Course Guide

RESNET

Home Energy Survey Professional (HESP) Course

*1st Two Days of **RESNET** Diagnostic HESP Course*

*1st Two Days of **BPI** Building Analyst Professional Course*

To be used in conjunction with

Residential Energy

by John Krigger and Chris Dorsi

Preface: Residential Energy Services Network (RESNET)

(Study the Source: Chapter 7 RESNET National Standard for Home Energy Audits)

www.resnet.us/standards/mortgage/amendments/2008/Audit.pdf

What is the Residential Energy Services Network (RESNET)

- An industry-based, not-for-profit membership corporation
- A national standards making body for building energy efficiency rating and certification systems in the USA

Who Recognizes RESNET?

- Mortgage industry for capitalizing energy efficiency mortgages
- Federal government agencies
  - IRS for tax credit qualification
  - U.S. EPA for ENERGY STAR labeled homes
  - U.S. Department of Energy for *Building America* program
- States for minimum code compliance in 16 states

What is a HERS Rating?

A relative energy use index called the HERS® Index Ratings provides a relative energy use index called the HERS Index – a HERS Index of 100 represents the energy use of the "American Standard Building" and an Index of 0 (zero) indicates that the Proposed Building uses no net purchased energy (a Zero Energy Building).

What are RESNET's 2009 Priorities

- Have RESNET Standards Become ANSI* Compliant
- Advocate Residential Energy Efficiency Strategic Initiatives to President and Congress
- Tap the Existing Homes Market

RESNET Energy Assessment Standard Categories of Services

LEVEL ONE - HESP

- In-Home Home Energy Survey – performed by a RESNET Certified *Home Energy Survey Professional (HESP)*
  - Insulation Visual Inspection
  - Doors and Windows
  - HVAC System
  - Visual Inspection of Common Air Leakage Areas

RESNET HESP Certification Requirements

(Meet the Requirements of the RESNET Code of Ethics

- Pass the online RESNET Energy Audit Exam
  - 50 questions
  - multiple choice
  - open book
  - Passing Score of 75%

- Sign with a HESP ***Provider*** who will provide QA/QC oversight
- Agree to follow Provider's QA/QC procedures including review of 10% of all surveys and/or audits performed
- Agree to the **Provider's complaint resolution process**
- Complete and provide to each client the **Home Energy Survey Standard Disclosure Form** [illegible]

Requirements for a Standardized In-Home Home Energy *Survey*

- Homeowner Interview
  - Energy Use
  - Comfort Problems
  - His/Her Interest in Energy Upgrades
  - Discussion of Current Energy Bills
- Provide Info on No-Cost/Low-Cost Do-It-Yourself Improvements
- Document and/or Inspect the Following:
  - R-Values per climate zone
  - Square foot and age of the home
  - Window Descriptions
  - HVAC (type, model, location, age, etc.)
  - Ductwork
    - location
    - type,
    - R-Value
  - Foundation Type
  - List of Possible Air Leakage Sites Throughout House
  - Visual Indications of Condensation
    - Around windows
    - On ceilings
    - At supply registers
    - (Is their a vent-less fireplace)
  - Exhaust Fans
    - Locations
    - Do they work?
    - Vented to the Outside
  - Number of Type of Water Fixtures
    - Sinks (sometimes called lavatory) with low-flow faucets
    - Low-flow toilets (sometimes called water closets) – have Integral Traps
  - Any ENERGY STAR Appliances, Appliance Age and Use

Required Inclusion in All In-Home Home Energy *Survey* REPORT

- All Collected Data
- Overview of How the House Works as a System
- Which Appliances are Energy Star and Which Are Not
- Whole-House Solutions

- ***Prioritized*** List of Recommended Upgrades
    - *Mechanical Equipment*
    - *Thermal Envelope (air and insulation)*
    - *Lighting*
    - *Appliances*
- Recommendations for Higher-Level Investigation
    - ***Diagnostic* Home Energy *Survey*** (if not performed)
    - ***Comprehensive* Home Energy *Analysis***
- Benefits of Reduction of Carbon Emissions*
- Concerns About Combustion Safety

Safety Notification Form Provided if There Are Obvious Problems

- **LEVEL TWO - Diagnostic HESP**
    - Can perform diagnostic testing such as:
        - Blower Door Test
        - Duct Leakage Test
        - Worst Case Depressurization Test
        - Thermal Imaging (IR)
    - Diagnostic Testing Must Be Performed According to RESNET Standards
    - Verification & Certification by the RESNET HESP Provider*

Home Energy Survey Limits

- Visual Inspections Only
- No Diagnostics
- Generalized Information Provided in the Report

- ***Diagnostic*** Survey Limits
    - CAN be performed by a certified Diagnostic HESP
    - Use of Some Diagnostic Equipment
    - In-Depth Report on How to Prioritize Energy Upgrade Recommendations *(based on bang for buck)*
    - CANNOT provide a Rating Score
    - Cannot provide **specific** energy savings analysis
    - **Estimates of energy savings may only be generalized**

Rating Field Inspector (RFI)

- trained to perform ALL the necessary inspections & diagnostic testing to produce an energy rating
- provides gathered data to a HERS Rater or CHEA, who produces report using RemRate, EnergyGauge or equivalent DOE approved software.

HERS Rater

Comprehensive Home Energy Analysis - **MUST BE** performed by a Certified HERS® Rater who has also completed RESNET Combustion Safety Training or BPI Building Analyst and MUST include:

- Computerized Energy Use Modeling
- Calculation of Specific Energy Savings that will result from recommended improvements
- A specific scope of work (specifications)

RESNET Certification Requirements

- Sign with a Home Energy Assessment/Rating ***Provider*** who will provide QA/QC oversight
- Agree to follow Provider's QA/QC procedures including review of 10% of all surveys and/or audits performed
- **Agree to the Provider's complaint resolution process (Complaints go the Provider)**
- Complete and provide to each client the Home Energy Survey Standard Disclosure Form
- Use only a RESNET approved report format as per the Provider

Preface: Building Performance Institute (BPI)

BPI

- Recognized Global Leader Supporting Development of Highly Professional Building Performance Industry
- Standards Setting
- Individual and Organizational Credentialing
- Rigorous Quality Assurance Program

BPI Certification Categories

  - Building Analyst Professional
  - Building Envelope Specialist
  - Heating Professional
  - AC/Heat Pump Professional
  - Multifamily Certifications
- BPI Accredited Contractor Company

BPI Building Analyst Professional

- Training & knowledge base
- Buildings and their systems
- Measurement & Verification of Building Performance
- BPI Standards and Project Specifications

Preface Practice Questions

1. According to RESNET Standards, which of the following is the HESP required to discuss with the homeowner?
    a. The age of the house
    b. The type of HVAC
    c. Any comfort problems they are experiencing
    d. Their thermostat setting

2. What must be completed for each home that receives a Home Energy Survey and provided to the client and homeowner?
    a. The RESNET Code of Ethics
    b. A scope of work for recommended improvements
    c. A list of recommended improvement contractors
    d. The Home Energy Survey Standard Disclosure Form

3. According to RESNET Standards, the HESP must inform the client of what type of low cost improvements?
    a. The ones with the quickest payback
    b. The ones that will save the most energy over time
    c. The ones the homeowner can do themselves
    d. The ones that a contractor could take care of while performing major repairs

4. What percentage of Home Energy Surveys is the QA Designee for HESP Provider required to annually evaluate for each surveyor?
    a. 3 per year
    b. Minimum of 3%
    c. Minimum of 5%
    d. Minimum of 10%

5. Who handles customer complaints about the services of a RESNET HESP?
    a. The Home Energy Survey Professional (HESP)
    b. The HESP Provider
    c. The RESNET Board of Directors
    d. The RESNET Executive Director

Chapter One: PRINCIPLES OF ENERGY

Energy: a measurable quantity of heat, work, or light.

- Potential Energy is *stored.*
- Kinetic Energy is *transitional*.

Two Major Approaches to the Wise – What's the difference?

- Energy Efficiency
- Energy Conservation

Categories of Residential Inefficiency

- Heating
- Heat Losses
- Air Leakage
- Water Heating
- Cooling
- Heat Gains
- Distribution Systems
- Appliances/Lighting
- Residential Behavior

Seasonal & Base-load Consumption

- Homes normally consume 40%-50% of energy for heating/cooling (seasonal)
- Base-load will remain fairly stable - based on plug loads, including:
  - vampire loads
  - consumer habits

Measurements for Energy Consumption (IMPORTANT!)

- Electrical energy: measured in **kW-hours.**
- Natural gas: measured in:
  - hundred cubic feet (1 **ccf**)
  - thousand cubic feet (1 **mcf**), or
  - a therm
- **1 ccf** = a **therm** which = approximately 100,000 **BTUs**
- **1 mcf** = a million BTUs (MMBTU)
- **1 cubic foot (1 cf) = 1000 BTUs**
- **1 Kilowatt Hour = 3412.14 BTUs**
- **1 million BTUs (1 MMBTU) = 293 Kilowatt Hours** (*1 BTU = 0.00293 KWH*)
- **Costs of different fuels (gas, oil, propane, electricity) are commonly compared in MMBTUs**

http://www.calculateme.com/Energy/KilowattHours/ToBTUs.htm ó¸2dz Ől·ƴdzăŜ Řdzƴ϶ I9{t 9ÈI·Yύ

Life-Cycle Costing

- Payback Period
- Annual Return
- Life-Cycle Cost
    - Compare the life-cycle cost of taking action with the life-cycle cost of not taking action.
    - If the cost of action is less over time than inaction, take action.

First Law of Thermal Dynamics

- Energy is Neither Created or Destroyed
    - It Only Moves from Here to There
    - And/or Changes Form

Second Law of Thermal Dynamics

- Heat Moves from High Temperature Regions to Low Temperature Regions
- Heat Always Travels from Hot to Cold
- All Things in Nature Go from Order to Disorder

Temperature and Heat

- Temperature is a measure of how fast the molecules in a substance are moving or vibrating
- Heat flows because of a difference in temperature between two areas (delta T)

The process of cooling involves removing energy from a system

BTU: British Thermal Unit

- The amount of heat required to raise the temperature of 1 lb. of water I degree Fahrenheit
- **q(BTU)=U x Ax ΔT**

Sample problem: What is the heat transfer of a ceiling having the measurements of 30' x 60' ceiling with R-38 insulation, if the inside temperature is 72° and outside temperature is 25°?

U = 1/R therefore: 1/38 = 0.026U
Area = 30 x 60 or 1800 sq/ft
ΔT = 72-25 or 47°

q(BTU) = 0.026 x 1800 x 47
q(BTU) = 2,200 btu/hr

Latent Heat

Unexpected or hidden heat, released or absorbed as a substance changes phases or states
Two latent heats are typically described: latent heat of fusion (melting), and latent heat of vaporization (boiling). The names describe the direction of heat flow from one phase to the next: solid → liquid → gas.

Supplemental explanation: The change is endothermic (absorbing energy) when the change is from solid to liquid to gas. It is exothermic (releasing energy) when it is in the opposite direction. For example, in the atmosphere, when a molecule of water evaporates from the surface of any body of water, *energy* is transported by the water molecule into a lower temperature air parcel that contains more water vapor than its surroundings.

Since energy is needed to overcome the molecular forces of attraction between water particles, the process of transition from water to water vapor requires the input of energy causing a drop in temperature in its surroundings. If the water vapor condenses back to a liquid or solid phase onto a surface, the latent energy absorbed during evaporation is released as sensible heat onto the surface. The large value of the enthalpy of condensation of water vapor is the reason that steam is far more effective as a heating medium than boiling water.

Sensible Heat

The heat required to change the temperature of a substance is called as sensible heat.

- Add 150 BTUs to a pound of water and its temperature increases 150°F to the temperature of 200°F.
- This sensible relationship ends at 212°F, water's boiling point.

Supplemental Explanation: **Sensible heat** is potential energy in the form of thermal energy or heat. The thermal body must have a temperature higher than its surroundings (see also latent heat). The thermal energy can be transported via conduction, convection, radiation or by a combination thereof. The quantity or magnitude of sensible heat is the product of the body's mass, its specific heat capacity and its temperature above a reference temperature. In many cases the reference temperature is inferred from common knowledge, i.e. "room temperature".

Energy vs. Power

Power is energy divided by time. It is the rate at which work is done or heat is released

In physics, **power** (symbol: *P*) is the rate at which work is performed or energy is transmitted, or the amount of energy required or expended for a given unit of time. As a rate of change of work done or the energy of a subsystem, power is:

$$P = \frac{W}{t}$$

where *P* is power, *W* is work and *t* is time.

The **average power** is the average amount of work done or energy transferred per unit time. The **instantaneous power** is then the limiting value of the average power as the time interval Δt approaches zero.

If a 100,000 BTU/hour furnace runs for 10 hours, it converted, 1 million BTUs of the fuel's potential energy to heat.

