

Heat Loss, Heat Gain, and Equipment Sizing

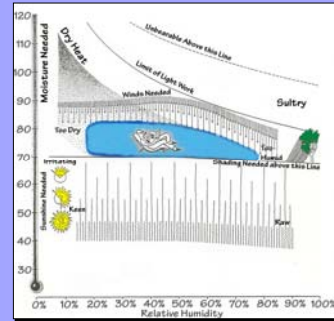
Better Buildings by Design Conference
2006

Sponsored by Efficiency Vermont

Rick Karg

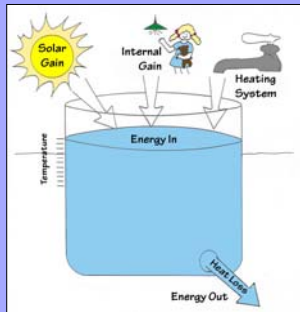
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Human Comfort Zone



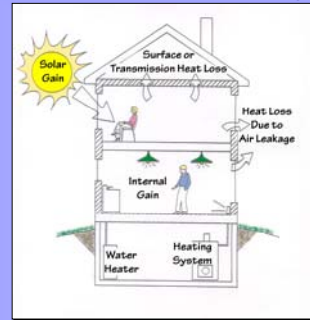
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Bucket Analogy



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The Thermal Envelope



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What We Will Talk About

- The importance of proper sizing.
- Basics of load calculation.
 - Surface heat transfer.
 - Air leakage heat transfer.
- Calculating design loads.
- Sizing conditioning systems.
- Example DHL problem.

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The Importance of Proper Sizing

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Problems with Oversizing, Heating

- Over sizing a heating system by more than 1.4 times (140%) can lead to:
 - Loss of seasonal efficiency (AFUE).
 - Higher equipment costs.
 - Comfort problems due to short cycling.
 - Premature degradation of the furnace and/or vent system.

Specification of Energy-Efficient Installation and Maintenance Practices for Residential HVAC Systems, Karg & Krigger, CEE, 2000.

7



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Problems with Oversizing, Heating

- Study found
 - 1.6 times oversizing in recent new construction.
 - 2.25 times oversizing in older homes.
- This leads to a loss in seasonal efficiency
 - In older atmospheric units of 9 to 15 percent.
 - No good data available for newer units, but probably less significant losses.

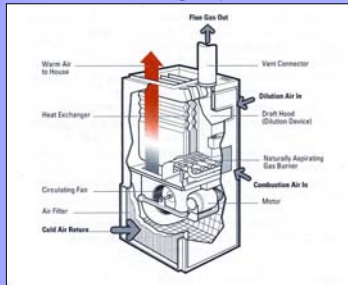
Improving Residential Gas Furnace and Boiler Installation Practices, Jennifer Thorne, ACEEE, 1998.

8



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Atmospheric Gas Furnace Category I

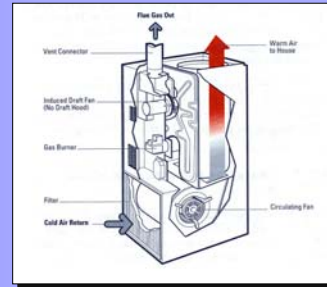


9



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Fan-Assisted Category I Mid-Efficiency

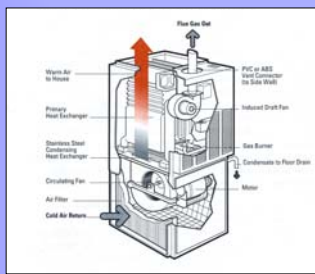


10



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High Efficiency Condensing Gas Furnace Category IV



11



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Problems with Oversizing, Cooling

- Oversizing a heat pump or air conditioner:
 - Loss of efficiency, both HSPF and SEER.
 - Higher equipment costs.
 - Comfort problems due to short cycling.
 - Cold, but moist – too humid – interior conditions.

Specification of Energy-Efficient Installation and Maintenance Practices for Residential HVAC Systems, Karg & Krigger, CEE, 2000.

12



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Problems with Oversizing, Cooling


- Study found
 - 50% average oversizing for heat pumps and air conditioners compared to *Manual J*.
 - Some research indicates that *Manual J*, 7th ed, leads to oversized heat pumps and air conditioners.
- This leads to a loss in seasonal efficiency of from 2 to 10 percent, depending on the study.

