Agenda

• HVAC Rater Checklist
• HVAC Contractor Checklist
  • How to Verify a Heating and Cooling Load Calculation
  • What is Behind a Load Calculation
  • Manual S
  • Residential Duct Design
  • ACCA Standard 5
HVAC Rater Checklist.

ENERGY STAR Qualified Homes

HVAC SYSTEM QUALITY
INSTALLATION RATER CHECKLIST

Learn more at energystar.gov
# HVAC Contractor Checklist

**Starts With Loads**

## 1. Whole-Building Mechanical Ventilation Design

1. Ventilation system designed to meet ASHRAE 62.2-2010 requirements.
2. Ventilation system does not utilize an outside air damper on the return side of the HVAC system, unless the system is designed to operate intermittently and automatically based on a timer and to restrict outdoor air intake when not in use, e.g., on mild outdoor days.
3. Documentation is attached with ventilation system type, location, design rate, and frequency and duration of each ventilation cycle.
4. If present, intermittently operating window-type ventilation system designed to automatically operate at least once per day and all 10% or every 24 hours.

## 2. Heating & Cooling System Design

3. Outdoor Design Temperature Location: 5% of time, 10% of time, 15% of time, 25% of time, Other.
4. Number of Occupants Served by System. 
5. Conditioned Floor Area in Rated Home: Square Feet.
7. Prevalent Window SHGC in Rated Home: SHGC.
8. Infiltration Rate in Rated Home: CFM.
9. Mechanical Ventilation Rate in Rated Home: CPM.
12. Design Heat Rate: BTU/h.
13. Insulation Factor: K.

## 3. Selected Cooling Equipment to be Installed

1. Condenser Manufacturer & Model.
2. Condenser Serial.
3. Evaporator/Fan Coil Manufacturer & Model.
4. Evaporator/Fan Cell Serial.
5. EER & SEER:

## 4. Selected Heat Pump Equipment to be Installed

1. Design Heat Pump efficiency: HSPF.
2. Performance at 17°F Capacity: BTU/h Efficiency: COP.
3. Performance at 40°F Capacity: BTU/h Efficiency: COP.
How to Verify a Heating & Cooling Load Calculation

The Step by Step Process for Verifying Residential Heating and Cooling Loads
ACCA Method

ACCA- Air Conditioning Contractors of America

Publish a series of manuals with step by step instructions detailing how to size and design a residential heating and cooling system
What are the Loads on the House?

Conductive
Convective
Latent Loads
Internal Gains
Duct Losses and Gains
Ventilation (if necessary)
Verifying Conductive Heat Transfer

UAT- “U A delta T” is the basic formula for calculating heat transfer due to conduction

HTM- Manual J combines the u-value and the delta T and calls it a heat transfer multiplier

Manual J has complete set of tables with HTMs listed for both heating and cooling

Cooling HTMs take radiation gains and losses into account for windows
Where does Delta T come from?

Delta T is the difference in temperature between the inside of the house and the outside at winter (heating) and summer (cooling) design temperatures.

Design temperatures are not the most extreme that occur during a season.

Design temperatures are the high and low that outdoor temperatures stay between 99 (or 97.5) percent of the time.

Boston design temps are 12 and 88 degrees (not zero and 95).
Design Temperatures

• Indoor:
  - Cooling: 75° / 50% relative humidity
  - Heating: 70°
• Outdoor:

<table>
<thead>
<tr>
<th>Location</th>
<th>Heating 99% Dry Bulb</th>
<th>Cooling 1% Dry Bulb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boston</td>
<td>12°</td>
<td>87°</td>
</tr>
<tr>
<td>East Falmouth</td>
<td>14°</td>
<td>82°</td>
</tr>
<tr>
<td>Lawrence</td>
<td>0°</td>
<td>87°</td>
</tr>
<tr>
<td>Worcester</td>
<td>5°</td>
<td>83°</td>
</tr>
</tbody>
</table>
Temperature Distribution by Hour for a Full Year (8,760 hours)
How to Check a U-Factor

U-Factors for the major components of the building can be checked quickly

Divide the HTMs by the design temperature difference (delta T) and the result will be the U-Factor

U-Factors to R-Factors is 1/U

Question any R-Factors that seem unreasonable
What about Area?

Finish checking conductive heat loss by verifying reasonableness of component areas

Look for a few related ratios:

1. Check the footprint area. Is there enough ceiling to cover it (is there way too much ceiling?)
2. Wall area should be close to conditioned floor area (within a few hundred square feet)
3. Window area should fall between 6% and 22% of the wall area
4. Houses usually don’t have more than a few exterior doors
So, to check conductive heat transfer...(UA deltaT)

Check the winter and summer design temperatures
Divide the HTMs by the winter and summer design Temps to get the U-Factors. Convert to R-factors to check for reasonableness
Look at the construction component areas
Verifying Convective Losses/Gains

Engineers have a complicated method for calculating losses due to air exchange

Manual-J has a simplified method that may not be as accurate on a case by case basis, but is close enough

Most home builders don’t have budget for this type of engineering analysis
Convective Losses & Gains

Need to know house volume to calculate.

Use Table 5A to Determine Air Changes per Hour under natural conditions (ACHnat)

Example: An 1800 sq/ft house that has “average” leakage would have a winter ACHnat of .38 and a summer ACHnat of .20.

