What Is Meant by Equipment Sizing?

- The goal of all HVAC equipment sizing is to find the best match between the house and the equipment.

- Optimal size is the best match, or balance, between the rate of heat loss or heat gain of the house and the capacity of the HVAC equipment.
The heating or cooling load of the house is how many BTUs/hr the house requires to maintain the required indoor temperature at design conditions.

Typical homes have heat loss rates of between 20,000 BTUs/hr and 80,000 BTUs/hr and cooling loads of between 12,000 Btus/hr and 40,000 Btus/hr.
the Customer Wants

- To be warm in winter
- To be cool in summer
ACCA HVAC Design Process

Manual J
- **Inputs:**
  - Weather data
  - Square footages
  - Insulation levels
  - U Values glass
  - SHGC
  - ACH
  - Duct multipliers
- **Outputs:**
  - Heating/cooling loads

Manual S
- **Inputs:**
  - Heating/cooling loads
  - Capacity tables
  - Fan data
- **Outputs:**
  - Unit selection

Manual D
- **Inputs:**
  - TEL
  - Fan data
- **Outputs:**
  - Friction rate
  - Duct sizes

Benefits
- Lower front-end costs
- Greater comfort
- Lower energy use

Manual J:
- **Benefits**
  - Low front-end costs
  - Greater comfort
  - Lower energy use

Manual S:
- **Benefits**
  - Greater comfort
  - Lower energy use

Manual D:
- **Benefits**
  - Lower energy use

Inputs:
- Weather data
- Square footages
- Insulation levels
- U Values glass
- SHGC
- ACH
- Duct multipliers

Outputs:
- Heating/cooling loads
- Capacity tables
- Fan data
- Unit selection
- Friction rate
- Duct sizes
the R-value that Matters...

Sq. Feet. Of Attic at Various R- Values Needed to Create One Ton of Heating load (12,000 Btus/hr.) Boise Idaho
BTUs Through 2,000 sq of Attic with Various R Values: Boise Idaho

- R-0: 45,000 BTUs per hour of heat loss
- R-7: 15,000 BTUs per hour of heat loss
- R-11: 10,000 BTUs per hour of heat loss
- R-19: 5,000 BTUs per hour of heat loss
- R-27, R-30, R-38: 2,000 BTUs per hour of heat loss

- **The Square Feet**
Manual J Heating Load Inputs

It’s pretty simple

This is the old Greek Formula: $UA\Delta T$

Limited Range in New Construction!

Duct Multiplier

$ACH$ and Ventilation

Selection Process

It’s an educated guess!

5 Choices

40K  60K  80K  100K  120K
Manual J Cooling Load Inputs

Critical Inputs include windows and Internal gain

- Surface areas, attics, walls, floors and R values
- Square Footage, U values
- Windows: U value SHGC, Shading, Orientation
- Duct Multiplier: Humans plus all their stuff that plugs in. It's growing fast
- Internal Gains: Narrower range in new construction
- ACH and Ventilation

Selection Process

7 Choices: 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 5.0
A word about Duct Multipliers
Contractors Usually Size

- Most contractors use the “telephone method” of sizing
- If the telephone doesn’t ring, it must be the right size
- This makes sense from the contractor’s perspective
HVAC Equipment Sizing

Or, “Relax, don’t panic.”

It’s easy and the answer does not matter as much as you might think.

(Most of the time)
**Why is Equipment Sizing Really Important?**

- **Furnaces:**
  - They have to be big enough to heat the house! Modern furnaces do not have much of a penalty for oversizing. People like to heat their house up in a hurry. Keep it within the next size up from the “right” size. Relax.

- **Air Conditioning:**
  - In the west, cool the house on the hottest day or the phone will ring. Keeping it within the next largest size is okay (make sure it’s installed right). Relax.

- **Heat Pumps:**
  - Must be big enough to heat the house down to 30°F. Time to sweat the details a little. Getting the right size is crucial to saving energy for heat pumps.
Furnaces:

1. Complete heat loss calculation at winter design conditions.

2. Size furnace not to exceed 140% of the heat load at winter design conditions (ACCA). Relax a little—oversizing on condensing gas furnaces increases the efficiency.

3. Sometimes you need the fan in a larger unit to handle big homes with an AC coil. It's ok to do this. (more later)

Relax: The oversizing penalty is really small or non-existent
If Heat loss of house was 45,000 BTU/hr, what furnace would be the right size?