National Energy Savings Potential from Addressing Residential HVAC Installation Problems, Neme, Proctor, and Nadol, EPA, 1999. 13

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Gas Furnace with Central Air



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Problems with Undersizing Heating/Cooling

- Inadequate heating or cooling capacity.
 - This is unusual.

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Residential HVAC Spec

www.cce1.org/resid/rs-ac/hvac.php3

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Replacing Steam Boilers – **Caution!**

- When replacing a steam boiler, the new boiler must be sized for the distribution system, not for the house.

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Basics of Load Calculation

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Heat Transfer Definitions - 1

- **Heat energy:**
 - Molecular motion, the lowest form of energy.
- **Temperature:**
 - Assignment of a value to the degree of molecular motion.
- **Absolute zero:**
 - The temperature at which molecular motion ceases (-460°F).

Heat Transfer Definitions - 2

- **Temperature difference:**
 - Difference between the indoor and outdoor temperatures, often referred to as ΔT ("delta T").
- **British Thermal Unit (BTU):**
 - The amount of thermal energy required to increase the temperature of one pound of water by one Fahrenheit degree. For the rest of the world, 1 Btu = 1055 Joules.

Heat Transfer Definitions - 3

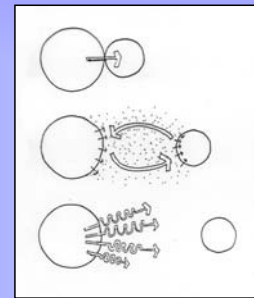
- **Internal heat gain:**
 - Heat gain from people and appliances that give off heat to the indoor environment.
- **Surface or transmission heat transfer:**
 - Heat transfer through solid building surfaces, including ceilings/roofs, walls, floors, windows, and doors.
- **Air leakage heat transfer:**
 - Results from infiltration and exfiltration.

Means of Heat Transfer

Conduction

Convection

Radiation



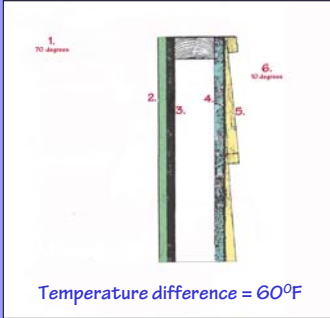
Transmission or Surface Heat Transfer

Transmission or Surface Heat Transfer is Dependent Upon

- Temperature difference between the indoors and outdoors.
- Heat transfer rate through surfaces (R-values or U-values). Surfaces include ceilings/roofs, walls, floors, windows, & doors.
- The size of the surfaces, in ft².

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Heat Transfer Through a Wall



Heat transfer

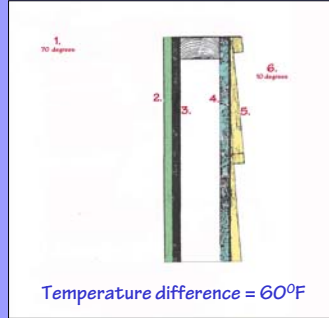
- Conduction
- Convection
- Radiation

Temperature difference = 60°F

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Heat Transfer Through a Wall



Heat transfer

- Conduction
- Convection
- Radiation

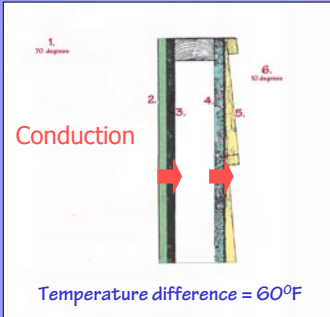
Heat Transfer from hot to cold, or high energy to low energy.

Temperature difference = 60°F

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Heat Transfer Through a Wall



Conduction

Heat transfer

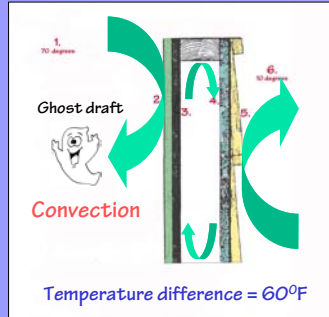
- Conduction
- Convection
- Radiation

Temperature difference = 60°F

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Heat Transfer Through a Wall