A blower door test for existing homes would be best.
Winter Infiltration Btuh

Step 1. Volume x ACH/60 = CFMnat
Step 2. 1.1 x CFMnat x delta T = Btuh

What should we check here?

1. Is the volume reasonable?
2. Does the ACH from Table 5A match the house description?
3. Is the Delta T correct?
Summer Infiltration HTM

Step 1. Summer Infiltration CFM: \( \text{ACHnat} \times \text{Volume} \times 0.0167 = \text{CFMnat} \)

Step 2. Summer Infiltration Btuh: \( 1.1 \times \text{CFMnat} \times \text{CTD} = \text{Btuh} \)

Summer infiltration is not just temperature gain (sensible load), but also moisture gain (latent load)
What About Latent Loads?

Need grains difference from Table 1 at 50% RH .68 x grains difference x CFMnat = Btuh
This is the Latent Cooling Load
Summer Infiltration Load Check

What are we looking for here to verify accuracy?:

1. Is the volume reasonable?
2. Does the ACH from Table 5A match the house description?
3. Is the summer ACH less than the winter?
4. Is the summer load split into latent and sensible?
5. Is that split ratio reasonable for the climate zone the house is in?
Internal Gains

Multiply number of occupants by 230 to get sensible gain

Multiply number of occupants by 200 to get latent gain

People should be placed in the room where they would most likely be at peak load. (not bedrooms)

Appliance sets: Stove, Fridge, DW = 1200 Btuh, Washer & Dryer = 1200 Btuh

Mechanicals: Heating & Cooling & DHW systems in conditioned space = 1200 Btuh
Internal Loads Verification

The number of occupants should be reasonable for the space (# beds +1)

If this is a room by room calculation, place the people where they would most likely be in the afternoon (peak load time)

Appliance sets are 1200 Btuh. The key here is “set”, not per appliance
Duct Losses & Gains

Duct losses & gains are in Tables 7A-D. Which table to use is based on duct config. & location

Use the winter & summer design temps. To determine Base Case Heat Loss Factor (BHLF), Base Case Sensible Gain Factor (BSGF) & Base Case Latent Gain (BLG)

Multiply the BHLF, BSGF & BLG by duct insulation R-value correction
Multiply the BHLF, BSFG & BLG by the duct leakage correction factor
This number x 100 is the percentage of heat loss or gain in the duct system
So to Check Duct Losses/Gains

Check the location
Check the insulation level
Check the leakage level
If you want to check it quick, look at Table 7, get these values and multiply them by each other.
Lowest possible = 6%, Highest = 65%
Ventilation (if necessary)

Defined as for occupants and equipment.

For occupants:

\[
\text{CFM}_{.35} = .35 \times \text{Above Grade Vol./60}
\]

Needed for Occ.:

\[
\text{CFM}_{\text{occ}} = 20 \times (\#\text{beds} + 1)
\]

For Equipment:

\[
\text{CFM}_{\text{comb}} = .\overline{5} \times \text{input Btuh of atm burners} \div 1000.
\]
Select the largest of the three ventilation needs (CFM_{35}, CFM_{occ}, or CFM_{comb})

Now, subtract the estimated cooling infiltration or \( \frac{1}{2} \) the estimated heating infiltration from the ventilation CFM.

Whichever produces the lowest ventilation rate is the one chosen.

Evaluate the ventilation CFM load as if it were infiltration.
Ventilation Checks

Correct Above Grade Volume
Correct or reasonable number of occupants
Btuh input of equipment either existing or proposed is reasonable or accurate
Conclusions

How deep do you want to dig?

1. Weather Station (delta T)
2. Infiltration Factors (ACHnat)
3. Duct Leakage Multiplier
4. U-Factors (HTM/delta T)
5. Internal Gains
6. Ventilation Loads
What is Behind a Load Calculation?

The Science Behind the Printout
1st Law of Thermodynamics

Energy is neither created nor destroyed

However:

- Energy moves from place to place
  And while moving
- Energy can change forms

2nd Law of Thermodynamics

Energy flows naturally from high concentrations to low concentrations.

- Temperature: Heat moves to cold
- Air Movement: High air pressure moves to low air pressure
- Moisture Transfer: Wet moves to dry
Temperature - Heat Transfer

Heat is a form of energy

Heat moves in all directions when there is a delta T and when in motion is referred to as “heat transfer”

Three types of heat transfer

• **Conduction**
  
  Winter – heat moving to outside

• **Convection**

• **Radiation**
  
  Heat moves in all directions and will move faster as temperatures outside or inside increase or decrease
British Thermal Unit (BTU)

A basic measure of heat energy

- It is an amount, not a rate (avoid 100K BTU heating systems!)

