One Thousand Years of Evolution: A Timeline

900 C.E.
Palisade wall: Closely spaced posts embedded in the ground.

1200
Timber frame: Stave construction, timber four-sided frame with vertical exterior weatherboards.

1600
Wattle and daub: Tar coated exposed frame with an early pre-evolutionary version of exterior stucco—Neanderthal Stucco. Board sheathing inner lining.
1900
Clapboard timber frame: Typical 1900 New England timber frame with plaster and lath interior lining and exterior board sheathing, rosin paper and clapboards.

1950
Platform frame: Typical 1950 American wood frame assembly with plywood sheathing and an interior gypsum board lining.

1990
Advanced frame: Insulating sheathing over 2x6 advanced frame.
Moisture Content vs. Relative Humidity

![Graph showing moisture content vs. relative humidity](image)

- **Equilibrium Moisture Content (EMC) %**
- **Relative Humidity (RH) %**
Fibers get much thicker than longer when they pick up moisture.

Studs get much wider and thicker, but not much longer, when they pick up moisture.
Zone of dimensional stability

Zone of movement

Zone of dimensional stability

8'

1 1/2"

9 1/4"

3"

13 3/4"
Does not move much here

16" (24")  16" (24")  16" (24")  16" (24")

Moves a lot here
Plain sawn log

Quarter sawn log
3” spray polyurethane foam (2 lb/ft³ density)

1½” metal stud wall

Gypsum board thermal barrier

3/4” drainage mat (filter fabric side facing up)

2” extruded polystyrene (XPS)

New concrete slab

Existing slab
Asphalt shingles
Roof underlayment
1/2" plywood roof sheathing

Two layers of 2" polyisocyanurate rigid insulation
Existing board roof sheathing
6" high-density (2.0 pcf) sprayed polyurethane foam insulation
Self-adhering ice/water membrane
4' from roof edge
Existing attic joists extended, widening soffit to accommodate exterior insulation
Metal starter strip with drip edge
1 X 3 trim
2 X 12 facia board
Continuous beadboard soffit
5/4" X 8" frieze board
Siding over 3/4" pressure treated wood strapping

Existing 2 X 6 wood rafter
1/2" gypsum board interior sheathing
Existing attic flooring removed at perimeter to allow for installation of sprayed polyurethane foam insulation seal to top plate
Existing interior plaster
Four layers of 2” rigid insulation
Sheathing tape
Wood siding
Membrane strip
1x4 furring strip
Trim
Flashing
Fully-adhered membrane
Plywood
Asphalt shingles
Fully-adhered membrane
Plywood
Tar paper
Board sheathing
Five layers of 2” rigid insulation
Crawl Spaces
Crawl spaces must be completely connected to either the outside or the inside
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Vented crawl spaces work

Unvented conditioned crawl spaces work
Don’t Do Stupid Things
Leaky air handling unit and supply ducts

Air handling unit

Supply

Return

Supply

Depressurized conditioned space inducing infiltration
Smart Thing
- wood siding
- water & air control membrane (building wrap)
- OSB sheathing
- joist
- sheet metal closure
- pier
- fiber cement board
wood siding

water & air control membrane (building wrap)

OSB sheathing

joist

sheet metal closure

pier

fiber cement board
Conditioned Crawlspaces Not Unvented Crawlspaces
Need Supply Air
50 cfm/1000 ft² of Crawlspace Area

Or
Dehumidification
4x10 transfer grille to first floor conditioned space

Interior wall

Subfloor

Floor joist

Duct open to crawlspace
Alternative Detail

Unfaced cavity insulation, cellulose or low density spray-applied foam insulation

Gypsum board with (latex) paint

Sealant, adhesive or gasket

Sealant at corner of bottom plate and subfloor or gasket under bottom plate

Unfaced cavity insulation, cellulose or low density spray applied foam

Sealant

Sill gasket

Protective membrane also acts as capillary break

Top courses filled solid

Rigid insulation (fire rated) (taped or sealed joints)

Masonry foundation wall

Continuous polyethylene vapor barrier/air barrier (all joints taped) taped to perimeter rigid insulation

Capillary break over footing

Concrete footing below frost depth

If exterior grade is lower than interior crawl space grade, no perimeter drain is necessary

Ground slopes away from wall at 5% (6in. per 10ft.)