Ghost draft

Convection

Heat transfer

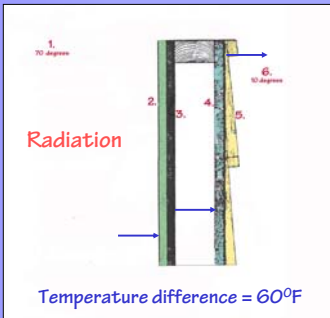
- Conduction
- Convection
- Radiation

Temperature difference = 60°F

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Heat Transfer Through a Wall



Radiation

Heat transfer

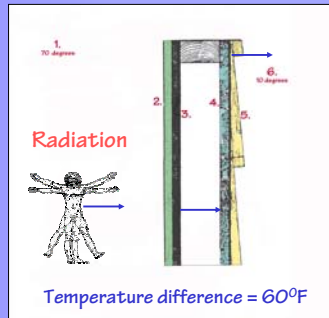
- Conduction
- Convection
- Radiation

Temperature difference = 60°F

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Heat Transfer Through a Wall



Radiation

Heat transfer

- Conduction
- Convection
- Radiation

Temperature difference = 60°F

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Heat Transfer Through a Wall

Temperature difference = 60°F

Heat transfer

- Conduction
- Convection
- Radiation

Heat Transfer without insulation

31

Heat Loss, Heat Gain, and Equipment Sizing

Heat Transfer Through a Wall

Temperature difference = 60°F

Heat transfer

- Conduction
- Convection
- Radiation

Heat Transfer with insulation

32

Heat Loss, Heat Gain, and Equipment Sizing

Surface Heat Transfer

	R
Interior Surface	.68
3/8" Gypsum Board	.32
3 1/2" Blanket Insulation (vapor barrier on warm side)	11.00
3/8" Plywood	.47
Bevel Siding	.81
Exterior Surface	.17
Overall R	13.45

33

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Surface Heat Transfer

- R-value is the resistance to heat transfer through a building surface. Surfaces include ceilings/roofs, walls, floors, windows, & doors.
- U-value is the heat transfer through a building surface.
- $R=1/U$
- $U=1/R$
- R-values may be added together, U-values may not.

34

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Heat Transfer Equations, Surface

Heat Loss = $\frac{\text{Area} \times \text{Temp. Difference}}{\text{R-value}}$

Heat Loss = Area x Temp. Difference x U-factor

35

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Taking Care of Business in Vermont

36

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The Driving Forces of Air Leakage

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What Causes Air-Leakage?

Fluid Flow Through a Hole

$$P_1 - P_2 = \Delta P$$

Must have:

1. Hole.
2. Pressure difference.

Drivers can be:

1. Wind.
2. Stack effect.
3. Mechanical forces.

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Wind-Driven Air Leakage

Factors:

- Wind speed.
- Leakage area.

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Stack-Effect Air Leakage

Cold weather only

Factors:

- Temp. difference.
- Leakage area.
- Effective height.

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Mechanically-Driven Air Leakage

Factors:

- Leakage area.
- Exhaust fan CFM.
- Heating system.

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Heat Transfer Due to Air Leakage

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Heat Transfer Due to Air Leakage is Dependent Upon:

- Temperature difference between the indoors and outdoors.
- Cubic feet of air leakage through the house for a given time period. The important part of the house is the above grade volume within the thermal envelope.

Heat Transfer Equation, Air Leakage

$$\text{Heat Loss} = \text{Volume} \times \text{ACH} \times \frac{0.0182 \text{ Btu}}{\text{ft}^3, \text{hr}, \text{F}^\circ} \times \text{Temp. Difference}$$

Calculating Design Loads

Calculating Heat Loss Heating

- To calculate heat transfer in a house, let's say heat loss, we must calculate the surface heat loss through all surfaces of the thermal boundary; and
- Calculate the heat loss resulting from air leakage through the thermal envelope (above grade only).
- Solar gain and internal gain are not losses in this case.

Calculating Heat Gain Cooling

- To calculate heat gain in a house we must calculate the surface heat gain through all surfaces of the thermal boundary; and
- Calculate the heat gain resulting from air leakage through the thermal envelope (above grade only).
- Solar gain and internal gain are loads in this case, so they must be considered.


Preparation

- Building measurement.
 - Determine thermal envelope boundaries.
 - Measure heat transfer surfaces to nearest 0.5 foot.
 - Make drawing.
- Determine design weather conditions.
- Determine the R-values and U-factors.

