HVAC Right-Sizing Part 1: Calculating Loads

Thursday, April 28
11:00 a.m. - 12:00 p.m. Eastern

Presented by: Mike Gestwick - National Renewable Energy Laboratory
Arlan Burdick, Anthony Grisolia – IBACOS, a Building America Research Team
Reduce energy use in new and existing residential buildings

Promote building science and systems engineering / integration approach

“Do no harm”: Ensure safety, health and durability are maintained or improved

Accelerate adoption of high performance technologies

www.buildingamerica.gov
15 Industry Research Teams

- CARB (Consortium for Advanced Residential Buildings)
- NorthernSTAR Building America Partnership
- Building America Retrofit Alliance (BARA)
- NAHB Research Center
- Fraunhofer USA
- ARIES Collaborative
- Building Energy Efficient Homes for America (BeeHa)
- Alliance for Residential Building Innovation (ARBI)
- IBACOS
- BA-PIRC (Building Industry Research Alliance)
- BIRA (Building Industry Research Alliance)
- Habitat Cost Effective Energy Retrofit Program
- PARR (The Partnership for Advanced Residential Retrofit)
- N.E.L.C. (The National Energy Leadership Corps)
About Our Speakers

• Building Performance Specialist
• Bachelors in Mechanical Engineering Technology
• LEED® Accredited Professional
• Formerly worked for a large-scale production homebuilding company

• IBACOS Services Manager
• Helps builders create construction standards
• Evaluates construction quality and comfort issues
• Performs quality assessments
The BIG PICTURE – Why Care?

3 Key Factors for Calculating Loads

1. Design Considerations *(15-18 min.)*

2. The Thermal Enclosure *(10 min.)*

3. Internal Loads *(5 min.)*

What Happens When You “Fudge” the Numbers?
Q&A: How to Participate

Type question in this box, select “Ask” (not the symbol of the raised hand)

HVAC Right-Sizing Part 1: Calculating Loads

Welcome to the Webinar! We will start at 11:00 AM Eastern Time

Be sure that you are also dialed into the telephone conference call:

Dial-in number: 800-857-960 ; Pass code: 849250

(if asked for a PIN #, press *0)
Webinar Poll
The BIG Picture
What is HVAC supposed to do?

• Keep the occupants of a home more comfortable by
  – Adjusting internal temperatures
  – Mixing air in rooms
  – Maintaining humidity levels

• Operate unnoticed

• Be energy efficient
Big Picture:

- New construction – 15% less energy each code cycle
- Existing homes – Homeowners updating with insulation, windows and more

Residential State Energy Code Status
AS OF JANUARY 1, 2011

NOTE:
These maps reflect only mandatory statewide codes currently in effect.
Instructions

1. Print this page.
2. Carefully cut out the holes.
3. Stand on curb across the street and hold page 1 foot from your face.
4. Find the hole that’s the closest match.
5. Size HVAC accordingly
Big Picture:

How many fingers do you put on the scale?

ACCA says NONE. Experience bears this out.

Just to be safe...
Enclosures are Improving
Rules of Thumb Haven’t

- Rooms have much lower loads
- More moisture is retained
- Less infiltration – or “natural ventilation”
Best Practice for Right-Sizing HVAC

Iterative Process

1. Load calculations
2. Equipment selection and sizing
3. Duct and register sizing
• The measure of energy the HVAC system needs to add or remove from a space to provide the desired level of comfort  
  – Btu/h  

• Not the size of the HVAC system  
  – First piece of information needed  
  – 12,000 Btu/h = 1 Ton Cooling

• *Can be* highly variable
Big Picture:

- Losses to the outside environment

- No credit is taken for solar gains or internal loads because the peak heat loss occurs at night during periods of occupant inactivity
Big Picture:

- Gains from the outside environment
- Solar Gains
- Internal Gains
- Sensible and Latent Components
Big Picture: How to Approach Manual J

- Designer should
  - Walk a house in production
  - Look at plans
  - Ask for all specifications

- Builder doesn’t have the info?
  Get the homes tested!
  - Duct leakage
  - Air tightness
Big Picture:

HVAC Design Impacts

• 1\textsuperscript{st} construction costs
• Comfort
• Indoor air quality
• Building durability
• Energy efficiency
• Higher customer satisfaction/ lower call backs
Key Factor #1: Design Considerations
Design Considerations

- Location of the House
- Size of the House
- Indoor Design Conditions
**Design Considerations:**