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Official Summer Climate Map of America

- Sometimes hot, dry
- Really blazing hot!
- Hot and really dry
- Blazing hot and really humid (hell)
- Hot and really humid
Design Conditions

Design Temperature is not the coldest day or hottest day of the year

- **Winter Design Conditions:** It only gets colder than this 1%-2.5% of the time
  - **Boise:**
    - Average coldest temp is -2° F (the mean extreme)
    - Winter Design Condition is 9° F
    - Summer: I don’t care about what the design temp is, I want it cool now

- **Portland:**
  - Winter 23° F
  - Summer 86° F
  - What about mean extreme?
Design Temp Do You Want?

Weather City Selection

Country
- Tuvalu
- Ukraine
- United Arab Emirates
- United Kingdom
- United States Minor Outlying Islands
- Uruguay
- USA

State/Province
- New York
- North Carolina
- North Dakota
- Ohio
- Oklahoma
- Oregon
- Pennsylvania

City
- Eugene
- Eugene
- Grants Pass
- Hillsboro
- Klamath Falls
- Klamath Falls Intl AP
- Medford
- Meacham
- Meacham
- Newport State Beach
- North Bend
- North Bend
- Pendleton
- Pendleton
- Portland
- Portland/Hillsboro
- Redmond
- Redmond

Cooling DB / WB
- Annual
  - Mean extreme (99 °F / 73 °F)
  - 0.4% (90 °F / 67 °F)
  - 1% (86 °F / 66 °F)
  - 2% (83 °F / 64 °F)
- Monthly
  - 0.4%
  - 1%
  - 2%

Heating DB
- 99% (27 °F)
- 99.6% (22 °F)
- Mean extreme (18 °F)

### Step # 3 Sizing Air Conditioner Units

**REMEMBER WE LIVE IN A DRY SUMMER CLIMATE!**

1. Find the outside design temp.

2. Determine your cfm.

3. Pick the lowest Entering Wet Bulb (EWB) temp

4. Locate the sensible capacity

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*Multipliers for Determining the Performance With Other Indoor Sections*
REMEMBER WE LIVE IN A DRY SUMMER CLIMATE!

1. Find the outside design temp.

2. Determine your cfm.

3. Pick the lowest Entering Wet Bulb (EBW) temp

4. Locate the sensible capacity

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<tbody>
<tr>
<td>TOTAL CAP</td>
<td>X0.98</td>
<td>X1.01</td>
<td>SENS. CAP</td>
<td>X0.94</td>
<td>X1.06</td>
</tr>
</tbody>
</table>
Where does the 60% sensible 40% latent myth come from?

- \( \frac{21,600}{36000} = 60\% \)

- This is one hot muggy house!

- This is not anyplace in the Northwest.

### Performance Data @ ARI Standard Conditions—Cooling: RANL- JEZ

<table>
<thead>
<tr>
<th>Outdoor Unit RANL-</th>
<th>Model Numbers</th>
<th>Indoor Coil and/or Air Handler</th>
<th>Total Capacity BTU/H [kW]</th>
<th>Net Sensible BTU/H [kW]</th>
<th>Net Latent BTU/H [kW]</th>
<th>EER</th>
<th>SEER</th>
</tr>
</thead>
</table>
Most parts of the West require only sensible cooling (very low humidity levels).

“Air conditioning” originally meant (in large part) dehumidification. Oversized equipment will not dehumidify well. In dry places, oversizing doesn’t matter since (almost) all cooling is sensible.

Insulation of the house is important to cooling load but windows and ducts are even more important.

Equipment output tables must be looked at carefully.
Heat Pump Sizing (For Heating) – It’s Complicated

Capacity of Furnaces and Heat Pumps at 47F and 35F

- Capacity values in BTUs/hr for different capacities and temperatures
- 80K 80% Gas Furnace
- 5 ton, 4 ton, 3.5 ton, 3 ton, 2.5 ton, 2 ton, 1.5 ton
- 47F and 35F temperatures

Legend:
- Orange bars represent 47F
- Blue bars represent 35F
Pump Goal

- The goal is to maximize the savings from heat pumps.

- HP savings are dependent on the following items to achieve the goal:
  - Correct sizing
  - A control strategy that minimizes the use of strip heat
  - A high efficiency heat pump

Keeping the electric strip heat off is the KEY to maximizing energy savings from heat pumps
To minimize the use of strip heat, these two steps must be taken:

1. Size the compressor large enough to provide all the heat needed as long as the outdoor temp is above 30° F (hint: 30° F is the “balance point”).

