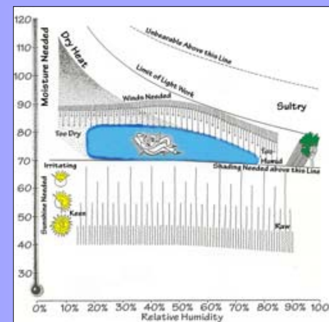
Heat Loss, Heat Gain, and Equipment Sizing

Better Buildings by Design Conference 2006

Sponsored by Efficiency Vermont

Rick Karg

Human Comfort Zone



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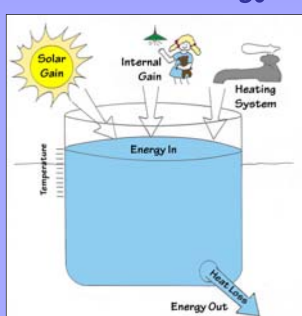
Bucket Analogy



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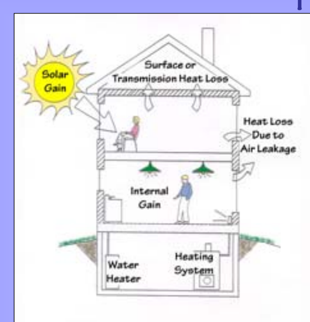
The Thermal Envelope



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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.

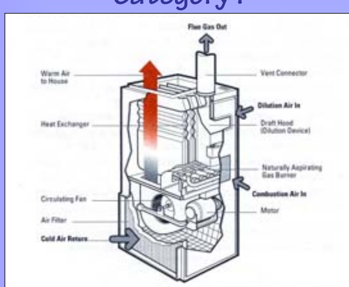
Problems with Oversizing, Heating

- 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.

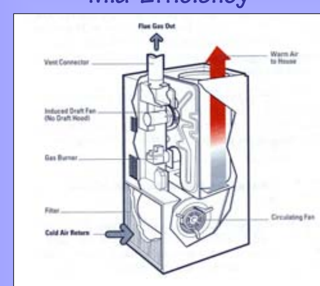
Atmospheric Gas Furnace

Category I



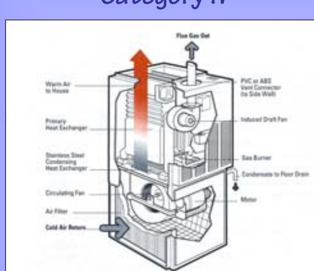
Fan-Assisted Category I

Mid-Efficiency



High Efficiency Condensing Gas Furnace

Category IV



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.

Problems with Oversizing, Cooling

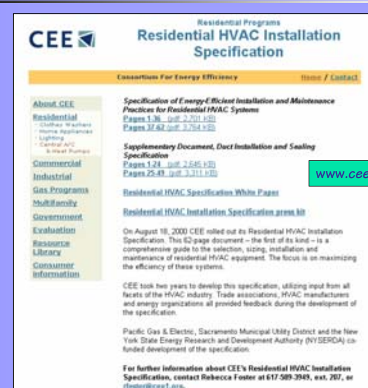
- Study found
  - 50% average oversizing for heat pumps and air conditioners compared to *Manual J*.
  - Some research indicates that *Manual J*, 7th ed, leads to oversized heat pumps and air conditioners.
- This leads to a loss in seasonal efficiency of from 2 to 10 percent, depending on the study.

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

Gas Furnace with Central Air

Problems with Undersizing Heating/Cooling

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



CEE

Residential Programs

Residential HVAC Installation Specification

Consortium For Energy Efficiency — Home / Contact

About CEE
Residential
- Clothes Washers
- Home Appliances
- Lighting
- Central A/C & Heat Pumps
Commercial
Industrial
Gas Programs
Multifamily
Government
Evaluation
Resource Library
Consumer Information

Specification of Energy-Efficient Installation and Maintenance Practices for Residential HVAC Systems
Pages 1-36 (pdf, 2,701 KB)
Pages 37-62 (pdf, 3,764 KB)

Supplementary Document, Duct Installation and Sealing Specification
Pages 1-24 (pdf, 2,645 KB)
Pages 25-49 (pdf, 3,311 KB)

Residential HVAC Specification White Paper

Residential HVAC Installation Specification press kit

On August 18, 2000 CEE rolled out its Residential HVAC Installation Specification. This 62-page document – the first of its kind – is a comprehensive guide to the selection, sizing, installation and maintenance of residential HVAC equipment. The focus is on maximizing the efficiency of these systems.

