R_o$ and $R_i$

| Component | $R_o$ | $R_i$ |
|---|---|---|
| Outside air film ($f_o$) | 0.17 | -- |
| Membrane | 0.24 | -- |
| Insulation | Unknown ($R_{INSUL}$) | -- |
| Kraft paper vapor retarder | 0.12 | -- |
| 2½ inch wood deck | -- | 2.32 |
| Inside air film ($f_i$) | -- | 0.62 |
| **Total** | **0.53 + $R_{INSUL}$** | **2.94** |

## Solve for $R_{INSUL}$

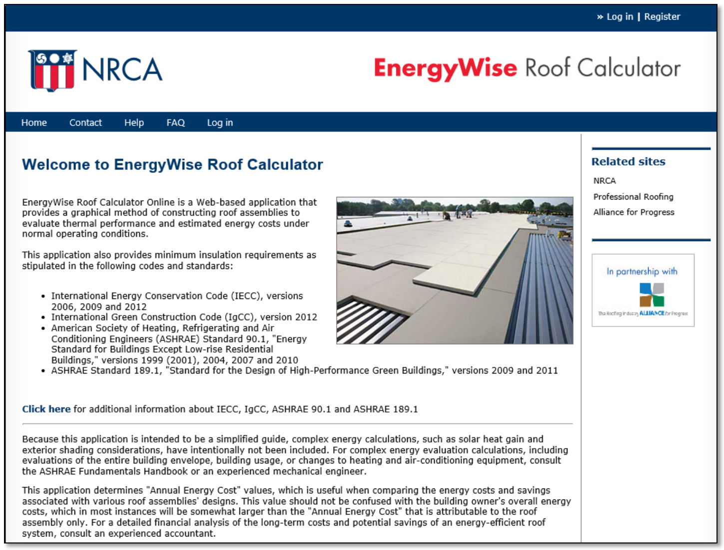
$$R_o = \frac{R_i\,(T_{dp} - T_o)}{(T_i - T_o) - (T_{dp} - T_o)}$$

$$0.53 + R_{INSUL} = \frac{2.94\,(60 - 0)}{(75 - 0) - (60 - 0)}$$

$$R_{INSUL} = 11.76$$

*Insulation with an R = 11.76 (or greater) is needed above the vapor retarder to prevent condensation*

## energywise.nrca.net




## Vapor retarder materials

- Bituminous vapor retarders:
  - Two plies of ASTM D2178, Type IV felt in moppings of hot asphalt
  - Polymer-modified bitumen sheet
- Non-bituminous vapor retarders:
  - Plastic sheets or films
  - Kraft paper or aluminum foil combinations

## Some additional considerations

Vapor retarder placement

- Board joints in rigid board insulation
- Mechanical fasteners

## Board joints

Heat loss through gaps at the joints between insulation boards can represent up to a 10% reduction in effective R-value

*A two-layer application of rigid board insulation with staggered and offset board joints is recommended*

## Mechanical fasteners

Mechanical fasteners through the cross-section of rigid board insulation can represent 3% to 8% losses in effective R-values.

*Mechanically-attach the bottommost layer and adhere subsequent layers with offset board joints.*

## Cooler and freezer buildings


TECH TODAY

### Design challenges

Cooler and freezer building designs present unique situations for roof system designers

by Mark S. Graham

Unlike most building types where interior environments are relatively moderate, interior conditions in cooler and freezer buildings often are the same or worse than typical exterior winter conditions. As a result, roof system designers of cooler and freezer buildings are presented with some unique design challenges and decisions.

Sound engineering is necessary when designing cooler and freezer buildings

#### Design considerations

In addition to typical considerations for conventional buildings, there are at least three fundamental design considerations that need to be resolved when designing buildings for low-temperature operations, such as coolers or freezers:

- Compensating for building thermal movement and avoiding potential damage to the roof system caused by thermal contraction and expansion
- Determining how much thermal insulation (R-value) is needed
- Controlling air and water vapor movement within a roof assembly and deciding whether to use one or more air and vapor retarders

#### Thermal movement

The conditions under which a cooler and freezer building will be constructed and subsequently operate need to be considered. For example, suppose a freezer building is 100 feet long and 200 feet wide with walls 20 feet high. If the building's structural framework is erected during the summer when the outdoor temperature is 70 F, the building's framework may be square and true.

