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Building Science

There's No Such Thing As A Free
Thermodynamic Lunch

Some Physics....

Arrhenius Equation

For Every 10 Degree K Rise
Reaction Rate Doubles

$$k = Ae^{-E_a/(RT)}$$

Damage Functions

Water

Heat

Ultra-violet Radiation

Damage Functions

Water

Heat

Ultra Violet Radiation

Oxidization (Ozone)

Fatigue (Creep)

The Three Biggest Problems In Buildings Are Water, Water and Water...

Laws of Thermodynamics

Zeroth Law – Equal Systems

First Law - Conservation of Energy

Second Law - Entropy

Third Law – Absolute Zero

2nd Law of Thermodynamics

In an isolated system, a process can occur only if it increases the total entropy of the system

Rudolf Clausius

Heat Flow Is From Warm To Cold

Moisture Flow Is From Warm To Cold

Moisture Flow Is From More To Less

Air Flow Is From A Higher Pressure to a
Lower Pressure

Gravity Acts Down

Moisture Flow Is From Warm To Cold
Moisture Flow Is From More To Less

Moisture Flow Is From Warm To Cold
Moisture Flow Is From More To Less

Thermal Gradient – Thermal Diffusion
Concentration Gradient – Molecular Diffusion

Moisture Flow Is From Warm To Cold

Moisture Flow Is From More To Less

Thermal Gradient – Thermal Diffusion

Concentration Gradient – Molecular Diffusion

Vapor Diffusion

Thermodynamic Potential



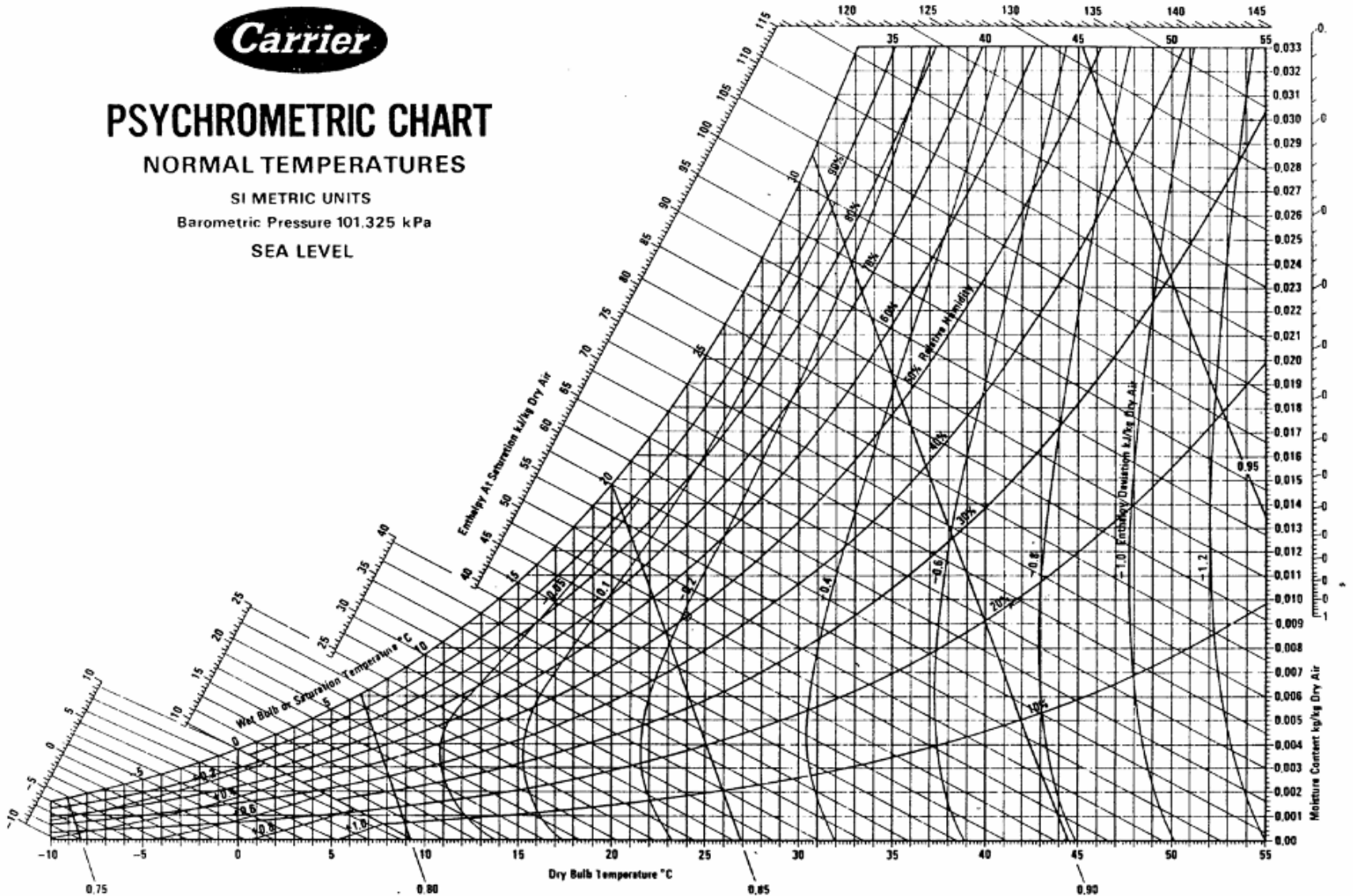
PSYCHROMETRIC CHART

NORMAL TEMPERATURES

SI METRIC UNITS

Barometric Pressure 101.325 kPa

SEA LEVEL



Below 0°C Properties and Enthalpy Deviation Lines Are For Ice

Volume m³/kg Dry Air

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Energy Flow









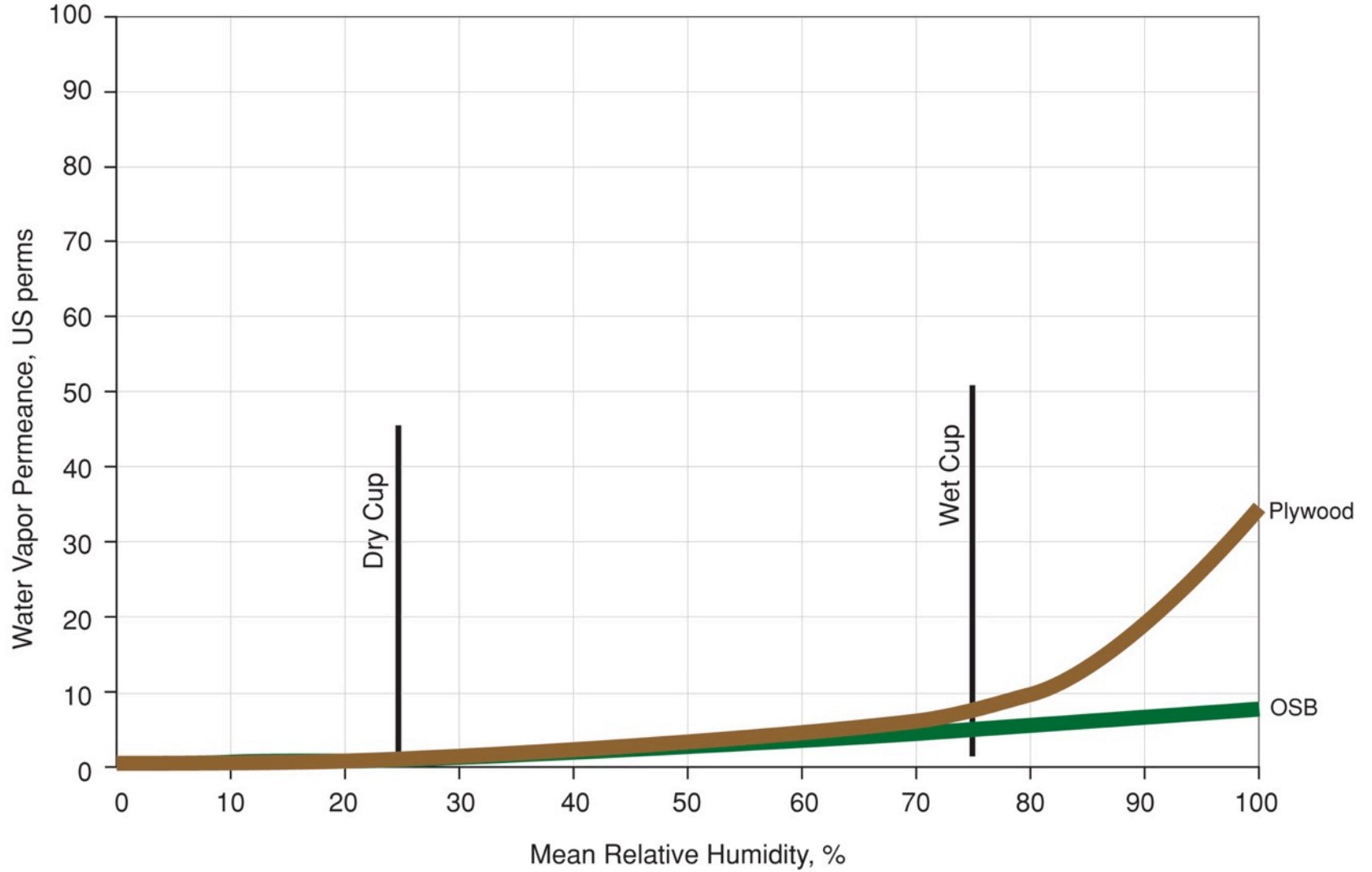


Materials





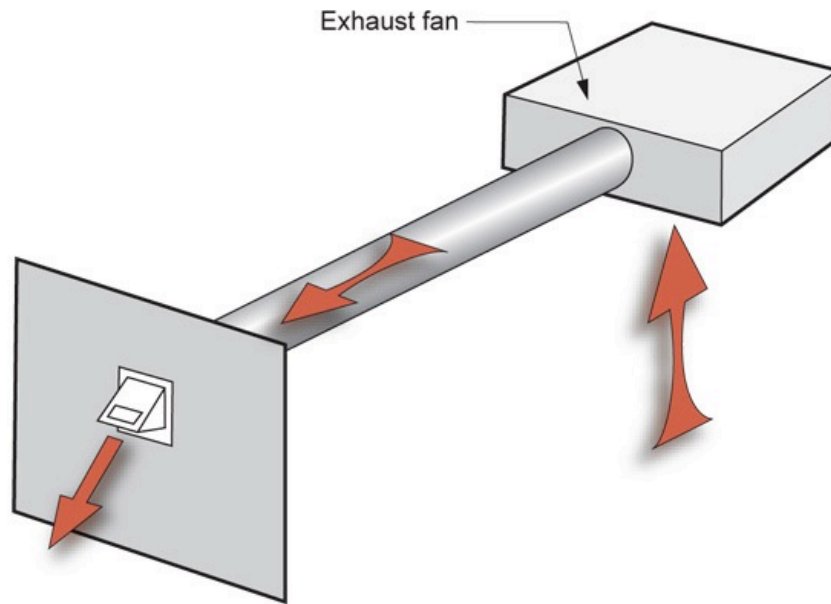
Water Vapor Permeance of Sheathing Materials

