Understanding Residential HVAC Equipment Sizing

Code Requirements for Manual S
(2012 IRC, IMC, IECC)

Objectives

• Participants shall understand the current and upcoming CT code requirements for residential mechanical equipment engineering (Manual J, S & D)
• Participants shall understand the relationship between Manual J load calculations and Manual S Equipment Selection
• Participants shall understand the need for Manual S equipment sizing (in accordance with the 2012 ICC code)

Topics

1. “Limited” Code Overview
2. Design Process Overview
4. Review & Examples
Handouts

- Copy of this presentation
- 2012 Connecticut Code Summary
- Design FAQ
- CT Code – QIV Comparison
- CT Municipal Design Table 2015
- Example OEM Engineering Data
- Example OEM Capacity Report
- Example Manual J-S Report
- Manual-S Demo Interpolation Spreadsheet

Example House #1

- West Haven, CT
- 2 Floors + Finished Attic
- Built 1930
- 1st Flr = 1145 sq.ft.
- 2nd Flr = 1145 sq.ft.
- Attic = 632 sq.ft.
- Total = 2922 sq.ft.
- Attic Ceilings Insulated
- Windows Updated
- New “insulated” siding

Example House #1
How do we typically go about “Engineering” a mechanical system for this house?

1. Determine scope of the project
2. Solicit contractor quotes
3. Hire contractor
4. Install system
5. Pay contractor

What is the correct way to go about “Engineering” a mechanical system for this house?

1. Determine scope of the project
2. Determine code requirements
3. Perform engineering analysis
4. Solicit bids
5. Hire contractor
6. Install system
7. Commission system
8. Pay contractor
Code Overview

2005 Connecticut Code Summary
(with 2009 Amendments)

2003 International Building Code. (IBC)
2003 International Existing Building Code (IEBC)
2003 International Plumbing Code. (IPC)
2003 International Mechanical Code. (IMC)
2009 International Energy Conservation Code (IECC)
2009 International Residential Code (IRC)
2011 National Electrical Code (NFPA-70) (NEC)

2012 Connecticut Code Summary
(Proposed Adoption Fall 2015)

2012 International Building Code. (IBC)
2012 International Existing Building Code (IEBC)
2012 International Plumbing Code. (IPC)
2012 International Mechanical Code. (IMC)
2012 International Energy Conservation Code (IECC)
2012 International Residential Code (IRC)
2014 National Electrical Code (NFPA-70) (NEC)
2011 Connecticut Amendment

Effective: Oct 6, 2011

SECTION 29-252-1d Amended...

DELETE 2006 IECC, substitute with 2009 IECC Amendments:

403.2.1 Duct Insulation Values prescribed must be installed values.

403.2.3 No building cavities may be used as supply or return “ducts” (2003 IMC/IRC allowed returns)

403.6 Equipment Sizing (Mandatory). Heating and cooling equipment shall be sized in accordance with ACCA Manual J, based on building loads calculated in accordance with ACCA Manual J or other approved methods – none listed.

Referenced Standard: ACCA Manual J-02, 8th edition (not 7)
Referenced Standard: ACCA Manual S-04

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2012 International Residential Code
2012 International Energy Conservation Code

N1103.6 (R403.6) Equipment sizing (Mandatory) & M1401.3 Sizing.
R403.6 Equipment Sizing (Mandatory).

“Heating and cooling equipment shall be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J or other approved heating and cooling calculation methodologies.”

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Code Comparison

<table>
<thead>
<tr>
<th>2009 Equipment Sizing</th>
<th>2010 Equipment Sizing</th>
<th>2011 Connecticut Amendment</th>
</tr>
</thead>
</table>

- Required
- Optional
The Design Process

SAY MAN, YOU DO MANUAL J’S?

IT WOULD BE A LOT COOLER IF YOU DID.
Design Process Overview

Affects CFM requirements, which affects duct loads

**Design Process Overview**

What is Manual J?

1. “Modeling” the peak building loads at local climatic conditions
2. Do NOT change outdoor or indoor design conditions. (This will create psychrometric errors)
3. Manual J (when performed aggressively) will still over-estimate actual loads by 10% to 40%
Local Design Conditions

All values derived from 2009 ASHRAE Handbook-Fundamentals Chapter 1 Psychrometrics Equations 3 & 4

What is Manual S?