Calculating POWER

- The heat content of one cord of hardwood is 20 million BTUs.
- If a woodstove burned a cord of wood in 200 hours, its POWER would be calculated by dividing the ENERGY (the 20 million BTUs in a cord of wood) by the TIME (the 200 hours it took to burn.
- 20 million BTUs ÷ 200 hrs = 100,000 BTUs/hour of POWER

Types of Heat Flow

Heat travels from areas of high temperature to areas of low temperature in three ways:

- Conduction
- Convection
- Radiation

Conduction – heat transfer through solid materials or objects touching

- The transfer of heat by **direct contact** of particles of matter
  - **Conduction is greater in solids**, where atoms are in constant contact
  - Metals (e.g. copper) are usually the best conductors of thermal energy
  - As density decreases so does conduction. Therefore, fluids (and especially gases) are less conductive

A heat pipe is a passive device that is constructed in such a way that it acts as though it has extremely high thermal conductivity.

Convection – always involves a fluid (air, water, gas)

- The movement of molecules within fluids (i.e. liquids, gases including air).
- Heated area has reduced density causing it to rise; lower density areas descend
- Heat causes a be carried passively by fluid motion which would occur anyway without the heating process (a he change in density

Supplemental Explanation: A common use of the term convection leaves out the word "heat" but nevertheless refers to heat convection: that is, the case in which heat is the entity of interest being carried and dispersed.

In one of two major types of heat convection, the heat may be carried passively by fluid motion which would occur anyway without the heating process (a change in density) at transfer process termed loosely as "forced convection").

In the *other* major type of heat convection, heating itself may *cause* the fluid motion (via expansion and buoyancy force), while at the same time also causing heat to be transported by this motion of the fluid (a process known loosely as natural convection, or "free convection"). In the latter case, the problem of heat transport (and related transport of other substances in the fluid due to it) is generally more complicated. Both forced and natural types of heat convection may occur together.

Convection Loops

- Heat added to one part of a fluid causes molecules to move faster.
- The heated area has reduced density causing it to rise; lower density areas descend.
- Heat causes a change in density.

Radiation

- Heat transferred from one object to another **through space**
- **Requires line of sight**

Radiation: Seasonal Changes – The sun's changing path across the sky

4 Types of Radiation Behavior

1. Emission
2. Reflection
3. Absorption
4. Transmission

Thermal radiation: electromagnetic radiation **emitted** from the surface of an object due to the object's temperature.

Why Do We Insulate?

- The un-insulated wall transmits energy through its air space by both convection and radiation.
- In an insulated wall, heat must conduct through tiny air pockets trapped by the insulation – a slower process

Heating Degree Day (HDD)

A unit of measurement to describe how long the temperature is below 65°F during each day, month or year

Take the average outdoor temperature for any day and subtract it from 65°F;
Example: High of 30°F, low of 0°F = average of 15°F. **65°F - 15°F = 50 HDDs.**

Example: The average temperature for a given day is 55°F. Since this value is 10 degrees lower than the reference point of 65°F then one would say this is a *ten degree-day*.

Anchorage, Alaska has 10,864 HDD/year **Miami Beach has 141 HDD/year**

Cooling-Degree Day

A unit for measuring the air temperature difference between the outdoors and 78°F over the hot summer season. Cooling-degree days measure the intensity of the summer climate.

Supplemental explanation: **Heating degree day** (**HDD**) and **cooling degree day** (**CDD**) are quantitative indices designed to reflect the demand for energy needed to heat or cool a home or business. They're derived from daily temperature observations, and the heating (or cooling) requirements for a given structure at a specific location are considered to be directly proportional to the number of heating degree days at that location.

The number of heating degrees in a day is defined as the difference between a reference value of 65°F (18°C) and the average outside temperature for that day. The value of 65°F is taken as a reference point because experience shows that if the outside temperature is this value then no heating or cooling is normally required. Occupants and equipment within a building usually add enough heat to bring the temperature up to a more comfortable level.

Four Comfort Factors:

1. Air temp
2. Relative Humidity
3. "Mean" radiant temp
4. Moving air

Humidity

- Air temperature & amount of water vapor in the air determine how much heat the air contains
- The higher the humidity at a given temperature, the more heat the air holds.

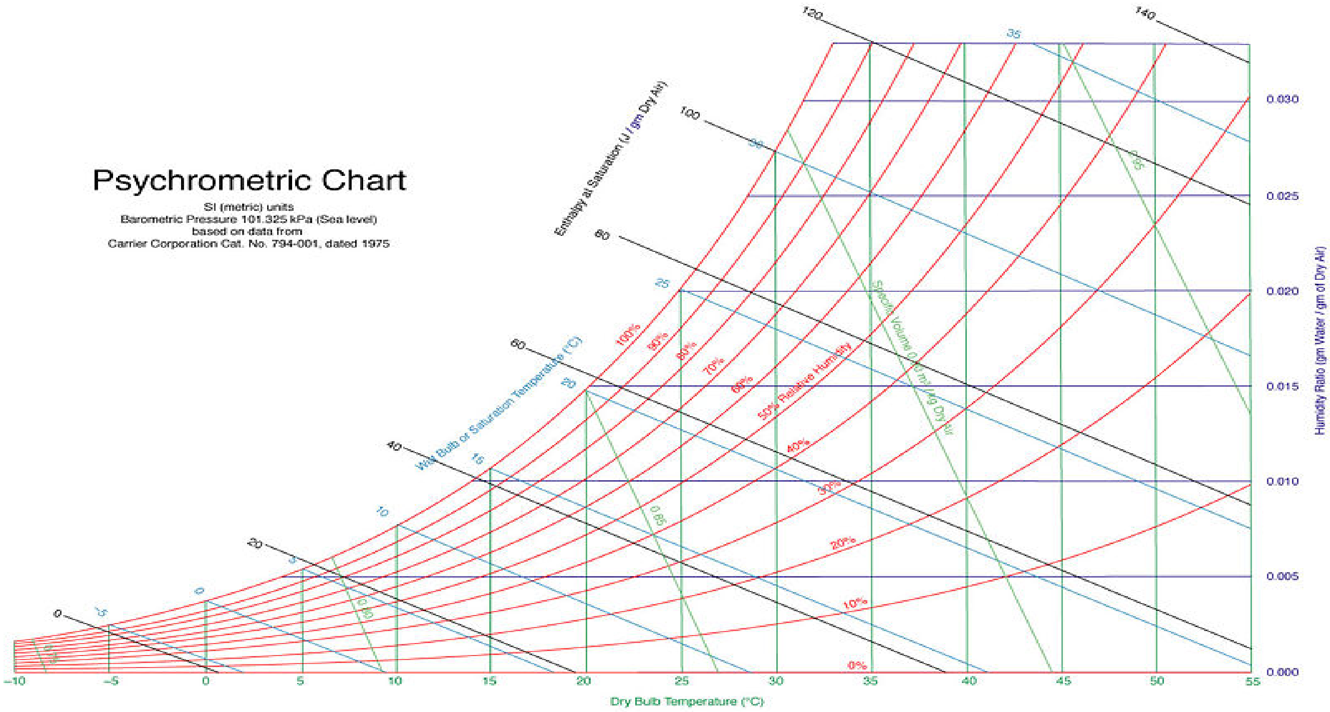
Relative humidity (RH)

- The percentage of moisture absorbed in the air compared to the maximum amount possible;
- Completely saturated air has an RH of 100%
- The ratio of the partial pressure of water vapor in a parcel of air to the saturated pressure of water vapor at a prescribed temperature

NOTE: A sling psychrometer is used for measuring relative humidity.

Indoor Relative Humidity

- **Warmer air can hold more moisture than colder air**
- **Most common range for comfort level in a home is 30%-50% RH**
- Indoor RH lower than 60% in the summer promotes comfort
- Indoor RH in winter should be less than 40% to prevent indoor condensation on cooler surfaces
- Example: sweating windows means too much moisture in the house; is there a vent-less fireplace?



Dew Point:

- The warmest temperature of an object in an environment where water condensation from surrounding air would form on that object
- The temperature at which water vapor will become liquid

Possible Areas of Condensation in a Home

- Windows
- Behind furniture on exterior walls
- On un-insulated ceiling areas
- On supply registers when furnace is off and an unvented fireplace is being used

Byproducts of Combustion

- Water
- Carbon Dioxide
- Carbon Monoxide

Chapter One Practice Questions

1. Which of the following is not among the four environmental factors that affect human comfort in the indoor environment?
    a. The temperature of the air
    b. The Delta T
    c. The relative humidity
    d. The mean radiant temperature

2. Three million Btus is equal to how many kWh?
    a. 293
    b. 10,238
    c. 879
    d. 50,000

3. What range of room relative humidity is considered ideal for home occupants?
    a. 10%-30%
    b. 30%-50%
    c. 40%-60%
    d. 50%-70%

4. When does condensation occur?
    a. When the temperature goes below the dew point.
    b. When the relative humidity of the air reaches 100%.
    c. When the temperature of a surface is less than the dew point.
    d. When the relative humidity of the outside air is above 60%.

5. One kWh equals
    a. 3413 Btu/hr.
    b. 0.000293 Btu
    c. 3412 Btu
    d. 1 Therm

6. Comfort is not a function of which of the following:
    a. air temperature
    b. mean radiant temperature
    c. relative humidity
    d. exfiltration

7. HESP PLUS*: What is the heat transfer for a ceiling having measurements of 30' x 60' with R-38 if the inside temperature is 72 and the outside temperature is 25?
    a. 22,000 btu/hr
    b. 2,200 btu/hr
    c. 1455 btu/hr
    d. 3,214,800 btu/hr

*HESP PLUS questions are beyond the scope of the HESP Exam.

8. Without changing the grains of water in the air, if the air is heated, the relative humidity will:
    a. increase
    b. decrease
    c. stay the same
    d. cause condensation

9. Convection is best exemplified by:
    a. Warm air exfiltrating into the attic from the house.
    b. Heat traveling through space.
    c. Diffusion and perm rating.
    d. Condensation on iced tea glass.

10. In what climate zone would a house be found that has 10,600 heating degree days and receives approximately 25 to 30 inches of rain a year?
    a. Cold
    b. Mixed humid
    c. Hot humid
    d. Hot dry

11. What is a common unit used when comparing fuels such as oil, gas and LP?
    a. mpg
    b. mmbtu
    c. gallons
    d. kwh

12. Approximately how many cubic feet of natural gas would be required to produce 275,000 Btus?
    a. 3.412
    b. 0.293
    c. 275
    d. 3412

Chapter Two: Energy & the Building Shell

Air Barriers

- Any interior or exterior sheeting (solid material) that offers resistance to airflow
- Energy Efficient buildings have a **thermal boundary** defined by insulation and an air barrier
- Most American homes use drywall as the air barrier

Building construction

- Protrusions and indentations to the building's shell provide increased surface area where the insulation and air barrier may not be continuous
- Protrusion Examples:
  - Bay windows
  - Dormers
  - Porches
- Indentation Examples:
  - Indentations
  - Recessed entrances
  - Windows
  - Porches

Structural Design – Two Classifications

- Skeletal – supported by columns and beams
- Planer – supported by panels

Balloon Framing

- Found in older homes,
- Wall cavities open to both the basement and attic
- Continuous exterior wall studs
- Fire-stopping necessary to:
  - isolate vertical and horizontal cavities
  - to limit the height of the wall cavity

Platform framing in modern homes features:

- Roof trusses or complicated cut roofs
- Platform framing
- 4' by 8' pieces of sheathing material for floors walls and ceilings

Energy Weaknesses is Typical Residences

- Usually concentrated around irregularities in the building shell
  - Porches
  - Roof overhangs
  - Shafts for chimneys or pipes
  - Protruded or indented doors and windows
  - Crawlspaces or basements connected to outdoors

Energy Weaknesses in Mobile Homes (6% of American Homes)

- Joints and holes in forced-air distribution systems.
- Torn or missing belly paper.
- Joints between sections and at perimeter.
- Plumbing penetrations.
- Joints between main structure and additions.

Energy Weaknesses in Multifamily Buildings

- Thermal Bridging
- Protrusions and Recesses
- Roof Protrusions and Penetrations
- Air Intake and Exhaust Vents

Thermal Breaks

- An element of low thermal conductivity placed in an assembly to reduce or prevent the flow of thermal energy between conductive materials.
    - Double paned windows - the air or gas between the panes stops the conductive thermal energy from passing through the glass.
    - Metal window or curtain wall framing - a separator material is sometimes used between the inner and outer frames to prevent the temperature outside to eventually transfer through the frame.
    - Concrete work - a single row of CMU block is commonly set between the inner concrete slab and exterior concrete work to prevent the transfer of heat or cold through the slab.
    - Garage doors - in some doors that have high R-rating insulation, a vinyl thermal break is used along the edges of each segment instead of rolled steel.
- **These components prevent direct linkage between indoors and outdoors through those conductive materials**

Building Shell Heat Flow

- Heat flows through the shell by two fundamental mechanisms
    1. Transmission
    2. Air Leakage
- Via Four Independent Pathways
    1. Floors/Foundations
    2. Walls
    3. Roofs/Ceilings
    4. Windows/Doors

Conductance vs. Conductivity

- Conductivity (k) is the ability of a material to conduct heat through its internal structure.
- Conductance depends on both the type of material and thickness.
- Conductance = conductivity multiplied by thickness, in units of W/m^2K.