2. Controls w/ outdoor thermostat (lockout strip heat above 35 or 40° F). This prevents unnecessary strip heat use (emergency heat will still work if wired correctly).
• The lowest outdoor temperature for which the output of the heat pump can heat the house by using the compressor only.

• Below this temperature, the strip heat is needed to help heat the house.

• If it’s a gas backed up heat pump, use economic considerations to determine balance point (usually around 40°F)
Why a 30° F balance point makes sense

Temperature Bins for Boise

There are 1553 hours between 30° F and 40° F. That’s equivalent to 65 days.
Seattle Temperature Bins:

There are 930 hours between 30° F and 40° F. That is equivalent to 39 days.
Heat Pump Balance Point Chart

1st plot the heat loss
45,000 BTUs at 9F

Heat Pump Capacity Ratings
2.5 ton
17F = 15,000
47F = 28,400
3 ton
17F = 21,600
47F = 34,200
3.5 ton
17F = 26,200
47F = 39,000
4 ton
17F = 29,200
47F = 47,000

Outdoor Air Temp F

Heat Loss, Thousand BTUs/hr.

-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75

2.5 ton BP=37
3 ton BP=33F
4 ton BP=25
3.5 ton BP=28
4 ton BP=25
Balance Point Using AHRI Data

Outside Air Temperature (OAT) vs. BTUs (x1000) for a 3 Ton HP system. The graph shows the temperature range between 17°F and 47°F, indicating the energy output in BTUs (x1000) for a single speed system.

- **3 Ton HP**
  - 17°F: 21,600 BTUs
  - 47°F: 34,200 BTUs

---

**Graph Details:**
- **Y-axis:** BTUs (x1000)
- **X-axis:** Outside Air Temperature (OAT)
- **Legend:**
  - **HP**
  - **HL**
Choose the size for the balance point, not the winter design temp. A three ton heat pump would provide a balance point of just below 30°F. Strip heat will supplement below 30°F. Strip heat must be sized to meet the heat at design conditions.
Variable Speed Equipment

- Lower operating costs
- Higher HSPF
- Typically higher output at 30F Balance Point
  - Home with higher heat loss could use 3 ton VSHP instead of 3.5 ton or higher single-speed heat pump
Variable Speed Equipment

- Less heat pump cycling above balance point
- Sizing VSHP can be tricky
- Over sizing/under sizing concerns
Cold Climate Heat Pumps (no aux heat needed?)

![Graph showing % Heating Capacity vs. Outdoor Temperature for MSZ-FE Hyper-Heating INVERTER]

- MSZ-FE09NA (H2i°) heat pump system
- MSZ-FE12NA (H2i°) heat pump system
Single Speed vs. Variable Speed

3 Ton Single Speed and Variable Speed HPs Using AHRI Data

<table>
<thead>
<tr>
<th>3 Ton HP</th>
<th>17°F</th>
<th>47°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Speed</td>
<td>21,600</td>
<td>34,200</td>
</tr>
<tr>
<td>Variable Speed</td>
<td>27,000</td>
<td>33,000</td>
</tr>
</tbody>
</table>

AHRI Outdoor Conditions

![Graph showing HP capacities at 17°F and 47°F for single speed and variable speed HPs.]
A new calculator is being developed that will provide the sizing for variable capacity units.
Sizing Considerations with DHPs
Size to meet the load of the zone(s) at design conditions

- Take into account supplemental sources and overall design

When sizing, the minimum capacity is nearly as important as the maximum capacity

- When the house load drops below minimum capacity, performance drops from severe short-cycling
- A look at the max/min capacity at 47° F can be an indicator of how the unit will perform in these conditions
- We call this the unit’s “turn-down ratio”.
- It varies greatly by model.