1. Iterative process using the “initial” loads from Manual J to select candidate equipment
2. Candidate equipment capacity is then adjusted based on:
   1. available CFM settings of air handler,
   2. altitude,
   3. outdoor air design temperature,
   4. return air entering conditions and,
   5. any line-set adjustments due to lifts or lengths

What is Manual D?

1. The process to design a ducted distribution system based on the CFM requirements determined by the Manual J and Manual S process.
2. Although re-engineering existing duct systems is not required – the designer/mechanic better be able to recognize the very common problems of insufficient return duct, grille and filter sizing.
3. If installing a hydronic only system, many of the Manual J software suites will help size baseboard lengths for the project.
Acceptable Software Tools/Methods

- Manual J is too complex to perform by hand or with a spreadsheet! The design practitioner **MUST** use approved software.
  - There are currently 6 software packages available for load calculations. They are NOT equal in their capabilities.

ACCA Approved Software

[www.acca.org/standards/software](http://www.acca.org/standards/software)
Software Not ACCA Approved

MrHVAC.com
HVAC-Calc
Fire Dragon Net
O’Brien Quick Loads Pro
Qwickload
Loadcalc.net

Code Officials Note: None of these packages will calculate duct loads or air-conditioning loads correctly. They may be close enough for hydronic heating loads, but they are not vetted by ACCA for either.

Acceptable Software Tools/Methods

• Manual S requires Psychrometric calculations and detailed OEM performance data. It can be preformed with charts and tables, however there are a lot of numbers involved and is easy to miss-read or transcribe numbers from OEM charts. It is better to use OEM software and either Psychrometric software, or other tool (including Manual J software) to perform the calculations when possible.
  – NONE of the current Manual J software suites does this perfectly or at all in some cases!

Acceptable Software Tools/Methods

• Manual D can be performed on paper and spreadsheet by someone familiar with the steps, however we highly recommend using the duct design calculators that are available in or as part of a design suite (Manual J)
Design Summary

• Manual J
  – Determine local conditions
• Manual S
  – Select equipment with capacity adjusted for local conditions
• Manual D
  – Based on design CFM requirements

Example House #1

1. Determine scope of the project
   1. Replace 1st floor furnace and Air Conditioner
   2. Replace boiler that serves 2nd floor and finished attic
   3. Add new air conditioner system to 2nd floor and attic

Example House #1

2. Determine code requirements
   1. Manual J (Entire building)
   2. Manual S (all systems)
   3. Manual D – New A/C system only
3. Perform engineering analysis

1. Manual J (Entire building)
2. Manual S (all systems)
3. Manual D – New A/C system only

### Local Design Conditions

<table>
<thead>
<tr>
<th>Room</th>
<th>General Conditions</th>
<th>CM/SM</th>
<th>1.2 X 1.5</th>
<th>2 X 1.5</th>
<th>2 X 2</th>
<th>2 X 2.5</th>
<th>2 X 3</th>
<th>2 X 3.5</th>
<th>2 X 4</th>
<th>3 X 4</th>
<th>3 X 4.5</th>
<th>4 X 4.5</th>
<th>5 X 5</th>
<th>6 X 6</th>
<th>7 X 7</th>
<th>8 X 8</th>
<th>9 X 9</th>
<th>10 X 10</th>
<th>11 X 11</th>
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<tbody>
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<td>Living Room</td>
<td>1</td>
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<tr>
<td>Kitchen</td>
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<tr>
<td>Bedroom</td>
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</tbody>
</table>

### Manual J – Load Calculations
Manual J – Load Calculations

Manual J – Load Calculations

Manual J – Load Calculations
Manual S

The Practical Definition

Manual S Definition

- The process by which the design practitioner determines the suitability of a candidate mechanical comfort system to meet the design loads of a building.
What is an AHRI Rating Document for?

- DOE requires it.
- It only tells us what it can do in a lab – for comparison to other systems at the same conditions.
- It does NOT predict how it will perform on our project!

Manual S Procedure

- Adjust capacity for the following effects/factors:
  1. Altitude
  2. Entering coil air conditions
     1. Adjusted for Duct gains/losses (leakage, R-values)
     2. Ventilation
  3. CFM Settings
     1. Airflow set for Sensible Heat Ratio (Cooling)
  4. Line-Sets
WHY?