The amount of heat needed to raise one pound of water one degree Fahrenheit

A kitchen match contains about one Btu of heat energy.
CONDUCTION

Heat Goes to Cold

Affected by:

• Insulation
  – Installation practices
• Windows
• Framing techniques

Photo © Kevin Kennefick 2001
**U-value**

*Rate* of heat energy (Btu) flowing through 1 s.f. of material, per hour, per 1° F

- Basis of heat loss calculations

**U-value** is “one over” **R-value** *(U=1/R)*

- Smaller U-values mean lower heat loss
- Larger U-values mean higher heat loss

**Windows and doors are rated in “U”**

**U values** can be averaged over surface areas

- But can’t be added in thermal path
The most common unit of measure for describing insulation performance

Inverse of U-value

“Resistance” to heat flow

R values can be added (in thermal path)

- But can’t be averaged over areas
CONVECTION

Heat transfer from a solid surface to a fluid in contact (usually in motion)

Refers to movement of fluid due to differential buoyancy (warm air is less dense than cool air)

Heat carried by a moving fluid (mass-flow)
  • How furnaces and boilers get heat to the rooms

Air leaving the building takes heat with it
  • Same amount of heat must be added to incoming air to maintain temp
  • Also mass-flow; typically referred to as “convection”
Convection: Driving Forces

Temperature is typically the dominant effect.
Stack Effect

Positive pressure (relative to outdoors)

Neutral Pressure Plane

Negative pressure (relative to outdoors)
RADIATION

Hot surfaces warm you up

- You feel heat through space, even if the air is cold
- You feel cold surfaces the same way

Function of temperature difference, area
Mean Radiant Temperature

Mean Radiant Temperature: $= 67^\circ F$
Surface Area

Mean Radiant Temperature: $= 63 \, ^\circ F$
What’s a UA anyway?

“UA” refers to the u-factor, times the area, of a given component.

UA is the heat transfer through that component:

- Example: 1000 s.f. of R-11 wall (u-factor=0.089):
  - \( U \times A = 0.089 \times 1000 = 89 \text{ BTU/HR/°F} \)

\( U \times A \times DT \) is the heat transfer at a given temp.

- Example: Heat loss at 70°F in, 90°F out: (Heat Gain)
  - \( 89 \times 20 = 1780 \text{ BTU/HR} \)
Average R-value Calculation: Steps 1 & 2

Example: 1000 s.f. of R-38 ceiling, 5 s.f. @ R-1:

STEP ONE: Convert R-values to u-factors (if necessary)

U = 1/R; here, 1/38 = 0.026 and 1/1 = 1

STEP TWO: Determine UA_{Total}

UA_{Total} = (U_1 \times A_1) + (U_2 \times A_2) + \ldots + (U_n \times A_n)

Here, UA_{Total} = (0.026 \times 995) + (1 \times 5) = 30.87
Average R-value Calculation: Steps 3 & 4

Example: 1000 s.f. of R-38 ceiling, 5 s.f. @ R-1:

**STEP THREE:** Convert $U_A_{\text{Total}}$ to $U_{\text{Overall}}$

$U_O = \frac{U_A_{\text{Total}}}{A_{\text{Total}}}$; here, $\frac{30.87}{1000} = 0.031$

**STEP FOUR:** Convert $U_{\text{Overall}}$ to $R_{\text{Overall}}$

$R_O = \frac{1}{U_O}$; here, $\frac{1}{0.031} = 32$

Unfortunately, the hard way is the right way!
Instantaneous (Design) Load: Convection (Mass flow)

Heat capacity of air = 0.018 btu / cu ft / °F

Heating or cooling load associated with an air stream:
• cu ft/min x 0.018 btu/cu ft/°F x 60 min/hr x °F

Btu/hr = CFM x 1.08 x DT
What About Radiation?

Not significant when calculating heating loads
Dominant heat transfer method when calculating cooling loads

1. How much glass area?
2. What direction does it face?
3. What type of glass is it?
4. Shading?
Manual-J supplies a Heat Transfer Multiplier (HTM)
This is a multiplier that takes into account the u-factor of the glass, the design delta T, and the radiation gain through the glass
It varies by direction
This number is multiplied by the area to calculate the heat gain through the window
Internal Gains

People make heat and moisture

- 230 Btu/h of sensible gain per person
- 200 Btu/h of latent gain per person

• Number of beds +1
• There are no adjustments made for entertaining guests
• 1200 Btu/h for an appliance SET
So, Simply Stated

Heating Load = Conductive Losses\(^1\) + Convective Losses\(^2\) – Internal gains

Cooling Load = Conductive Gains\(^1\) + Convective Gains\(^2\) + Radiation Gains\(^3\) + Internal Gains

\(^1\) UA\(\Delta T\)

\(^2\) CFMn x 1.08 x \(\Delta T\)