When the building is put into operation and its interior and structural framework cools to the building's internal operating temperature, which can be about -20 F, the lateral framework may contract about ¾ of an inch because of thermal movement and longitudinal members may contract about 1½ inches. Also, the stresses created by these movements are considerable and typically will be greatest at the building's corners. Thermal movement and stresses also can significantly affect a roof system if not properly addressed.

Sound engineering judgement is necessary when designing the structural framework for cooler and freezer buildings to address thermal movement and stresses. NRCA suggests placing structural expansion joints to divide the building envelope into relatively square (and not rectangular) segments. Also, the design of expansion joints can be critical.

#### Thermal insulation

Determining how much thermal insulation (R-value) is necessary within a roof system also needs to be closely evaluated. In typical situations, roof surface temperatures during summer months can be as high as 160 F depending on the cooler or freezer building's geographic location and roof color. Interior temperatures on cooler or freezer buildings may be held at -20 F for months, or the space may not be in use and the refrigerating equipment may not be operating. The resulting interior-to-exterior temperature differential through a roof assembly may be as high as 180 F.

Calculating the temperature and vapor pressure gradients across a roof assembly (and wall assembly) may be useful.

When selecting specific insulation types to achieve necessary R-values, designers also need to consider the insulation's in-service temperature within the assembly's temperature gradient. Polyisocyanurate insulation, for example, has a relatively high R-value at 75 F but notably decreased R-values at lower or higher temperatures.

#### Air and vapor retarders

Also, designers need to consider the placement of a vapor retarder and possibly a separate air retarder.

For cooler and freezer buildings, there is no question the most effective location for a vapor retarder is on the outside of the insulation—a continuous, adhered roof membrane can serve this purpose. The only time there will be a reversal of vapor drive direction is when the exterior temperature drops below the interior temperature; these conditions would need to exist for long time periods before a reverse vapor pressure differential could cause vapor migration damage.

Special consideration also needs to be given to designing roof-to-wall junctures, building expansion joints and any roof system penetrations to ensure air and vapor seals are continuous. The roof system's vapor retarder layer should be made continuous with and be interconnected to the vapor retarder of the wall system.

Failure to provide a continuous vapor barrier and air seal will result in moisture infiltration and accumulation of ice on interior surfaces.

NRCA recommends designers provide detailed specifications and drawings to ensure their design intentions are known to bidders and installers.

MARK S. GRAHAM is NRCA's vice president of technical services.

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## Condensation control guidelines

Steep-slope roof assemblies

*Historically, condensation control for steep-slope roof assemblies has been addressed with attic ventilation*

**Historic guidelines:**

- 1:150 ratio: (1 sq. ft. of ventilation for every 150 sq. ft. of horizontally-projected ceiling area)
- 1:300 ratio exception allowed if a ceiling vapor retarder is included in the roof assembly

*Research has shown there is little or no technical basis for these historic attic ventilation guidelines*

*Also, more isn't necessarily better…*

## ***International Building Code, 2009 Edition***

**1203.4 Attic Spaces.** Enclosed attics and enclosed rafter spaces formed where ceilings are applied directly to the underside of roof framing members shall have cross ventilation for each separate space by ventilating openings protected against the entrance of rain and snow. Blocking or bridging shall be arranged so as not to interfere with the movement of air. A minimum of 1 inch (25 mm) of airspace shall be provided between the insulation and the roof sheathing. The net free ventilating area shall not be less than 1/300 of the space ventilated with 50 percent of the required ventilating area provided by ventilators located in the upper portion of the space to be vented at least 3 feet (914 mm) above the eave or cornice vents with the balance of required ventilation provided by eave or cornice vents.

## ***International Residential Code, 2009 Edition***

**R806.2 Minimum area.** The total net free ventilation area shall not be less than 1/150 of the area of the space ventilated except that a reduction of the total area to 1/300 is permitted, provided a least 50 percent and not more than 80 percent of the required ventilation area is provided by ventilation located in the upper portion of the space to be ventilated at least 3 feet (914 mm) above the eave or cornice vents. As an alternative, the net free cross-section ventilation area may be reduced to 1/300 when a vapor retarder having a transmission rate not exceeding 1 perm ($5.7 \times 10^{-11}$ kg/s $m^2$ Pa) is installed on the warm-in-winter side of the ceiling.