Dampproofing

Rigid insulation

Adhesive

Protective membrane

Building paper (behind rigid insulation)

Stucco

Flashings

Sill gasket
Smart Thing
Any type of flooring/floor finish

Floor sheathing (OSB or plywood)

Foil-faced isocyanurate
Any type of flooring/floor finish

Floor sheathing (OSB or plywood)

Airspace

Foil-faced isocyanurate

Cavity insulation
Mechanical Systems
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Cooling System To Make It Cold
Mechanical Systems
Cooling System To Make It Cold
Dehumidification System To Make It Dry
Mechanical Systems
Cooling System To Make It Cold
Dehumidification System To Make It Dry
Heating System To Make It Warm
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Heating System To Make It Warm
Energy Recovery System To Keep It Cold and Dry and Warm and Comfortable
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Energy Recovery System To Keep It Cold and Dry and Warm and Comfortable
Distribution System To Make It Uniform
Mechanical Systems
Cooling System To Make It Cold
Dehumidification System To Make It Dry
Heating System To Make It Warm
Energy Recovery System To Keep It Cold and Dry and Warm and Comfortable
Distribution System To Make It Uniform
Range Hoods Are A Special Kind of Hell
Don’t Try to Combine Them......
Cooling System makes it cold
Dehumidification System makes it dry
Heating System makes it warm
ERV keeps it cold and dry and warm and comfortable
Distribution System makes it uniform
Build Tight - Ventilate Right
Build Tight - Ventilate Right
How Tight?
What’s Right?
Air Barrier Metrics

Material  0.02 l/(s-m2) @ 75 Pa
Assembly  0.20 l/(s-m2) @ 75 Pa
Enclosure 2.00 l/(s-m2) @ 75 Pa

0.25 cfm/ft2 @ 50 Pa
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Getting rid of big holes</td>
<td>3 ach@50</td>
</tr>
<tr>
<td>Getting rid of smaller holes</td>
<td>1.5 ach@50</td>
</tr>
<tr>
<td>Getting German</td>
<td>0.6 ach@50</td>
</tr>
</tbody>
</table>
Best

As Tight as Possible - with -
Balanced Ventilation
Energy Recovery
Distribution and Mixing
Source Control - Spot exhaust ventilation
Filtration
Material selection
Worst

Leaky - with – Nothing
Spot Ventilation in Bathroom/Kitchen
Exhaust Ventilation – with – No Distribution and No Mixing
Three Types of Controlled Ventilation Systems

Exhaust Ventilation
Supply Ventilation
Balanced Ventilation
Induced exfiltration
Ventilation Rates Are Based on Odor Control
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Health Science Basis for Ventilation Rates is Extremely Limited
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The Applicable Studies Focus on Dampness
ASHRAE Standard 62.2 calls for 7.5 cfm per person plus 0.03 cfm per square foot of conditioned area

Occupancy is deemed to be the number of bedrooms plus one
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Occupancy is deemed to be the number of bedrooms plus one

Outcome is often bad – part load humidity problems, dryness problems, energy problems
IRC 2015 and 2018 calls for 7.5 cfm per person plus 0.01 cfm per square foot of conditioned area

Occupancy is deemed to be the number of bedrooms plus one
3 Bedroom House – 2,500 ft²
30 cfm plus 75 cfm
105 cfm
3 Bedroom House – 2,500 ft²
30 cfm plus 25 cfm
55 cfm
3 Bedroom House – 2,500 ft²
30 cfm plus 25 cfm
55 cfm
With Balanced and Distributed 30 percent credit
38.5 cfm
Dilution For People
Source Control For The Building
- Uncomfortably Dry*
- Comfort Range*
- Uncomfortably Wet*

Relative Humidity (RH) %

Target Range

Winter
Summer
Recommended Range of Relative Humidity
Above 25 percent during winter
Below 70 percent during summer
Kitchen Exhaust Hoods
Unconditioned make-up air 60 - 70% of hood exhaust
Move cabinets farther apart.

Hood wider than cook top and extended outboard past head space.

Move hood up to provide headroom.

Interlocked make-up air.
Clothes Dryers
Fireplaces
Approaches
Return air

Supply air

Bedroom

Heat exchange
ventilator

Bath

Kitchen

Exhaust air

Outside air

Exhaust air

Interlocked kitchen hood make-up air
- Bedroom
- Bedroom
- Bath
- Bath
- Heat exchange ventilator
- Kitchen
- PTHP
- Exhaust air
- Outside air
- Exhaust air
- Interlocked kitchen hood make-up air