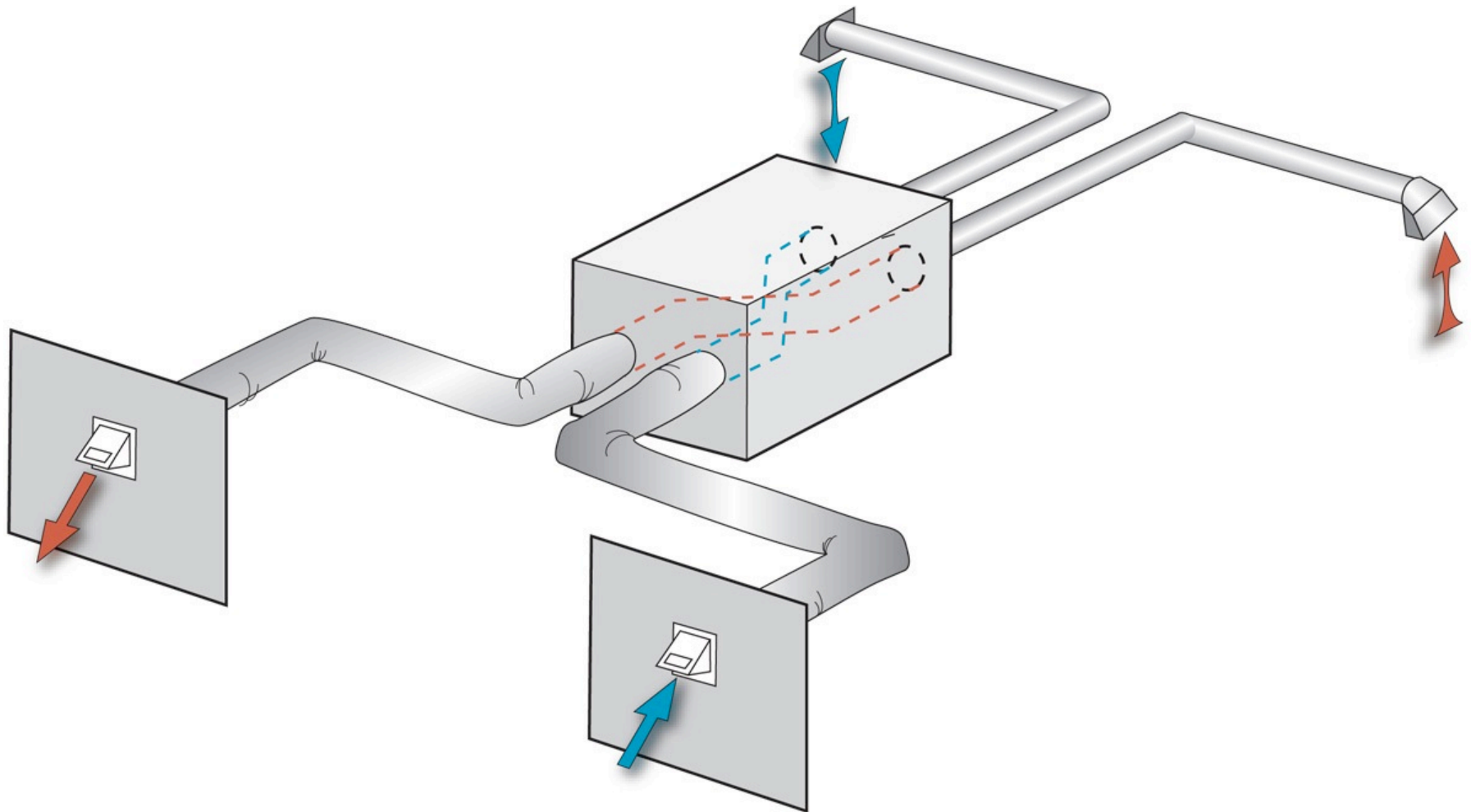




Airtightness

Typical	5 ach@50
Getting rid of big holes	3 ach@50
Getting rid of smaller holes	1.5 ach@50
Getting Passive	1.0 ach@50