## Attic ventilation

*IBC 2009 and IRC 2009 are not consistent*
*…and conflict to some extent.*

*IBC 2009 and IRC 2009 are also not consistent with industry guidelines.*

## Steep-slope roof assemblies

Condensation control guidelines

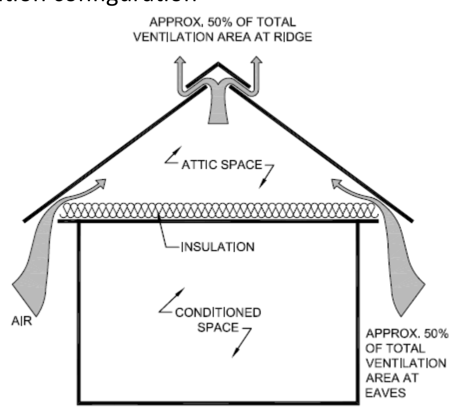
- Attic ventilation
- Unvented attics

## Attic ventilation components

## Suggested guidelines

Static ventilation configuration

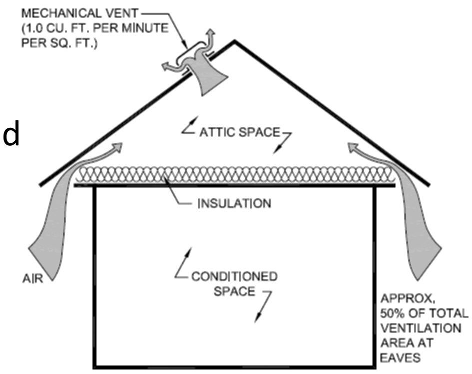
- Balanced
- 1:150 ratio
- Jan. ≤ 30 F:
  - Vapor retarder
- Slope 8:12:
  - Increase ventilation



## Suggested guidelines

Mechanical ventilation

- 1 CFM ≈ 1:150 ratio
- Eave/soffits vents req'd
- Jan. ≤ 30 F:
  - Vapor retarder
- Slope 8:12:
  - Increase ventilation




## Average January temperature less than 30F

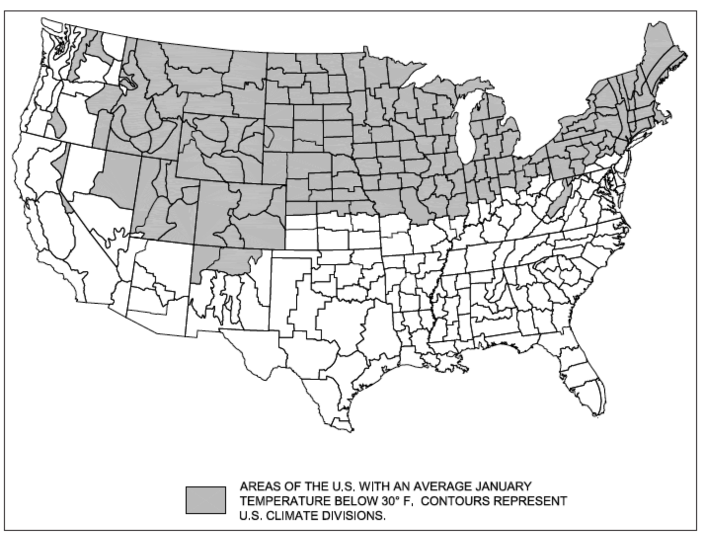
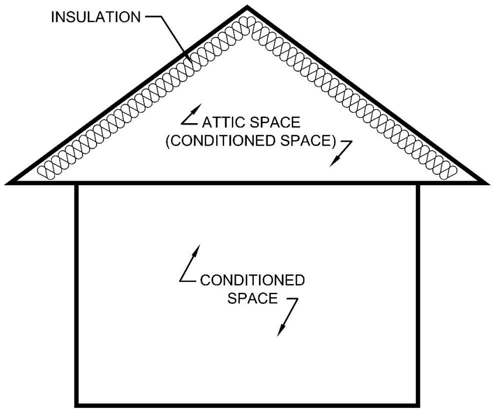