\(^3\) HTM x Area
### HVAC Contractor Checklist

**Next – Select Equipment**

### ENERGY STAR Qualified Homes, Version 3 (Rev. 02)

#### HVAC System Quality Installation Contractor Checklist

<table>
<thead>
<tr>
<th>1. Whole-Building Mechanical Ventilation Design</th>
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<td>1.1 Ventilation system designed to meet ASHRAE 62.2-2010 requirements</td>
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<tr>
<td>1.2 Ventilation system does not utilize an air-side duct to the return side of the HVAC system. If the system is designed to operate intermittently and automatically based on a timer and to restrict outdoor air intake when the HVAC system is off, ensure that the system is designed to operate at least once per day and at least 10% of every 24 hours.</td>
</tr>
<tr>
<td>1.3 Documentation is attached with ventilation system type, location, design rate, and frequency and duration of each ventilation cycle.</td>
</tr>
<tr>
<td>1.4 If necessary, intermittently-operating whole-house ventilation systems designed to automatically operate at least once per day and at least 10% of every 24 hours.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Heating &amp; Cooling System Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Heat Loss / Gain Methods: Manual / ASHRAE 209 / Other</td>
</tr>
<tr>
<td>2.2 Duct Design Method: Manual / ASHRAE 209 / Other</td>
</tr>
<tr>
<td>2.3 Equipment Selection Method: Manual / ASHRAE 209 / Other</td>
</tr>
<tr>
<td>2.4 Orientation of Rated Home: North, South, East, West</td>
</tr>
<tr>
<td>2.5 Number of Occupants Served by System:</td>
</tr>
<tr>
<td>2.6 Conditioned Floor Area in Rated Home:</td>
</tr>
<tr>
<td>2.7 Window Area in Rated Home:</td>
</tr>
<tr>
<td>2.8 Prevalent Window (SWH2) in Rated Home:</td>
</tr>
<tr>
<td>2.9 infiltration Rate in Rated Home:</td>
</tr>
<tr>
<td>2.10 Mechanical Ventilation Rate in Rated Home:</td>
</tr>
<tr>
<td>2.11 Design Load Heat Gain:</td>
</tr>
<tr>
<td>2.12 Design Load Heat Loss:</td>
</tr>
<tr>
<td>2.13 Design Sensible Heat Gain:</td>
</tr>
<tr>
<td>2.14 Design Sensible Heat Loss:</td>
</tr>
<tr>
<td>2.15 Design Latent Heat Gain:</td>
</tr>
<tr>
<td>2.16 Design Latent Heat Loss:</td>
</tr>
<tr>
<td>2.17 Design Duct Static Pressure:</td>
</tr>
<tr>
<td>2.18 Full Load Calculations Report Attached</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Selected Cooling Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Condenser Manufacturer &amp; Model:</td>
</tr>
<tr>
<td>3.2 Condenser Serial #:</td>
</tr>
<tr>
<td>3.3 Evaporator / Fan Coil Manufacturer:</td>
</tr>
<tr>
<td>3.4 Evaporator / Fan Coil Serial #:</td>
</tr>
<tr>
<td>3.5 AHRI Reference #:</td>
</tr>
<tr>
<td>3.6 EER / SEER:</td>
</tr>
<tr>
<td>3.7 EER / SEER:</td>
</tr>
<tr>
<td>3.8 Refrigerant Type: R-410A</td>
</tr>
<tr>
<td>3.9 Fan Speed Type: Variable (ECM)</td>
</tr>
<tr>
<td>3.10 Listed Sys. Latent Capacity at Design Cond.:</td>
</tr>
<tr>
<td>3.11 Listed Sys. Sensible Capacity at Design Cond.:</td>
</tr>
<tr>
<td>3.12 Listed Sys. Total Capacity at Design Cond.:</td>
</tr>
<tr>
<td>3.13 If Listed Sys. Latent Capacity (Value 3.10) + Design Latent Heat Gain (Value 2.12) ENERGY STAR qualified only if install:</td>
</tr>
<tr>
<td>3.14 AHRI Heat Pump Equipment:</td>
</tr>
<tr>
<td>3.15 AHRI/CEI Heat Pump Equipment:</td>
</tr>
<tr>
<td>3.16 Heat Pump Equipment:</td>
</tr>
</tbody>
</table>

| 4. Performance at 17°F: |
| 4.1 Performance at 17°F: Capacity: BTUH, Efficiency: COP |
| 4.2 Performance at 47°F: Capacity: BTUH, Efficiency: COP |

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Manual S

A very quick look at the essential points
How do I get started?

Accurate load calculation (no rules of thumb)
Operating conditions at the building site
Estimating cooling CFM
Equipment selection data summary
Cooling data must be comprehensive
Blower Performance data
ARI Certification data
Load Calculations

Manual or Right-J

Some manufacturer’s software are okay (Elite)

Heat loss or gain is always calculated the same way. UAdeltaT for conduction, CFMn x 1.08 x delta T for convection. Use lookup tables for summer radiation heat gain.
Operating Conditions at Building Site

The capacity of DX coils will be affected by outdoor air temp. for air source.

The capacity of water source cooling will be affected by entering water temp.

Should choose the Manual-J 2 ½ % dry bulb temp for AS. (some exceptions)

For water source, local ground water temp for “open” loop or for closed loop the water temp of the circulating water.
Estimating Cooling CFM

Calculate the sensible heat ratio (SHR) sensible load/total load

Determine best temperature for supply air
- SHR is high, LAT can be warmer (58 F)
- SHR is low, LAT has to be cooler (54 F)

<table>
<thead>
<tr>
<th>Blower Heat Gain</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sensible</td>
<td>23038</td>
</tr>
<tr>
<td>Total Latent</td>
<td>3589</td>
</tr>
<tr>
<td>Total Cooling Load</td>
<td>26628</td>
</tr>
</tbody>
</table>

(ACCA Presentation Man S)
SHR, LAT and TD

How are they related?

- SHR < .80, the LAT=54 and the DT is 21 F

- SHR > .80 but < .85, the LAT=56 and the DT is 19 F

- SHR > .85, the LAT=58 and the DT is 17 F
Determine the sensible heat ratio (SHR).