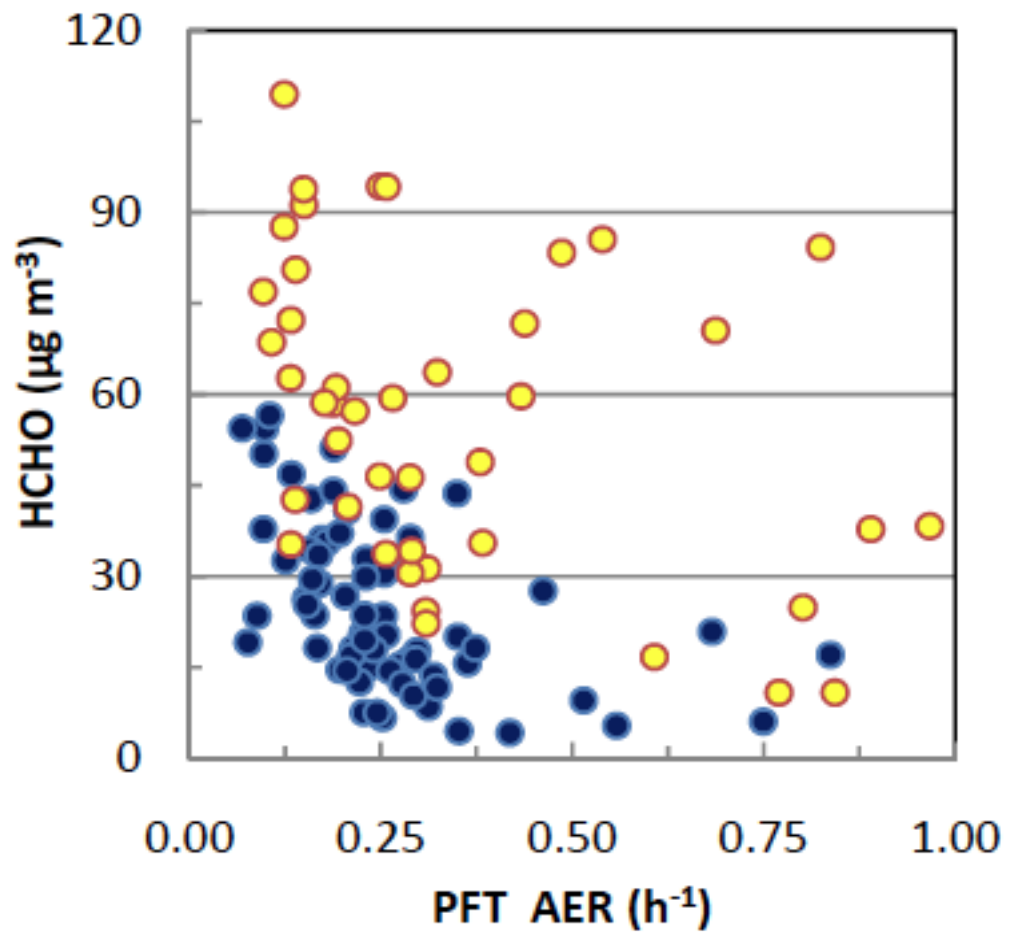
Ventilation Rates

Dilution Is Not The Solution To Indoor Pollution

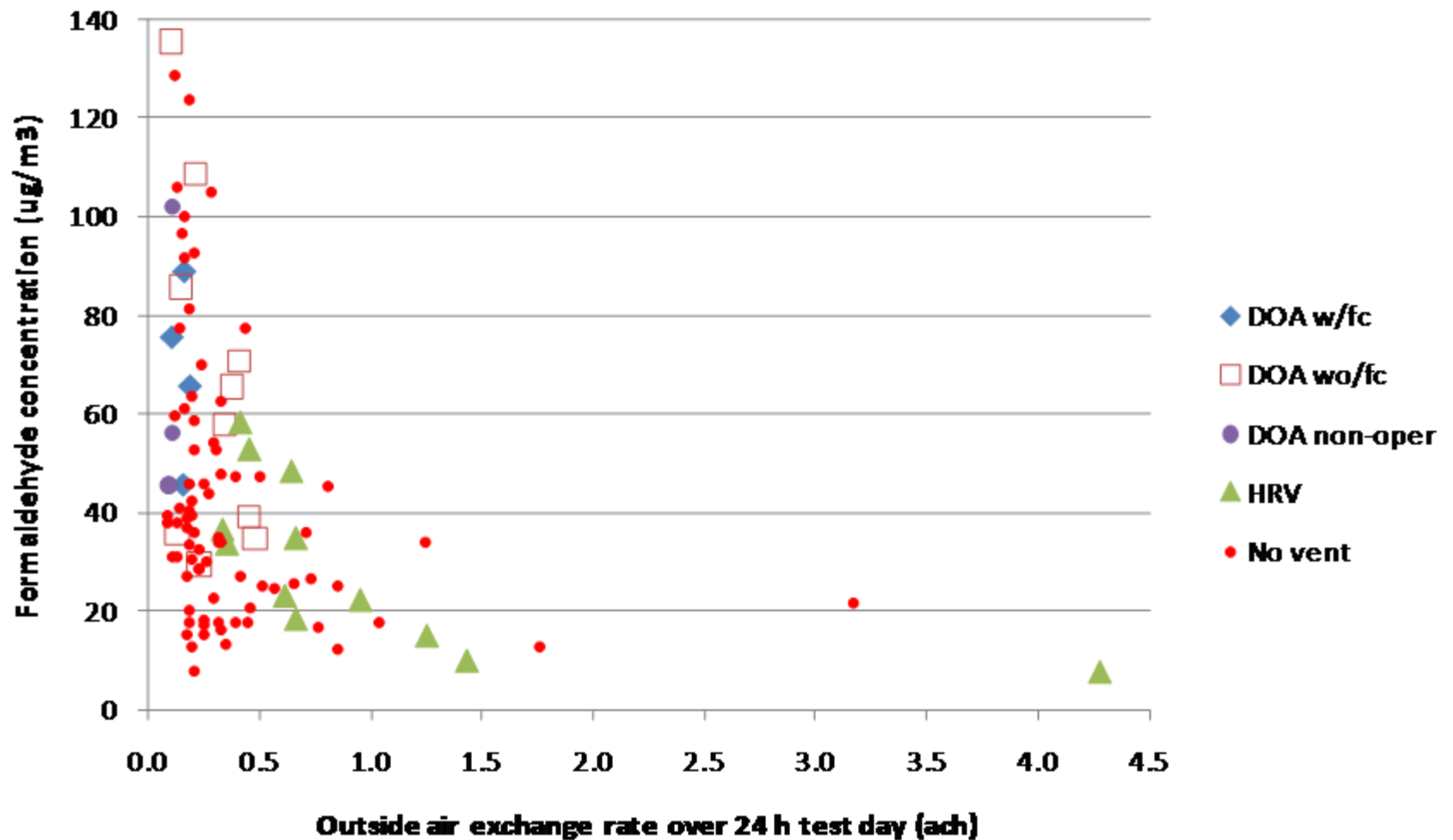
Source Control

Dilution For People

Source Control For The Building

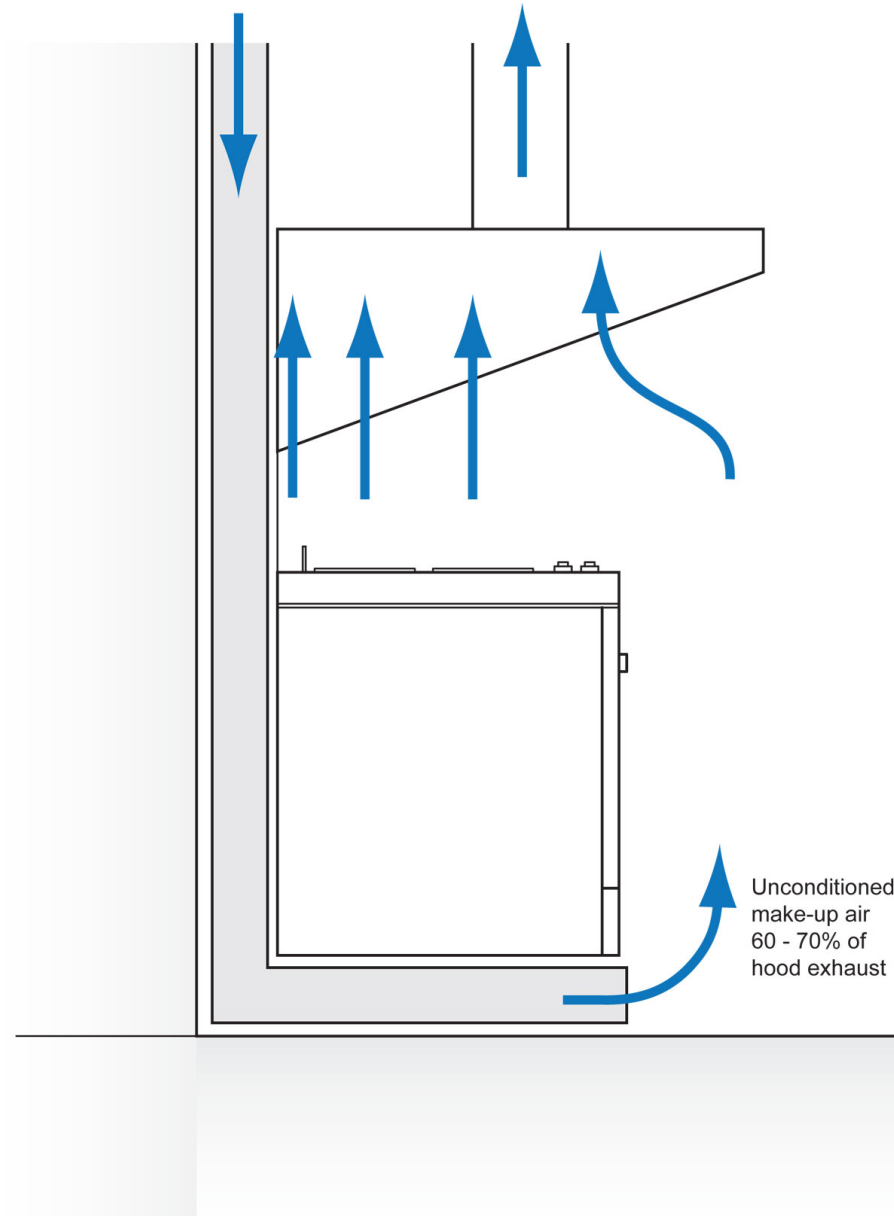


Formaldehyde sample concentration versus PFT measured outside air exchange rate over the test day