- **Latitude**
- **Elevation**
- **Outdoor temperature and relative humidity**

---

**Location of the House**

**Outdoor Design Conditions for the United States**

<table>
<thead>
<tr>
<th>Location</th>
<th>Elevation</th>
<th>Latitude</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feet</td>
<td>Degrees</td>
<td>Heating f%</td>
<td>Cooling f%</td>
</tr>
<tr>
<td>Florida</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apalachicola</td>
<td>20</td>
<td>29</td>
<td>36</td>
<td>90</td>
</tr>
<tr>
<td>Belle Glade</td>
<td>17</td>
<td>26</td>
<td>44</td>
<td>91</td>
</tr>
<tr>
<td>Cape Kennedy AP</td>
<td>10</td>
<td>28</td>
<td>42</td>
<td>90</td>
</tr>
<tr>
<td>Daytona Beach AP</td>
<td>31</td>
<td>29</td>
<td>37</td>
<td>60</td>
</tr>
<tr>
<td>Fort Lauderdale</td>
<td>10</td>
<td>26</td>
<td>50</td>
<td>90</td>
</tr>
<tr>
<td>Fort Myers AP</td>
<td>15</td>
<td>26</td>
<td>47</td>
<td>63</td>
</tr>
<tr>
<td>Fort Pierce</td>
<td>25</td>
<td>27</td>
<td>42</td>
<td>60</td>
</tr>
<tr>
<td>Gainsville AP</td>
<td>152</td>
<td>29</td>
<td>33</td>
<td>92</td>
</tr>
<tr>
<td>Homestead, AFB</td>
<td>7</td>
<td>25</td>
<td>52</td>
<td>90</td>
</tr>
<tr>
<td>Jacksonville AP</td>
<td>20</td>
<td>30</td>
<td>32</td>
<td>63</td>
</tr>
<tr>
<td>Jacksonville/Cecil Field NAS</td>
<td>50</td>
<td>30</td>
<td>34</td>
<td>95</td>
</tr>
<tr>
<td>Jacksonville, Mayport Naval</td>
<td>16</td>
<td>30</td>
<td>39</td>
<td>92</td>
</tr>
<tr>
<td>Key West AP</td>
<td>4</td>
<td>24</td>
<td>50</td>
<td>69</td>
</tr>
<tr>
<td>Lakeland CO</td>
<td>214</td>
<td>28</td>
<td>41</td>
<td>91</td>
</tr>
<tr>
<td>Melbourne</td>
<td>15</td>
<td>28</td>
<td>43</td>
<td>91</td>
</tr>
<tr>
<td>Miami AP</td>
<td>11</td>
<td>25</td>
<td>50</td>
<td>90</td>
</tr>
<tr>
<td>Miami Beach CO</td>
<td>8</td>
<td>25</td>
<td>48</td>
<td>89</td>
</tr>
<tr>
<td>Miami, New Tamiami AP</td>
<td>10</td>
<td>25</td>
<td>49</td>
<td>91</td>
</tr>
<tr>
<td>Milton, Whiting Field NAS</td>
<td>200</td>
<td>30</td>
<td>31</td>
<td>63</td>
</tr>
<tr>
<td>Ocala</td>
<td>90</td>
<td>29</td>
<td>34</td>
<td>93</td>
</tr>
<tr>
<td>Orlando AP</td>
<td>100</td>
<td>28</td>
<td>42</td>
<td>93</td>
</tr>
<tr>
<td>Panama City, Tyndall AFB</td>
<td>18</td>
<td>30</td>
<td>37</td>
<td>69</td>
</tr>
<tr>
<td>Pensacola CO</td>
<td>30</td>
<td>30</td>
<td>32</td>
<td>92</td>
</tr>
</tbody>
</table>

Source: ACCA Manual J Version 8, Table 1A
Design Considerations:

Orientation

The orientation of the house must be considered in the cooling load calculation due to changing solar heat gains at various times of the day.
Design Considerations: Location of the House

Best Case = East 36,000 Btu/h
Worst Case = North West 41,000 Btu/h
5,000 Btu/h difference
Design Considerations:

- Square footage
- Volume
- Number of bedrooms

Size of the House
Design Considerations:

- Indoor temperature
- Relative humidity

**Indoor Design Conditions**

Cooling Season = 75°F, 50% RH

Heating Season = 70°F, 30% RH

Source: MJ8 and ASHRAE Comfort Zone Chart
Fudge Factor #1

What happens when you fudge heating and cooling set points?

