
Limitations of residential load calculations, ACCA Manual S requirements, ANSI/CSA/IGSHPA C448 guidelines, and other topics that help put residential equipment selection into perspective

Jeff Hammond
Executive Director, IGSHPA
Topics*

- Overview
- Residential Load Calculation
- ACCA Manual S Equipment Sizing
- ANSI/CSA/IGSHPA C448 Standard
- Ductwork Requirements
- Hydronic Design Considerations
- Q&A

*Preview of new CRD Course!
Design/Sizing Overview

• Even the best system will perform poorly if not designed or installed properly

• A geothermal heat pump has less refrigerant circuit components than a split system air conditioner, but design parameters for geo are often misunderstood

• Water quality is crucial to longevity

• Training and understanding of design and application is a must for happy customers
Residential Load Calculation

HRAI F280 in Canada
ACCA Manual J Overview

• Industry standard for residential load calculation
• ACCA - Air Conditioning Contractors of America
• 8th Edition

HRAI F280 in Canada
ACCA Manual J Overview

• Limitations of Manual J
  • Residential heat loss/gain calculations only
  • Not intended for . . .
    • Structures with solarium or atriums
    • Structures with swimming pools/hot tubs
    • Active or passive solar homes
    • Underground homes
    • Homes with exceptional amounts of glass
    • Commercial loads
ACCA Manual J Overview

• Manual J Assumptions
  • Length to width ratio between 1:1 and 3:1
  • Total glass & door area is 10% - 30% of wall area
  • All walls are completely exposed to wind
  • One kitchen and two bathroom exhaust fans, one dryer vent
Calculation Methods

• Manual (use form J-1)
• Software
  • Right-J / Right-F280 (WrightSoft)
  • RHVAC (Elite)
  • Manufacturers’ versions
  • “Freeware” spreadsheets
### Manual J Example #1: St. Louis

**Design Data**

Reference City: St. Louis, Missouri, United States  
Building Orientation: Front door faces N  
Latitude: 38 Degrees  
Elevation: 535 feet  
Altitude Factor: 0.981

<table>
<thead>
<tr>
<th>Season</th>
<th>Outdoor Dry Bulb</th>
<th>Outdoor Wet Bulb</th>
<th>Outdoor Rel Hum</th>
<th>Indoor Rel Hum</th>
<th>Indoor Dry Bulb</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>8</td>
<td>7.07</td>
<td>n/a</td>
<td>n/a</td>
<td>72</td>
<td>45</td>
</tr>
<tr>
<td>Summer</td>
<td>93</td>
<td>75</td>
<td>44%</td>
<td>50%</td>
<td>72</td>
<td>n/a</td>
</tr>
</tbody>
</table>

**Check Figures**

Supply CFM: 1,965 CFM per Square ft: 0.425  
Square ft. of Room Area: 4,628 Square ft. per ton: 1,612  
Volume (ft³) of Cond. Space: 39,957

**Building Loads**

Total Heating Required Including Ventilation Air: 52,995 Btuh  
Total Sensible Gain: 31,451 Btuh  
Total Latent Gain: 2,994 Btuh  
Total Cooling Required Including Ventilation Air: 34,445 Btuh

**Notes**

Rhvac Online is an ACCA approved Manual J, D and S computer program. Calculations are performed per ACCA Manual J 8th Edition, Version 2, and ACCA Manual D. All computed results are estimates as building use and weather may vary. Be sure to select a unit that meets both sensible and latent loads according to the manufacturer's performance data at your design conditions.
### Design Data

<table>
<thead>
<tr>
<th>Reference City:</th>
<th>Minneapolis, Minnesota, United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Orientation:</td>
<td>Front door faces N</td>
</tr>
<tr>
<td>Daily Temperature Range:</td>
<td>Medium</td>
</tr>
<tr>
<td>Latitude:</td>
<td>44 Degrees</td>
</tr>
<tr>
<td>Elevation:</td>
<td>834 feet</td>
</tr>
<tr>
<td>Altitude Factor:</td>
<td>0.970</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Season</th>
<th>Outdoor Dry Bulb</th>
<th>Outdoor Wet Bulb</th>
<th>Outdoor Rel Hum</th>
<th>Indoor Rel Hum</th>
<th>Indoor Dry Bulb</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>-12</td>
<td>-12.38</td>
<td>n/a</td>
<td>n/a</td>
<td>72</td>
<td>n/a</td>
</tr>
<tr>
<td>Summer</td>
<td>89</td>
<td>73</td>
<td>47%</td>
<td>50%</td>
<td>72</td>
<td>40</td>
</tr>
</tbody>
</table>