Since conductivity is the reciprocal of resistivity, the total resistance of a material is calculated by dividing total thickness by total conductivity. The following table shows a list of building materials and their thermal conductivity for dry (indoor) and wet (outdoor) conditions.*

Conductivity of Building Materials

Group	Material	Thermal conductivity (W/mK)	
		Dry	Wet
Metal	Aluminium	204	204
	Copper	372	372
	Lead	35	35
	Steel, Iron	52	52
	Zinc	110	110
Natural stone	Basalt, Granite	3.5	3.5
	Bluestone, Marble	2.5	2.5
	Sandstone	1.6	1.6
Masonry	Brick	0.6-0.7	0.9-1.2
	Sand-lime brick	0.9	1.4
		0.5-0.7	
Concrete	Gravel concrete	2.0	2.0
	Light concrete	0.7-0.9	1.2-1.4
	Gypsum board	0.23-0.45	
	Gypsum cardboard	0.20	
	Rock wool	0.04	
Plasters	Cement	0.9	1.5
	Gypsum	0.5	0.8
Organic	Cork (expanded)	0.04-0.0045	
	Linoleum	0.17	
	Fiber board	0.08-0.12	0.09-0.17
Wood	Hardwood	0.17	0.23
	Softwood	0.14	0.17
	Plywood	0.17	0.23
	Hard-board	0.3	
	Chipboard	0.1-0.3	
	Wood chipboard	0.1-0.2	
Synthetics	Polyester (GPV)	0.17	
	Polyethylene, Polypropylene	0.17	
	Polyvinyl chloride	0.17	
Synthetic foam	Polystyrene foam, exp. (PS)	0.035	
	Polyurethane foam (PUR)	0.025-0.035	
	PVC-foam	0.035	
Cavity isolation	Cavity wall isolation	0.05	
Air	Air	0.023	
Soil	Woodland soil	0.8	
	Clay with sand	0.9	
	Damp sandy soil	2.0	
	Soil (dry)	0.3	
Floor covering	Floor tiles	1.5	
	Parquet	0.17-0.27	
	Wool	0.07	

Thermal Bridging

- When very conductive materials are touching, heat flows rapidly through the shell.
- Even a small surface area of contact can transfer a lot of heat
- Aluminum window frames can create cold interior surfaces in winter
- West-facing masonry walls create hot surfaces in summer

Thermal Bridging

- Using less conductive gaskets, called **thermal breaks,** between conductive materials reduces the rapid heat flow.
- Wood studs provide a thermal bridge
- Gaps in the insulation allow convection currents

Thermal Bypasses - The most common of energy wasters

- A design or building flaw which allows heat to enter or leave the building and increases the cost of heating and cooling the home.
- Compromises the thermal properties of the insulating and sheathing materials
- To avoid: air barrier and insulation should be touching

Air Leakage Through Penetrations in the Shell

- Leakage Rate is measured in:
  - CFM per square foot
  - CFM per linear foot for joints between materials

Effective Air Barrier

- Any airtight and continuous building component:
  - Insulation
  - Interior sheeting
  - Air-barrier building paper

Windows & Doors

- Low thermal resistance combined with significant surface area
- Create comfort problems in 3 ways:
  1. **Infiltration allows cold air to enter**
  2. Convective currents are formed when air near colder window surface cools, becomes denser and flows downward
  3. Body heat radiates from warm skin to the cold window surface

Fenestration and R-Value

A unit of thermal resistance used for comparing insulating values of different materials
The higher the R-Value, the greater its insulating properties & the slower heat flows through it

Defining the Thermal Boundary

- Conditioned space should have a thermal boundary (thermal envelope) surrounding it
- Should consist of insulation and an air barrier

- Some buildings contain unconditioned spaces – not heated or cooled
    - Attics
    - Crawlspaces
    - Attached garages

Wind Washing - When wind-driven air flows through insulation, reducing its thermal resistance

Knee Walls and Hot Walls

- Knee Walls: Upper parts of walls with conditioned space on one side, attic on the other
- Hot Walls: 2nd story walls with conditioned space on one side, attic on the other.
- Both wall types are SUPPOSED to have code approved sheathing on the attic side

Basements and Crawlspaces

- No general rules when determining whether to include them in the thermal boundary
- Important Consideration: ease and cost of sealing and insulating the floor versus the foundation walls

Six design elements that should be included in a crawlspace

1. **Drying**
2. **Safe combustion appliance operation**
3. **Correct thermal performance**
4. **Fire safety materials**
5. **Radon management**
6. **Pest management**

Visual Inspection

- Thorough analysis of construction and components without invasive testing
- **Includes HVAC system, the insulation and the air sealing**
- For a new home- performed after insulation is installed but before drywall

Questions for an Exterior Inspection

- What vertical shafts come through the roof? Are flashings installed correctly?
- Do the walls have penetrations or indentations (porches, bay windows, etc.) with thermal bypasses?
- Are there major seams between the building components?
- Was it built at once or in several parts? Is the garage attached?
- Is the exterior shell tight or leaky?

Questions for an Interior Inspection

- What areas are used and unused?
- Where is the existing thermal boundary? Is it in the right place?
- What penetrations (plumbing, electrical, HVAC) break wall, floor or ceiling continuity?
- What indentations or shafts protrude from outdoors or unconditioned space?

- Are there protruding structures? If so, do they allow air to enter the building?
- Is the insulation and air barrier continuous at the perimeter of the protrusions or indentations?
- What are the current & potential health & safety concerns?

Sources of Internal Heat Gains:

- People
- Equipment
- Lights
- Windows

Diagnostic Testing

- Blower doors – used to check the air barrier of the house for leakage
- Duct blasters – determines how much leakage there is in an HVAC system
- Balometer – used to find airflow in CFM from ducts, supply or return

Infrared Imaging

A non-invasive diagnostic technique in which an infrared camera is used to view temperature variations within the structure

Infrared Imaging May Help Detect & Prevent:

- Roof failures
- Comfort Issues
- Moisture
- Heat & Air Issues
- Insulation Issues
- Potential electrical problems
- Mechanical Equipment Hot Spots

Infrared provides documentation of problems that often go unseen during standard inspections

R-Value and U-Factor

- R-Value measures a component's thermal RESISTANCE (resistance to heat transfer)
- U-Factor measures a component's thermal transmittance (how fast heat moves through it)
- R = 1/U
- U – 1/R

Calculating Heat Transmission - Definitions to Know (HESP-PLUS)

U = (A1xU1)+(A2xU2)

- R-Value Rule of Thumb for Insulation is 3.5 inches
- **U-Value** (U-Factor): the amount of heat that will flow through 1 square foot of a component or a building wall having a temperature difference of 1ºF from one side to the other
- **R-values can be added together; install R-10 insulation to and R-5 wall it becomes R-15**
- **U-values cannot be added; used to calculate power and energy needed for heating**
- **U-value gives the amount of heat that transmits thru a sq/ft of building cross-section**
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More Definitions to Know

- **Thermal Mass**: a property that enables some massive building materials to absorb, store and later release significant amounts of heat.
- **Thermal Mass Factor**: multiplied by the calculated R-value to estimate a higher value due to the thermal mass effect.
- **Effective R-value* (RESNET)**: reference to the ability of high-mass materials, when used in certain ways, to achieve better energy performance than would be expected if only the commonly accepted (steady-state) r-value or u-factor of that material were considered.
- **Effective R-Value** (BPI):** the weighted R-value of batt insulation based on the installation quality of Good, Fair, or Poor

Calculating Furnace Output, Input and Efficiency

- Output Rating/Heating Efficiency = Input Rating
- Heating Efficiency = Output Rating/Input Rating

Example: What is the heating efficiency of a furnace with an input of 120,000 BTUH and an output of 100,000 BTUH?

100,000/120,000 = 0.83 Efficiency

AFUE = Average Fuel Utilization Efficiency

Calculating a Heating Load (Manual J) - (HESP PLUS)

$q = U \times A \times \Delta T$ or $q = A \times \Delta T/R$

Where:

q = BTUs/hour (BTUH)

A = area in square feet

ΔT = desired indoor temperature minus the Design Temperature

R = R-Value (thermal resistance)

U = U-factor (thermal transmittance)

U = 1/R

R = 1/U

$q = U \times A \times \Delta T$ (used for calculating the BTU heat transfer of a wall or ceiling)

Design Temperature

That temperature that is equaled or exceeded 99% of the time during the 3 coldest months of

- **December**
- **January**
- **February**

Heat Load Calculation Example (HESP PLUS):

The combined wall and ceiling area of a house is 2320 sq/ft with an effective R-value of 19. The house is in Frederick, MD where the Winter Design Temperature is 7°F. The desired indoor temperature is 72° therefore the ΔT = 65°F.

q (*Heat Loss in BTUH*) = 2320 x 65 ÷ 19 = 7,937 BTUH

Real heat load calculations employ separate calculations for walls, windows, ceilings and floors with their different u-factors.

Calculating Cooling Load – (performed by engineer or HVAC Contractor)

- Spring, Summer & Fall – excess heat can accumulate within bldgs
- Heat Gain Comes from 4 Sources
  1. Solar
  2. Air Leakage
  3. Internal Gains
  4. Transmission through the shell (Q

Calculating <u>CONDUCTIVE</u> Heat Loss (HESP PLUS)

- **Q(BTUs/year) = U x A x HDD x 24 x 0.75**
  - Q = BTUs/year transferred through the component
  - U = Composite R-value component converted to U-factor
  - A = Net area of the component, gross minus widows/doors
  - HDD = Heating Degree Days for the location
  - *24 = Number of hours in a day*
  - *0.75 = Correction factor to ensure savings are not overstated*

- **Example: 895 sq/ft of walls with R-4 in Philly (annual HDD is 4759)**
  - 0.25 x 895 x 4759 x 24 x 0.75 = 19.2 MMBTUs/year

- **Improve the insulation from R-4 to R-13 (U=.08) and recalculate:**
  - 0.08 x 895 x 4759 x 24 x 0.75 = 6.1 MMBTUs/year
  - That's an energy savings of 13 MMBTUs/year)
  - 13 MMBTUs = 130 therms
  - At $0.80/therm that's a annual $ savings of $104 from reducing *conductive* heat loss

Calculating <u>CONVECTIVE</u> Heat Loss

- **Q(BTUs/year) = CFMn x 1.08 x HDD x 24 x.75**
  - Q = seasonal BTUs saved
  - 1.08 = heat capacity of a cubic foot of air over an hour (0.018 BTUs x 60 minutes)
  - HDD = Heating Degree Days for the location
  - *24 = Number of hours in a day*
  - *0.75 = Correction factor to ensure savings are not overstated*
  -

Example: Originally tested at 2000 CFM50; after air-sealing it was reduced to 1100 CFM50
This = 900 CFM50 savings. The 1-story house is in Philly with 4759 HDD.
Convert CFM savings to CFMn using: CFMn = CFM50 ÷ N factor
CFMn = 900CFM50 ÷ 19 = 47.4 CFMn

- **47.4 x 1.08 x 4759 x 24 x .75 = 4.4 MMBTUs = 44 therms SAVED**

Elite Software

- Utility and government programs prefer software calculations for standardized procedures
- Elite offers 30 calculation programs

Comprehensive Analysis and Rating Reports

- **REM Rate Software** - calculates energy loads for:
  - ✓ Heating & cooling
  - ✓ hot water
  - ✓ lighting & appliances
- Also calculates energy consumption and costs for:
  - ✓ new and existing homes
  - ✓ single-family and multifamily

EXAMPLE CALCULATIONS (HESP PLUS):

Calculating overall average R-Value of an Area *(Residential Energy page 68)*

A 1000 sq/ft attic has 750 sq/ft insulated to R-30 and 250 sq/ft to R-19. What is the overall average R-value of the attic?

Use the formula: $U = (A_1 \times U_1) + (A_2 \times U_2)$

Remember U = 1/R Therefore, the U-value of the R-30 insulation is 1/30 U = .033
The U-value of the R-19 insulation is 1/19 U = .053

U = (.75 x .033) + (.25 x .053)
U = .025 + .013
U = .038
R = 1/.038
R = 26.3

Calculating the heat transfer of a surface

What is the heat transfer for a 20' x 40' ceiling with R-38 insulation if the inside temperature is 72^{o} and outside in 35^{o}?

Use the formula: $Q = U \times A \times \Delta T$ *where Q=BTUH* *A=area* ΔT= temperature difference

U-value of the R-38 is 1/38 or .026. The area is 20 x 40 = 800 sq/ft. ΔT = 72-35 = 37^{o}

Q = .026 x 800 x 37
Q = 770 BTUH

Chapter Two Practice Questions

1. If the thermal mass increases,
    a. The steady state R-value will also increase.
    b. The steady state R-value will decrease.
    c. The steady state R-value is not affected by the thermal mass.
    d. The steady state R-value is multiplied by the thickness of the thermal mass component.

