Basic Building Science

Funding

Funding for this class was provided by the Alaska Housing Finance Corporation (AHFC).

This course is designed to empower homeowners with the knowledge to live in and maintain a safe, energy efficient home.

Disclaimer

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Topics for today:

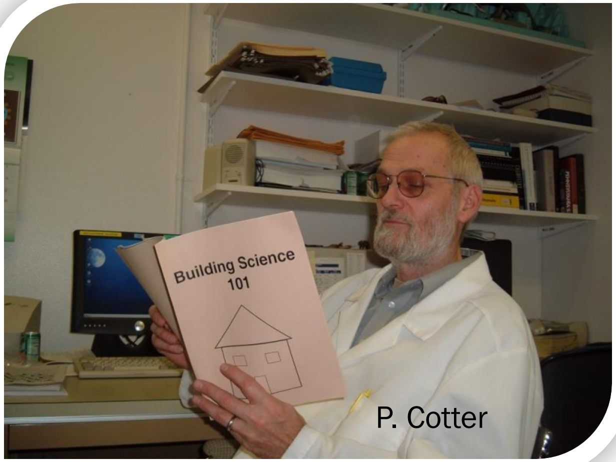
- AHFC programs
- House as a system/Pressure
- Heat
- Air
- Moisture

AHFC Energy Efficiency Programs:

- Home Energy Rebate Program
  - www.akrebate.com
- Weatherization Assistance Program
- New Home Rebate
- Second Mortgage for Energy Conservation
- Energy Efficiency Rate Reduction Mortgage
- www.ahfc.us

Energy Flow & Physics

- Knowledge of building science can help new construction and existing buildings with improved performance:
  - Cost
  - Comfort
  - Durability
- Understand
  - Occupants
  - Building components/systems
  - Environment
- Focus on
  - Pressure • Heat • Air • Moisture



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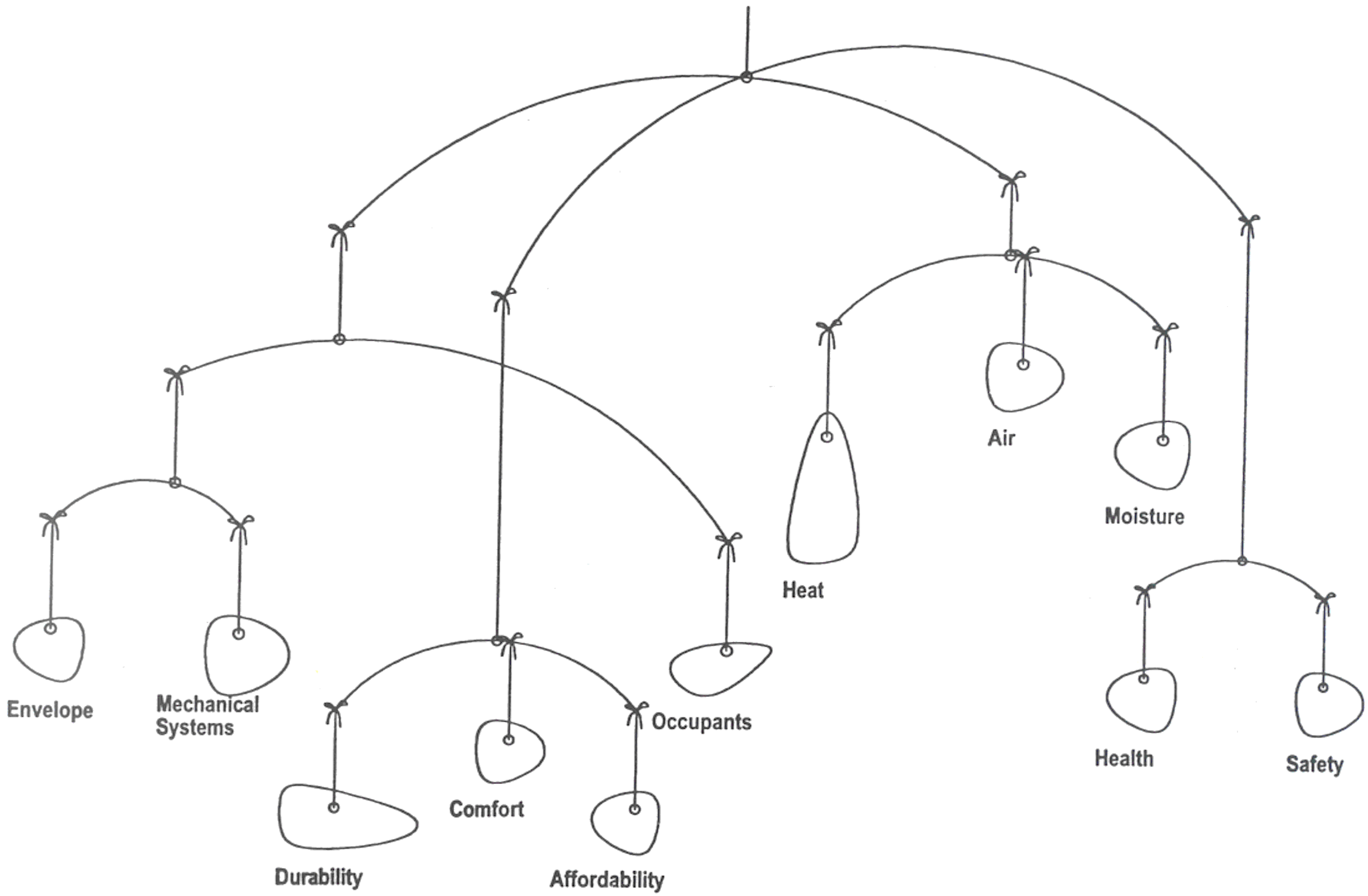
The house is a system

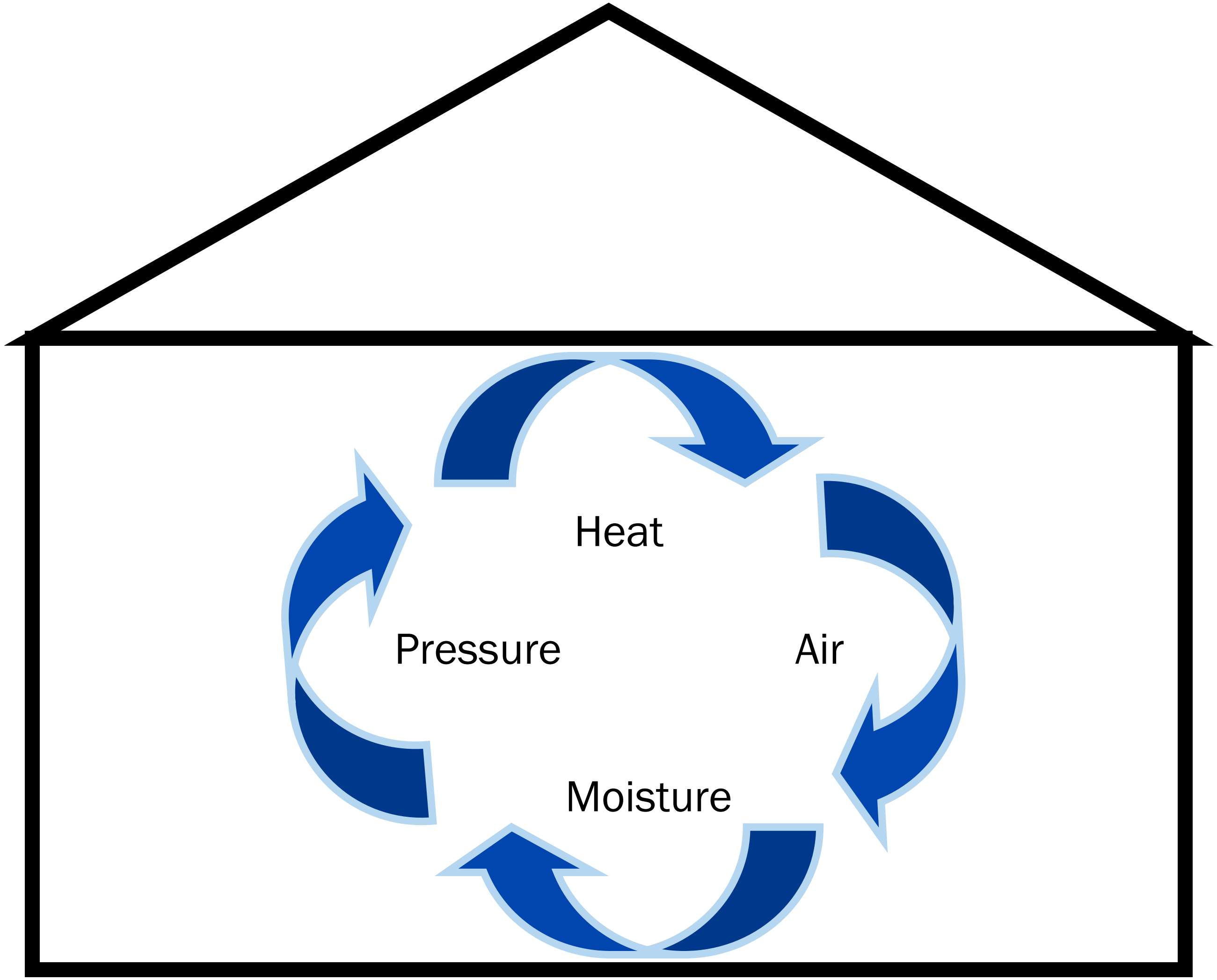


Where we live

- Median house size = 1300sf
- Median average area/resident = 500sf
- Trouble maintaining temperature = 26%
- Drafty = 45% (37% SE)