<table>
<thead>
<tr>
<th>Chicago Outdoor/Indoor Design Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
</tr>
<tr>
<td><strong>Outdoor Design Conditions</strong></td>
</tr>
<tr>
<td>89°F $\Delta$ 73°F $\text{wb}$ Temp Cooling</td>
</tr>
<tr>
<td>2°F Temp Heating</td>
</tr>
<tr>
<td><strong>Indoor Design Conditions</strong></td>
</tr>
<tr>
<td>75°F Temp 50% RH Cooling</td>
</tr>
<tr>
<td>70°F Temp 30% RH Heating</td>
</tr>
</tbody>
</table>

Table 3 Chicago Manipulated Outdoor/Indoor Design Conditions
Fudge Factor #1

Fudging set points = 10,400 Btu/h additional cooling load, potentially over-sizing the cooling system by 1 ton
Webinar Poll
Questions?
Key Factor #2:
Thermal Enclosure
Evolution with Code Changes

**Code House**
- Opaque Areas: 24%
- Windows: 29%
- Ductwork: 26%
- Infiltration: 16%
- Internal: 5%

**IECC 2006**
- Opaque Areas: 32%
- Windows: 37%
- Infiltration: 17%
- Internal: 8%
- Ductwork: 6%

**IECC 2009**
- Opaque Areas: 30%
- Windows: 45%
- Internal: 13%
- Infiltration: 12%
- Ductwork: 0%
Enclosure: Key Factors to Consider

- Insulation values
- Window specification
- Air tightness
- External and internal shading
Enclosure:

- Walls
- Ceilings
- Floors

Insulation Values
**Enclosure:**

**A** U-Factor measures how well a product prevents heat from escaping a home or building. U-Factor ratings generally fall between 0.20 and 1.20. The lower the U-Factor, the better a product is at keeping heat in. U-Factor is particularly important during the winter heating season. This label displays U-Factor in U.S. units. Labels on products sold in markets outside the United States may display U-Factor in metric units.

**B** Solar Heat Gain Coefficient (SHGC) measures how well a product blocks heat from the sun. SHGC is expressed as a number between 0 and 1. The lower the SHGC, the better a product is at blocking unwanted heat gain. Blocking solar heat gain is particularly important during the summer cooling season.

**C** Visible Transmittance (VT) measures how much light comes through a product. VT is expressed as a number between 0 and 1. The higher the VT, the higher the potential for daylighting.

**D** Air Leakage (AL) measures how much outside air comes into a home or building through a product. AL rates typically fall in a range between 0.1 and 0.3. The lower the AL, the better a product is at keeping air out. AL is an optional rating, and manufacturers can choose not to include it on their labels. This label displays AL in U.S. units. Labels on products sold in markets outside the United States may display AL in metric units.

**E** Condensation Resistance (CR) measures how well a product resists the formation of condensation. CR is expressed as a number between 1 and 100. The higher the number, the better a product is able to resist condensation. CR is an optional rating, and manufacturers can choose not to include it on their NFRC labels.
Enclosure:

- Orientation
- Size
- Thermal conductivity
- Solar Heat Gain Coefficient (SHGC)
Impact of Window Specification on Peak Cooling Load

- U = 0.35 SHGC = 0.30 versus U = 0.28 SHGC = 0.26
- When buildings are well insulated and air sealed windows are more critical
The target ventilation and infiltration rate must be accurately represented in the data input.

In humid climates, the impact on the latent cooling load can be significant.
Enclosure:

Air Tightness

Blower Door is a Critical Tool

HVAC contractors need proof
Enclosure: Internal and External Shading
Questions?
Key Factor #3: Internal Loads
Internal Loads

- # of occupants
- Electronics
- Lighting
- Appliances
Internal Loads

- System location
- Ductwork
  - Location
  - Insulation value
  - Leakage
What Happens When You “Fudge” the Numbers?

Intentional or accidental manipulation of the design parameters can lead to large variations in the load.
Case Study: Examples of Numbers Gone Wrong

- Two Climate Zones
  - CZ2 Orlando FL
  - CZ5 Chicago IL

- Two Houses
  - 2223 ft² slab-on-grade
  - 2223 ft² on full basement

- Multiple runs through WrightSoft with common errors/safety factors
  - Altered outdoor/indoor design conditions
  - De-rated insulation, window performance, shading characteristics
  - Exaggerated infiltration and ventilation
  - Combined all safety factors for a grossly exaggerated load
Fudge Factor #1 – Design Conditions

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Manipulated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outdoor Design Conditions</strong></td>
<td><strong>Outdoor Design Conditions</strong></td>
</tr>
<tr>
<td>93°Fdb 76°Fwb Temp Cooling</td>
<td>96°Fdb 79°Fwb Temp Cooling</td>
</tr>
<tr>
<td>42°F Temp Heating</td>
<td>30°F Heating</td>
</tr>
<tr>
<td><strong>Indoor Design Conditions</strong></td>
<td><strong>Indoor Design Conditions</strong></td>
</tr>
<tr>
<td>75°F Temp 50%RH Cooling</td>
<td>70°F Temp 30% RH Cooling</td>
</tr>
<tr>
<td>70°F Temp 30% RH Heating</td>
<td>75°F Temp 50%RH Heating</td>
</tr>
</tbody>
</table>