2. The "design temperature" is the temperature equaled or exceeded 99% of the time during what three winter months?
    a. October, November, and December
    b. November, December, and January
    c. December, January, and February
    d. January, February, and March

3. The term "thermal mass" refers to a material having:
    a. A low thermal resistance
    b. A high thermal resistance
    c. A very low U-factor
    d. The ability to store heat

4. What is the air entering a structure through cracks and/or holes called?
    a. Conduction
    b. Exfiltration
    c. Radiation
    d. Infiltration

5. HESP PLUS: 1185 square feet of an attic is insulated to R-30. There is 15 square feet of attic hatch insulated to R-3. What is the R-value for the entire attic?
    a. 29.66
    b. 27.03
    c. 0.037
    d. 0.27

Chapter Three: AIR LEAKAGE

Air Leakage

- Includes Both Infiltration and Exfiltration and requires:
  1. A hole
  2. A pressure difference (ΔP)
- **Air leakage accounts for 5%-40% of space-conditioning costs**
- **Air barrier** plus **insulation** = **thermal boundary**

Term to Know: DIGITAL MANOMETER

- Measures pressure differential (ΔP)between 2 locations
  - Pascals (pa)
  - Inches of Water Column (wc or iwc)
- May convert ΔP to cubic feet per minute (cfm) airflow using an airflow scale or electronic calculator

Converting *Pascals* to *Inches of WC*

- 1 PA = 0.004 inches WC
- 250 PA = 1 inch WC

Stack Effect – Air Temperature, Density & Pressure

- Cooler air is more dense than warmer air
- Density difference creates ΔP – causes air to move
- Warm air, being more buoyant, rises & exits through higher openings
- Cool Air enters through lower openings
- **CONVECTIVE AIR MOVEMENT**

Mechanical Exhausts Contribute to House Depressurization

- Consume air for within the house
  - Range Hood -100 cfm
  - Bath exhaust - 50 cfm
  - Dryer vent – 200 cfm
  - Central Vacuum – 200 cfm
  - Open Fireplace (no fire) – 100 cfm
  - Possibly the HVAC - ??

Chimneys, Thermal Bypasses and Exhausts

- Create negative pressure within the house because they exhaust air out
- A fan bringing air into the home can lower the NPP

Neutral Pressure Plane

- Line that separates the building's areas of negative & positive pressure.
- At the NPP, there is no ΔP between inside and outside the house
- Below the NPP, the air pressure inside is lower than outside
- Above the NPP, the air pressure is higher than outside

To Lower the Neutral Pressure Plane, Seal:

- Ceiling/attic penetrations
- Plate lines
- Furrdowns, dropped ceilings
- Around electrical boxes
- Around HVAC boots and boxes
- Fireplace cavities
- Crawlspace penetrations

Controlling Air Leakage in the Building Envelope

- Major Air Leakage Occurs via Unsealed Penetrations:
  - Between the conditioned space and the attic
  - Between the conditioned space and the basement or crawlspace
- **The ceiling plane is highest priority for controlling building envelope leakage**

Wind Pressure

- Increased by the height of the house
- Wind blowing against the windward side creates a high pressure that drives outside air into the home
- Wind creates a low pressure on the leeward side that exhausts air out of the home

Blower Doors – What Do They Do?

- Depressurize the building to amplify air leakage so it can be measured
- Used to estimate the house's natural air exchange rate (ventilation rate)
- Measures air leakage across the entire building envelope
- Assists in locating specific air leakage locations
- Most practical way to predict energy savings from air sealing measures
- Single-point test at -50 Pa is most common
- Multi-point testing across a series of different building pressures can provide more data

Looking For Air Leaks

- Depressurizing the house is most common
  - ✓ can actually feel air coming in
  - ✓ makes leaks easier to find
- "**Over-sealing" is an outdates term; we now know to:**
  - ✓ make the house as tight as possible, AND
  - ✓ include planned ventilation

Important Blower Door Terms

- CFM50 – reading of airflow at the door when ΔP is -50 pa
- ACH50 – air changes per hour @ -50 pa
  - ➢ (CFM50) x (60 minutes per hour) / (air volume)
- ACHn or NACH – natural air changes per hour
  - ➢ ACH50 / n
  - ➢ n = factor developed by LBL to convert ACH50 to NACH
  - ➢ n can vary according to # of stories & wind-shielding, but **the n factor commonly used is 20**

- CFMnat = CFM50 / n
- Baseline – building pressure relative to the outside before turning on blower door and fan sealed

Example: The blower door placed on a house with 20,000 cubic feet of air volume read 250 cfm at -50 Pascals. What is the NACH? What is the CFMnat?

ACH50 = 2500 CFM50 x 60 minutes per hour / 20,000 cubic feet
ACH50 = 7.5
NACH = ACH50 / n
NACH = 7.5 / 20
NACH = .38 natural air changes per hour

CFMnat = CFM50 / n
CFMnat = 2500 / 20
CFMnat = 125 cfm

Building Tightness (RESNET)

- ASHAE 62.2 set minimum ventilation rates for buildings
- For Houses:
  - **Minimum CFM = 7.5 (# of bedrooms + 1) + .01 (total sq/ft)**

Example: According to ASHRAE 62.2, what would be the minimum ventilation rate for a 2500 sq/ft home with 4 bedrooms?

CFM = 7.5 (4 bedrooms + 1) + .01 (2500 sq/ft)
CFM = 37.5 + 25
CFM = 63

ASHRAE 62-89 Minimum Building Airflow Standard (BPI)

- 0.35 x house volume ÷ 60
- 15 cfm per occupant – **whichever is greater**
- BPI **recommends** mechanical ventilation when the measured CFM50 is between 70% - 100% of BAS
- BPI **REQUIRES** mechanical ventilation when the measured CFM50 is less than 70% of BAS

(HESP PLUS) BPI Example: 2500 ft^2 house, 8 ft ceilings, 5 occupants

- 0.35 x 20,000/60 = 117 cfm **OR**
- 15 x 5 occupants OR= 75 cfm **WHICHEVER'S HIGHER**

- **Minimum CFM50 = BAS x Height Adjusted N-factor**
- **For New York the N-factor for 2 story house is 15.4**
- **BAS in CFM50 = 117 cfm x 15.4 = 1797 CFM**
- **70% of 1797 = 1258 CFM50**
- **<1258 CFM50 REQUIRES mechanical ventilation according to BPI**

(HESP PLUS) Calculating *Convective* Heat Loss (Due to Air Leakage)

- **Q(BTUs/yr saved) = CFMn x 1.08 x HDD x 24 x.75**
  - Q = seasonal BTUs saved
  - 1.08 = heat capacity of a cubic foot of air over an hour (0.018 BTUs x 60 minutes)
  - HDD = Heating Degree Days for the location
  - *24 = Number of hours in a day*
  - *0.75 = Correction factor to ensure savings are not overstated*

- **Example**: Originally tested at 2000 CFM50; after air-sealing it was reduced to 1100 CFM50 = 900 CFM50 savings. The 1-story house was in Philly with 4759 HDD.
    - Convert CFM savings to CFMn using: CFMn = CFM50 ÷ N factor (*See BPI Standards for Chart*)
        - CFMn = 900CFM50 ÷ 19 = 47.4 CFMn

- 47.4 x 1.08 x 4759 x 24 x .75 = 4.4 MMBTUs = 44 therms SAVED

Consequences of Negative House Pressure

- Moisture (< 3 Pa)
- Radon (< 3 Pa)
- Pesticides (< 3 Pa)
- Sewer gases (< 3 Pa)
- Combustion Appliance Back drafting (3-5 Pa)
- Combustion spillage/flame rollout (6-10 Pa)

Consequences of Positive House Pressure

Moisture condensation within building cavities during cold weather (<3 PA)

Backdrafting

- When normal movement of combustion products up the flue is reversed
- Combustion products enter the building instead
- Back drafting can occur @ negative 3-5 Pa
- Flame Rollout (spillage) can occur at negative 6-10 PA
    - **Soot marks or heat stressed metal near the gas burner are evidence of previous flame rollout**

To Test for Backdrafting:

- Measure ΔP from combustion appliance zone to outside
    - Turn on all exhaust appliances
    - May need a long hose
- Utilize CO^2 detector

Testing Air Barriers for Leakage

- Using a BD at -50 Pa, measure ΔP to areas outside the air barrier (unconditioned cavities)
- The closer to -50 Pa the ΔP is, the more outside leakage there is to that area.
- Read Krigger pages 82-86 carefully

Duct Leakage

- **Typically wastes 10% -30% of energy needed for heating and cooling**
- May add an additional one ton of AC to overcome duct leakage (Read Krigger 86-89 carefully)

Blowing and Sucking *(Krigger p. 86-89)*

- If duct system is located outside the conditioned space:
    - **Leaks in the Supply Duct will cause the conditioned space to SUCK** (be depressurized)
    - **Leaks in the Return Duct will cause the conditioned space to BLOW** (be pressurized)

When Ducts are in the Conditioned Space

- Duct leakage testing is unnecessary if the ENTIRE SYSTEM is within the conditioned space.
- For a HERS rating, a new home, the entire system must be visible within the conditioned space to avoid duct leakage test. (example: within an unvented, insulated attic or crawlspace)

Duct Sealing Diagrams - Largest leaks are normally:

- At building cavities
- At supply and return plenum, coil and unit connections
- At supply boot and return box and sheetrock connections

Duct Materials

- Flex duct
- Duct board
- New high density polyethylene composite
- Building cavities (NOT recommended)

Pressure Pan

- Gasketed pan connected to a manometer
- Used to temporarily block registers & measure blower door induced duct pressure at register
- The lower the number, the tighter the duct system

The Duct Blaster™ - Used for 2 Measurements

- **Total**: measuring leakage to inside and outside the house
- **Outside**: measuring leakage outside the conditioned space
  - ➢ Perform with a blower door on the house at the same time
  - ➢ The ΔP between house and duct must be zero

Sealing Ducts with Mastic

- Mastic makes the best sealer for all duct and HVAC unit applications
- Metal tapes meet most code requirements
- Avoid fabric tapes (duct tape) on field joints

Air Leakage at Cathedral Ceiling w/Recessed Light

Moisture and reduced R-values, due to air convection, are common

Air Leakage at Floor/Wall Junction

Even with a foam sealer under the bottom exterior plates, the plates should be caulked to the slab

Floor Cavities Connected to the Outdoors

Even with a foam sealer under the bottom of the exterior plates, plates should be caulked to the slab.

Porch Roof Leakage

Areas like this can allow air & moisture into either walls or ceiling & into floor cavities between stories

Airflow through Concrete Block

Air moves slowly but steadily through both concrete block and soil.
Faster air exchange can result from missing mortar, open cores and holes in their interior & exterior

Other Air Leakage Points

- Dropped ceilings
- Plumbing/electrical/HVAC penetrations
- Attic and Basement Stairs
- Recessed Light Fixtures
- Fireplaces/Chimneys (especially metal ones)
  - **NEED AN OPERATIONAL FIREPLACE DAMPER**
- Furrdowns

Choice of Air Sealing Methods and Materials Depends On:

- The leak's size, shape, location and visibility
- The air-sealing material's compatibility with existing substrates
- The ΔP that it has to resist

Air Leakage Through Solid Materials

See chart on page 73 of *Residential Energy*

Air-Sealing Materials

- Caulking and Backer Rod
- Thin panels
- Hand stuffing
- Blown insulation
- Mastic
- Liquid or canned foam
- Gaskets
- Tapes
- Adhesives
- ***No polyethylene in wall assemblies***

NOTE:

Tracer gas is somewhat more accurate for predicting natural air change rate because tracer-gas testing occurs under natural conditions, unlike blower door testing which occurs under pressurized conditions and then converted to an estimate of what would occur under natural condtions.

Tracer gas actually measures the airflow of buildings under normal conditions by introducing a known quantity of gas and timing how long it takes to "flush out." It is seldom used, except for research, because it is cumbersome, only gives results for the specific weather at the time, and does not reveal the locations of leaks. When performing a 50CFM blower door test, we determine the airflow at -50PA of pressure. (We wouldn't have enough flow to measure at normal conditions.)

Chapter Three Practice Questions

1. How many Pascals on average are in one inch of water column?
   a. 100
   b. 400
   c. 250
   d. 50

2. What is the air entering a structure through cracks and/or holes called?
   a. Conduction
   b. Exfiltration
   c. Radiation
   d. Infiltration

3. If a duct system is leaking on the supply side, what is a possible consequence?
   a. Insufficient air to different areas of the house.
   b. The house will have negative pressure WRT the outside.
   c. There may be comfort complaints.
   d. All of the above.

4. Where is the most likely place for the most air infiltration in a home?
   a. The dryer vent
   b. Plate penetrations
   c. Between the drywall and the top plates.
   d. A return chase opened to the attic.

5. If a multi point blower door test is performed instead of a single point blower door test, what additional information can be gained?
   a. the infiltration rate at any pressure difference
   b. the estimated natural air exchange rate
   c. the skill of the blower door operator
   d. the estimated cost of the leakage

6. If a house has a duct system and air handler in an unconditioned attic and there is equal leakage in the return system and in the supply system, how would the house pressure be affected when the air handler is operating?
   a. The house goes positive
   b. The house pressure is not affected
   c. The house pressure goes negative
   d. Not enough information is provided

7. For a house and assuming the stack effect is the only driving force, the house will leak:
   a. Above the neutral pressure plane
   b. Below the neutral pressure plane
   c, At the neutral pressure plane
   d. Above and below the neutral pressure plane

8. When preparing for a blower door test with the use of a digital manometer the initial house pressure reading is a measure of what 2 effects on the house?
   a. Stack effect and wind
   b. A low neutral pressure plane
   c. System pressures and leakage
   d. Exhaust and wind

9. A duct leakage test is performed at what standard pressure?
    a. 50 Pascals
    b. 40 Pascals
    c. 35 Pascals
    d. 25 Pascals

10. Where is the leak in a return of an HVAC system located if the house is pressurized while the system is running?
    a. Inside the conditioned space.
    b. Outside the conditioned space.
    c. Half inside and half outside the conditioned space.
    d. Leaks in the return system do not positively pressure the house.