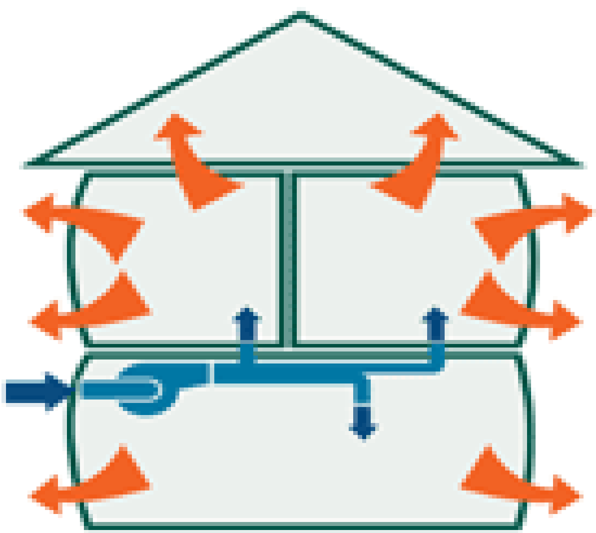
Data from AK Housing Assessment 2005

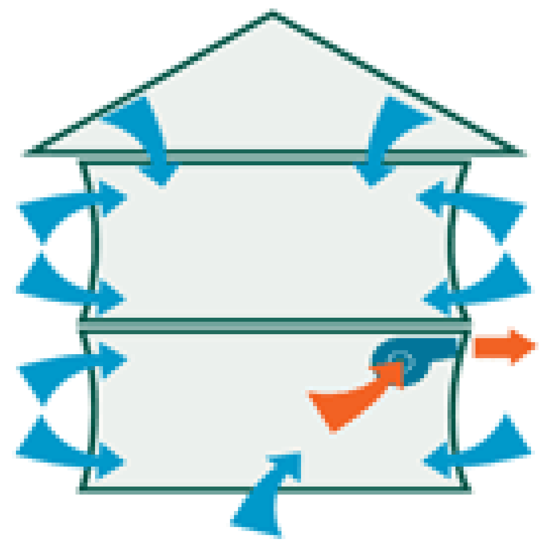
At home with the PHAM



When dealing with house pressures...

- Positive = pushing outward
  - Inflating a balloon
- Negative = pushing inward
  - Collapsing