Results - Orlando Manipulated Outdoor/Indoor Design Conditions

<table>
<thead>
<tr>
<th></th>
<th>Baseline Load</th>
<th>Manipulated Load</th>
<th>Change In Load Btu/h</th>
<th>Change In Load %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Load</td>
<td>23,600 Btu/h</td>
<td>37,800 Btu/h</td>
<td>14,100 Btu/h</td>
<td>60 %</td>
</tr>
<tr>
<td>Sensible Cooling</td>
<td>16,600 Btu/h</td>
<td>22,900 Btu/h</td>
<td>6,300 Btu/h</td>
<td>38 %</td>
</tr>
<tr>
<td>Latent Cooling</td>
<td>4,100 Btu/h</td>
<td>7,100 Btu/h</td>
<td>3,000 Btu/h</td>
<td>73 %</td>
</tr>
<tr>
<td>Total Cooling</td>
<td>20,700 Btu/h</td>
<td>30,100 Btu/h</td>
<td>9,400 Btu/h</td>
<td>45 %</td>
</tr>
</tbody>
</table>
### Chicago Building Component Manipulations

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Manipulated</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Windows U = 0.35, SHGC = 0.5</em></td>
<td><em>Windows U = 0.45 SHGC = 0.5</em></td>
</tr>
<tr>
<td><em>Walls R19</em></td>
<td><em>Walls R17</em></td>
</tr>
<tr>
<td><em>Attic R38</em></td>
<td><em>Attic R30</em></td>
</tr>
<tr>
<td>Full credit for eaves, 50% exterior bug screens, light colored blinds at</td>
<td>No credit for eaves, no bug screens, no blinds</td>
</tr>
<tr>
<td>45 degrees closed</td>
<td></td>
</tr>
</tbody>
</table>
### Results - Chicago Building Component Manipulations

<table>
<thead>
<tr>
<th>Component</th>
<th>Baseline Load</th>
<th>Manipulated Load</th>
<th>Change In Load Btu/h</th>
<th>Change In Load %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Load</td>
<td>41,700 Btu/h</td>
<td>46,300 Btu/h</td>
<td>4,600 Btu/h</td>
<td>11%</td>
</tr>
<tr>
<td>Sensible Cooling</td>
<td>17,400 Btu/h</td>
<td>22,400 Btu/h</td>
<td>5,000 Btu/h</td>
<td>28%</td>
</tr>
<tr>
<td>Latent Cooling</td>
<td>3,200 Btu/h</td>
<td>3,200 Btu/h</td>
<td>0 Btu/h</td>
<td>0%</td>
</tr>
<tr>
<td>Total Cooling</td>
<td>20,600 Btu/h</td>
<td>25,700 Btu/h</td>
<td>5,100 Btu/h</td>
<td>24%</td>
</tr>
</tbody>
</table>
Fudge Factor #2 – Manipulating Thermal Enclosure Design

+ 4,600 Btu/h Heating
+ 5,600 Btu/h Total Cooling
## Orlando Ductwork Conditions Manipulations

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Manipulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Tightness level Supply} = 0.06 \text{ cfm/ft}^2$</td>
<td>$\text{Tightness level Supply} = 0.12 \text{ cfm/ft}^2$</td>
</tr>
<tr>
<td>$\text{Tightness level Return} = 0.06 \text{ cfm/ft}^2$</td>
<td>$\text{Tightness level Return} = 0.24 \text{ cfm/ft}^2$</td>
</tr>
<tr>
<td>$\text{Insulation} = \text{R8}$</td>
<td>$\text{Insulation} = \text{R6}$</td>
</tr>
</tbody>
</table>
Fudge Factor #3 – Ductwork Conditions

Results - Orlando Ductwork Conditions Manipulations

+ 3,500 Btu/h
Total cooling

Loads

IBACOS | Alliance
**Fudge Factor #4 – Ventilation / Air Infiltration**

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Manipulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating season infiltration = 0.19 ACHn (5.04 ACH50)</td>
<td>Heating season infiltration = 0.43 ACHn (11.39 ACH50)</td>
</tr>
<tr>
<td>Cooling season infiltration = 0.10 ACHn (2.65 ACH50)</td>
<td>Cooling season infiltration = 0.23 ACHn (6.09 ACH50)</td>
</tr>
<tr>
<td>Ventilation balanced 60 cfm to meet ASHRAE standard 62.2 without energy or heat recovery</td>
<td>Ventilation exhaust only 100 cfm</td>
</tr>
</tbody>
</table>
Fudge Factor #4 – Ventilation / Air Infiltration