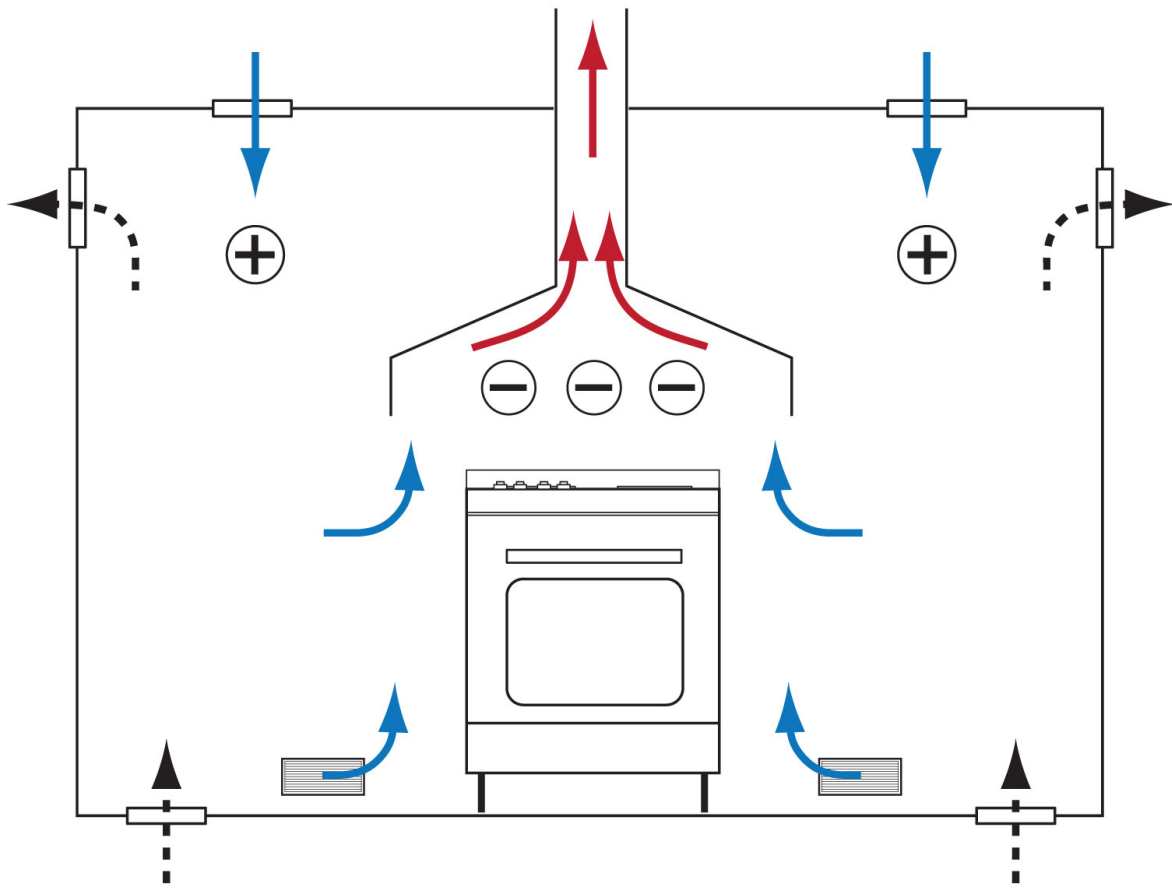


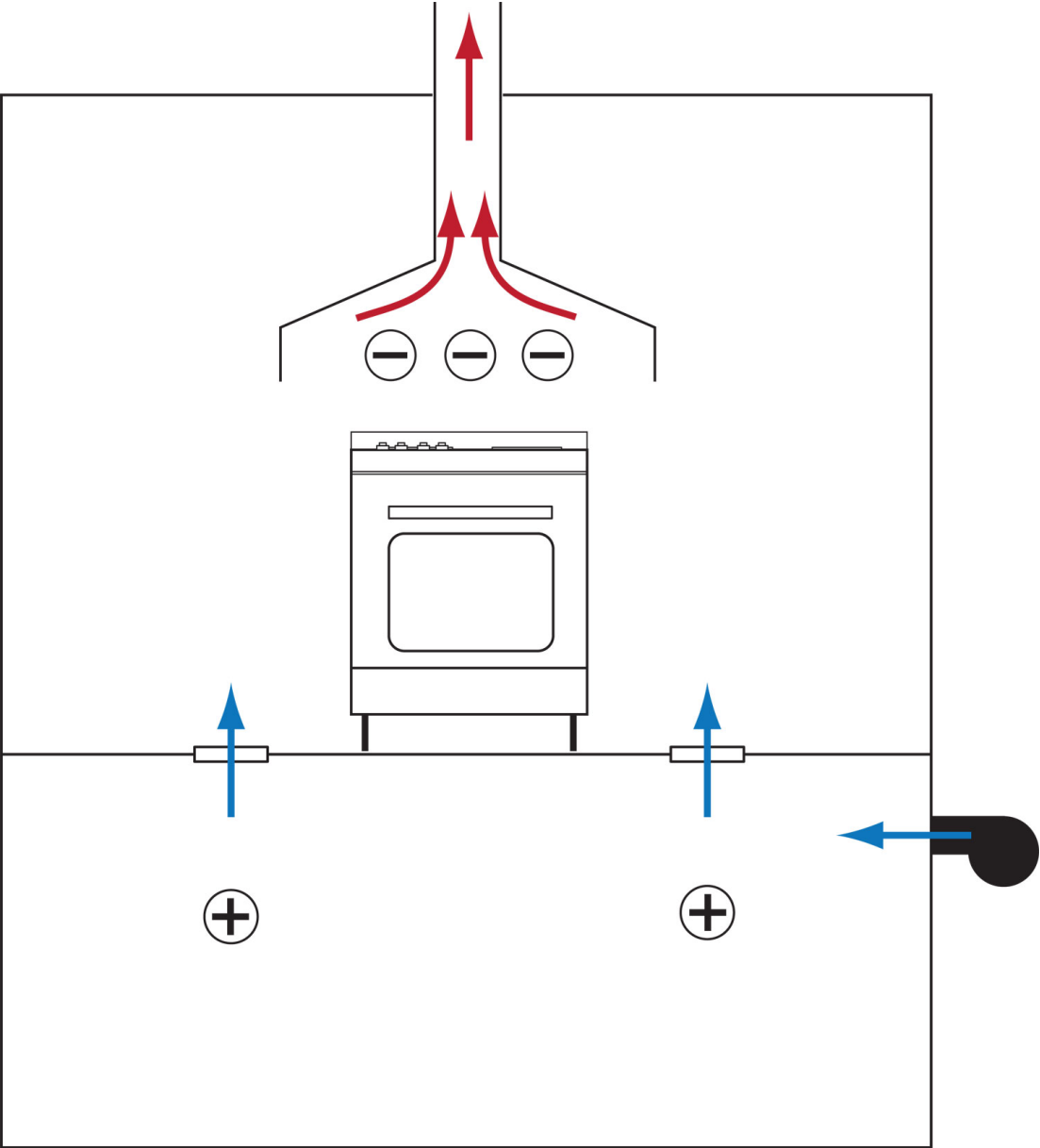
Pressures

Kitchen Exhaust Hoods









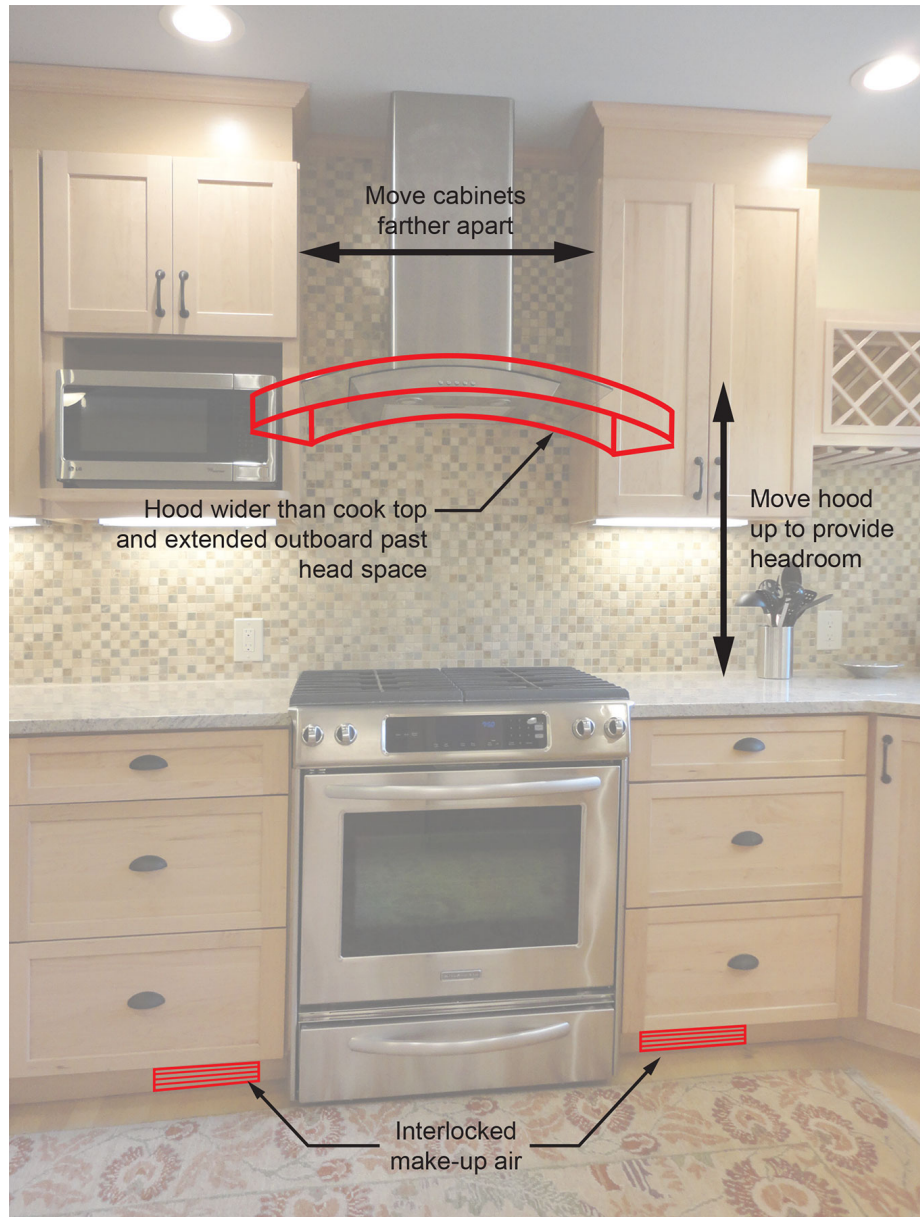
