11. HESP PLUS: A blower door test is performed on an existing house at the standard pressure. There's a roof over the back porch attached to the exterior wall of the house. A pressure probe is placed in the porch covering and the pressure is found to be -25 Pascals wrt the house. What can we tell about this area?
    a. There is not enough information.
    b. The area is almost completely outside the conditioned space.
    c. The area is almost completely inside the conditioned space.
    d. The area is half in and half outside of the conditioned space.

12. Which following procedure(s) is deemed THE most accurate way of measuring duct leakage?
    a. Blower door and pressure pan
    b. Blower door subtraction method
    c. Blower Door and duct pressurization tests together
    d. Tracer gas

13. How does one find the CFMnat?
    a. CFMnat = CFM50 / n
    b. CFMnat = CFM50 / volume
    c. CFMnat = CFM50 * 60 / volume
    d. CFMnat = ACH50 * volume / 60

Use the formulas on page 267 of Residential Energy to solve the following questions:

14. A round room having a diameter 12' and a ceiling height of 12-foot would have a volume of approximately:
    452 sq ft
    1356 cu ft
    144 cu ft
    5493 cu ft

15. A house is measured to be 35' x 47'. What is the area of the floor and what is the perimeter?
    a. 1176 and 140
    b. 5544 and 132
    c. 1008 and 140
    d. 1645 and 164

16. (HESP PLUS) A room's dimensions are 30'x 30' with a wall height of 10' and a vault height of 18' above the floor. What i the area of the vaulted ceiling?
    a. 1020 square feet
    b. 1080 square feet
    c. 7200 square feet
    d. 2080 square feet

Chapter Four: INSULATION

Density of Insulation

- A minimum density is necessary to prevent setting and eliminate air currents
- R-Value can vary with different temperatures and density
- Compressing fiberglass and wool to a specific density increases R-Value per inch until optimal density is reached
- After optimal density, further compression decreases R-Value per inch (up to 25%)
- R-Value of fiberglass is calculated at 70°F and a specific density

Rule of Thumb (RESNET) – for BPI, use the charts in their standards
All insulation types have an R-Value of 3.5 per inch of thickness

Insulation R-Value is affected by:

- **Thermal Bridging:** heat transfer through materials
- **Density and Type:** after optimal density, further compression can reduce R-Value
- **Convection** (from within): 15%-50% loss in R-Value for air infiltration
- **Gaps/Voids:** up to 30% loss of R-Value for only 4% edge gaps
- **Wetness:** water conducts heat better than air

Krigger pages 102-103

Installation Factors Affecting Insulation Performance

- Gaps: areas where insulation does not completely fill the cavity
- Voids: areas where insulation is missing
- Compression: as behind a electrical wire/box or stuffed in a small space
- Misalignment: Installed in the wrong place (insulating the garage ceiling instead of the bonus room floor)

All Insulation Installations Are Not the Same

For new homes, the Rater grades the installation I, II or III

RESNET Grade III Insulation Installation

- Substantial gaps and voids, with missing insulation amounting to greater than 2% of the area, but less than 5% of the surface area it's intended to occupy
- Includes insulation that is not in substantial contact with the sheathing on at least one side of the cavity or
- Insulation that is open (unsheathed) on one side and exposed to the exterior

RESNET Grade II Insulation Installation

- Moderate to frequent installation defects
- Gaps around wiring, electrical outlets, plumbing and other intrusions
- Rounded edges or “shoulders”
- Incomplete fill amounting to between 0.5% and 2% of the insulated area

NOTE: To be Grade II or better, wall insulation must be enclosed by an air barrier (sheathing) on all 6 sides and must be in substantial contact with the sheathing material on at least one side (interior or exterior) of the cavity

RESNET Grade I Insulation Installation

- Installed to manufacturers instructions or industry standards
- Uniformly fills each cavity side-to-side and top-to-bottom
- Without substantial gaps or voids
- Less than 0.5% problem areas

BPI Effective R-Values for ATTIC Batt Insulation (Page 8 of BPI Technical Standards)

- Measure insulation thickness
- Determine Condition of installation:
    - o Poor – Gaps over 5% of insulated area (Equivalent to a ¾" space along a 14.5" batt
    - o Fair – Gaps over 2.5% of insulated area (Equivalent to a ⅜" space along side a 14.5" batt
    - o Good- No gaps or other imperfections
- Look-up effective R-value in the chart on page 8

Default R-Values for Other Insulation Types (page 7 of BPI Tech Standards)

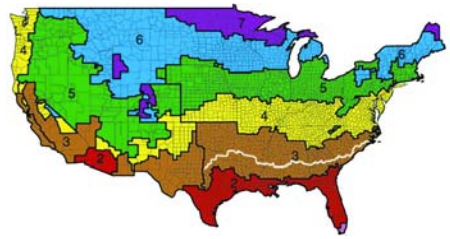
Typical Insulation R-values

Insulation Type	R-value per inch	Typical Applications
Cellulose, loose fill	3.7	Attic Floor
Cellulose, high density	3.2	Walls, Enclosed Cavities, Framing Transitions
Fiberglass, batts	3.0*	Basement Ceiling, Open Stud Walls, Attic Floor*
Fiberglass, loose fill	2.8	Attic Floor, Walls (existing)
Fiberglass, loose fill, fluffed below manufacturer's standards	uncertain	Do not install, or correct by blowing over with higher density
Rockwool	3.0	Attic Floor, Walls, Basement Ceiling (may be loose or batts)
Vermiculite	2.7	Attic Floor
Poly-isocyanurate, rigid board	7.0	Foundation Walls, Attic Access Doors
Polystyrene, expanded rigid board	4.0	Foundation Walls, Sill Plate
Polystyrene, extruded rigid board	5.0	Foundation Walls, Sub-Slab, Sill Plate
Low Density Urethane, sprayed foam	3.7	Attics, Walls (new construction); Sill Plate, Band Joist, Framing Transitions
Urethane, sprayed foam	6.0	Attics, Walls (new construction); Sill Plate, Band Joist, Framing Transitions
Urea Formaldehyde Foam	4.0	Attics, Walls (existing)

**see chart below for existing fiberglass batt evaluation*

Inspecting Insulation in Existing Homes

- Check beside plumbing or a telephone, cable or electrical box with a **non-metallic probe** to determine the presence and type (also us IR scan when possible)
- **Take depth readings at 4 different places in the attic and average**



KNOW THE AMOUNT OF INSULATION REQUIRED INN YOUR CLIMATE ZONE

Insulation Types

- Fiberglass is the most popular in the U.S.
- Cellulose is next most popular – made from recycled paper or treated wood fibers
  - Blown-in blanket (BIB) or spray is easier to achieve Grade 1
  - Plastic foam (4 x 8 sheets, ¼ – 4 inches thick)
- Polyurethane & Polystyrene Panels (Rigidity adds structural strength)
- Sprayed or Injected
  - Polyurethane
  - Polyisocyanurate
  - Polystyrene
  - BioBased
  - Icynene
  - Demilec

EIFS: Exterior Finish & Insulation System

Correct Installation is Extremely Important

Increases R-value by a factor of 1.2 to 2.6, depending on climate

Facing and Barriers

- Facings protect the insulation surface
- May provide an air barrier
- Retard water vapor diffusion
- Facilitate fastening
- Help hold insulation together
- **Effectiveness as air barrier depends on flawless insulation & taping of all joints**

Vapor Barriers

- Various facings are attached to insulation during manufacturing
- Vapor Barriers are usually NOT Air barriers
- RESNET: No polyethylene (visqueen) or any material that does not allow vapor movement

Attic Ventilation (BPI Standards)

- For every 300 sq/ft of attic floor WITH a VDR, you need 1 sq/ft foot of free vent
- For every 150 sq/ft of attic floor WITHOUT a VDR, you need 1 sq/ft of free vent
- Venting should be divided equally between the peak (either gable or ridge vent) and the soffit

Installing Attic Ventilation

- When the cavity depth is small, or angles are an issue, a variety of insulation materials may be required to get the desired R-Value needed to reduce heating/cooling loss
- It is important to attain a continuous R-Value across the entire attic floor
- **It is CRITICAL TO AIR SEAL before or while installing insulation**

Radiant Barriers

- Normally applied to the underside of the rood decking
- Will drop attic temperature 20°F to 30°F
- Has to have air against the side with the barrier (attic)

Where to Insulate? Any wall separating conditioned space from unconditioned space

Blowing Loose-Fill Insulation: Need one high hole and one low hole for each cavity

Interior Foundation Insulation

- Insulation directly against brick may cause moisture problem – need air space
- Better to insulate interior block first, then frame wall

Exterior Foundation Insulation

- Installing retrofit foundation insulation means digging down 2 feet or more
- Foam must be protected from solar radiation and mechanical damage by a protective layer of metal or plastic above ground

Methods of Supporting Floor Insulation

In cold climates, floor insulation is usually less expensive and more effective than foundation insulation when basement or crawlspace isn't used

Energy Efficient Trusses

- **Raised-Heel Trusses** – allow for full depth of insulation to be installed to exterior wall
- **Scissor Trusses** – frame cathedral ceilings and eliminate the thermal resistance and moisture problems associated with narrow cavities

Foam Blocks and Panels

- Insulated Concrete Forms (ICFs)
- Structurally Insulated Panels (SIPs) - Pulte Science

Chapter Four Practice Questions

1. HESP PLUS: A 1000 square foot attic has 750 sq/ft insulated to R30 and 250 sq/ft insulated to R-19. What is the overall average R-value of the attic?
   a. 0.038
   b. 27.25
   c. 26.3
   d. 38

2. HESP PLUS: A 2 x 4 exterior stud wall has R-15 batts, sheathing with 0.5 R-value and drywall with R-0.4. The inside air film has an R-value of 0.68; the outside air film has an R-value of 0.17. The framing factor is 25%. A 2x4 stud has an R-value of 4.5. What is the area weighted average R-value and U-value?
   a. 11.76 and 0.85
   b. 11.76 and 0.085
   c. 11.5 and 0.087
   d. 9.75 and 0.103

3. What does the term "effective R-value" imply?
   a. The insulation is installed correctly
   b. Non insulating materials are not present
   c. The R-value is better than the steady state rating
   d. The R-value is a weighted average of all materials

4. Besides an IR camera, what is a non-invasive way to determine if there is insulation in an exterior wall?
   a. Make a small hole in the wall behind a large piece of furniture
   b. Remove a faceplate from an outlet or switch and inspect around the box
   c. Go to the attic and insert a small mirror into a plate penetration
   d. Knock on the wall and listen for a dull rather than hollow sound

5. What's a relatively easy, effective way to determine if there's insulation in an attic without an access?
   a. Drill a small hole in the roof deck and look through it with a camera
   b. Remove a ceiling light fixture and inspect and probe with a metal rod
   c. Access the cavity from its end or holes in the ceiling
   d. Take off a small piece of exterior siding and peer inside

6. How many inches of insulation are usually found at the bottom chord of a commonly used roof truss?
   a. 4 inches
   b. 3 ½ inches
   c. 3 inches
   d. 2 ½ inches

7. For an existing house with a crawlspace, where do you inspect to evaluate the crawlspace insulation?
    a. Peering from the crawlspace access
    b. The exterior of the foundation walls
    c. The floor above the crawlspace
    d. The floor above the crawlspace and the assembly of the foundation wall

8. In a vented crawlspace, if the nail ends penetrating the subfloor above the insulation are rusty, it's a good indication of what?
    a. The contractor used cheap nails
    b. Warm moist air has been circulating above the floor insulation because the insulation was not properly installed
    c. Cold air in the winter caused condensation in crawlspace
    d. The living area has been flooded in the past

9. The attic of an old home has six inches of blown-in fiberglass insulation uniformly applied across the attic floor. What would be the approximate R-Value?
    a. R-30
    b. R-26
    c. R-19
    d. R-15

Chapter Five: WINDOWS & DOORS

Parts of a Window

- Glass Assembly – One or more glass panes with spacers & gaskets if needed
- Sash – Frame for the glass assembly; may be movable for ventilation or fixed
- Frame – Surrounds the sash and is attached to the building
- Rough Opening – Structural framing around the window, to which it's attached

Window Characteristics

- Often the weakest link for heat transmission through the building shell
- Thermal transmittance (**U-factor**) and **solar heat gain** are the most important energy considerations

U-Factor (U-Value)

- The measure of heat transmission thru the glass
- U-value of glass = the # of BTUs that will pass thru each sq/ft area, per degree of temperature difference
- The lower the U-value, the greater a window's resistance to heat flow - the better its insulating value.
- Insulating value is indicated by R-value, the inverse of U-value.