CEE took two years to develop this specification, utilizing input from all facets of the HVAC industry. Trade associations, HVAC manufacturers and energy organizations all provided feedback during the development of the specification.

Pacific Gas & Electric, Sacramento Municipal Utility District and the New York State Energy Research and Development Authority (NYSERDA) co-funded development of the specification.

For further information about CEE's Residential HVAC Installation Specification, contact Rebecca Foster at 617-589-3949, ext. 207, or rfoster@cee1.org.

Residential HVAC Spec

www.cee1.org/resid/rs-ac/hvac.php3

Replacing Steam Boilers – Caution!

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

Basics of Load Calculation

Heat Loss, Heat Gain, and Equipment Sizing

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).

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Heat Loss, Heat Gain, and Equipment Sizing

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.

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Heat Loss, Heat Gain, and Equipment Sizing

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.

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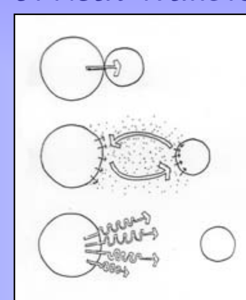
Heat Loss, Heat Gain, and Equipment Sizing

Means of Heat Transfer

Conduction

Convection

Radiation



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Heat Loss, Heat Gain, and Equipment Sizing

Transmission or Surface Heat Transfer

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Heat Loss, Heat Gain, and Equipment Sizing

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 ft^2.

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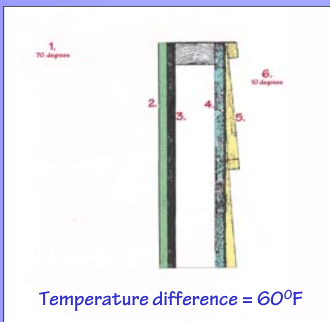
Heat Loss, Heat Gain, and Equipment Sizing

Heat Transfer Through a Wall

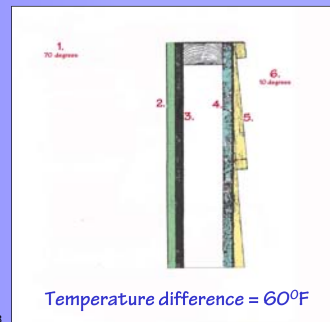


Heat transfer
- Conduction
- Convection
- Radiation

25 R.J. Karg Associates

Heat Loss, Heat Gain, and Equipment Sizing

Heat Transfer Through a Wall



Heat transfer
- Conduction
- Convection
- Radiation

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

Wait 3

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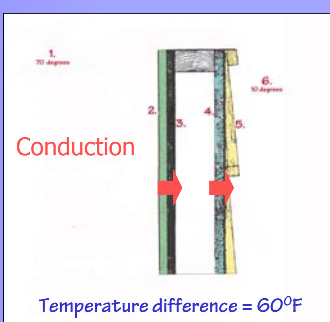
Heat Loss, Heat Gain, and Equipment Sizing

Heat Transfer Through a Wall



Heat transfer
- Conduction
- Convection
- Radiation

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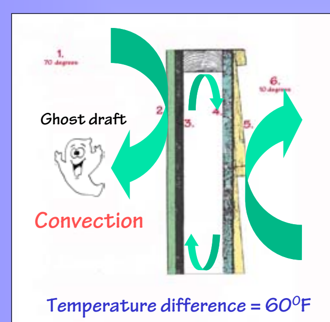
Heat Loss, Heat Gain, and Equipment Sizing