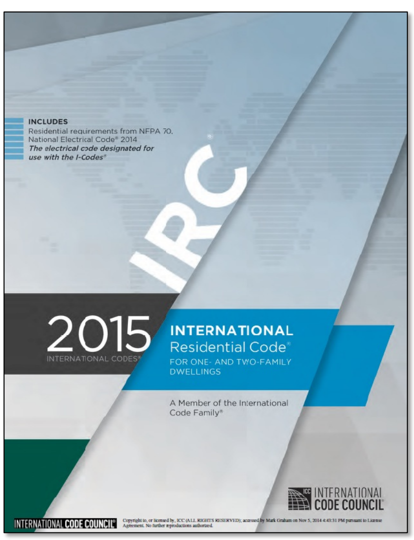

*Figure 2-3: Areas of the U.S. with an average January temperature below 30 F, composite 1981-2012 data. Map is based on data provided by NOAA/ESRL Physical Sciences Division, Boulder, Colo., from its website, www.cdc.noaa.gov. Contours represent U.S. Climate Divisions.*

## An alternative: Unvented, conditioned attic




NRCA

## Technical requirements




IRC 2015, Sec. R806.5 contains the most current technical requirements applicable to unvented attics.

IBC 2015, Sec. 1203.3 contains requirements similar to those of IRC 2015, but note First Printing Errata, November 16, 2015 for several printing corrections

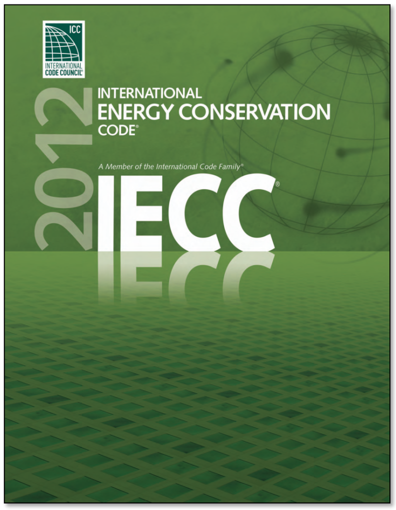
NRCA

*The conditioned, unvented attic is considered a viable alternative to attic ventilation*

## **Air retarder guidelines**

Low- and steep-slope roof assemblies

## ***International Energy Conservation Code, 2012 Edition***




- "Commercial" unless "Residential"
- Residential Building: For this code, includes detached one- and two-family dwellings and multiple single-family dwellings (townhouses) as well as Group R-2, R-3 and R-4 buildings three stories or less in height above grade plane

NRCA

## Air retarders – Residential buildings

IECC 2012, Section R402.4-Air Leakage (Mandatory)

**R402.4 Air leakage (Mandatory)**. The building thermal envelope shall be constructed to limit air leakage in accordance with the requirements of Sections R402.4.1 through R402.4.4.

**R402.4.1 Building thermal envelope.** The building thermal envelope shall comply with Sections R402.4.1.1 and R402.4.1.2. The sealing methods between dissimilar materials shall allow for differential expansion and contraction.

**R402.4.1.1 Installation.** The components of the building thermal envelope as listed in Table R402.4.1.1 shall be installed in accordance with the manufacturer's instructions and the criteria listed in Table R402.4.1.1, as applicable to the method of construction. Where required by the code official, an approved third party shall inspect all components and verify compliance.

**R402.4.1.2 Testing.** The building or dwelling unit shall be tested and verified as having an air leakage rate of not exceeding 5 air changes per hour in Climate Zones 1 and 2, and 3 air changes per hour in Climate Zones 3 through 8. Testing shall be conducted…

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## Roofing-specific adaptation of Table R402.4.1.1

*International Energy Conservation Code, 2012 Edition*

| Air Barrier and Insulation Installation | |
|---|---|
| **Component** | **Criteria** |
| Air barrier and thermal barrier | A continuous air barrier shall be installed in the building envelope.<br>Exterior thermal envelope contains a continuous air barrier.<br>Breaks or joints sin the bar barrier shall be sealed.<br>Air-permeable insulation shall not be used as a sealing material. |
| Ceiling/attic | The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier sealed.<br>Access openings, drop down stair or knee wall doors to unconditioned attic spaces shall be sealed. |

## Air retarders – Commercial buildings

IECC 2012, Section C402.4-Air Leakage (Mandatory)

**C402.4 Air leakage (Mandatory).** The thermal envelope of buildings shall comply with Sections C402.4.1 through C402.4.8.

**C402.4.1 Air barriers.** A continuous air barrier shall be provided throughout the building thermal envelope. The air barriers shall be permitted to be located on the inside or outside of the building envelope, located within the assemblies composing the envelope, or any combination thereof. The air barrier shall comply with Sections C402.4.1.1 and C402.4.1.2.