NRFC (National Fenestration Rating Council) Window Label – Rates Windows

- Provides U-Factor (U-value)
- Solar Heat Gain Coefficient (SHGC)
- Shading Coefficient (SC)
- Visible Transmittance (VT)

Recommended U-factors by Climate

- **Northern:** U-factor of 0.35 or less. If AC loads are minimal, U-factors as high as 0.40 are also energy-efficient IF the Solar Heat Gain Coefficient is 0.50 or higher.
- **North/Central:** U-factor of 0.40 or less. The larger your heating bill, the more important a low U-factor becomes.
- **South/Central:** U-factor of 0.40 or less. The larger your heating bill, the more important a low U-factor becomes.
- **Southern:** low U-factor helpful during cold days when heat is needed and during hot days to keep the heat out, but it is less important than SHGC in warm climates. Select windows with a U-factor lower than 0.75 and preferably lower than 0.60.

Projection (Overhang) The shading impact of an overhang can be found by measuring the distance of the projection from the exterior wall surface and the distance (height) between the top of the window and the bottom edge of the overhang.

Heat Gain & Shading Terms

- **SHGC** – the ratio of solar heat *passing* ***through*** the glass to solar heat ***falling on*** the glass at a 90° angle. (Single pane = 0.87)
    - for hot, sunny climate, recommend a SHGC < 0.50
    - South-facing windows used for passive solar heat need SHGC of 0.70 or more
- **SC** – compares the solar transmittance of a glass assembly with its exterior and
    - interior shading devices to that of a single pane of glass with SC of 1
    - The shading coefficient is always greater than the SHGC.
- **VT** – measures how much visible light is admitted by the window glass
    - important because one of window's main functions is to admit light
    - reflective coatings/tints can help but are not always acceptable
        - **reflective coatings & tints can reduce visible transmittance by up to 30%**

Energy Characteristics of Typical Glass Options

Glazing Type	***U-factor***	***R-Value***	***SHGC***	***VT***
Single Glass	1.1	0.9	0.87	0.90
Insulated Glass	0.50	2.0	0.76	0.81
High SHGC, Low-e insulated glass	0.30	3.3	0.74	0.76
Medium SHGC, Low-e insulated glass	0.26	3.8	0.58	0.78
Low SHGC, Low-e insulated glass	0.29	4.2	0.41	0.70
Triple glazed with 2 low-e coatings	0.12	8.3	0.50	0.65

Examining Windows

- Examine frames to determine the type of material used.
- Open & examine to see if it’s made of metal, wood, or vinyl.
- Tap frame with fingernail or knuckle to test if it's vinyl or metal. Wood frames are usually thicker than metal.
- If it’s dual-pane or multiple-pane & is metal framed, determine if a thermal break is present by looking for two separated metal extrusions connected by a rubber spacer.
- Ask the customer for documentation if you can't tell.

Low-e Insulated Glass Unit (IGU) *(Krigger p.125)*

- Low-e Coating – retards emission of radiant heat from that pane
- Employs a seal spacer between 2 (**or multiple**) glass panes
- Outside 1 / Inner Side 2 / (sealed space) / Inner Side 3 / Inside 4
- For warm climates, the coating goes on surface 2 (on the outer glass)
- For cold climates, the coating goes on surface 3 (on the inner glass)

Match Test for Distinguishing Standard (clear) vs. Enhanced (low-e) Insulated Glass

- Hold a match or a pen light up in front of the window
- There should be **one reflection** per pane or coating, including low-e and tinting (e.g., a **double-paned** window with **low-e** AND **tint** should show 4 reflections)
- Compare to glazing samples with and without tinting;
- Compare the windows within the space, since tinting is often applied only to certain windows in a house;
- Look for low-e label or etching on the glass.
- **OR PURCHASE AN ELECTRONIC Lh ² -E DETECTOR**

Window Condensation

- Leads to deterioration of the window and the opening around it
- See chart that plots the outdoor temperature and RH where condensation will commence relative to the R-Value (Krigger p.125)

Door Components

- Most doors have similar components
- Solid wood doors are the most common exterior door in residences
- Newer doors are either steel or fiberglass with foam insulation inside
- Exterior doors are sold as pre-hung units; includes:
- frame, stop, hinges, threshold and door

Door Sealing

- The gap at the bottom is usually the largest leakage
- Use adjustable door bottoms or sweeps
- best jamb-mount weather strip is the bronze v-seal

Chapter Five Practice Questions

1. In addition to U-factor, SHGC, surface area, and orientation, what other aspect affecting window performance, with regard to the software, must be determined?
   a. Shading
   b. Window type (casement, slider, etc)
   c. Sash type
   d. Manufacturer

2. The correct means of identifying the compass direction of a wall is to be outside and:
   a. Have your back to the wall & read the compass
   b. Look for moss growing on the side of the house
   c. Face the wall & read the compass
   d. Call the builder

3. In new homes, what component of the house generally allows the most heat transfer?
   a. the windows
   b. the ceilings
   c. floors over unvented crawlspaces
   d. bonus room floor over a garage

4. When using a metal-framed window, what feature(s) can be used to reduce the heat loss or gain?
   a. Introducing a thermal break
   b. Placing Argon gas between the panes
   c. Adding a Low-e coating
   d. All of the above

5. By holding a match close to a window assembly, you can sometimes verify the presence of:
   a. Moisture between the panes.
   b. The presence of a Low-E coating.
   c. Whether there is some gas besides air between the panes.
   d. A high SHGC number.

What is the typical R-Value for a double-paned window with a wood frame?

1.2
1.5
2.0
2.5

Which of the following is true regarding a window with a low emissivity coating?

It has a SHGC of .75
It has multiple panes of glass
It has an R-Value of 1.3
It has a U-Value of .32

Chapter SÌÈ: HEATING

Combustion Heating Principals

- Combustion gases leave the combustion chamber through the heat exchanger's flue, which connects to a chimney
- Combustion is rapid oxidation
- Oxygen combines with the carbon and hydrogen, splitting the hydrocarbon molecule

Combustion: The Chemical Reaction

- A heat yielding chemical reaction - starts with hydrocarbon (natural gas) and oxygen
- Complete combustion produces carbon dioxide and water
- Incomplete combustion also produces carbon monoxide and unconverted oxygen
- Percentage of O^2 in the flue gases informs us about fuel-air mix
- Oxygen combines with the carbon and hydrogen, splitting the hydrocarbon molecule

Combustion Flue

- Passageway for venting combustion gases
- Space between the heat exchangers sections, or
- Tube within the heat exchanger

Open vs. Sealed Combustion

- Traditional combustion equipment relied on natural draft.
- Today's more efficient equipment does not waste as much energy or send as much heat up the chimney, weakening natural draft. Sealed units are 90% efficient.
- Natural draft can be overcome by conditions that depressurize the house, leading to spillage & back drafting.
- Sealed combustion equipment draws its combustion air directly from outside the home.
- Air intakes and exhaust are sealed off from the inside of the home, reducing the chance for spillage.

Atmospheric Gas Burner vs. Power Burners

- Atmospheric are most common – completely open
- Power Burners are closed – air is supplied via draft induced fan or duct fan

Draft

- The force that brings combustion air into the chamber and propels the combustion gases out through a chimney or vent
  - Induced Draft
  - Fan-Assisted Negative Draft (burns more efficiently)

Types of Efficiency Ratings

- **Fuel Burning Efficiency**
  - % of fuel's potential energy converted to heat at the flame
  - Most modern oil-fired and gas heaters have FBE of over 99%
- **Steady-State Efficiency (SSE)**
  - % of heat captured by heating fluids: air, water or steam
  - accounts for fuel-burning losses and chimney losses
  - can be measured with CO^2 sensing devices AFTER 10-15 minutes
- **Annual Fuel Utilization Efficiency (AFUE)**
  - Lab tested efficiency
  - Most commonly used to rate a furnace
  - % of potential energy in the fuel makes it into the heating distribution ducts or pipes on a seasonal basis
- **Delivered Heating Efficiency**
  - (also called Seasonal Efficiency)
  - % of fuel's potential that actually heats the living space
  - counts distribution losses
  - delivered heating efficiency can be as low as 35%

AFUE is the Accepted Rating for Furnaces

- An annual or seasonal efficiency rating based on the cyclic on/off operation and any associated energy losses by the unit which is affected by the occupant and weather changes
- See AHRI for efficiency ratings or go to *Krigger p. 178-179*

Intermittent -Ignition Devices - save energy by eliminating the need for a standing pilot light

Combustion Air

- The outdoor make-up air needed to replace air used for combustion
- Combustion air is usually assumed to be provided by air leakage

Steady-State Efficiency (SSE)

- A performance rating for space heaters;
- A measure of the percentage of heat from combustion of gas which is transferred to the space being heated under specified steady state conditions.
- Accounts for the % of either oxygen or CO^2 within the combustion gas temperature

Natural Gas Furnace

- Most widely used heating type in U.S.
- Heat Exchanger: device used to transfer heat from a fluid (liquid or gas) to another fluid where the two fluids are physically separated

Where would be the highest operating pressure in a forced-air system?

Static Pressures

- » The total pressure on the air handler measured at both the supply & return plenums
- » The pressures are usually measured in inches of water column.
- » Usually highest pressure readings come from the supply plenum.
- » Add the top and bottom ΔPs (ignoring + or -) – should not exceed 0.5 inches of WC

Energy Efficient Gas Furnaces (90%-95%):

1. EXTRA GAS EFFICIENCY - secondary heat exchanger extends heat transfer for higher efficiency use of heating fuel.
2. QUIET, NEARLY CONTINUOUS COMFORT - Direct-drive variable speed blower operates at speed needed to deliver quiet, dependable heating & humidity control.
3. EFFICIENCY AND COMFORT - gas valve with 2 stages of heating operates up to 90% of the time; low-stage most of the time - High stage for extreme winter conditions.
4. RELIABILITY - igniter is reliable and robust; can count on heating when you need it.
5. INTELLIGENT OPERATION - furnace control board does the thinking for you
6. IMPROVED INDOOR AIR QUALITY - standard air cleaner cabinet accessory enhances IAQ.

Changing Air Filters

- Dirt reduces air movement and efficiency if it builds up on filters, fan and heat exchanger
- Filters have a MERV rating:
  - Normal: 6-8
  - Better: 10-12

Forced Air Furnace Configurations

- The blower moves air through the heat exchanger where the combustion of oil or gas or electricity heats the air
- ARI and AHRI – provide combined efficiencies of heating and air equipment
- The model plate contains the following info:
  - input BTUH
  - temperature rise
  - type of gas
  - model number
  - manufacturer name
  - manufacturer date
  - condenser and coil also have spec plates

Hydronic Heat Emitters

Modern fin-tube convectors are an improvement over old-style hydronic radiators, because the fin-tube radiator is longer & is installed on the floor where it provides better air convection and mixing.

Gas Fireplaces

- gas fireplaces and inserts are becoming more popular
- primarily for visual appeal, but can provide room heat

Vent-less Fireplaces

- Will add carbon monoxide to the room environment
- Will add water vapor to inside the structure
- Can cause some O^2 depletion
- UL Approved but a BAD IDEA

Woodstoves

- Ben Franklin invented
- moved heat source from the large, drafty fireplace to the room center
- new models have EPA efficiency between 63% - 78%
- pose fire hazard if installed improperly – need at least 16 inches to closest wall

Electric Heat

- Cleaner, more convenient than gas or other fuels
- Are usually 100% efficient
- Put out more KWH of heat than KWH of energy consumed
- They don't convert forms of energy, they simply transfer it
- Choice may depend on cost of electricity to cost of gas in your area

Electric Heat Pumps

- The most efficient type of electric heat, particularly in southern U.S.
- Newer ones operate efficiently down to 0°F

Heat Pump Efficiency Ratings *(Krigger p. 179)*

- Coefficient of Performance (COP)
  - How many more times efficient a particular pump is compared to electrical resistance
  - Defined as the output of heat moved in watt-hours divided by the watt-hours of electrical input required to operate
  - **COP is the BEST efficiency rating for Heat pumps**
- Heating Seasonal Performance Factor (HSPF)
  - The number of BTUs the heat pump produces for each kwh of electricity it uses
  - **HSPF is the MOST COMMON rating for Heat Pumps** óŎ2ƴúŊI-Ŋè ú2 YŊɅƎƎŜŊú

Electric Room Heaters

- Strip Heaters
- Radiant Heaters
- Liquid Filled Heaters

Expressions of Efficiency Ratings

- Heating Season Performance Factor (HSPF) – applies to Heat Pumps
- Coefficient of Performance (COP) – applies to Heat Pumps
- Annual Fuel Utilization Efficiency (AFUE) – applies to Combustion Furnace
- Seasonal Energy Efficiency Ratio (SEER) – applies to Air Conditioners

Note the Residential Energy Glossary on pages 251-262

Chapter Six Practice Questions

1. What is the best term to express the efficiency of a gas furnace and an air conditioner?
   a. HSPF / SEER
   b. AFUE / COP
   c. COP / HSPF
   d. AFUE / SEER

2. Heat pumps may get heat from the following sources except:
   a. The ground
   b. The air
   c. A water source
   d. The wood framing

3. A heat pump can have an efficiency greater than 100 percent because:
   a. It has no combustion inefficiencies like a gas furnace.
   b. It moves heat from one place to another instead of converting fuel to heat.
   c. The second law of thermodynamics does not apply to the refrigerant cycle.
   d. The heat produced by the compressor motor is captured and utilized.