Measured in Pascals

Units of Pressure

1 PSI = 6,894 Pascals

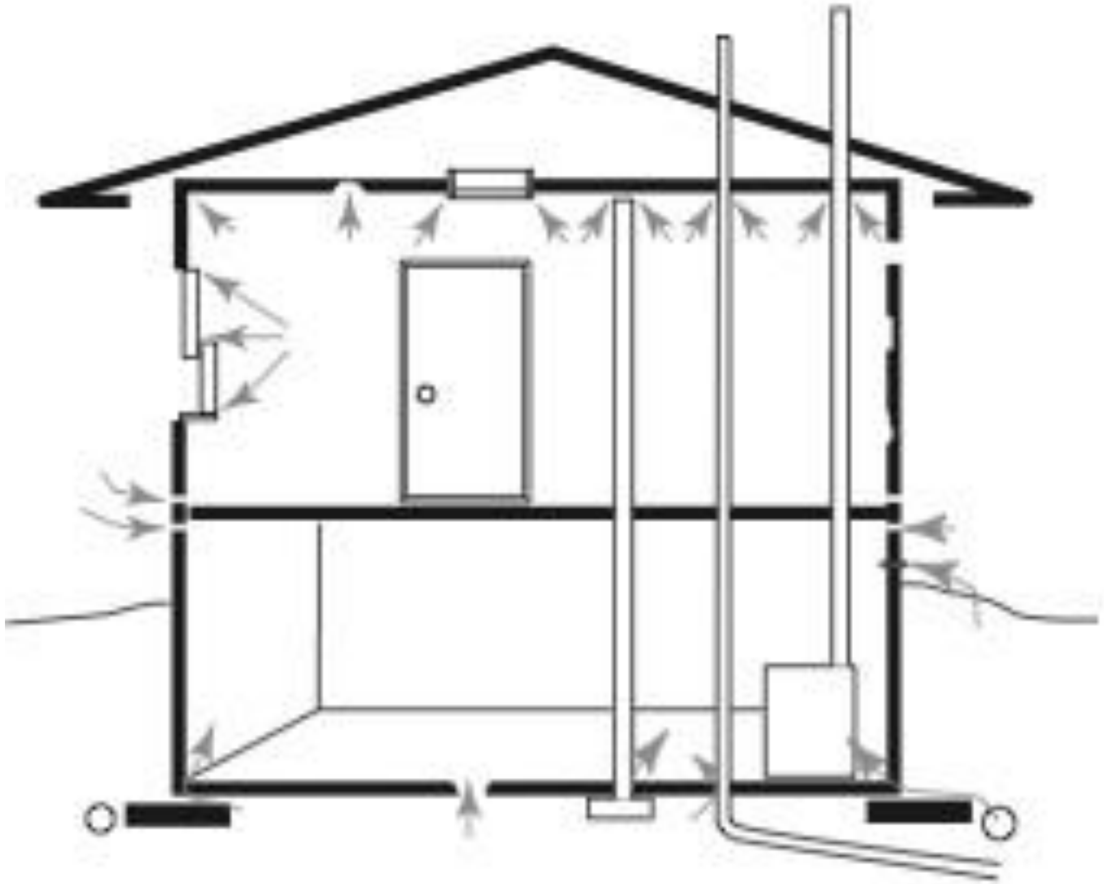
Pressure differences arise from

Stack effect

Wind

Flues and Vents

Stack Effect



stack effect

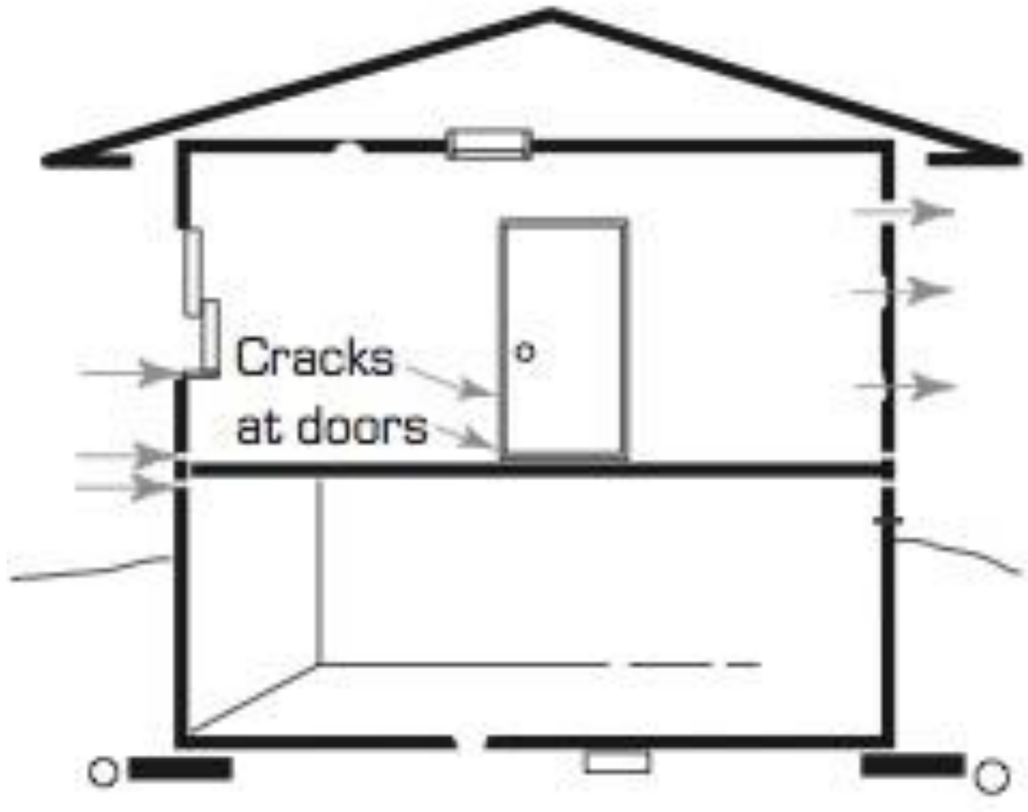
Stack Effect

Efficiency Vermont

Stack Effect

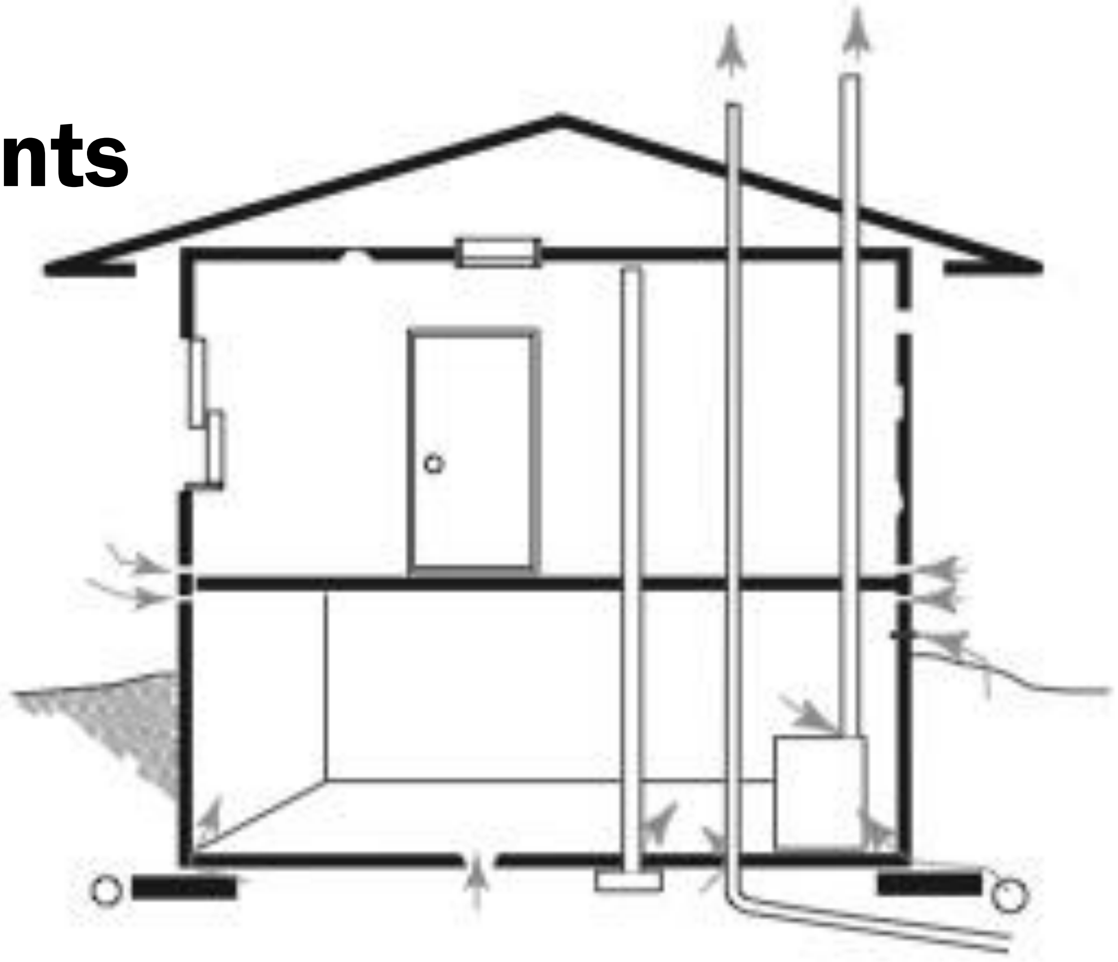
ACHP

Wind Effect



wind effect

Flues and Vents



flue and vent effect

The point of all this pressure

- Homes, and their occupants, are dynamic
- House pressures are dynamic
- Pressure dynamics in houses are affected by?

Btu - British Thermal Unit

- a quantity of heat
- 1 Btu = amount of heat needed to raise 1 lb of water, 1 ^{o}F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~ 1 btu

~ 140,000 of these per gallon fuel oil

Wouldn't it be great…

If we could get the same, or more, comfort with fewer BTUs

Measuring energy use

- What techniques are used?
- What are the units?
- What do they mean?

Energy use and your energy rating

Home Energy Rating Certificate

The Home Located At:

1234 Snow Filled Circle
Anchorage, Alaska

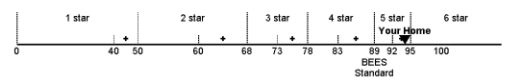
Has Been Energy-Rated As:

★★★★★ +

Five Star Plus

Overall Efficiency of Home

94.0 points



BEES Compliance

Pass

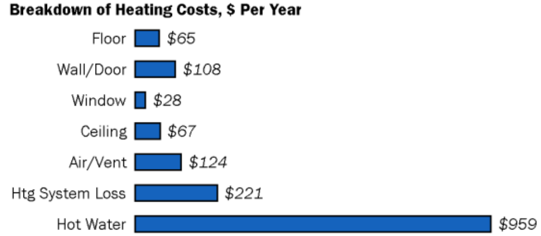
Amount of CO2 Produced by the Home

15,598 pounds per year

Projected Annual Energy Costs

$2,547 per year

Breakdown of Heating Costs, $ Per Year



Client: Happy Homeowner **Rater**: Rater A, Raters R Us **Date**: 1/29/2014
Rater's City: Anchorage, AK 99504 **Contact**: 907 330-9187, Notsocold@winter.us, FAX 907 330-8197
ver. 2.3.1.0, library: 9/24/2013, file: Happy Homeowner.hm2, Rating Type: BEES

I certify that this Rating is true and correct, to the best of my knowledge and belief: ______________________

Rater Signature

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Energy Cost and Features Report

Property: Happy Homeowner
1234 Snow Filled Circle
Anchorage, Alaska

House: Single Family
Living Floor Area: 1,264 square feet
No Attached Garage

Rater: Rater A
Raters R Us
4400 Boniface Parkway
Anchorage, AK 99504

Rating: BEES

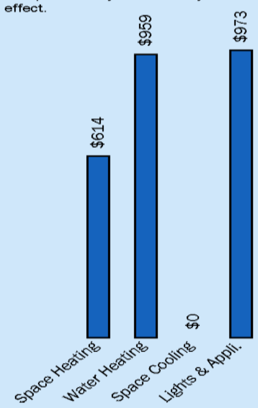
Envelope Efficiency	
Floor Insulation	R-53.1
Wall/Door Insulation	R-25.8
Ceiling Insulation	R-51.8
Window R-Value	R-4.35
Window to Wall Ratio, Living Space	10.1%
South Facing Window Area	42 square feet
Air Leakage	3.3 Air Changes per Hour at 50 Pascals 0.15 Air Changes per Hour Natural
Space Heating System	
System Efficiency	84%
Fuel Type	#2 Oil
Supplemental Fuel	Birch Wood
Thermostat Setting	70.0 degrees F
Setback Thermostat	Yes, Controls Entire Home
Water Heater	
Efficiency	76%
Location	Conditioned Space
Fuel Type	#2 Oil
Space Cooling System	None Present
Ventilation	Continuous Ventilation withou
Other	
Number of Occupants	5
Clothes Dryer Fuel	Electricity
Cooking Range Fuel	Electricity
Miscellaneous Lights/Appliance Use	Average

VENTILATION WARNING: The measured air tightness of this home indicates that it may not provide sufficient ventilation air (for acceptable indoor quality) as defined by ASHRAE 62.2 2010, without adequate mechanical ventilation equipment. If whole house mechanical ventilation equipment has been installed, it is recommended that it be properly maintained and operated. If no whole house mechanical ventilation equipment has been installed, it is strongly recommended that the homeowner consider an investment in this improvement. (A test of the building's ventilation air rate would help determine the importance of a mechanical ventilation system in this home.)

ver. 2.3.1.0, library: 9/24/2013, file: Happy Homeowner.hm2

Estimated Annual Energy Costs

Actual use and costs may vary from these estimates depending upon weather conditions, occupant life styles and utility rates currently in effect.



Electricity: $0.1444/kWh, #2 Oil: $3.78/gallons, Birch Wood: $230/cords
Space Heating: 109 kWh of Electricity, 112 gallons of #2 Oil, 0.77 cords of Birch Wood
Water Heating: 254 gallons of #2 Oil
Space Cooling:
Lights & Appliances: 6,738 kWh of Electricity

Look for this page in your rating

AkWarm Energy Flows Report

Client:
Home at:

Energy Flows below are in Btu/hour

Month	Hours	Gross Loss	Gross Internal	Useable Internal	Gross Solar	Useable Solar	Natural Infil cfm
Jan	744	28,141	2,853	2,853	260	257	138
Feb	678	25,623	2,770	2,770	659	657	136
Mar	744	22,496	2,657	2,657	1,348	1,345	131
Apr	720	16,468	2,544	2,544	1,568	1,549	122
May	744	11,196	2,461	2,461	1,519	1,478	118
Jun	720	7,349	2,431	2,431	1,651	1,530	109
Jul	744	5,540	2,461	2,461	1,528	1,335	95
Aug	744	6,335	2,544	2,544	1,250	1,160	94
Sep	720	9,919	2,657	2,657	953	948	102
Oct	744	16,754	2,770	2,770	647	644	119
Nov	720	23,418	2,853	2,853	354	350	130
Dec	744	27,639	2,884	2,884	158	156	136

Annual Energy Flows

Gross Loss: 146.4 MMBtu

Gross Internal: 23.3 MMBtu
Useable Internal: 23.3 MMBtu
Internal Utilization: 1.000

Gross Solar: 8.7 MMBtu
Useable Solar: 8.3 MMBtu
Solar Utilizati[illegible]

Net Heat Load: 114.8 MMBtu

December UA Values and Design Heat Loss

Living Space UA: 491.8 Btu/hr/deg-F
Garage UA: 0.0 Btu/hr/deg-F
Design Heat Loss (70 deg Indoor, 70 deg Garage): 43,278 Btu/hour

The above value is the required heat output of the heating system. However, heating systems are labeled based on Input Btu/hour. The necessary heating system size (input [illegible] assuming 85% efficiency, and adding a [illegible] Safety Margin) is:
Necessary Heating [illegible]

AkWarmCalc ver. 2.0.4.0, Energy Library ver. 4/10/2009

December UA Values and Design Heat Loss

Living Space UA: 491.8 Btu/hr/deg-F
Garage UA: 0.0 Btu/hr/deg-F
Design Heat Loss (70 deg Indoor, 70 deg Garage): 43,278 Btu/hour

Heat Flow…

…In Alaska, buildings generally = Heat Loss

Temperature Gradients (ΔT) matter!