**Results - Orlando**
Ventilation/Infiltration Manipulations

- + 1,900 Btu/h Total cooling
- but 1,100 of that is Latent

**Graph Details:**
- **Y-axis:** Btu/h
- **X-axis:** Loads
  - Heating
  - Sensible Cooling
  - Latent Cooling
  - Total Cooling

**Legend:**
- Orlando Baseline Loads
- Orlando Manipulated Infiltration / Ventilation
Combined “Safety Factors” - Chicago

<table>
<thead>
<tr>
<th></th>
<th>Baseline Load</th>
<th>Manipulated Load</th>
<th>Change In Load Btu/h</th>
<th>Change In Load %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Load</td>
<td>41,700 Btu/h</td>
<td>64,700 Btu/h</td>
<td>23,000 Btu/h</td>
<td>55 %</td>
</tr>
<tr>
<td>Sensible Cooling</td>
<td>17,400 Btu/h</td>
<td>31,600 Btu/h</td>
<td>14,200 Btu/h</td>
<td>82 %</td>
</tr>
<tr>
<td>Latent Cooling</td>
<td>3,200 Btu/h</td>
<td>9,100 Btu/h</td>
<td>5,900 Btu/h</td>
<td>184 %</td>
</tr>
<tr>
<td>Total Cooling</td>
<td>20,600 Btu/h</td>
<td>40,600 Btu/h</td>
<td>20,000 Btu/h</td>
<td>97 %</td>
</tr>
</tbody>
</table>

![Results - Chicago Combined Manipulations](image)
### Combined “Safety Factors” - Orlando

<table>
<thead>
<tr>
<th></th>
<th>Baseline Load</th>
<th>Manipulated Load</th>
<th>Change In Load Btu/h</th>
<th>Change In Load %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Load</td>
<td>23,600 Btu/h</td>
<td>57,200 Btu/h</td>
<td>33,600 Btu/h</td>
<td>142 %</td>
</tr>
<tr>
<td>Sensible Cooling</td>
<td>16,600 Btu/h</td>
<td>40,200 Btu/h</td>
<td>23,600 Btu/h</td>
<td>142 %</td>
</tr>
<tr>
<td>Latent Cooling</td>
<td>4,100 Btu/h</td>
<td>13,900 Btu/h</td>
<td>9,800 Btu/h</td>
<td>239%</td>
</tr>
<tr>
<td>Total Cooling</td>
<td>20,700 Btu/h</td>
<td>54,000 Btu/h</td>
<td>33,300 Btu/h</td>
<td>161 %</td>
</tr>
</tbody>
</table>

#### Results - Orlando Combined Manipulations

![Bar chart showing the comparison between baseline loads and combined manipulated loads for Heating, Sensible Cooling, Latent Cooling, and Total Cooling.](chart_image)
Questions?
Wrap Up
Resources

- IBACOS – Building America “Guide to Heating and Cooling Load Calculations for High Performance Homes”
Iterative Process

1. Load calculations
2. Equipment selection and sizing
3. Duct and register sizing
Builder Members

Beazer Homes  History Maker Homes  Pine Mountain Builders
Charter Homes  Hubbell Homes  Pulte Homes
Cobblestone Homes  Imagine Homes  Richmond American
Darling Homes  Insight Homes  S&A Homes
Dominion Homes  K. Hovnanian  Shea Homes
Doucette Communities  KB Home  studio26 homes
DSLD Homes  Keystone Custom Homes  Tindall Homes
e-co lab  Landmark Renovation  Veridian Homes
EQA Communities  Meritage Homes  Wathen-Castanos
Harvard Communities  Mistick Construction  Wayne Homes
Highland Homes  Orleans Homes  Winchester Homes

Supported by:
More Questions?

Arlan Burdick  
*Building Performance Specialist*
406-548-7472  
[aburdick@ibacos.com](mailto:aburdick@ibacos.com)

Anthony Grisolia  
*Services Manager*
412-915-4061  
[agrisolia@ibacos.com](mailto:agrisolia@ibacos.com)

Interested in Innovation? Join the  
Alliance®  
[www.theresearchalliance.org](http://www.theresearchalliance.org)
Thank you for attending the webinar

If you have any comments or ideas for future webinars, please email webmasterbtp@nrel.gov

Visit www.buildings.energy.gov/webinars.html to download today’s presentation and to register for announcements of upcoming webinars.