> **Exception:** Air barriers are not required in buildings located in Climate Zones 1, 2 and 3.

[Continued…]

**C402.4.1.2 Air barrier compliance options.** A continuous air barrier for the opaque building envelope shall comply with Section C402.4.1.2.1, C402.4.1.2.2, or C402.4.1.2.3.

**C402.4.1.2.1 Materials.** Materials with an air permeability no greater than 0.004 cfm/ft$^2$ (0.02 L/s · m$^2$) under a pressure differential of 0.3 inches water gauge (w.g.) (75 Pa) when tested in accordance with ASTM E 2178 shall comply with this section. Materials in Items 1 through 15 shall be deemed to comply with this section provided joints are sealed and materials are installed as air barriers in accordance with the manufacturer's instructions.

1. Plywood with a thickness of not less than 3/8 inch (10 mm).
2. Oriented strand board having a thickness of not less than 3/8 inch (10 mm).
3. Extruded polystyrene insulation board having a thickness of not less than 1/2 inch (12 mm).
4. Foil-back polyisocyanurate insulation board having a thickness of not less than 1/2 inch (12 mm).
5. Closed cell spray foam a minimum density of 1.5 pcf (2.4 kg/m$^3$) having a thickness of not less than 1-1/2 inches (36 mm).

[Continued….]

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6. Open cell spray foam with a density between 0.4 and 1.5 pcf (0.6 and 2.4 kg/m$^3$) and having a thickness of not less than 4.5 inches (113 mm).
7. Exterior or interior gypsum board having a thickness of not less than ½ inch (12 mm).
8. Cement board having a thickness of not less than 1/2 inch (12 mm).
9. Built up roofing membrane.
10. Modified bituminous roof membrane.
11. Fully adhered single-ply roof membrane.
12. A Portland cement/sand parge, or gypsum plaster having a thickness of not less than 5/8 inch (16 mm).
13. Cast-in-place and precast concrete.
14. Fully grouted concrete block masonry.
15. Sheet steel or aluminum.

[Continued…]

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**C402.4.1.2.2 Assemblies.** Assemblies of materials and components with an average air leakage not to exceed 0.04 cfm/ft$^2$ (0.2 L/s · m$^2$) under a pressure differential of 0.3 inches of water gauge (w.g.)(75 Pa) when tested in accordance with ASTM E 2357, ASTM E 1677 or ASTM E 283 shall comply with this section. Assemblies listed in Items 1 and 2 shall be deemed to comply provided joints are sealed and requirements of Section C402.4.1.1 are met.

1. Concrete masonry walls coated with one application either of block filler and two applications of a paint or sealer coating;

2. A Portland cement/sand parge, stucco or plaster minimum 1/2 inch (12 mm) in thickness.

**C402.4.1.2.3 Building test.** The completed building shall be tested and the air leakage rate of the *building envelope* shall not exceed 0.40 cfm/ft$^2$ at a pressure differential of 0.3 inches water gauge (2.0 L/s · m$^2$ at 75 Pa) in accordance with ASTM E 779 or an equivalent method approved by the code official.

*IECC 2012's air barrier requirements significantly limit roof system designs in "commercial buildings" (as defined by IECC 2012)*

## Air retarder exception added

IECC 2015, Sec. C503 - Alterations

6. *Air barriers* shall not be required for *roof recover* and roof replacement where the *alterations* or renovations to the building do not include renovations or *repairs* to the remainder of the building envelope.

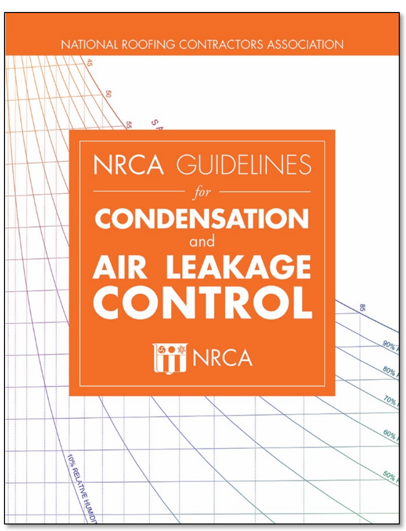
## In summary

- Remember the fundamentals:
  - Relative humidity varies with temperature
  - Dew point is condensation temperature
  - Vapor drive: Hot → Cold
- "Self-drying" roofs:
  - Downward drying ≥ moisture up-take
  - Additional considerations for "cool" roofs
- Vapor retarders