- ΔT = temperature difference
  - Across wall, floor, etc.
  - Ex.
- Big ΔT = greater driving force for heat transfer
- How?
  - Conduction, convection, radiation

Size matters!

- Juneau

  Inside = 70°F

  Outside = 1°F

  Wall = R-20

- Barrow

  Inside = 70°F

  Outside = -41°F

  Wall = R-35

Heat

Conduction, Convection, Radiation

1) Conduction

- Through solid objects

Compare

Conduction - R vs. U

- R-Value
  - Resistance (Ex. R - 4 window)
  - Additive (Ex. 0.9 + 11 + 1.25 = 12.15)
  - Inverse of conductivity - R = 1/U
- U-factor
  - Conductivity – amount of heat moving through a material (Ex. U - 0.25 window)
  - Not additive
  - Inverse of resistance - U = 1/R

The Good and the Bad

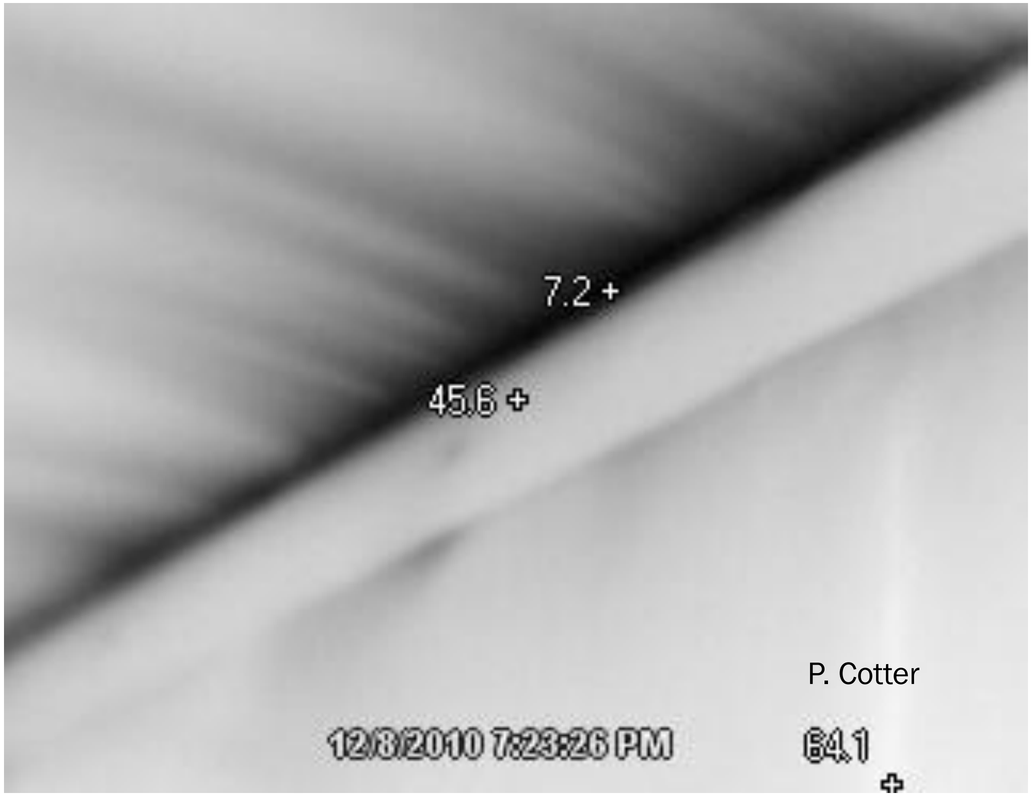
- Good conductors make great cookware
  – High U, low R
  – Aluminum, steel

- Bad conductors make great outhouse seats
  – Low U, High R
  – Foam, still air

Ex. Aluminum vs. insulated fiberglass window frames

2) Convection

- Through air
  - Its about density, really - stack effect, etc…



3) Radiation

- The movement of heat away from an object by electro-magnetic waves (or infrared rays)

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Air

For Air to Flow…

1) Pressure Difference
   - Flow from High to Low
   - More predictable than both death or taxes

2) Pathway

Where buildings leak

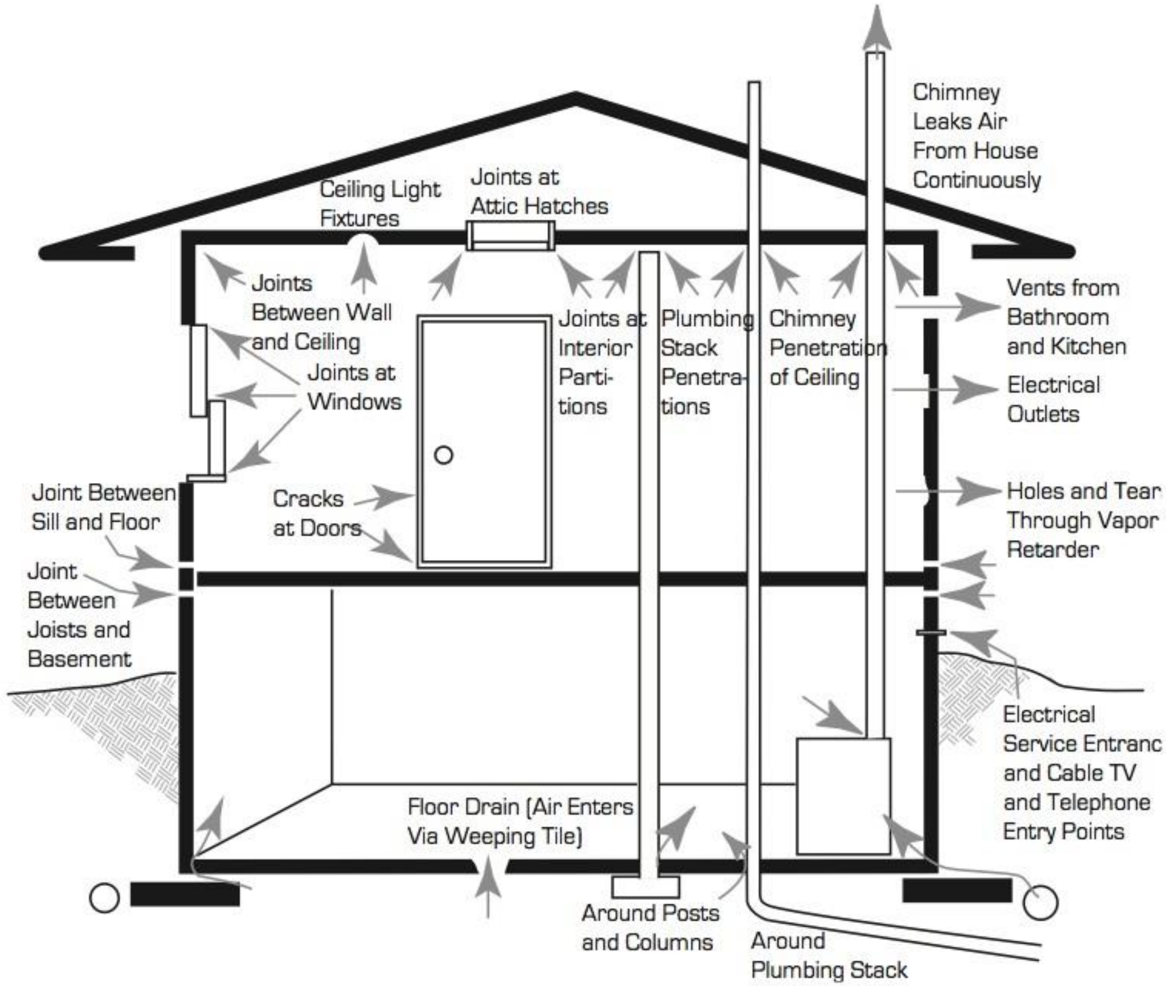


Figure 2.8: Air leakage points in a house.

Unintended air flow results in

- Heat loss
- Increased likelihood of moisture problems

Sealing air leaks* can reduce

- heat loss
- likelihood of moisture problems

*Care must be taken – excessive air sealing without proper ventilation may be extremely dangerous

Building Air....