- SHR = \frac{\text{Sensible Load}}{\text{Total Cooling Load}}

- SHR = \frac{23,038 \text{ BTUH}}{26,628 \text{ BTUH}} = 0.865
Sensible Heat Equation

Once the TD is calculated the cooling CFM can be calculated

- \( CFM = \frac{\text{Sensible Load}}{1.1 \times TD} \)

- Cooling CFM will determine blower size
Ball Park Estimate for Blower Cfm

CFM = \frac{\text{Sensible Load}}{1.1 \times TD}

CFM = \frac{23,038 \text{ BTUH}}{1.1 \times 17^\circ \text{ TD}} = 1,232 \text{ CFM}

Possible data table Cfm + or - 15% ≈ 1,050 Cfm to 1,415 Cfm

(ACCA Presentation Man S)
Blower Performance Data

Supplied by the equipment manufacturer
Can be a table or fan curve
Should show the designer
  - Model number and btu capacity
  - CFM flow at different speeds
  - CFM flow should vary by ESP
# Equipment Selection Summary Data

<table>
<thead>
<tr>
<th>Design Loads: Latent &amp; Sensible, Heating</th>
<th>Outdoor Conditions: Summer dry &amp; wet bulb, winter dry bulb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room Conditions: Dry bulb cooling, relative humidity, dry bulb heating</td>
<td>Air @ Indoor Coil: Dry bulb cooling, wet bulb cooling, dry bulb heating</td>
</tr>
<tr>
<td>Air Flow Estimate: TD from Table 1-4 &amp; CFM from equation</td>
<td>Water Temperature: Late Summer, late Winter</td>
</tr>
</tbody>
</table>
Select capacity for medium fan speed (preferred). The outdoor design temperature is 90 F, so we should interpolate capacity values for 90 F, but we will just use 95 F to demonstrate procedure.
At 1,000 Cfms: Total Cap = 28,020 Btu/h (Ok); Sensible Cap = 27,560 Btu/h (OK); Latent Cap = 460 Btu/h (Not OK)
A fan speed increase (1,125 Cfms) will not help because it causes latent capacity to go to zero.
The reason this unit does not have much sensible capacity is because the indoor coil is relatively large for the condensing unit (designed for a dry climate).

(ACCA Presentation Man S)
1,000 CFM, 95 F, 63 F EWB
Total cap = 28,700 Btuh
Sensible cap = 21,200 Btuh
Latent cap = 7,700 Btuh
Latent load = 3,590 Btuh
XS Lat cap = 4,110 Btuh
½ XS Lat = 2,055 Btuh
Net Sens cap = 23,255 Btuh
Req Sens cap = 23,040 Btuh
Unit is in range
Speeding up blower to 1,125 Cfm increases total cap by 2% and increases sensible cap by 6%.

This unit has a relatively small indoor coil for the condensing unit (good for very humid climate).
ARI Certification Data

AHRI data is only for comparing performance of various makes and models of cooling units and heat pumps. It is not the same as manufacturer’s data. AHRI only provides a units TC not its Latent or sensible. Coil performance is based on CFM, AHRI no data. AHRI data is not site specific.
Step 1 Choosing the Appliances

Has to satisfy BTU (both heating and cooling (latent & sensible))

Fan has to be able to supply needed CFM at a reasonable ESP

Read the footnotes on the table/chart, these will tell you what air side devices have or have not been accounted for
## Sample Blower Table

<table>
<thead>
<tr>
<th>Model</th>
<th>Speed</th>
<th>.4 ESP</th>
<th>.5 ESP</th>
<th>.6 ESP</th>
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<tbody>
<tr>
<td>HC40-60</td>
<td>Low</td>
<td>535</td>
<td>407</td>
<td>350</td>
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<tr>
<td></td>
<td>Med</td>
<td>575</td>
<td>445</td>
<td>405</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>602</td>
<td>500</td>
<td>450</td>
</tr>
<tr>
<td>HC40-80</td>
<td>Low</td>
<td>625</td>
<td>595</td>
<td>550</td>
</tr>
<tr>
<td></td>
<td>Med</td>
<td>735</td>
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<td>625</td>
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<td>780</td>
<td>730</td>
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**Footnotes**

1. Filter pd included
2. DX coil not included
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<td>High</td>
<td>812</td>
<td>780</td>
<td>730</td>
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</tbody>
</table>

**Footnotes**

1. Filter pd included
2. DX coil not included
Air Source Heat Pumps

Sizing should be based on the cooling load

After equipment selection a “balance point diagram” can be used to evaluate heating

Equipment selection for ASHP cooling is same as for cooling only
Balance Point Diagram

Balance point of a system is when the capacity of the heat pump =s the load on the structure
The balance point can be found by graphing the structure heat load and the system heating capacity on the same graph
The intersection is the balance point
Balance Point Considerations

Should not adjust balance point by oversizing (poor cooling perf)
Can only adjust capacity by changing unit
Can adjust shell efficiency and this will change the load vs capacity point
Supplementary heat source below balance point
Ground/Water Source Heat Pumps

Capacity dependant on ground or EWT.
EWT is affected by loop type and well type.
EWT can be estimated using the following
  -cooling peak=Extreme Summer Temp-10
  -heating peak=Extreme Winter Temp+40
These formulas should be used for closed loop or re-injection wells.
GHP Balance Point