Look for a unit with at least a 4:1 ratio or higher between its maximum and minimum capacity at 47° F
Comparison of Nominal 1-ton DHP Models

Manufacturer's Stated Heating Capacity at 47 deg F (Btu/hr)

"Rated" Capacity
Ductless Heat Pumps

Comparison of Nominal 2-ton DHP Models

Manufacturer's Stated Heating Capacity at 47 deg F (Btu/hr)

"Rated" Capacity
Ductless Heat Pumps

Projected Usage in kWh vs Previous Period

- This Month: 18 kWh
- Last Month: 102 kWh

DHP Downstairs, Minute by Minute View for Today
Ductless Heat Pumps
What we Have Learned

- Sizing and Selection is REALLY important!
- Placement is really important
- Homeowner education is really important
- There are BIG differences between models with same nominal size

Heating Cooling Loads Must Be Calculated

Detailed Capacity Must Be Known
<table>
<thead>
<tr>
<th>Heated Zone Sq. Ft</th>
<th>2 X 4 wall</th>
<th>2X6 Wall</th>
<th>Built since 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;500</td>
<td>• 15K</td>
<td>• 12K</td>
<td>• 9K</td>
</tr>
<tr>
<td>500 to 750</td>
<td>• 18K</td>
<td>• 15K</td>
<td>• 12k</td>
</tr>
<tr>
<td>&gt;750</td>
<td>• 24K</td>
<td>• 18K</td>
<td>• 15K</td>
</tr>
</tbody>
</table>
Energy Trust’s Heat Pump Pilot

- Energy Trust – Oregon territory
- 110 manufactured homes
- Flat fee to participant
- RFP, limited contractor pool
$1000 copay from the participant
~$3500 from Energy Trust
Heat pump, crossover repair
What wasn’t included:
- Furnace replacement
- Electrical panel upgrades
- Duct sealing
Keeping Prices Down

- Avg. 8.5 HSPF
- Contractors bid a fixed price by system tonnage
- Tight specs around what was and wasn’t included in the offer
- Incentive rammed up to the limits of cost-effectiveness
- Contractors floated the Energy Trust payment
- Contractors were encouraged to offer financing
# Pump Sizing Guidelines

<table>
<thead>
<tr>
<th></th>
<th>2X4 walls</th>
<th>2X6 walls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single wides</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single wide</td>
<td>2 ton</td>
<td>1.5 or 2 Ton</td>
</tr>
<tr>
<td>Double wides</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28 X48</td>
<td>2 ton</td>
<td>2 ton</td>
</tr>
<tr>
<td>28X52</td>
<td>2.5 ton</td>
<td>2 ton</td>
</tr>
<tr>
<td>28X 56</td>
<td>2.5 ton</td>
<td>2 ton</td>
</tr>
<tr>
<td>28 X60</td>
<td>2.5 ton</td>
<td>2 ton</td>
</tr>
<tr>
<td>28X72</td>
<td>3 ton</td>
<td>2.5 ton</td>
</tr>
</tbody>
</table>
Never Underestimate the Power of a Good Contractor

- 2 contractors sold almost all the systems
- Both had extensive MH contacts
- One did a mailer, one worked their network
- Both contributed significantly to the final technical spec
What Contractors Said

- “We got energy saving heat pumps into the hands of people couldn’t otherwise afford it and it was good for our business.”

- “It was a platform to educate homeowners about energy efficiency.”
Results

- 110 heat pumps sold
- 0 applications rejected
- Contractors paid within 30 days 100% of the time
- Average cost $4700
The Really Good Results Are…….

An Average savings of 3,400 kWh/year

Reached a segment of the market that did not know they were in the market
What was found