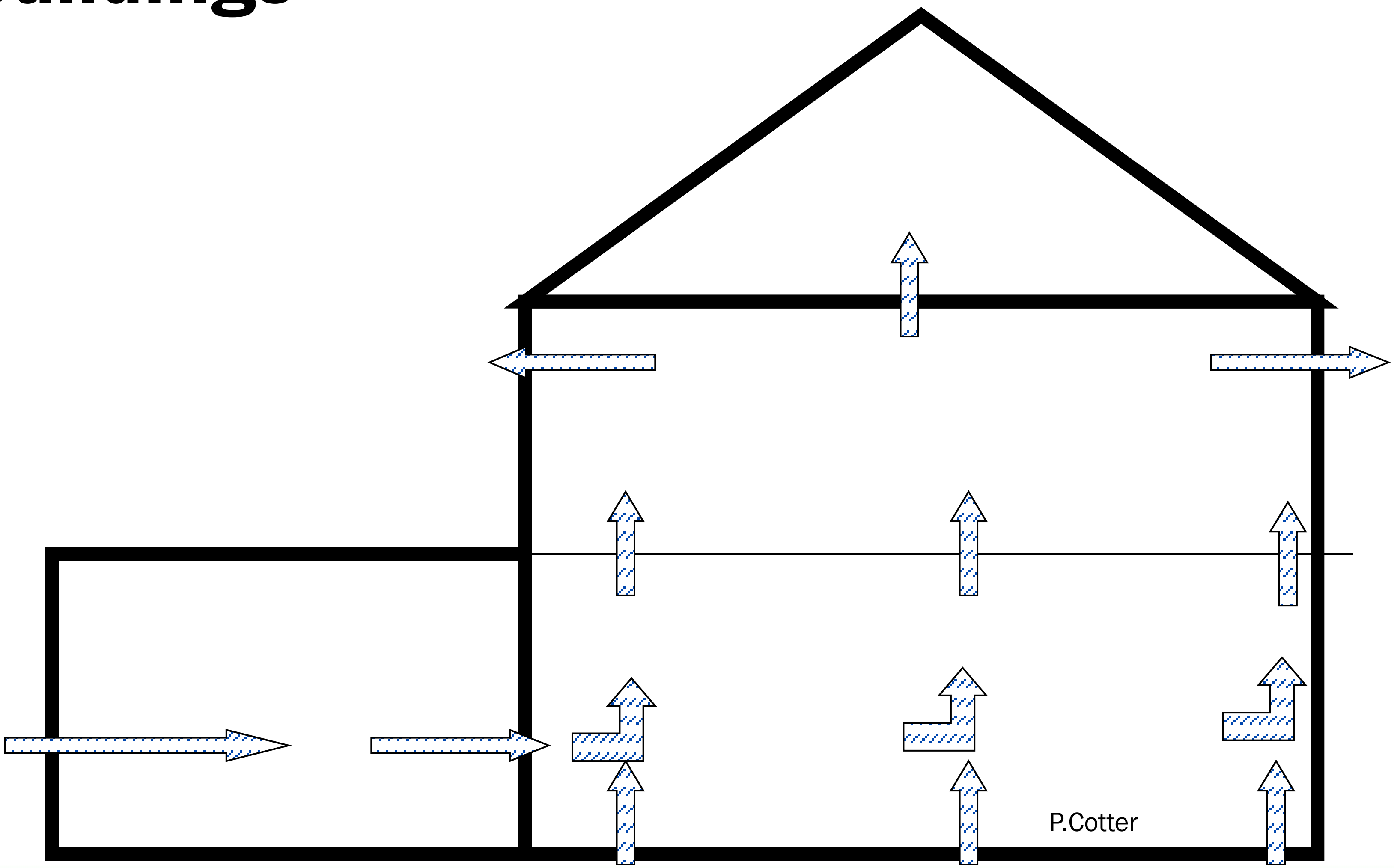
Leaves High

THE STACK EFFECT

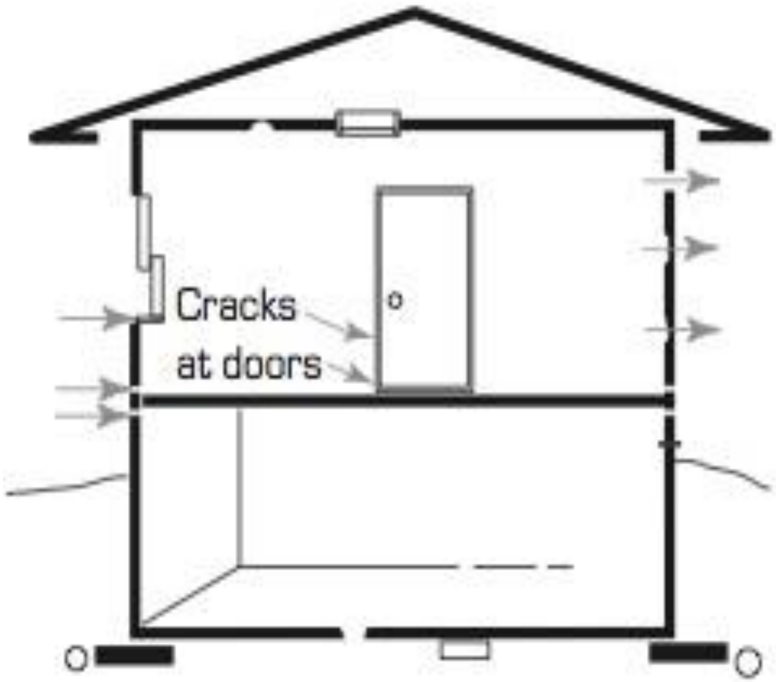
Enters Low

When air warms, it becomes less dense (more buoyant) and it rises

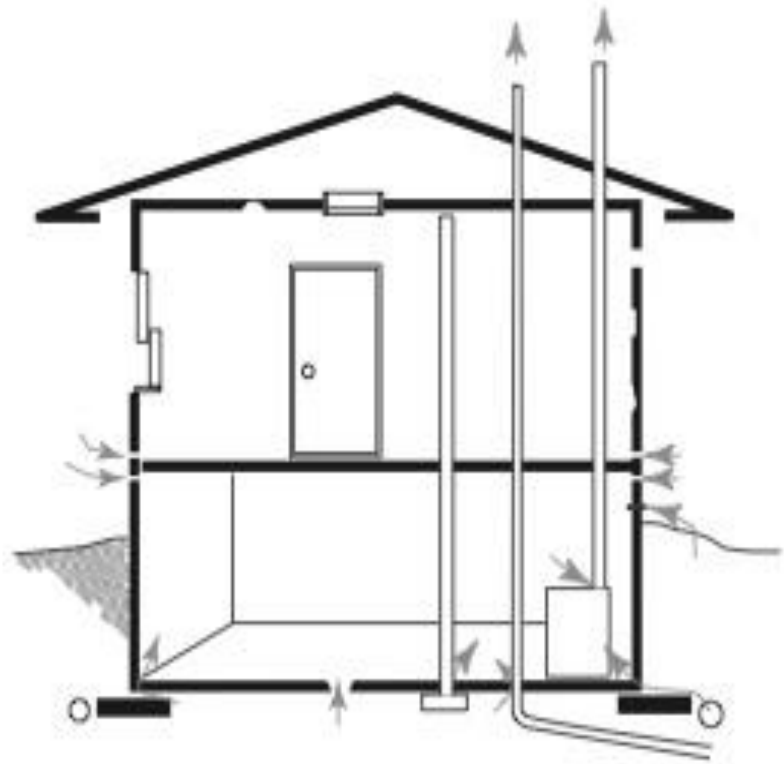
General airflow pattern in cold climate buildings



Other influences on airflow



wind effect



flue and vent effect

APPLIANCE	EXHAUST FLOW (CFM)
down draft cooktop exhaust fan	300+
clothes dryer	150-240
central whole house exhaust	100+
central vacuum	100
bathroom exhaust fan	35+
“balanced” HRV type system	???
fireplace	250
kitchen range exhaust fan	150 - 1000
old, open front wood fireplace	300
old, wood stove (door ports)	65
airtight wood stove	25
natural draft water heater	30
natural draft boiler or furnace	125
power vented boiler or furnace	25

Moisture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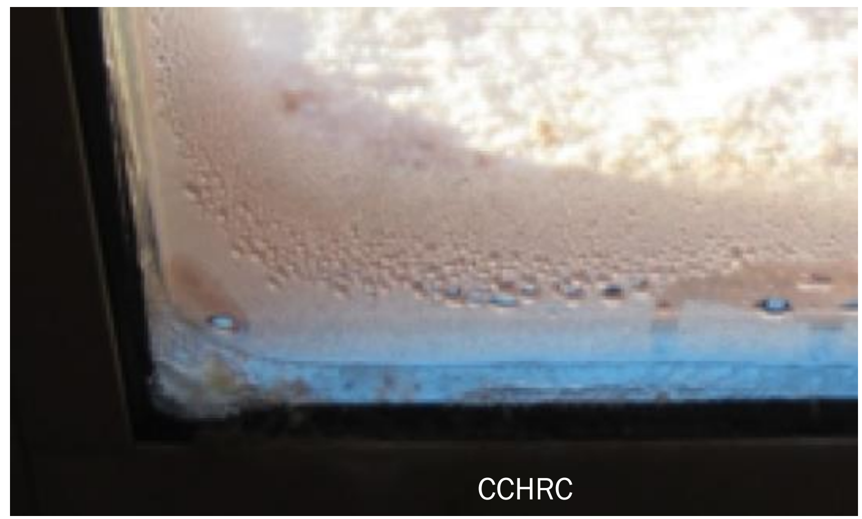
Where does water come from?