Clothes Dryers





Fireplaces

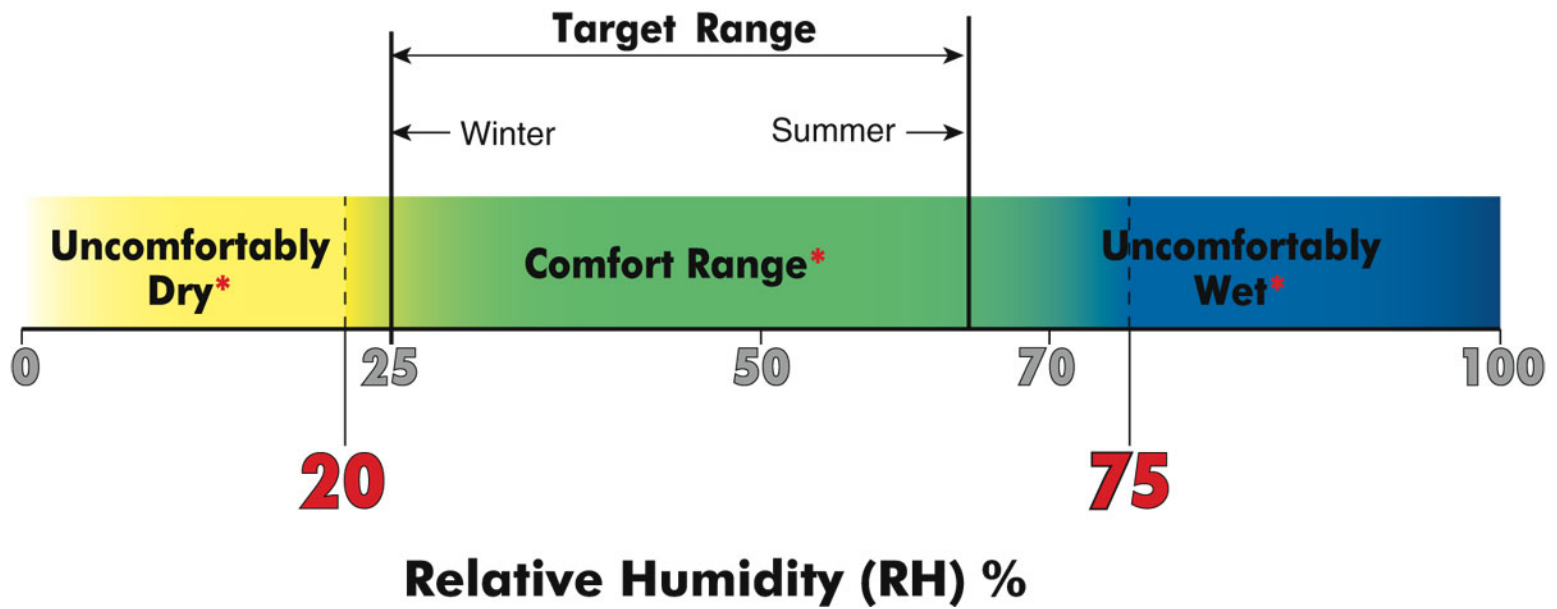








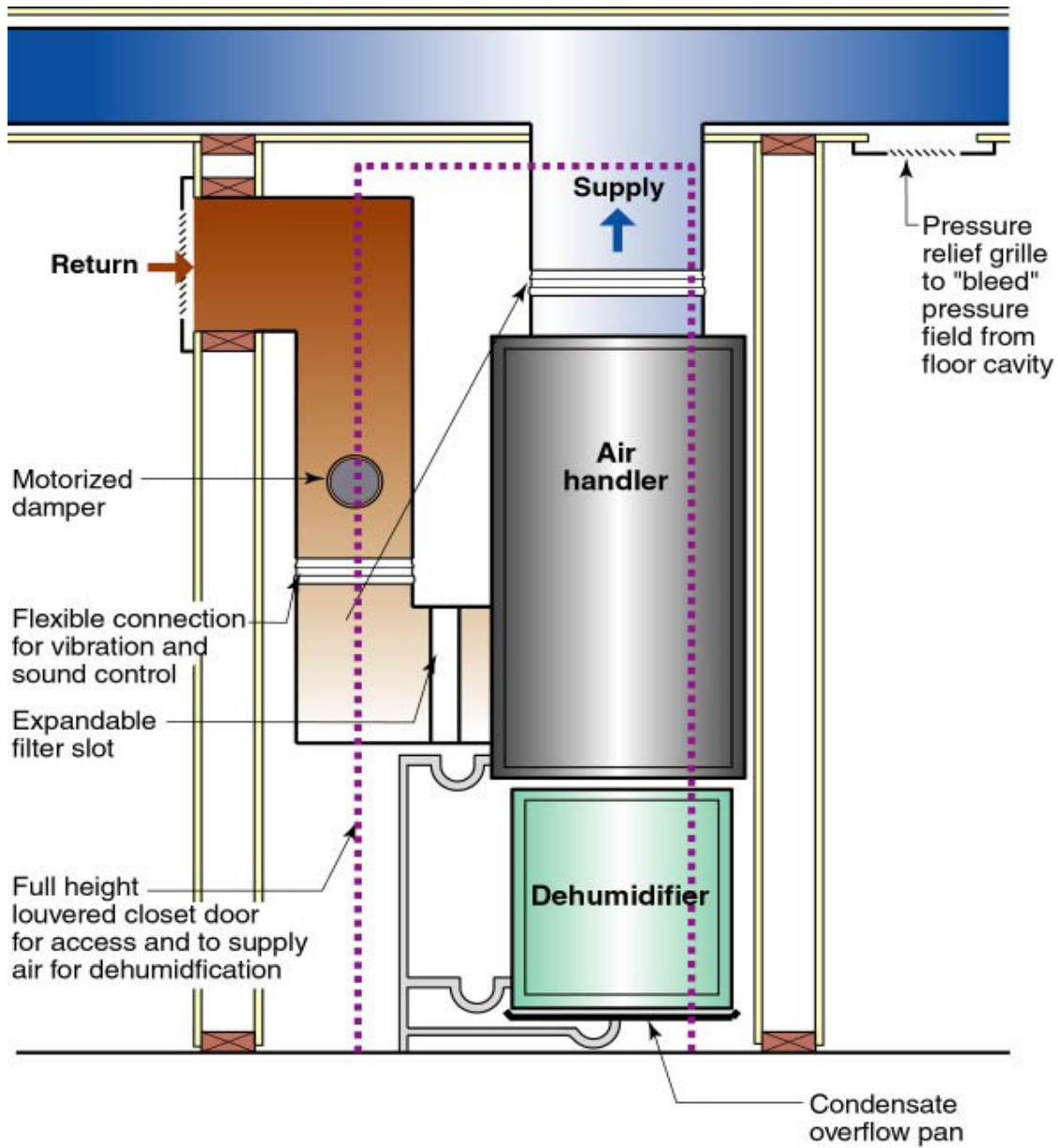
Relative Humidity