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Design Temperature, Heating

- The design temperature difference.
 - The outdoor design temperature (-7°F for Burlington),
 - Is subtracted from the indoor design temperature (70°F everywhere),
 - To get the design temperature difference, ΔT .

49 

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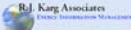
Sizing Conditioning Systems

50 

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Sizing Heating Systems

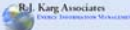
- Calculate Design Heat Load (DHL) using method based on Manual J, *Residential Load Calculation*.
- Multiply DHL by proper sizing multiplier to find heating system *output*.
- Find appropriate unit in GAMA directory or other resource of system listings.
- Calculate room heat loss for sizing distribution system.

51 

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Sizing Cooling Systems

- Calculate Design Cooling Load (DCL) using method based on Manual J, *Residential Load Calculation*.
 - Design sensible load.
 - Design latent load.
- Determine proper Sensible Load Ratio (SLR).
 - $SLR = \text{Sensible load} / \text{Total load}$.
- Select appropriate cooling system.

52 

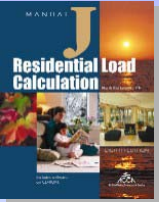
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Residential Load Calculation for Heating/Cooling System Sizing

- Manual J, 8th edition (\$79.95 member/\$125.95 non-member).

Air Conditioning Contractors of America
 2800 Shirlington Road, Suite 300
 Arlington, VA 22206
www.acca.org

Order by Phone:
 888-290-2220 or
 703-575-4477



53 

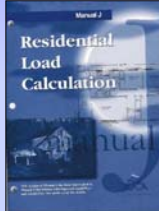
Heat Loss, Heat Gain, and Equipment Sizing

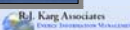
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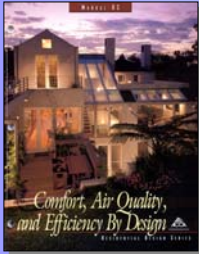
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Other ACCA Manuals for Sizing

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Sizing Software



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Sizing Multipliers

- Heating
 - Gas: 1.0 – 1.1 times DHL.
 - Oil: 1.1 – 1.2 times DHL.
 - Heat pump (heating only): 0.75 – 1.15 times DHL.
- Cooling
 - Sensible cooling: 1.0 – 1.15 times Design Sensible Load (DSL).
 - Latent cooling capacity: 1.0 times Design Latent Load (DLL).

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GAMA Directory Sample

Page 18 SECTION 1 - GAS FURNACES October 2002

Model Number	Config- ation	Foot Notes	Heat Cap Input MBTU/hr	Eff. %	AFUE %	Model Number	Config- ation	Foot Notes	Heat Cap Input MBTU/hr	Eff. %	AFUE %
AMERICAN STD. INC., UNITARY PRODUCTS GROUP						#ADC120C9608* DH1,3,4,7 120.0 112 80.1161 119.0 91.0					
Trade Name: Freedom 80 Single Stage						#AUC120C9608* U H1,3,4,7 120.0 113 70.1262 117.2 92.1					
NATURAL OR PROPANE GAS NON-WEATHERIZED						#AUX120C9608* U H1,3,4,5,7 120.0 113 84.1320 117.0 92.1					
#ADD140C9608* DH1,3,7 140.0 113 77.1444 134.2 80.0						Additional Footnotes					
Additional Footnotes						7. The 12th character in the model number shall be a number from 0 to 9.					
Trade Name: Freedom 90 Two Stage						NATURAL OR PROPANE GAS NON-WEATHERIZED					
#AUY0608P93W* U H1,3,4,5,7 60.0 56 52 199 49.7 93.0						#ADY0608P93W* DH1,3,4,5,7 60.0 56 62 200 50.1 92.1					
#AD0608P924P* DH1,3,7 40.0 32 77 360 26.7 80.0						#ALY0608P93W* U H1,3,4,5,7 80.0 73 61 205 65.9 92.5					
#AU0608P924C* U H1,3,7 40.0 32 95 426 26.8 80.0						#ADY0608P93W* DH1,3,4,5,7 80.0 74 67 332 65.2 92.5					
#ADD0608P93Q* DH1,3,7 60.0 47 87 704 54.6 80.0						#ALY1008P94W* U H1,3,4,5,7 100.0 93 69 452 98.5 93.0					

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Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment
www.gamanet.org and then look under "product certification" and then "product directories"

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Example Design Heat Load Problem

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