Differs slightly from ASHP
ASHP is a line that has a slope
GSHP is a straight line at a constant value (EWT)
Wherever that line intersects is where supplemental heat will be required
So, in Conclusion

Need the heating and cooling loads
Need the cooling CFM (or heating if no A/C)
Need the manufacture’s data
Need site specific information (sometimes)
AHRI data is good to verify total capacity if coils are not listed by manufacture
**HVAC Contractor Checklist**

**Design our Ducts**

*Did you know This is Code?*
Residential Duct Design

ACCA Manual D Method for Sizing Heating & Cooling Ducts
Design Considerations

Rambling Floor Plans: Have very diverse loads at diverse times. Should zone

Multi-Level Plans: Connected by open stairwells or balconies. Heat stratification is a problem. Careful design and continuous low speed fan operation can minimize this

Incompatible Construction Features: Rooms on slabs, conditioned basements, attic rooms, etc.

Incompatible Glass Areas: East glass vs. West glass, thermostat placement etc.

Summer Loads vs. Winter Loads: Seasonal branch damper adjustments

Occupants
Supply Duct System Types

Classified by their Geometry, Supply Outlet Location, and Material

1. Geometry: Trunk & Branch, Radial, Perimeter Loop (pros & cons Sect. 1-6, 7, & 8)
2. Supply Outlet Location: Perimeter, Ceiling, Inside Wall. (ACCA Manual T)
3. Material: Many different materials. Generally see “hard duct”, flex duct, duct board, PVC (high velocity)
Return Duct System Types

Return duct systems primarily described by number of return openings

1. Central
2. Multiple
3. Every Room
Secondary Return Classifications

Location: High Wall, Low System (floor or low wall)

• Place returns where convenient and aesthetic. Returns DO NOT affect air movement or patterns in the room (Manual T, section 7)

Geometry: Like supplies, they can be trunk & branch, radial, perimeter
Duct Efficiency

Try to place appliances and ducts in conditioned space.

If ducts are run in unconditioned space they must be sealed and insulated.

Thoroughly Sealed, Lots of Insulation

Seal and Insulate the Ducts

Cooling ducts and vapor retarders

Seal and Insulate the Ducts
Basic Principles of Residential Duct Design

Units are inches of water column “IWC”

Blower Performance: the amount of air (CFM) that is delivered by a blower depends on the resistance (pressure) that the blower has to work against

Blower data can be summarized in a table or a graph
Blower Performance Data

Some furnaces are heat only
Some are designed for heating & cooling
Blower data generally supplied with technical information from manufacturer

Must have this blower data to design the system
# Furnace Blower Performance

The 93 size provides 1,600 Cfm @ 0.60 IWC

<table>
<thead>
<tr>
<th>Model</th>
<th>Blower Speed</th>
<th>CFM @ External Static Pressure (IWC) with filter in place</th>
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<td></td>
<td>Blower Speed</td>
<td>0.20</td>
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<td>USA-GASF45</td>
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<td>1,087</td>
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<tr>
<td></td>
<td>Low</td>
<td>1,033</td>
</tr>
</tbody>
</table>

(ACCA Presentation Man D)
Duct Performance

The resistance that the blower works against is created by the air side devices and the duct work

Duct performance can be graphed also

When duct performance and blower performance are plotted on the same graph, we get the “system operating point”

If the system operating point does not supply the required CFM:
– Change the fan speed
– Alter the duct geometry
– Change the duct material (flex to hard)
Air Side Devices

Secondary equipment consists of optional components that are added to the base system

– DX coils
– Dampers
– Humidifiers
– Media, HEPA, or Electro-Static Filters

Secondary equipment causes an increase in the resistance to the air flow. This must be accounted for.
Basis for Calculating Available Static Pressure

Based on Blower Performance Data

Air Side Accessory Device Pressure Drop Data

These two sets of data are used to determine Available Static Pressure (ASP)

ASP is the amount of pressure left over after all of the air side device pressure drops have been subtracted from the ESP that a fan can produce
Total Equivalent Length (TEL)

Duct runs consist of straight sections and various fittings.
Pressure loss is associated with both.
The total pressure drop that is associated with a duct run is the sum of the pressure losses of the straight runs and the fittings.
If a fitting had the same pressure drop as 30 feet of straight duct, it would have an equivalent length of 30 feet.
System TEL

A systems’ TEL is the sum of the longest TEL of the supply side and the longest TEL of the return side.

They need to be carefully calculated using the TELs for various fittings and configurations that are listed in Appendix 3 of Manual D.

The TEL of the longest supply run and the TEL of the longest return run need to be found and calculated.

These two TELs are added together and a system TEL is used in the friction equation.
Panned joist and stud spaces are not recommended by ACCA because of leakage problems. See Manual D, 3rd Edition Sections 4-5 and A10-5, and Appendix 3, Group 7.