Recommended Range of Relative Humidity

Above 40 percent during winter

Below 60 percent during summer



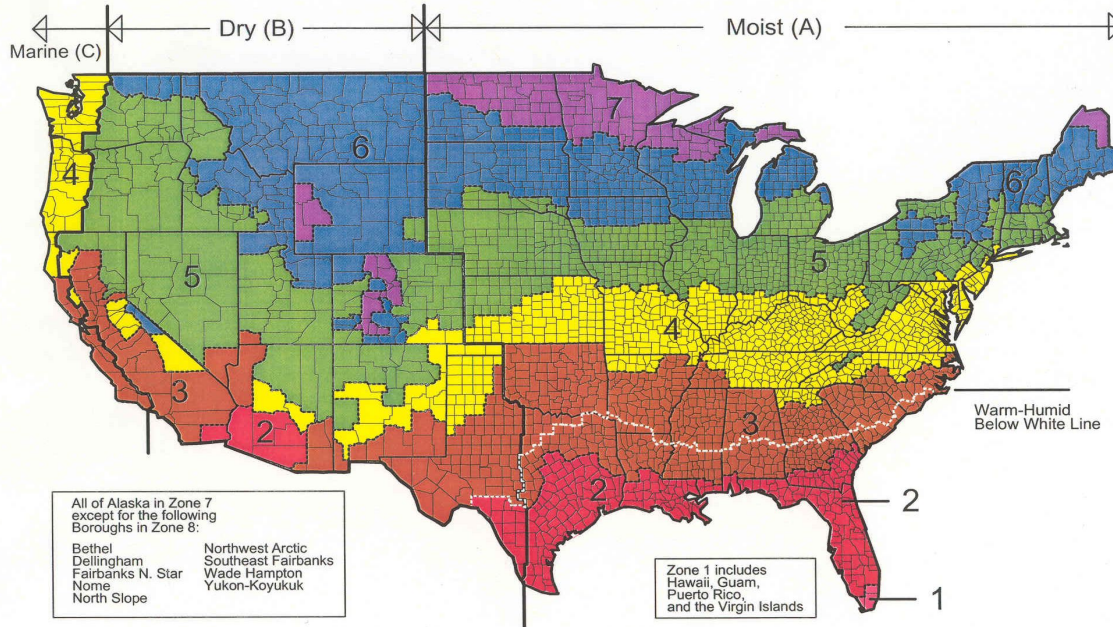




Net Zero Buildings.....