## In summary - continued

- Attic ventilation
  - Unvented attics alternative
- Air retarders
  - Energy code requirements
  - May limit roof assembly designs in "Commercial" buildings

## Reference documents

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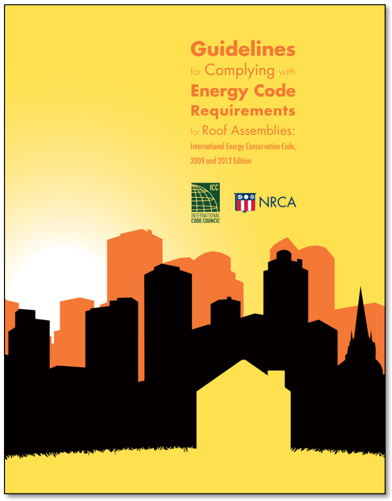
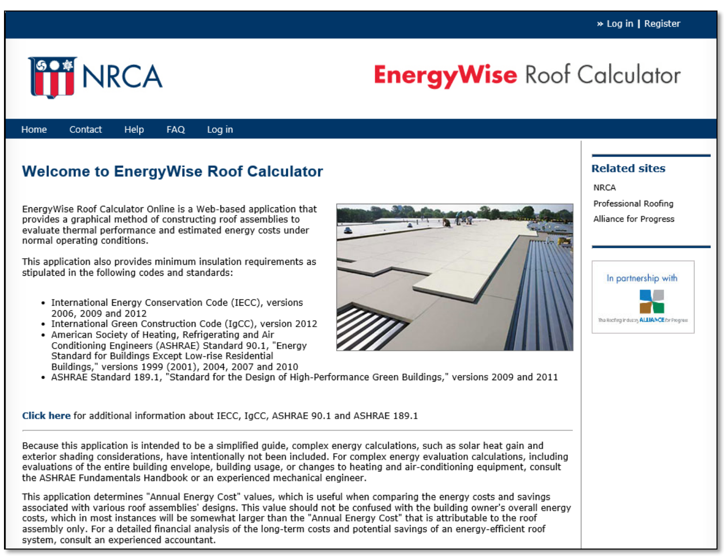
## Energy Codes Manual (2009 & 2012 Codes)

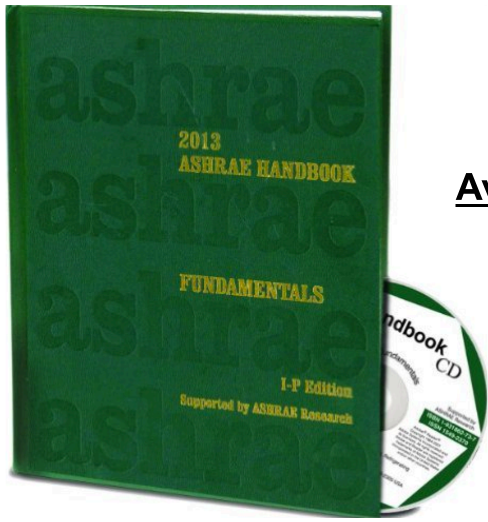



- Based upon IECC 2009 with ASHRAE 90.1-07 option and IECC 2012 with ASHRAE 90.1-10 option
- Includes roofing-related code text and NRCA commentary on each section
- Appendix has county-specific prescriptive R-value tables
- Co-branded with ICC; NRCA promotes to industry and ICC promotes to code officials

## energywise.nrca.net



## Reference documents




**Available from ASHRAE**
www.ashrae.org

## Previously, we said…

*"When in doubt, leave it out…"*

## Now we can say…

*"When in doubt, think it out…"*

## Acknowledgement to the "founding fathers"

Moisture control in roof assembles

Wayne Tobiasson
U.S. Army Corps of Engineers (retired)

Joe Lstiburek
Building Science Corp. ("semi"-retired)

Bill Rose
University of Illinois at Urbana-Champaign (retired)

**Mark S. Graham**
Vice President, Technical Services
National Roofing Contractors Association
10255 West Higgins Road, 600
Rosemont, Illinois 60018-5607

(847) 299-9070
mgraham@nrca.net
www.nrca.net

Twitter: @MarkGrahamNRCA
Personal website: www.MarkGrahamNRCA.com