- Why do we need to do a load calculation (Manual J) and equipment selection (Manual S) on an existing house?
  - Can’t I just use the same size as what was already there before if the customer isn’t complaining?

BECAUSE

- The original system was MOST likely not properly engineered to begin with,
- Buildings change over time:
  - Weatherization
  - Improvements: Insulation, windows, etcetera...
  - Additional space: additions, finished basements, attics, etcetera.
- Modern equipment doesn’t necessarily work the same as the system that is being replaced.

SO?

- OK – so isn’t equipment selection based on the loads? Can’t I just pick as system based on the loads?
- Well no!

Manual J Equipment Selection

Equipment capacity is rated at certain laboratory conditions. The designer needs to determine how it will operate at local climatic and building operating conditions.
AHRI Rating – Cooling (& HP’s)

- Doesn’t include affects of:
  - Altitude
  - Duct thermal gains/losses
  - Duct static pressures
    - Affects fan power and heat
    - Affects airflow and actual Sensible Heat Ratio
  - Outdoor air temperature (difference)
  - Line-sets
    - Charge adjustments to compensate for length, lifts, size

AHRI Rating – Heating (Combustion)

- Doesn’t include affects of:
  - Altitude
  - Duct thermal gains/losses (not significant)
  - Duct static pressures
    - Affects fan power and heat (not significant)

Manual S (Equipment Selection)
Line Sets

Design Conditions - Ducts

Ventilation
Manual S (Equipment Selection)

75°F dB @ 50% R.H.
(62.5°F wb)

Indoor
• DB
• WB

Return Ducts
• Sensible
• Leakage

Ventilation Effect

Final Condition
• DB
• WB

77.2°F dB / 64.5°F wb?

Entering Air

OEM Engineering Data

587 CFM
63.7°F wb
OEM Engineering Data

Interpolate OEM Data

OEM Tools
Using 3rd party coils

- Manual S requires extended performance rating data.
- OEM must provide tools or custom calculations to meet the requirements for Manual S.
  - Many 3rd party coils do not currently provide such tools, or
  - 3rd party coils instructs designer to use OEM data for their products!
Using 3rd party coils

What About Heating?

<table>
<thead>
<tr>
<th>TABLE 18 – Altitude Derate Multiplier for U.S.A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALTITUDE</td>
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<tr>
<td>FT.</td>
</tr>
<tr>
<td>0–2000</td>
</tr>
<tr>
<td>2001–3000</td>
</tr>
<tr>
<td>3001–4000</td>
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<tr>
<td>4001–6000</td>
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<td>6001–8000</td>
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<td>7001–9000</td>
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<tr>
<td>8001–10,000</td>
</tr>
<tr>
<td>9001–15,000</td>
</tr>
</tbody>
</table>

*Derate multiplier factors are based on midpoint altitude for altitude range.

What About Heating?

<table>
<thead>
<tr>
<th>TABLE 11 – ORIFICE SIZE AND MANIFOLD PRESSURES FOR GAS INPUT RATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALTITUDE RANGE</td>
</tr>
<tr>
<td>AT ALTITUDE</td>
</tr>
<tr>
<td>Ft.</td>
</tr>
<tr>
<td>2000</td>
</tr>
<tr>
<td>1000</td>
</tr>
<tr>
<td>500</td>
</tr>
<tr>
<td>200</td>
</tr>
</tbody>
</table>

This is an example for 94% AFUE Natural Gas Furnace
**Sizing Goals**

ACCA's summary page of sizing parameters.

There are important footnotes for differences between wet climate zones and dry climate zones as well as cold winters and not so cold winter zones.