4. Heat pumps do not get heat from which of the following?
   a. The building's materials
   b. Ambient air
   c. The ground around the site
   d. Water features around the site

5. Which term below is most commonly used as the efficiency term for a heat pump when the unit is in the heating mode?
   a. AFUE
   b. SEER
   c. HSPF
   d. COP

6. The COP is defined as
   a. The amount of energy required to raise the temperature of one hundred pounds of water10°F
   b. The output of a gas furnace in Btus divided by the kwh of electricity used to run the fan.
   c. The output of a heat pump in watt-hours of heat moved divided by watt-hours of electrical input.
   d. How many Btus a heat pump provides per watt-hour of electricity.

7. HESP PLUS: An existing house has the following HVAC equipment: 80% AFUE gas furnace, 120,000 Btu, input costing $1500 per year to operate, and gas costing $0.65 per therm. An HVAC contractor has recommended the following be installed to save money: an air source heat pump having a COP of 4.0. Electricity costs $0.093 per kWh. What is the most economical route for the homeowner to take?
   a. The gas unit should be replaced.
   b. The gas unit should be left.
   c. There is not enough information to calculate operating costs.
   d. You cannot calculate savings without knowing the age of the gas furnace.

Chapter Seven: LIGHTING and APPLIANCES

Three Basic Uses for Lighting

- Ambient (security and safety)
- Task (work area)
- Accent (for making an area more visually comfortable)

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Five Basic Types of Lighting

- Incandescent
- Fluorescent
- High-Intensity Discharge
- Low-Pressure Sodium
- LED lights

An average household dedicates 5% to 10% of its energy budget for lighting.

Incandescent

- short 1500-2000 hour life span
- The oldest , most common and energy wasteful light bulb
- 10% of the energy consumed goes to generating light
- 90% of the energy consumed creates heat
- Extra heat increases the cooling load

Fluorescent

- Widely used in commercial and institutional buildings
- Most popular are the 8 ft-75 watt and the 4 ft-40 watt
- 3-4 times more efficient than incandescent bulbs
- Lamp life is 10 times longer

Compact Fluorescents

- Less electrical usage
- **Decrease the cooling load**
- **Increase the heating load**
- 3-4 times (75%) more efficient than incandescent bulbs
- for Energy Star, have to use the pin type fixtures

High-Intensity Discharge

- Used for outdoor lighting or large indoor spaces (arenas)
- HIDs have long lamp life and high efficiency

High-Pressure Sodium

- Similar to fluorescents
- Maintain light output better than any other lamp
- Very popular for outdoor lighting
- Excellent for replacing older bulbs

Light Emitting Diode Technology (LED) Lights

- In 2009, American Airlines parent company AMR Corp. is replacing 1,600 lights in its parking garage with energy-efficient LED lights to save $130,000 a year.
- The switch to light-emitting diode technology is part of the "Take A Load Off, Texas" program offered by Oncor. Oncor, the regulated utility that operates North Texas power lines, will give AMR $362,887 in incentives to change the lights.
- Also used for:
  - Task and reading lamps
  - Linear strip lighting (under kitchen cabinets)
  - Recessed lighting/ceiling cans
  - Porch/outdoor/landscaping lighting
  - Art lighting
  - Night lights
  - Stair and walkway lighting
  - Retrofit bulbs for lamps

Lighting Efficiency

- Replace lamps and/or fixtures with those that use lower wattage
- Install lighting controls
- Use artificial light less, use daylight more
- Perform simple light maintenance

Evaluating Energy Efficiency of Appliances

- Look on unit plate for model, serial # and date
- Energy Star rated appliances have Energy Star label
- **The Energy Star label indicates that an appliance meets a set of standards for using significantly less energy than standard products of the same type**

Energy Sucking Appliances

- 90% of appliance energy is consumed by:
  - Refrigerators
  - Washers (clothes and dish)
  - Dryers

Appliance Rating Organizations

- AHAM – American Home Appliance Manufacturers Association rates washers and dryers
- ACEE - American Council for an Energy Efficient Economy
- AHRI – Air Conditioning Heating Refrigeration Institute
- GAMA has now merged with Air Conditioning, Heating & Refrigeration Institute (AHRI)

Dishwashers

- 80%-90% of energy consumed is by the water heater providing hot water
- Older washers require water supplied to be 130°F to clean
- Newer models have a booster heater, using less water heating energy

Clothes Washers and Dryers

- Horizontal axis washers (front loaders) use 50%-75% less energy than top loaders – cost more
- Costs 10 times more to dry a load of clothes than to wash it
- Energy Factor or Modified Energy Factor is how efficiency is rated

Rating Washing Machines *(Krigger p. 192-193)*

- **The Association of Home Appliance Manufacturers (AHAM)** rates washers and dryers using:
  - **Energy Factor** (EF), or
    - Old rating describes how many cubic feet of clothes can be washed per hour
  - **Modified Energy Factor** (MEF)
    - New rating describes how many cubic feet of clothes can be washed **and dried** per hour
    - MEF gives higher rating to machines that spin clothes dryer

Refrigerators ***(Krigger p. 193-194)***

- Account for 9%-15% of a household's total energy usage
- For higher efficiency, consider:
- Manual defrost over automatically
- Freezer on top, frig on bottom rather than side-by-side
- Chest freezer instead of upright
- One larger unit over two smaller ones
- New refrigerators use 50% less electricity than a 1990 model

Chapter Seven Practice Questions

1. One not so obvious benefit of installing energy efficient appliances is that they
    a. can all be included in the HERS rating
    b. have longer warranties
    c. can reduce air conditioning costs
    d. are more attractive

2. Which of the following appliances typically uses the most household energy?
    a. Clothes dryer
    b. Refrigerator
    c. Washing machine
    d. Dishwasher

3. What percentage of energy consumed by an incandescent light bulb actually goes to generating light?
    a. 40%
    b. 30%
    c. 20%
    d. 10%

4. When determining the age of a refrigerator, what letter represents the year the model was made?
    a. 1st
    b. 2nd
    c. 3rd
    d. 4th

5. Which of the following is the best resource for finding efficiencies of an electric water heater?
    a. AHRI
    b. GAMA
    c. NRFC
    d. WEG

Chapter Eight: COOLING

Summer Comfort

- Excess summer solar energy makes many buildings uncomfortable
- Indoor air circulation is key element for comfort in warm weather
- Air movement increases evaporation rate of moisture on the skin – cools the body

Four Types of Heat Gain *(Krigger p. 199)*

- Solar Heat – roof and windows (50% of total heat gain)
- Internal Heat Gains – light, appliances, etc.
- Air Leakage – hot air in, cool air outstanding
- Heat Transmission – through the envelope

Major Sources of Unwanted Heat as % of Total Heat Gain

Solar Gains
- Windows 20-30%
- Roof 10-20%
- Walls 5-10%

Internal Gains
- Heat 15-25%
- Humidity 5-15%

Air Leakage
- Heat 5-20%
- Humidity 5-25%

Indoor/Outdoor Temp Difference 5-10%

Window Shading Considerations

- Direction the house faces – **(north/south is best)**
- To find orientation, read a compass from outside with back to exterior wall or window
- Location of shade trees, overhangs and other objects/structures
- Total surface area of the window
- Depth of overhang and height from top and bottom of window to overhang (required to document for HERS Rating or Comprehensive Analysis)

West facing windows contribute solar heat in the afternoon, when we want it least

Radiant Barriers

- Normally applied to underside of roof
- Can drop attic temperature 20-30°F

Reducing Internal Heat

- Energy Efficient Appliances – Double Benefit
  - less energy use
  - save on cooling costs
- Limit Hot Water Use - reduce temperature
- Use Kitchen/Bath Fans to Remove Moisture

- Reduce Cooking at Hottest Times
- Dry Clothes on a Line in Nice Weather

Cooling with Ventilation – Depends On

- Temperature and humidity of evening and morning air
- Amount of shade around the building
- Opening/closing windows & blinds at the right time
- Using fans at the right time

Sizing AC Units

- Size is the most important consideration for achieving comfort/minimizing energy cost
- Standard practice to oversize HVAC by 30%-100% to ensure its big enough
- Rules of Thumb are Easy to Remember, but Not Necessarily Correct

NEW RULE

- During the 70s-80s, contractors used the 1 ton for every 500 sq/ft – **BUT IT'S WRONG**
- Manual J is a calculation procedure developed by the AC Contractors of America

Sizing AC Units

- Cooling comfort is produced by lowering air temperature AND removing humidity
- The AC can remove moisture properly only if is appropriately sized so it will run 10-15 minutes before dehumidification begins.
- Weatherization of a home with an oversized AC may cause it to run less or “short-cycle;” by running less frequently, it cannot remove as much humidity from the indoor air.
- Moisture removal capacity is measured by the **Sensible Heat Factor** (SHF)
- Recommended SHF for humid climates is 0.5 to 0.77 to adequately remove humidity and prevent fungal growth

Energy Efficiency

- Most common term for the energy efficiency of central AC is SEER
- SEER is the number is computed by dividing the cooling capacity (in BTUH) by the watts of electrical power used

SEER or EER = $\frac{\text{BTUs per hour heat removed}}{\text{Watts of electricity power drawn}}$

AC Capacity

- Measured in BTUs per hour or “tons” of cooling
- 1 ton = 12,000 BTUs per hour

Thermostat Control

- Turning thermostat past desired temperature will not make the AC coil the home any faster and will waste energy
- Programmable thermostats work best for oversized systems that can recover from setback quickly – in that case may save 5-15%

Improved Forced-Air Circulation

- Blockage or leaks of supply or return air ducts and registers can depressurize portions of the home, resulting in poor AC performance and increased envelope air leakage
- Incorrect refrigerant charge (delta T)
- Yearly maintenance and service
- **The air handler should supply about 400 cfm/ton of air to the house**

Airflow & Performance

- When the AC is operating the temperature drop between return and supply air should be 15° to 20°F dry bulb or 8°F to 12°F wet bulb
- Measurements can indicate a problem with airflow or refrigerant level and estimate cooling rate and COP
- Studies show 50% of AC units not sufficiently charged during installation

Chapter Eight Practice Questions

1. What is a possible problem associated with an oversized air conditioner?
    a. Poor dehumidification
    b. Short cycling
    c. Higher electrical bills
    d. All of the above

2. What is the best term to express the efficiency of a gas furnace and an air conditioner?
    a. HSPF / SEER
    b. AFUE / COP
    c. COP / HSPF
    d. AFUE / SEER

3. A five-ton air conditioner has how many cubic feet per minute and Btu?
    a. 12,000 / 60,000
    b. 400 / 12,000
    c. 2000 / 60,000
    d. 500 / 5000

4. One of the consequences of a tighter house is
    a. Moisture levels in the house may increase.
    b. Less ventilation is required.
    c. More air infiltration is required because all houses need to "breathe".
    d. Double pane windows are required to prevent loss of conditioned air.

5. An AC system having a capacity of 30,000 Btu/hr would be said to have how many tons?
    a. 2 tons
    b. 3 tons
    c. 2.5 tons
    d. 5 tons

6. When installing correctly-sized equipment instead of oversized equipment in a house, the need to install tighter ducts increases in importance because:
    a. The blower operates a higher percentage of time
    b. The oversized equipment has a worse warranty
    c. The oversized equipment has a better warranty
    d. Moisture accumulates on the ductwork

7. To be included inside the thermal boundary, an attic kneewall would have
    a. Ductwork in the attic space behind it
    b. An insulated and access door with an gasket
    c. Insulation on the back of the kneewall
    d. A radiant barrier on the deck of the attic behind the wall

Chapter bïyŜ: WATER HEATING

Water Heaters Use Energy in 3 Ways *(Krigger p. 219-220)*

- **Demand** – energy is used for heating incoming cold water up to the temperature set point as hot water in the tank is used
- **Standby** – accounts for heat loss through the storage tank's walls - account for 20%-60% of the total water-heating energy
- **Distribution** – losses of heat escaping through the pipes and fixtures while hot water flows

Water Heating Efficiency

- **Hourly peak hot water flow-rate** (gallons/hour) – the recovery capacity; most important design consideration
- **Storage capacity** – the amount of water the tank holds
- Ideal storage capacity is 8-10 gallons per person or 30-65 gallons per living unit

Two Organizations Rate Water Heaters

- American Council for an Energy Efficient Economy (ACEE)
- **Air Conditioning, Heating & Refrigeration Institute (AHRI)**

Storage Water Heaters (Gas & Electric)

- Most common – combine heating device, heat exchanger & storage tank into 1 unit
- Electric water heaters don't need a flue; easier to install
- Electric water heaters have higher energy factors and lower recovery capacities

3 Types of Wasted Energy with Gas & Oil Water Heaters

3. Excess air flowing through the burner, flue & chimney during combustion.
4. Dilution air entering flue at the draft diverter.
5. When burner is off, surrounding indoor air circulates through burner & flue, carrying heat away from the water & up chimney.