Net Zero Buildings.....
75 percent conservation
25 percent renewables

Map of DOE's Proposed Climate Zones



March 24, 2003

Conservation

5 – 10 – 20 – 40 – 60 – 1.5

Windows, Slab, Crawl/Basement, Wall, Roof

1.5 ach@50 with ERV

Renewables – IECC 2 and 3
2,500 ft² home - 7.5 kw PV

Conservation – IECC 2 and 3

5 – 10 – 20 – 40 – 60 – 1.5

Windows, Slab, Crawl/Basement, Wall, Roof

1.5 ach@50 with ERV

....Distributed Thermal Mass....







Light and Tight.....

beat

Mass and Glass.....

But.....

the time constant now matters

Conservation – IECC 2 and 3

5 – 10 – 20 – 40 – 60 – 1.5

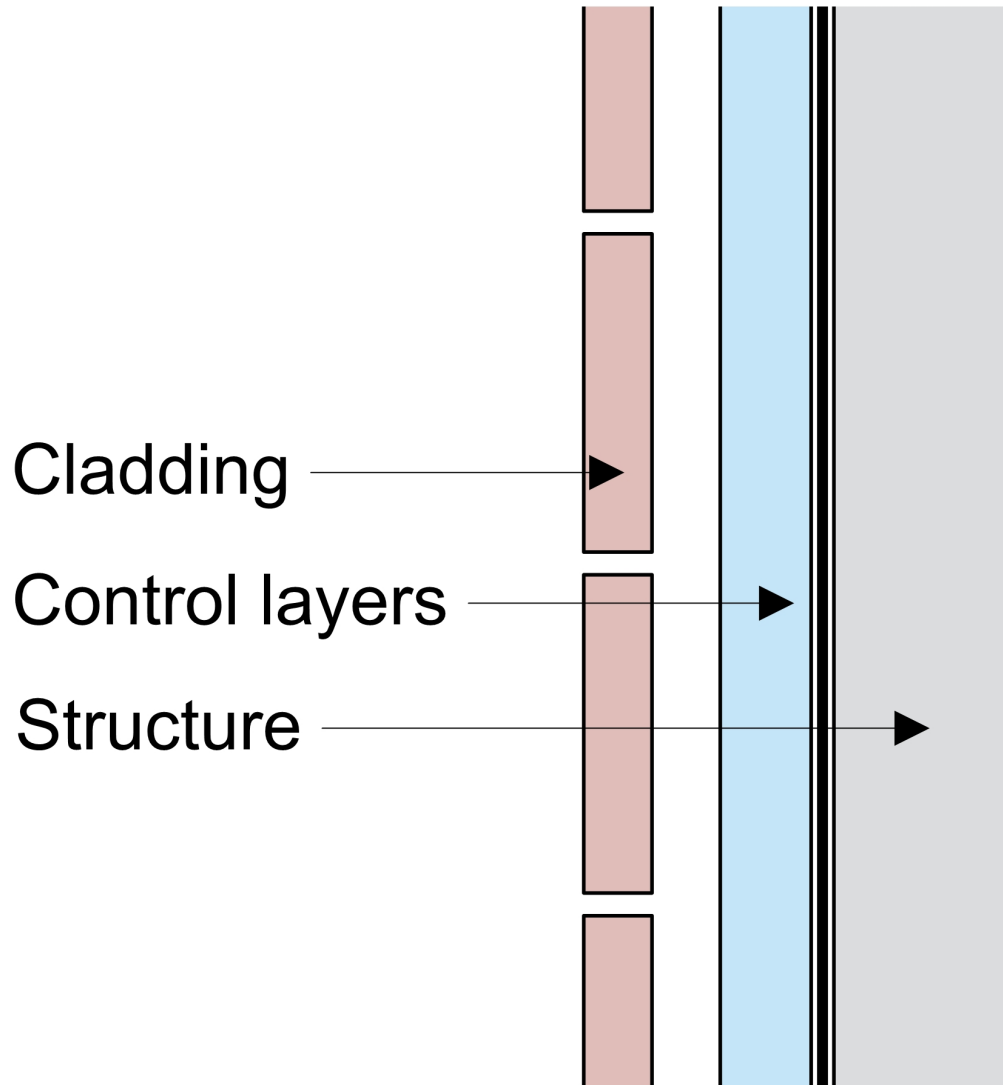
Windows, Slab, Crawl/Basement, Wall, Roof

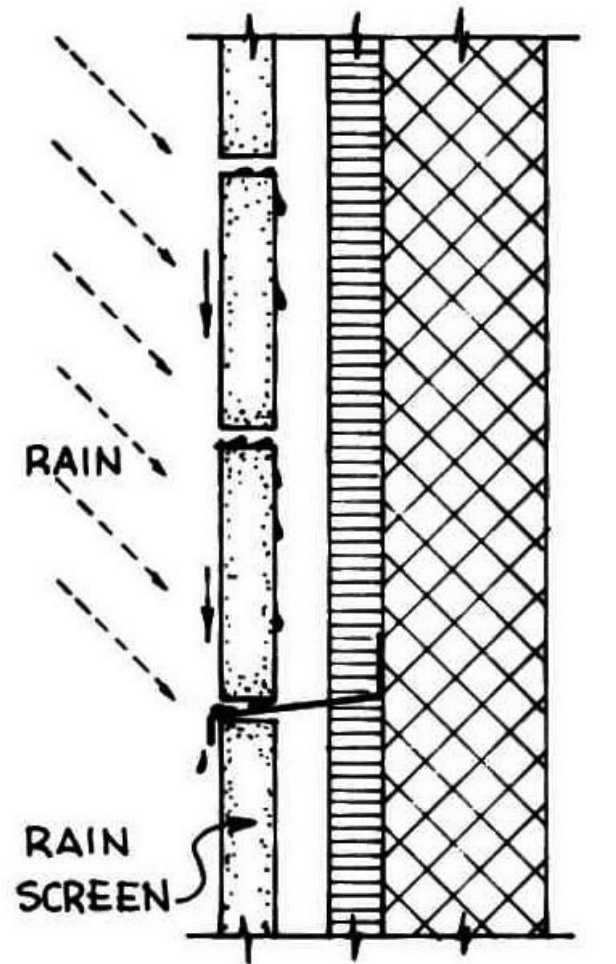
1.5 ach@50 with ERV

....Distributed Thermal Mass....

....Plus a Ford F-150 electric....







**WATER THAT PENETRATES
IS DIVERTED OUTWARD
BY FLASHINGS**