(ACCA Presentation Man D)
Pressure Drop vs. Friction Rate

Pressure Drop is equal to the total pressure loss that occurs between any two points in a system (expressed in IWC)

Friction Rate is equal to the pressure loss that occurs between two points in a system that are separated by a specific distance. Friction charts and slide rules use 100’ as the reference distance (expressed in IWC/100)

To use the duct calculator, pressure drop data must be converted to the friction rate that is associated with 100 feet of duct run
Friction rates are not chosen

Friction rates are calculated

- “a six inch duct will deliver 100 cfm”
- “I always design my system using .1 as the friction rate”

\[
FR = \frac{ASP \times 100}{TEL}
\]
Example

If a blower could move 1000 cfm against a pressure of .20 IWC and the TEL of the duct system (sum of straight runs and fittings) was 300 ft...

$$FR = 0.20 \times \frac{100}{300} = 0.067 \text{ IWC/100 ft}$$

This is the friction rate that would be used to size the ducts. Not 0.1 IWC/100.
A Few Miscellaneous Items

It is not recommended to design systems with a friction rate below .06 or above .18

The velocity of the air inside the system is an important consideration

- Supply velocities between 300 – 900 feet per minute (fpm)
- Return velocities below 700 fpm

There should be a few bends between the fan and the return grille for sound attenuation
Chapter 8

This is the chapter with the step by step process spelled out

This chapter discusses a few very important considerations that need to be reviewed before starting
CFM vs. Velocity

Noise caused by excessive velocity, or poor throw caused by too low a velocity are important considerations. Final duct size may be a compromise between getting adequate airflow and keeping the run quiet. A duct sizing worksheet has been developed to help with this process.
### Effective Length Calculation Sheet

<table>
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<tr>
<th>Element</th>
<th>Supply Run ID Number</th>
<th>Element</th>
<th>Return Run ID Number</th>
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</table>

**Effective Length Worksheet**
### Sizing Worksheet

**Duct Sizing Worksheet**

HF = Blower CFM / Manual J Heat Loss = ( ) / ( ) = ________

CF = Blower CFM / Manual J Sensible Heat Gain = ( ) / ( ) = ________

<table>
<thead>
<tr>
<th>Supply Duct System</th>
<th>Run - Trunk</th>
<th>H-BTUH</th>
<th>C-BTUH</th>
<th>H-CFM</th>
<th>C-CFM</th>
<th>Dan CFM</th>
<th>Round Size</th>
<th>Velocity</th>
<th>Final Size</th>
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**Return Duct System**

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<tr>
<th>Run - Trunk</th>
<th>Associated Supply Runs</th>
<th>H-CFM</th>
<th>C-CFM</th>
<th>Dan CFM</th>
<th>Round Size</th>
<th>Velocity</th>
<th>Final Size</th>
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</table>
Designer Responsibilities

Ensure that the pressure drop associated with the longest possible circulation path (longest supply TEL + longest return TEL) does not exceed the ASP

That the velocity that is associated with any section does not exceed the recommended limit
Balancing Dampers

Systems could be designed with multiple friction rates, each rate applying to a particular run

• very time consuming to design
• velocity would be an issue
• non-standard run out sizes would be required

These factors make this impractical, therefore a properly designed system will not be self-balancing

Balancing dampers must be installed at the BEGINNING of each supply run out
Manual D

Loaded with very good information that every residential HVAC designer should know
If you only ever read a few chapters, make it 3 & 8.
Appendix 3 is crucial to process
Appendix 1 has all of the design equations
If there is time we have an example

Will This Duct System Work?
Duct Sizing for Furnace & A/C Replacements
HVAC Contractor Checklist

Next is Set Up

Some might say Commissioning.
ACCA Standard 5

HVAC Quality Installation Specification
Minimum criteria for quality HVAC installation

- Proper Installation/Sizing
- Proper Maintenance
- Proper Servicing
- Customer Education

• Residential

- AC and Heat Pumps up to 65K
- Furnaces up to 225K
- Boilers up to 300K
HVAC System Types This Standard Applies To

Heating

• Heat Pumps
• Hot Water Coil, Fin Tube, Unit Heaters/Vent
• Electric Resistance Coils
• Hot Air Furnaces
• Radiant equipment
Applicable Systems (Cont)

Cooling

• Heat Pumps
• Rooftop Single or Multi Zone
• PTACS, Mini-splits
Section 3, Requirement 1

Heat Loss/Gain Calculation

- Room by Room for new structure or existing structure where new ducts added
- Block Load for existing w/out duct modifications
- Load Calc worksheets must be in work file
Selected equipment will be properly sized

- For AC & HP, sensible and latent loads will be covered
- AC & HP sized between 95 and 115% of load
  - 95-125% for HP in heat dominated climate
- Fossil furnaces 100-140% of load
- Fossil boilers 100-115%
- ACCA Manual S or CS, OEM Guidelines
- Documentation in work file
Section 4: Installation

Air Flow
Refrigerant Charge
Electrical Requirements
On Rate for Fuel Fired
Combustion Venting
System Controls
Air Flow

• Requirements:
  - Air flow w/in 15% of design or OEM Recommendation

• Acceptable Procedures:
  - Pressure matching
  - Anemometer (pitot traverse)
  - Flow grids
  - Pressure drop or Temperature Rise

• Documentation
  - Field data on start up sheet & service records
Refrigerant Charge

• Contractor evidence of one of the following
  • Superheat w/in 5° F of OEM (55° + outside)
  • Subcool w/in 3° F of OEM (60° + outside)
  • Or any OEM approved method

• Start up sheet or service record documentation will include
  - system conditions
  - calculations conducted
  - results obtained
  - field data & operating conditions
Electrical Requirements