ACHP



CCHRC

Relative Humidity

- Amount of water vapor in air RELATIVE to how much water vapor that air can hold
- Depends on TEMPERATURE

Dewpoint Temperature

- The temperature at which water vapor changes to liquid

- Dependent on temperature and amount of moisture in the air

Dew point on interior glass surface

Double Pane

Triple Pane

Why RH matters…

If warm air holds more water than cold air,

AND

this warm air leaks through building assemblies,

AND

it hits cold surfaces,

THEN

we have a moisture problem

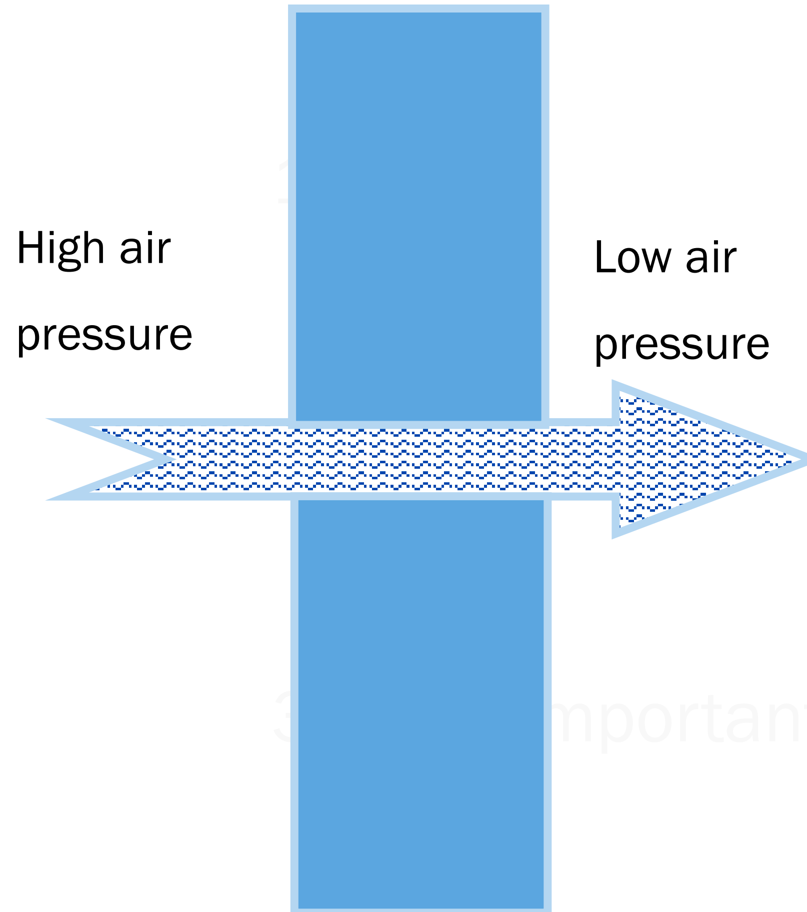
Water vapor moves through assemblies via

1. Air transport

2. Diffusion

Air transport of water*

Water vapor in air moves from high pressure to low pressure

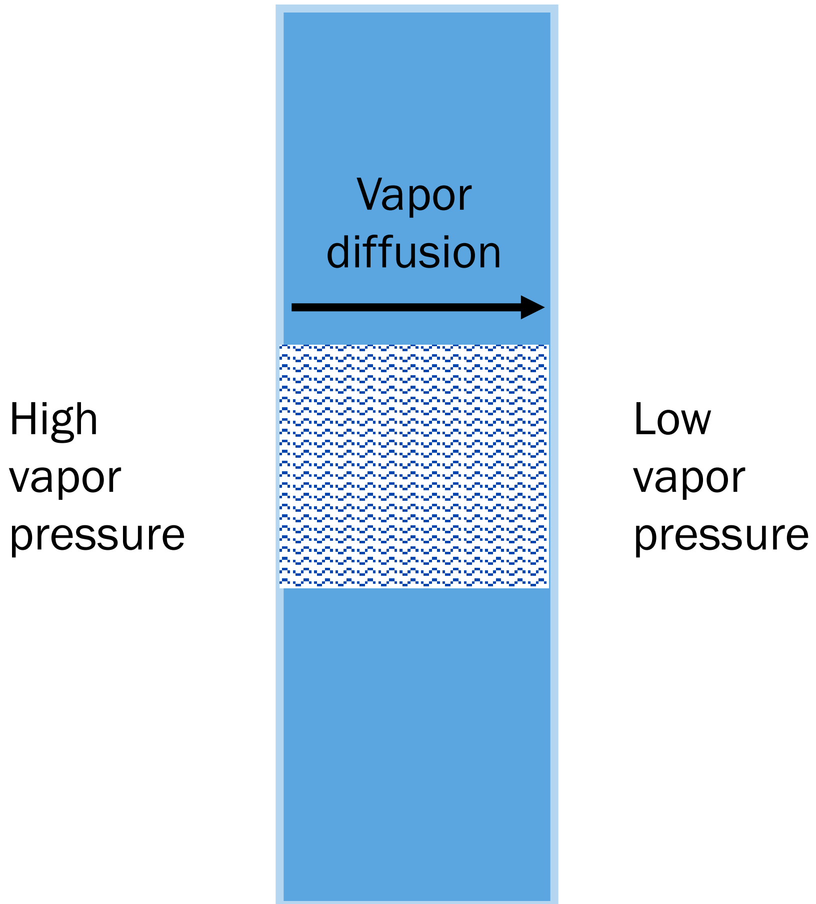


*Most water vapor is transported this way!