Heat Transfer Through a Wall



Heat transfer
- Conduction
- Convection
- Radiation

Click 1

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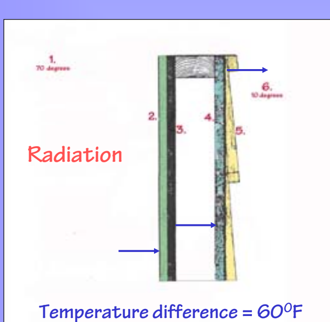
Heat Loss, Heat Gain, and Equipment Sizing

Heat Transfer Through a Wall



Heat transfer
- Conduction
- Convection
- Radiation

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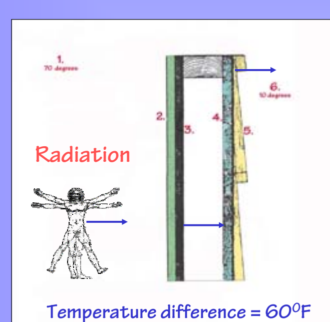
Heat Loss, Heat Gain, and Equipment Sizing

Heat Transfer Through a Wall



Heat transfer
- Conduction
- Convection
- Radiation

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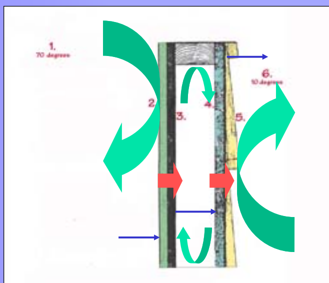
Heat Transfer Through a Wall

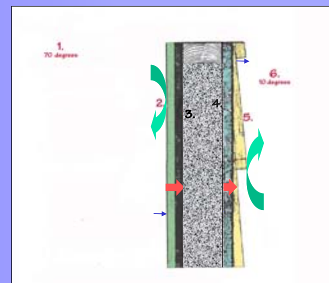


Temperature difference = 60°F

Heat transfer
- Conduction
- Convection
- Radiation

Heat Transfer without insulation

Heat Transfer Through a Wall

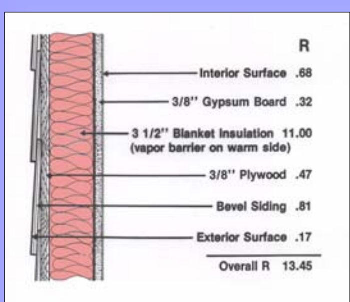


Temperature difference = 60°F

Heat transfer
- Conduction
- Convection
- Radiation

Heat Transfer with insulation

Surface Heat Transfer



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.

Heat Transfer Equations, Surface

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

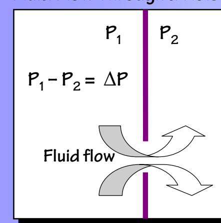
$$\text{Heat Loss} = \text{Area} \times \text{Temp. Difference} \times \text{U-factor}$$

Taking Care of Business in Vermont

The Driving Forces of Air Leakage

What Causes Air-Leakage?

Fluid Flow Through a Hole



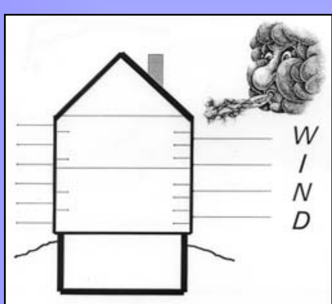
Must have:

1. Hole.
2. Pressure difference.

Drivers can be:

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

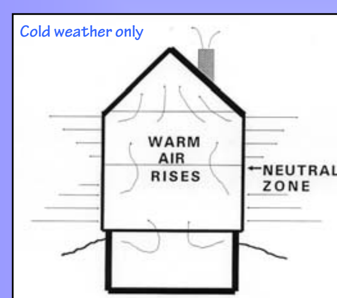
Wind-Driven Air Leakage



Factors:

- Wind speed.
- Leakage area.

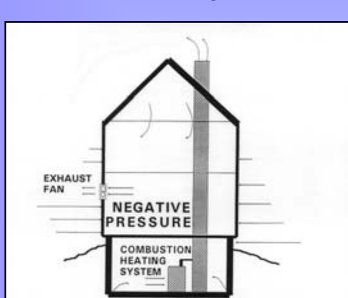
Stack-Effect Air Leakage



Factors:

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

Mechanically-Driven Air Leakage



Factors:

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

Heat Transfer Due to Air Leakage

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.