• Contractor shall provide evidence of
  - line & low voltage within acceptable % of OEM recommendations (w/ voltmeter)
  - Amperage within acceptable % of OEM recommendations (w/ amp meter)
  - Wiring size & grounding per NEC

• Acceptable procedures
  - verify measurements w/ nameplate values

• Documentation
  - comply w/ OEM specs
  - documentation or checklist on file
On Rate for Fuel Fired

Contractor provide evidence of

- Gas fired w/in 5% of nameplate firing rate w/ correct temperature rise
- Oil fired has correct nozzle flow rate and angle per name plate
  1. Oil pump pressure matches nozzle @ OEM spec
  2. Temperature rise per name plate

Acceptable Procedures

- Gas: clock the gas meter & check temp rise
- Oil: nozzle input, pump pressure, temp rise & combustion analysis

Document the field measurements or checklist in field file.
Combustion Venting System

Contractor provide evidence of
- Cat I vent to OEM & NGFC specs or IFGC specs
  or
- Cat II, III, IV sized per OEM specs
  or
  - Cat II, III, IV sized per local code

• Acceptable Procedures
  - Cat I: compare actual installation to gas vent tables
  - Cat 2: compare actual installation to OEM specs

• Documentation:
  - Field data on start up sheet or service record
System Controls

Contractor shall ensure proper selection of

- operating & safety controls per OEM specs
- operating & safety controls lead to proper sequencing per OEM specs

• Acceptable Procedures:
  - OEM literature to support controls selection
  - verification of correct sequencing per OEM specs by testing

• Documentation:
  - Controls match OEM specs, checklist on file
Section 5
Duct Distribution Aspects

Duct Leakage
- Ducts inside leak less than 10% of design air flow
- Ducts outside leak less than 6% of design air flow
- Energy Star Home ducts leak less than 4% of conditioned floor area
- Meet code if they exceed above requirements

• Test Methods
  - Duct pressurization, blower door subtraction, hybrid of above other two

Documentation
  - Field data on start up sheet or service record, document on checklist in work file
Section 5 (cont)

Air Flow Balance

- Contractor provide evidence of
  1. NewCon or new ducts air flows w/in 20% or 25 cfm of design flows
  2. Existing const w/ no duct modifications-no requirements
  3. Or meet local code if more stringent

Acceptable Procedures

- Flow hood, anemometer, pitot tube traverse.

Documentation

- Field data on start up sheet or service record, checklist
Section 6
System Documentation

• Contractor shall document installation
  - copies of all applicable construction drawings, calcs, operating manuals etc w/in easy reach of customer
  - record model and serial number of all installed equipment

• Acceptable Procedure
  - contractor shall confirm all listed requirements met

• Documentation
  - written documentation or checklist in job file, signed document by customer confirming receipt
Section 6  
Owner/Operator Education

Contractor shall conduct the following

- instruct customer on system operation
- explain system maintenance requirements
- explain warranty procedure & responsibilities
- provide contact information for warranty

Acceptable Procedures

- contractor shall confirm all listed requirements are met

Acceptable Documentation

- written job documentation or checklist in job file
- signed document by customer confirming receipt
Appendices

Appendix 1: Additional Elements for Quality Installations
Appendix 2: Definitions
Appendix 3: Contractor Management Documentation
Appendix 4: Bibliography & Resources
Version 3 HVAC Requirements

**Professional credentialing** - HVAC contractors installing systems in ENERGY STAR Version 3 homes must be credentialed by an EPA–recognized third–party oversight organization. Intended to help EPA ensure that contractors installing systems in ENERGY STAR qualified homes have the knowledge, skills, and abilities to perform required QI work. At this time, this credential is available through ACCA's Quality Assured (QA) Contractor Program.

For additional information
- [www.energystar.gov/newhomeshvacor](http://www.energystar.gov/newhomeshvacor)
- energystarhomes@energystar.gov
Here is the Standard

FREE

PDF copy download

www.acca.org/quality
ACCA QA Program

Gaining Recognition:

– Orientation
– Review
– Preparation
– Application / Participation Agreement
– Payment
ACCA QA Program

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Payment

- $59 (list price) $39 (ACCA Mbr)
- One time: App. pro. fee, $275
- Annual fee, $1,120 (list price)

$ 820 (ACCA Mbr)
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<tr>
<th>Section</th>
<th>Description</th>
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<tbody>
<tr>
<td>1. HVAC System Design</td>
<td>Fundamental design requirements for HVAC systems</td>
</tr>
<tr>
<td>2. Heating &amp; Cooling System Design</td>
<td>Calculations for heating and cooling requirements</td>
</tr>
<tr>
<td>3. HVAC Equipment</td>
<td>List of equipment to be installed</td>
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<tr>
<td>4. Heat Pump Equipment</td>
<td>Specifications for heat pumps</td>
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**Footnotes:**
- [1] ASHRAE 2005 or Other
- [2] Office or Other
- [5] Manual D or Other
- [7] Manual O or Other
- [8] Manual G or Other
- [9] Manual H or Other
- [10] Manual I or Other
- [12] Manual L or Other
- [13] Manual M or Other
- [14] Manual N or Other
- [15] Manual P or Other
- [16] Manual Q or Other
Thank you!