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**Sizing Factors for Connecticut**

<table>
<thead>
<tr>
<th>General Cooling Capacity Factors</th>
<th>Equipment Tested and Rated by AHRI</th>
<th>Multi/Variable Speed Compressors</th>
<th>GWHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Maximum sizing factor</td>
<td>1.15</td>
<td>1.20 (multi), 1.30 (variable)</td>
<td>1.25 (single), 1.30 (multi), 1.35 (variable)</td>
</tr>
<tr>
<td>Latent</td>
<td>Minimum = 1.0 (may go to 1.50 or higher if needed to meet sensible minimum)</td>
<td>Minimum = 1.0 (may go to 1.50 or higher if needed to meet sensible minimum)</td>
<td>Minimum = 0.90</td>
</tr>
<tr>
<td>Sensible</td>
<td>Minimum = 0.90</td>
<td>Minimum = 0.90</td>
<td></td>
</tr>
</tbody>
</table>


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**Sizing Heat Pumps**

- Heat Pumps are sized to the COOLING load only.
- The balance of any heating that cannot be met by the compressors shall be provided by a supplemental system (stage)
  - Electric resistance
  - Hot water coil
  - Baseboard
  - Radiant
A/C Sizing Exceptions

- For cooling - multi / variable speed systems usually come only in 1-ton increments. The latest Manual S addresses this with the higher sizing factors, however you may still end up over the maximum on smaller houses (loads).
  - Sizing factors are static and make it more difficult for smaller loads (smaller houses have a penalty versus larger houses).
  - Base/old sizing factor is 1.15, now up to 1.3 for high-end variable refrigerant flow systems

Sizing Boilers

- For heating with boilers that also serve DHW, an additional water load sizing should be considered given that peak heating loads usually occur just before dawn, and it is possible that occupants may be using showers at the same time.
  - Newest Manual S tries to address this with upper limit factor of 2.0 (base/old limit is 1.4).
  - Better addressed by adding storage tank (60 gal +) and sizing boiler within 1.4 factor, or
  - Use Tankless water heater!

Newer Variable Capacity Systems

- Allowed to oversize by 30% (1.3 sizing factor)
- Heat Pumps are sized to COOLING load
- High-End Heat Pumps
  - Use higher capacity compressor (digital or DC drive), and
  - May have capacity controls to limit system capacity
- A/C units (some examples):
  - Mini-splits (not all)
  - Lennox XC-25
  - Maytag IQ Drive series
  - Waterfurnace 7-series
Contractors tend to size replacements “like for like”. This results in potential (significant) issues with airflow and draft (flue gasses condensing prematurely)!
Oversizing

Manual S – Documents

Resources

- www.ct.gov/dcs/
- publiccodes.cyberregs.com/icod/index.htm
- www.acca.org
- www.hvac-quality.com
Duct Sealing Note

• Seal Duct system correctly – these are examples of thoughtlessness!

Duct Sealing Note

• Ducts get sealed first, then insulated.
  — In this case, these ducts are lined.

Blower Door – Infiltration Testing
Infiltration Testing

• IECC 2009: Optional

• IECC 2012: 3 Air Changes per Hour at 50 pascals aka 3 ACH50 (0.2 l.w.c.)

Infiltration Comparison

<table>
<thead>
<tr>
<th>Type of Treatment</th>
<th>ACH50</th>
<th>ACHNat*</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012 Connecticut Code</td>
<td>3.0</td>
<td>0.17 - 0.23</td>
</tr>
<tr>
<td>New home with special airtight construction and a controlled ventilation system</td>
<td>1.5 – 2.5</td>
<td>0.10 – 0.17</td>
</tr>
<tr>
<td>Energy efficient home with continuous air barrier system</td>
<td>4.0 – 6.0</td>
<td>0.27 – 0.41</td>
</tr>
<tr>
<td>Standard new home</td>
<td>7.0 – 15.0</td>
<td>0.47 – 1.01</td>
</tr>
<tr>
<td>Standard existing home</td>
<td>10.0 – 25.0</td>
<td>0.68 – 1.69</td>
</tr>
<tr>
<td>Older, leaky home</td>
<td>20.0 – 50.0</td>
<td>1.35 – 3.38</td>
</tr>
</tbody>
</table>

*The conversion between ACH50 and ACHNat is only an estimate for normal exposure for 2-story homes. ACHNat is used in load calculations.

Infiltration & Duct Leakage

• Both affect heat loss/gain and comfort.
• Both can cause unwanted effects to combustion appliances.
• Both affect the sizing of the A/C system and CFM requirements – which can affect duct sizing.
• Duct leakage can drive (or induce) building infiltration.
Thank you

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10:00 AM