Design Temperature, Heating

- The design temperature difference.
  - The outdoor design temperature (-7^{0}F for Burlington),
  - Is subtracted from the indoor design temperature (70^{0}F everywhere),
  - To get the design temperature difference, ΔT.

Sizing Conditioning Systems

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.

Sizing Cooling Systems

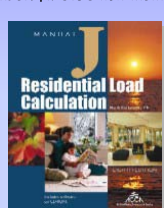
- Calculate Design Cooling Load (DCL) using method based on Manual J, *Residential Load Calculation*.
  - Design sensible load.
  - Design latent load.
- Determine proper Sensible Load Ratio (SLR).
  - SLR = Sensible load/Total load.
- Select appropriate cooling system.

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



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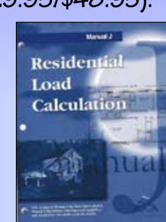
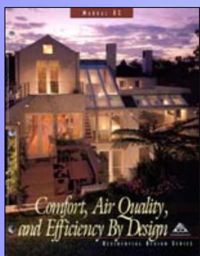
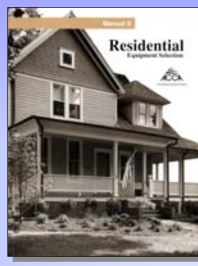


Other ACCA Manuals for Sizing





Heat Loss, Heat Gain, and Equipment Sizing

Sizing Software

www.elitesoft.com

Heat Loss, Heat Gain, and Equipment Sizing

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).

Heat Loss, Heat Gain, and Equipment Sizing

GAMA Directory Sample

Page 18 SECTION 1 - GAS FURNACES October 2002

AMERICAN STD. INC., UNITARY PRODUCTS GROUP

Trade Name: Freedom 80 Single Stage

NATURAL OR PROPANE GAS NON-WEATHERIZED

Model Number	Configur-ation	Foot Notes	Input MBTUH	Heat Cap MBTUH	PE Watts	Eae kWh/yr	Ef MMBTU/yr	AFUE %
# ADD140C960F*	DH	1,3,7	140.0	113	77	1,444	134.2	80.0

Additional Footnotes
7. The 12th character in the model number shall be a number from 0 to 9.

Trade Name: Freedom 80 Two Stage

NATURAL OR PROPANE GAS NON-WEATHERIZED

Model Number	Configur-ation	Foot Notes	Input MBTUH	Heat Cap MBTUH	PE Watts	Eae kWh/yr	Ef MMBTU/yr	AFUE %
# ADD040R924F*	DH	1,3,7	40.0	32	77	380	36.7	80.0
# AUD040R924K*	U H	1,3,7	40.0	32	95	426	36.8	80.0
# ADD060R936F*	DH	1,3,7	60.0	47	82	704	54.6	80.0
# ADC120C960B*	DH	1,3,4,7	120.0	112	80	1,161	119.0	91.0
# AUC120C960B*	U H	1,3,4,7	120.0	113	70	1,262	117.2	92.1
# AUX120C960C*	U H	1,3,4,5,7	120.0	113	84	1,320	117.0	92.1

Additional Footnotes
7. The 12th character in the model number shall be a number from 0 to 9.

Trade Name: Freedom 90 Comfort R

NATURAL OR PROPANE GAS NON-WEATHERIZED

Model Number	Configur-ation	Foot Notes	Input MBTUH	Heat Cap MBTUH	PE Watts	Eae kWh/yr	Ef MMBTU/yr	AFUE %
# AUY060R9V3W*	U H	1,3,4,5,7	60.0	56	52	199	49.7	93.0
# ADY060R9V3W*	DH	1,3,4,5,7	60.0	56	62	200	50.1	92.1
# AUY080R9V3W*	U H	1,3,4,5,7	80.0	73	61	265	65.9	92.5
# ADY080R9V3W*	DH	1,3,4,5,7	80.0	74	67	332	65.2	92.5
# AUY100R9V4W*	U H	1,3,4,5,7	100.0	93	69	452	98.5	93.0

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"

Heat Loss, Heat Gain, and Equipment Sizing

Example Design Heat Load Problem