<table>
<thead>
<tr>
<th>Site ID</th>
<th>City</th>
<th>Year Built</th>
<th>Sq. ft.</th>
<th>MH Type</th>
<th>Tonnage</th>
<th>Strip Heat Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>683853</td>
<td>Bend</td>
<td>1996</td>
<td>1400</td>
<td>Double-wide</td>
<td>2</td>
<td>49%</td>
</tr>
<tr>
<td>683890</td>
<td>Bend</td>
<td>1997</td>
<td>1400</td>
<td>Double-wide</td>
<td>2</td>
<td>14%</td>
</tr>
<tr>
<td>677995</td>
<td>Bend</td>
<td>1997</td>
<td>1620</td>
<td>Double-wide</td>
<td>2.5</td>
<td>9%</td>
</tr>
<tr>
<td>139287</td>
<td>Oregon City</td>
<td>1991</td>
<td>1292</td>
<td>Double-wide</td>
<td>2</td>
<td>7%</td>
</tr>
<tr>
<td>25106</td>
<td>Oregon City</td>
<td>1991</td>
<td>1080</td>
<td>Double-wide</td>
<td>2</td>
<td>5%</td>
</tr>
<tr>
<td>690344</td>
<td>Terrebonne</td>
<td>1997</td>
<td>1296</td>
<td>Double-wide</td>
<td>2</td>
<td>4%</td>
</tr>
<tr>
<td>689461</td>
<td>Bend</td>
<td>1997</td>
<td>1200</td>
<td>Double-wide</td>
<td>2</td>
<td>3%</td>
</tr>
<tr>
<td>543542</td>
<td>Oregon City</td>
<td>1995</td>
<td>1800</td>
<td>Double-wide</td>
<td>3</td>
<td>2%</td>
</tr>
<tr>
<td>497998</td>
<td>Oregon City</td>
<td>1995</td>
<td>1290</td>
<td>Double-wide</td>
<td>2</td>
<td>2%</td>
</tr>
<tr>
<td>325913</td>
<td>Bend</td>
<td>1988</td>
<td>1980</td>
<td>Double-wide</td>
<td>3</td>
<td>2%</td>
</tr>
<tr>
<td>690383</td>
<td>Oregon City</td>
<td>1996</td>
<td>1296</td>
<td>Double-wide</td>
<td>2</td>
<td>1%</td>
</tr>
<tr>
<td>689451</td>
<td>Bend</td>
<td>1995</td>
<td>1810</td>
<td>Double-wide</td>
<td>3</td>
<td>1%</td>
</tr>
<tr>
<td>583813</td>
<td>Oregon City</td>
<td>1987</td>
<td>1296</td>
<td>Double-wide</td>
<td>2</td>
<td>0%</td>
</tr>
<tr>
<td>562026</td>
<td>Oregon City</td>
<td>1990</td>
<td>1568</td>
<td>Double-wide</td>
<td>2.5</td>
<td>0%</td>
</tr>
<tr>
<td>520339</td>
<td>Portland</td>
<td>2014</td>
<td>1500</td>
<td>Double-wide</td>
<td>2.5</td>
<td>0%</td>
</tr>
<tr>
<td>467510</td>
<td>Bend</td>
<td>1997</td>
<td>1400</td>
<td>Single-wide</td>
<td>2</td>
<td>0%</td>
</tr>
<tr>
<td>231255</td>
<td>Oregon City</td>
<td>1990</td>
<td>1400</td>
<td>Double-wide</td>
<td>2.5</td>
<td>0%</td>
</tr>
<tr>
<td>467251</td>
<td>Bend</td>
<td>1997</td>
<td>1400</td>
<td>Double-wide</td>
<td>2.5</td>
<td>0%</td>
</tr>
<tr>
<td>683842</td>
<td>Oregon City</td>
<td>2013</td>
<td>1917</td>
<td>Double-wide</td>
<td>3</td>
<td>0%</td>
</tr>
</tbody>
</table>
## What We Found

<table>
<thead>
<tr>
<th>Aux Heat Ratio</th>
<th>Delta Capacity</th>
<th>% Below or Above</th>
<th>Thermostat Settings</th>
<th>Reasons for high aux heat ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1173489</td>
<td>0</td>
<td>2114</td>
<td>9%</td>
<td>Strip heat locked out at 35F.</td>
</tr>
<tr>
<td>1156226</td>
<td>0</td>
<td>-6009</td>
<td>-20%</td>
<td>Max Savings</td>
</tr>
<tr>
<td>231255</td>
<td>0</td>
<td>-3272</td>
<td>-11%</td>
<td>Max Savings</td>
</tr>
<tr>
<td>562026</td>
<td>0</td>
<td>-5961</td>
<td>-20%</td>
<td>Max Savings</td>
</tr>
<tr>
<td>1171519</td>
<td>4</td>
<td>54</td>
<td>0%</td>
<td>Max Savings</td>
</tr>
<tr>
<td>139287</td>
<td>7</td>
<td>-5427</td>
<td>-23%</td>
<td>Max comfort</td>
</tr>
<tr>
<td>1138572</td>
<td>9</td>
<td>-11966</td>
<td>-40%</td>
<td>Set to Max Comfort, Very low capacity</td>
</tr>
<tr>
<td>1156212</td>
<td>14</td>
<td>-1709</td>
<td>-7%</td>
<td>Max Savings</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Homeowner used deep set backs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Locked out compressor at 35F</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Locked out</td>
</tr>
</tbody>
</table>
Preliminary Conclusions

- All thermostats can cause control problems
  - But connected thermostats can find them!
- Maybe by comparing run times and using connected thermostats, "problem" homes or systems can be found.