Vapor diffusion

Important, but responsible for less vapor transport than occurs through air

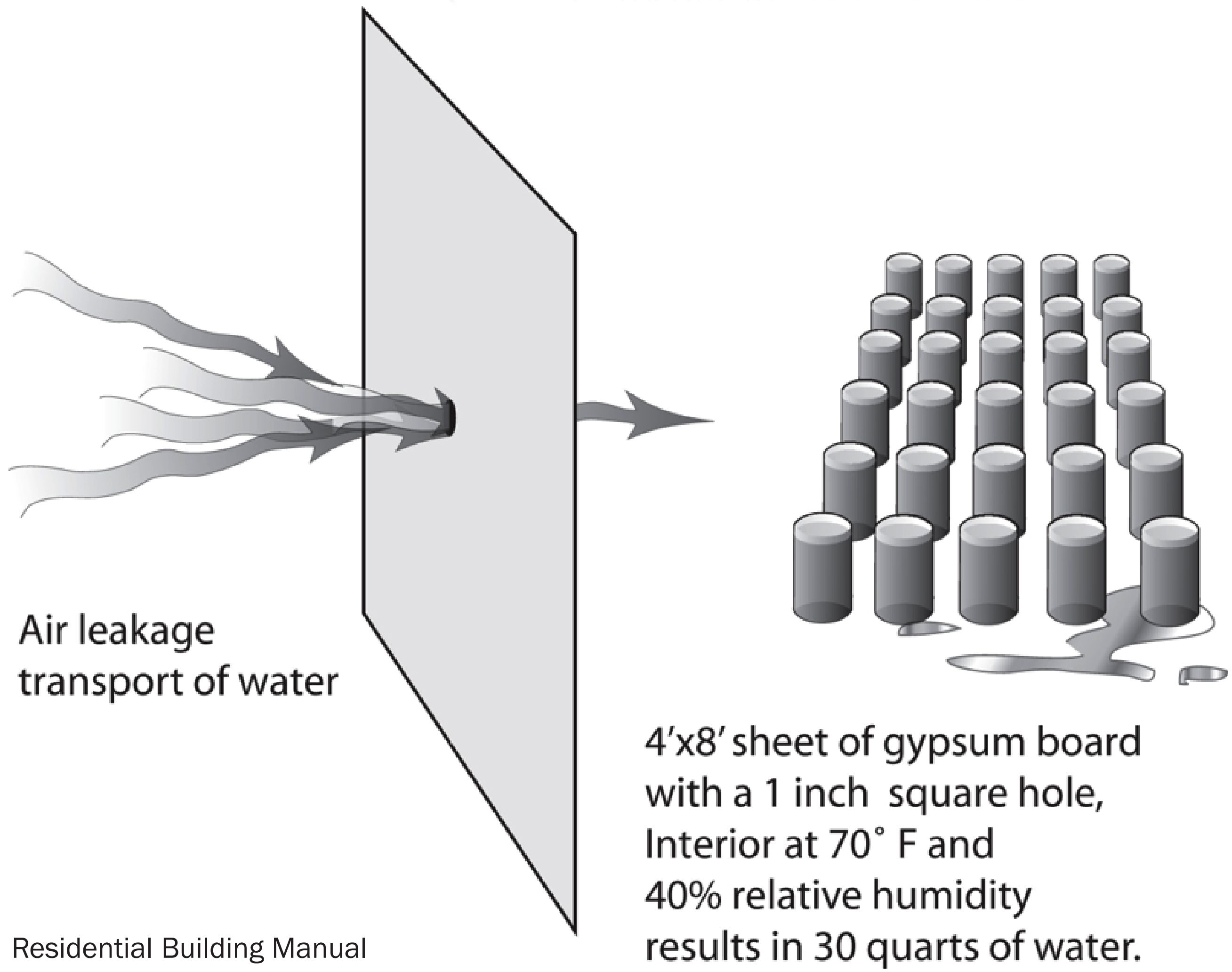
1) Slow
2) Low volume



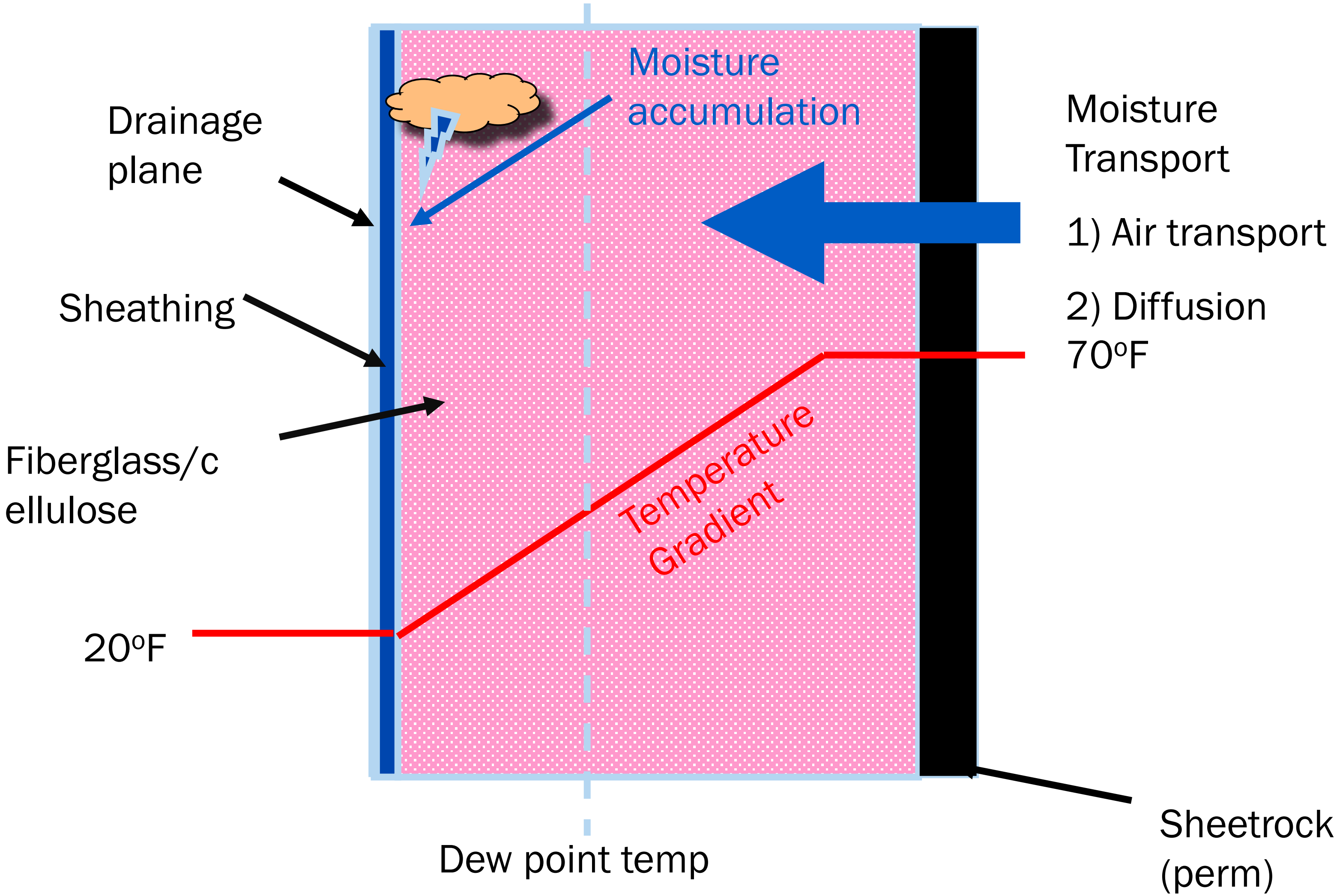
In a heating season…

100x more water moves thru this 1 inch square hole via air transport

than moves thru this entire 4X8 sheet of sheetrock via diffusion



Residential Building Manual



Drainage plane
Sheathing
Fiberglass/cellulose
20ºF
Moisture accumulation
Moisture Transport
1) Air transport
2) Diffusion
70ºF
Temperature Gradient
Dew point temp
Sheetrock (perm)

But RH has other implications…

- Durability
- Health
- Indoor air quality
- Comfort

What should winter RH be in the home?

Depends who you ask, but

30 – 45%

is a good target.

PHAM Rules

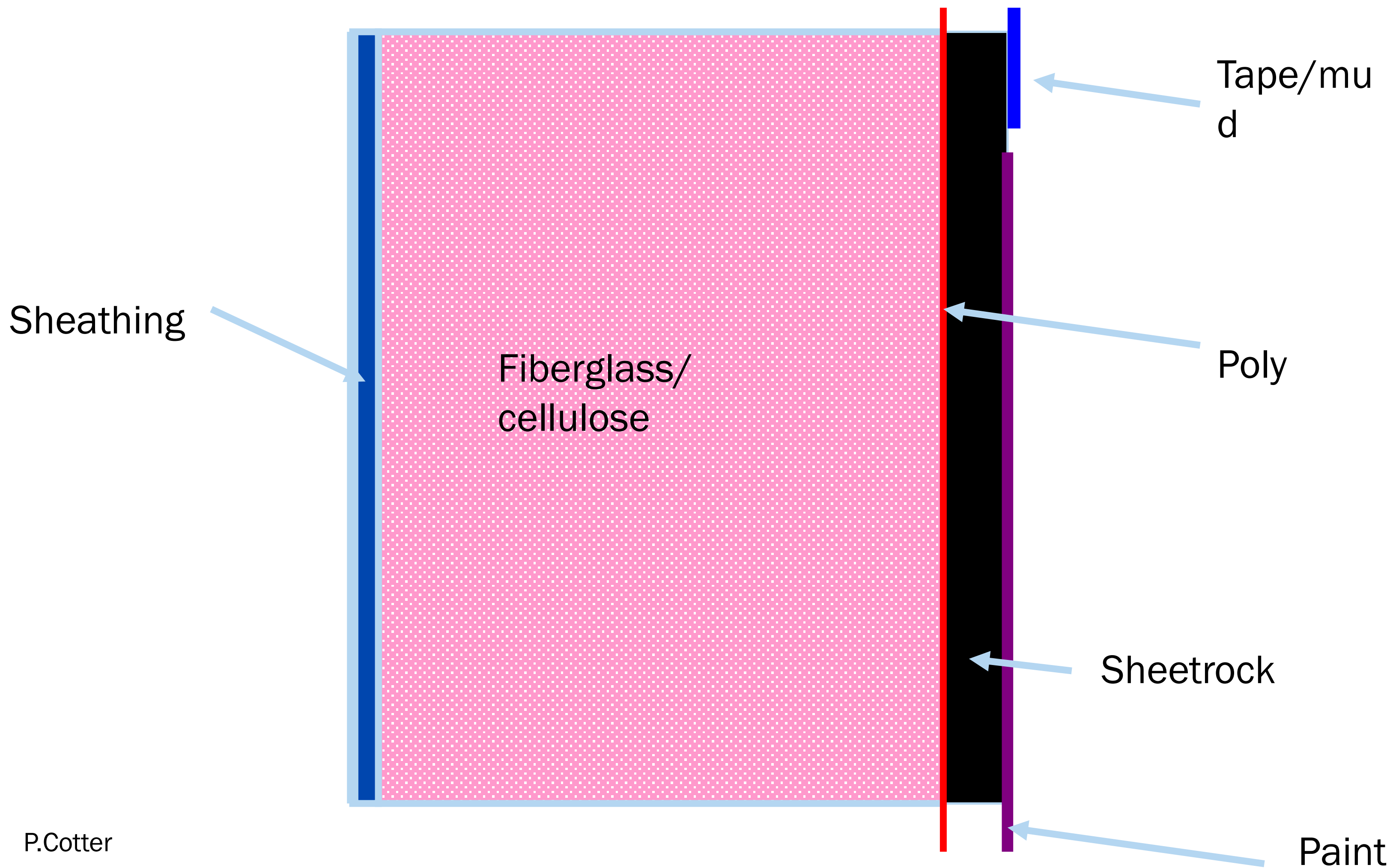
- Pressure drives air movement
- Heat moves from warm to cold.
- Air out equals air in.
- Moisture moves from warm to cold.
- Moisture moves from more to less.
- Rain follows gravity.
- Stuff gets wet, can it dry?
- Things happen at surfaces and connections.