Improved Combustion Storage Water Heaters

- **Fan-assisted gas water heater** - draft-induced fan controls draft, minimizes excess air to increase efficiency
- **Atmospheric sealed-combustion water heater** – lower excess air and no dilution air, giving them a higher recovery efficiency

Tankless Gas Water Heaters

- Heat water as it flows through the heat exchanger
- Specify sealed combustion (direct vent) units only
- AKA: instantaneous water heaters

Tankless Electric Water Heaters

- Generally serve just a single fixture like a shower or sink
- Large power draw

Alternative Water Heaters
Solar units are classified as active or passive depending upon whether they use a pump to circulate water

3 Strategies for Energy Efficient Retrofits

- Reduce the use or waste of hot water
- Reduce standby losses from storage tank & pipes
- Reduce distribution losses through pipes & fittings

Tank Insulation
To increase efficiency, the **total R-value** for any type of hot water storage tank should be **R-15 to R-35**, depending on the cost of fuel.

Pipe Insulation

- Slows heat losses as water moves through the distribution pipes.
- Reduces loss of convected heat through pipes near tank.
- Delivers water 2° to 4°F hotter than un-insulated pipes, ***allowing for lower tank setting and lower energy costs.***

Set HW Temperature to 120°F

- slows mineral buildup
- protects from scalding
- reduces corrosion
- decreases energy consumption

Removing Sediment

- Sediment is water-borne dirt, scale that settle to the tank's bottom.
- Scale is dissolved minerals that precipitate from hot water.

Chapter Nine Practice Questions

1. The stated DOE labeled efficiency of an electric water heater is designated by what term?
    a. EF
    b. SEER
    c. COP
    d. AFUE

2. Which of the following organizations is the best resource for finding the efficiency of an electric water heater?
    a. GAMA (Gas Appliance Manufacturers Association)
    b. AHRI (Air Conditioning Heating & Refrigeration Institute)
    c. WHEC (Water Heater Efficiency Committee)
    d. NRFC (National Fenestration Ratings Council)

3. Which of the following account for 20-60% of the total water heating energy?
    a. Water demand
    b. Water standby
    c. Water distribution
    d. Water leakage

Chapter Ten: HEALTH AND SAFETY

Health and Safety Rule #1

- DO NO HARM!!!
  - To Yourself
  - The Occupants
  - The Workers
  - The House

Carbon Monoxide *(Krigger p. 236)*

Concentration of CO in Air	Inhalation Time and Symptoms
35 ppm	OSHA's time weighted average limit for continuous exposure in any 8-hour period
200 ppm	OHSA's Short Term Exposure Limit (15 minutes). Slight headache, tiredness, dizziness, nausea after 2-3 hours
400 ppm	Frontal headaches within 1-2 hours; life threatening after 3 hours
800 ppm	Dizziness, nausea and convulsions within 45 minutes; unconscious within 2 hours. Death within 2-3 hours
1600 ppm	Headache, dizziness and nausea within 20 minutes. Death within 1 hour
3200 ppm	Headache, dizziness and nausea within 5-10 minutes. Death within 30 minutes
3400 ppm	Headache, dizziness and nausea within 1-2 minutes. Death within 10-15 minutes
12,800 ppm	Death within 1-3 minutes

Indoor Radon Gas

- Known Human Carcinogen (Class A)
- Accounts for over 21,000 U.S. Lung cancer deaths annually
- EPA recommends ALL homes be tested regardless of their geographic location
- Houses with slab-on-grade, crawlspace, walk-out basement foundations can all be contaminated
- Comes in as soil gas is drawn into the home due to 3 Pa or less -ΔP (stack effect)
- Leading cause of lung cancer in non-smokers, 2nd leading cause overall

Environmental Tobacco Smoke

- Accounts for 5000 U.S. Lung cancer deaths annually
- ETS contains more than 3800 chemicals, many are carcinogens
- Primary carcinogen is radioactivity from PO-210
- ETS is responsible for 39% of all exposure to indoor pollutants
- Major triggering mechanism for asthma

Nitrogen Oxides, Hydrocarbon Dust and VOCs

- Nitrogen Oxides are created naturally by the combustion of hydrocarbons in the air, which is about 80% nitrogen

- Fine hydrocarbon dust and VOCs can be released into the air by wood stoves, unvented kerosene heaters and cigarette smoke

- Other common sources of VOCs include:
  - solvents
  - cleaners
  - paints
  - varnishes
  - furniture
  - carpet
  - drapery

Biological Particles
- Bacteria & Viruses
- Dust Mites (high humidity)
- Cockroaches
- Cats (dander is highly allergenic)
- Fungi (high humidity)

~~Mold~~ Bio-contamination: Structural issue as well as indoor air quality issue

Asbestos and Fiberglass *(Krigger p. 239)*
- Asbestos is a known human carcinogen (Type A)
- Most building products with asbestos were phased out in the 1970s
- Asbestosis – lung scarring from asbestos dust deposited in the lungs
- Mesothelioma – unique cancerous lung tumor linked to Amphibole asbestos

MSDS Sheets
- Product information provided by the manufacturer, detailing the potential health/safety hazards and required precautions for dealing with the material
- MSDS for all materials used on the job and installed in the home must be kept on each crew vehicle and made available to workers and clients upon request

Moisture in Residences (Krigger p.239)
- Water reduces thermal resistance of insulation and may cause permanent damage
- Water leads to building deterioration resulting from plant and animal pests – possibly negating energy conservation measures
- Water allows dust mites and fungi to thrive – both can be a danger to respiratory health

Four Categories of Moisture Movement in Residences (Krigger p. 239-241)
- **Liquid Flow** – driven by gravity or air pressure, water flows into cracks and holes (roof and plumbing leaks)
- **Capillary Seepage** – capillary suction draws water seepage from the ground
- **Air Movement** – carries water vapor into and out of the building due to ΔP and holes for entry.

If the air reaches saturation (dew point), condensation will occur

- **Vapor Diffusion** – water will move through solid objects

Preventing Water Vapor and Humidity Problems (Krigger p. 240)

- Moisture moves inside during wet seasons and outside during dry seasons
- Slope ground away from foundation
- Install rain gutters and downspouts that direct water away from the house
- Use perforated drain tile around foundation, under walks
- Gravel bed (large stone) as a capillary break under the slab
- Sump systems

Sources of Water Vapor (Krigger p, 243)

- Humidifier
- Condensation
- Perspiration
- Range
- Firewood
- Earth in the crawlspace
- Aquariums
- Plants
- Showers
- Laundry
- Wet Clothes
- Unvented Fireplaces (condensation)

Summary of Moisture Sources

- Bulk Moisture
  - Rain and groundwater thru basement walls
  - Clogged gutters, leaky roofs
  - Leaky pipes
  - Ice dams
- Water Vapor
  - Cooking, Cleaning Respiration
- Condensation

Steps to Reduce Condensation (Krigger 242-244)

- Reduce RH
- Equalize pressure between indoors and outdoors
- Install or improve vapor barrier
- Ventilate by bringing in dryer outdoor air
- Remove moisture by cooling indoor air below the dew point
- Add insulation

Controlling Moisture

- In a 100 sq/ft air-sealed wall, over the course of a year only 1 cup of water can diffuse through drywall without a Vapor Diffusion Retarder, HOWEVER..
- 50 cups can enter through a 1/2-inch diameter hole!
- **The most important measure you can take to reduce moisture transport through walls and ceilings is to Install an Effective Air Barrier**

Vapor Barriers:

Vapor barriers are most important in cold climates where the difference in humidity between cold, dry outdoor air and warm moist indoor air forces indoor moisture through the walls and ceilings. **Therefore, vapor barriers in cold climates should face the indoors.**

In warm climates with AC and heating, moisture comes from outside to inside in summer and from inside to outside in winter. In these instances, it may be best NOT to install vapor barriers; instead design the wall cavities to be porous to drying from either side. Unclog or install widow sill weep holes to the outside.

ASHRAE 62-89 Minimum Building Airflow Standard (BAS) for BPI Standards

- 0.35 x house volume ÷ 60 or 15 cfm per occupant – whichever is greater
- **BPI recommends mechanical ventilation when the measured CFM50 is between 70% - 100% of BAS**
- **BPI REQUIRES mechanical ventilation when the measured CFM50 is less than 70% of BAS**

Example: **2500 ft^2 house, 8 ft ceilings, 5 occupants**

- **0.35 x 20,000/60 = 117 cfm OR**
- **15 x 5 occupants OR= 75 cfm WHICHEVER'S HIGHER**
  - **Minimum CFM50 = BAS x Height Adjusted N-factor**
  - **For New York, N-factor of 2 story house is 15.4**
  - **BAS in CFM50 = 117 cfm x 15.4 = 1797 CFM**
  - **70% of 1797 = 1258 CFM50**
  - **<1258 CFM50 REQUIRES mechanical ventilation according to BPI**

ASHRAE 62.2 for RESNET Standards

- 7.5 cfm (# bedrooms + 1) + 0.01 cfm (sq/ft of conditioned space)

ASHRAE recommends that homes receive at least 0.35 air changes per hour (ACH) or 15 cfm per person whichever is greater

Their latest standard, ASHRAE 62.2 specifies:

Rate CFM = 7.5(# of bedrooms + 1) + .01(Total sq/ft)

Sample Problem:

For a 3500 sq/ft house with 4 bedrooms, what is the ASHRAE recommended ventilation rate?

Rate(CFM) = 7.5(4+1) + .01(3500 sq/ft)

Rate(CFM) = 37.5 + 35

Rate(CFM) = 73 cfm of ventilation

Heat Recovery Ventilation (HRV) and Energy Recovery Ventilation (ERV)

- Difference between HRVs and ERVs:
- HRVs transfer heat only
- ERVs transfer both sensible heat and latent heat (moisture) between airstreams

HRVs (Krigger p. 247)

- Often installed in conjunction with balanced whole-house ventilation systems
- Core is a flat-plate aluminum or polyethylene air-to-air heat exchanger in which the supply and exhaust airstreams pass one another with minimal mixing
- Heat travels through the core by conduction from the warmer to the cooler airstream

ERVs (Krigger p. 248)

- Reduces the cost of conditioning ventilation air
- greater the difference in temperature or moisture between airstreams, the more energy that's recovered
- Condensate is collected and carried to a drain
- In cold climate, ERVs transfer moisture as well as heat to the cold incoming air
- In warm climate, they keep outdoor humidity outdoors

Other Questionable Ventilation Strategies (Krigger p. 248-249)

- **Exhaust Only**: Turn on an exhaust fan, air will come in somewhere *(may depressurize and cause soil gas entry)*
- **Supply Only**: Positively pressurized the house with a fan bringing air into the conditioned space. *(Not good in winter in a cold climate)*
- **Ventilating Attics & Crawlspaces**: (*Never a good strategy)*

Dehumidifiers (Krigger p. 249)

- Removes moisture and raises nearby air temperature
- Can be an efficient space heater for areas that need it
- Air conditioners should be designed to adequately remove moisture, though often not the case
- Avoid using dehumidifiers and AC at the same time

Recommended Resources (in addition to *Residential Energy* by John Krigger and Chris Dorsi)

- RESNET 2006 Mortgage Industry HERS Standards
- Observational Diagnostics www.sivadhome.com/library.htm
- The *Energy Auditor Field Guide*
- *Residential Construction Academy*, Michael Joyce

IMPORTANT Note for Exam Prep:

- The use of PVC pipe in residential construction 1st began on the 1960s.
- Another name for a sink is a lavatory.
- Asbestos ceased to be used in most construction in the 1980s and declined in use during the 1970s.
- Low-Flow Toilets (water closets) have integral traps

Chapter Ten Practice Questions

1. Choose the best definition for the term "permeance".
    a. It is the measure of vapor through a specific material per unit of thickness.
    b. It is a measurement of how long a component will last.
    c. It is any energy conservation improvement with a permanent lifecycle.
    d. It is the evaporation rate of moisture on the human skin.

2. Which of the following forces can drive mass water into a structure?
    a. Gravity
    b. Pressures made by wind
    c. Capillary action
    d. All of the above

3. A vapor retarder, when used in a hot-humid climate, is installed on what portion of the home's exterior wall?
    a. The inside of the wall
    b. Never applied to the wall
    c. The outside of the wall
    d. It doesn't matter where it is placed

4. If a house is under a small negative pressure (<3 pa) wrt outside, which of the following health and safety issues are most likely to be a concern?
    a. Entry of soil gas into the home
    b. Window condensation
    c. Back drafting of combustion appliances
    d. Spillage of a hot water heater

5. According to ASHRAE 62.2, what would be the approximate ventilation rate for a 2500 square foot home with 4 bedrooms?
    a. 30
    b. 75
    c. 47
    d. 63

6. A person exposed to levels of carbon monoxide of 400 ppm for 1 to 2 hours would probably exhibit which of the following health effects:
    a. Dizziness
    b. Nausea
    c. Blurred vision
    d. Serious headache

8. In what decade did the use of most asbestos-based building products decline?
    a. 1950-1960
    b. 1960-1970
    c. 1970-1980
    d. 1980-1990

9. When does condensation occur?
    a. When the temperature goes below the dew point.
    b. When the relative humidity of the air reaches 100%.
    c. When the temperature of a surface is less than the dew point.
    d. When the relative humidity of the outside air is above 60%.

10. What is the most likely negative health effect in a house having more supply side leaks than return leaks?
    a. Pollutants drawn indoors
    b. Depressurization
    c. Moisture diffusion through foundation wall
    d. Inadequate makeup air