Air Barriers and Vapor Barriers*

- Air Barriers block air
  - Most solid materials
  - Cannot have holes to work properly
  - In homes it is typically a system
    - Paint, drywall, tape, mud, polyethylene…
- Vapor Barriers block diffusion of water vapor
  - Can also be system
  - Often it is polyethylene (visqueen)

*Vapor retarder is the more modern term

Air Barrier Assembly



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Where should Air/Vapor Barriers be?

On the warm side of the insulation

P. Cotter

M. George

Water vapor permeability

- “Perm” rating
  - Refers to diffusion
  - Differs by material
  - Measured in “perms”

- The point
  - Higher perm rating = water vapor moves more easily through it

Some Perm Ratings

- ½" plywood/OSB ~ 0.5
- ½" sheetrock ~ 20
- Concrete ~ 3
- 15lb asphalt felt ~ 3
- 1" blueboard ~ 2
- 1" beadboard ~ 4
- Tyvek house wrap ~ 55
- Typar house wrap ~ 12

Vapor Permeability Rule*
for Cold Climates

Generally, from inside to outside, vapor permeability of materials should increase

*"Rule" is used loosely

What is a weather barrier?

- Prevents intrusion of air/water into building components

- Typically located behind the siding

- Typically vapor permeable

Material Properties

R-value and U-factor

- R-Value
  - Resistance to heat flow
  - High R-value = better insulator
  - Often used to describe insulation performance
- U-factor
  - Conductance of heat flow
  - Low U-factor = better insulator
  - Most often used for windows and doors

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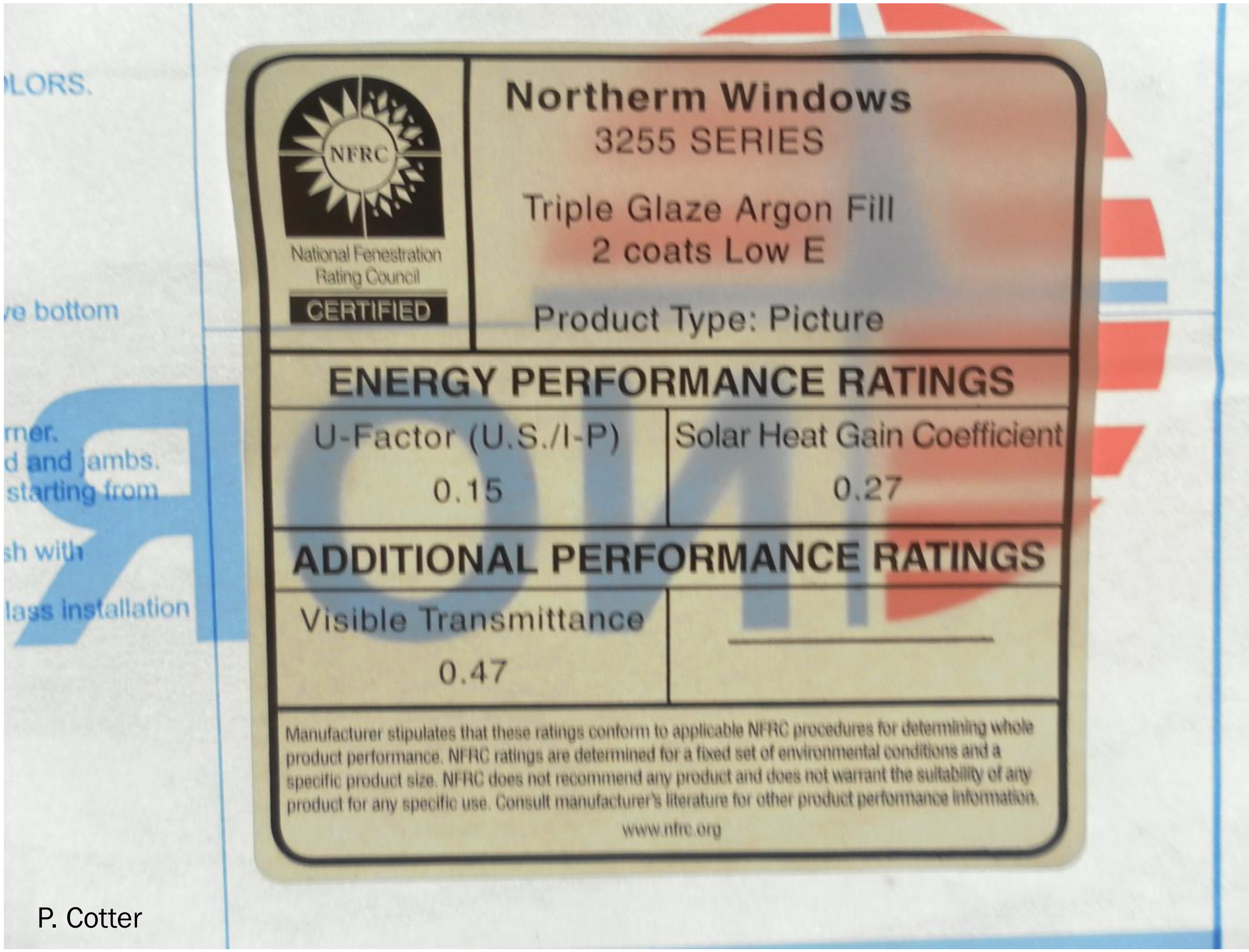
A U-factor



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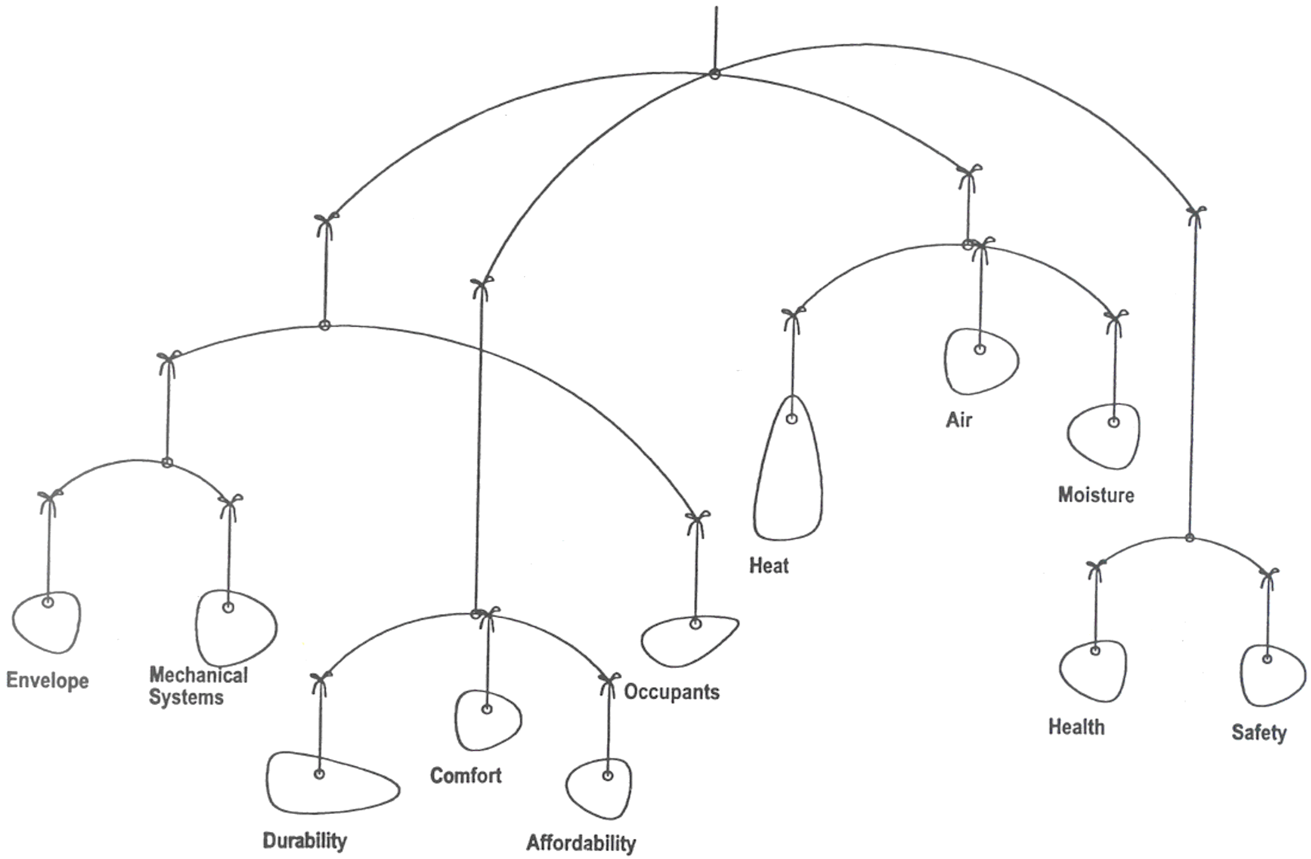
R and U Rules for Cold Climates

- Insulation should have high R-Value

- Doors and Windows should have low U-factor

The house is a system!



Resources

- AHFC - Research Information Center
- Alaska Residential Building Manual
  www.ahfc.us
- Cold Climate Housing Research Center
  www.cchrc.org
- One stop shop for AK Energy Efficiency information
  www.akenergyefficiency.org