### Check Figures

<table>
<thead>
<tr>
<th>Supply CFM:</th>
<th>2,602 CFM per Square ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square ft. of Room Area:</td>
<td>4,628 Square ft. per ton.</td>
</tr>
<tr>
<td>Volume (ft³) of Cond. Space:</td>
<td>39,957</td>
</tr>
</tbody>
</table>

### Building Loads

- **Total Heating Required Including Ventilation Air:** 69,434 Btuh
- **Total Sensible Gain:** 29,655 Btuh
- **Total Latent Gain:** 2,758 Btuh
- **Total Cooling Required Including Ventilation Air:** 32,413 Btuh

**Notes**

Rhvac Online is an ACCA approved Manual J, D And S computer program. Calculations are performed per ACCA Manual J 8th Edition, Version 2, And ACCA Manual D. All computed results are estimates as building use And weather may vary. Be sure to select a unit that meets both sensible And latent loads according to the manufacturer's performance data at your design conditions.
ACCA Manual S
Equipment Sizing

CSA C448 in Canada
ACCA Manual S Overview

• Sets equipment sizing limits
  • Minimum capacity
  • Maximum oversizing factors

• Provides two different climate guidelines
  • Heating degree days less than twice the cooling degree days (St. Louis example)
  • Heating degree days twice or greater than cooling degree days (Minneapolis example)

• Requirement in the International Residential Code
## Manual S Factors

### Overview of Size Limits for Residential HVAC Equipment

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Attributes of Local Climate Notes b, c</th>
<th>Issue</th>
<th>Minimum (deficient) and Maximum(excessive) Capacity Factors. d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-Air and Water-Air Cooling-Only &amp; Heat Pump</td>
<td>Mild Winter or Has a Latent Cooling Load</td>
<td>Total</td>
<td>0.90 to 1.15, 1.25</td>
</tr>
<tr>
<td>Air-Air and Water-Air Heat Pump Only</td>
<td>Cold Winter and No Latent Cooling Load</td>
<td>Total</td>
<td>Minimum capacity = Manual J total cooling load plus 15,000 Btu/h; Minimum factor = 0.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Latent</td>
<td>Latent capacity for summer cooling is not an issue.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sensible</td>
<td>Not an issue (determined by the limits for total cooling capacity).</td>
</tr>
</tbody>
</table>

- **Single-Speed Compressor**
  - Air-Air: GLHP, GWHP
  - Multi- and Variable-Speed Compressor
    - Air-Air: GLHP, GWHP
    - GWHP: 1.30 or 1.35

- **CSA:**
  - 105% htg
  - 125% clg

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a) Central ducted; ductless single-split; ductless multi-split equipment. AHRI: Air Conditioning, Heating and Refrigeration Institute.
b) Mild winter: Heating degree days for base 65°F divided by cooling degree days for base 50°F less than 2.0. Cold winter = 2.0 or more.
c) Latent cooling load: Manual J sensible load divided by Manual J total load less than 0.95. No latent load = 0.95 or more.
d) Minimum and maximum capacity factors operate on the total, latent, and sensible capacity values produced by an accurate Manual J load calculation (per Section 2 of the Eighth Edition of Manual J, version 2.0 or later). Multiply a size factor by 100 to convert to a percentage. For example, 1.15 excess capacity = 115% excess capacity.
e) GLHP: Ground loop heat pump (water in buried closed pipe loop).
f) GWHP: Ground water heat pump (ground water from well, pond, lake, river, etc., flows through equipment and is discarded).
St. Louis Example

• Considered a “mild winter” based upon heating/cooling degree days
• Sensible cooling capacity = 31,451 Btuh
• Total capacity < 1.2 x Manual J tot. clg. Load*
  • $34,445 \text{ Btuh} \times 1.2 = 41,334$

• *Or the next closest size
Sensible capacity is not sufficient -- 31,451 Btuh Sens. Load (doesn’t meet 90% min. requirement)

### 3 Ton Full Load Performance

<table>
<thead>
<tr>
<th>EWT °F</th>
<th>Flow GPM</th>
<th>WPD PSI</th>
<th>FT</th>
<th>Full Load Heating</th>
<th>Full Load Cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Af inflow CFM</td>
<td>Lat (DB) °F</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>4.5</td>
<td>0.9</td>
<td>2.0</td>
<td>1240</td>
<td>107.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1380</td>
<td>104.4</td>
</tr>
<tr>
<td>7.0</td>
<td>7.0</td>
<td>1.6</td>
<td>3.8</td>
<td>1240</td>
<td>109.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1380</td>
<td>106.1</td>
</tr>
<tr>
<td>9.0</td>
<td>9.0</td>
<td>2.3</td>
<td>5.4</td>
<td>1240</td>
<td>110.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1380</td>
<td>107.0</td>
</tr>
<tr>
<td>90</td>
<td>4.5</td>
<td>0.8</td>
<td>1.9</td>
<td>1240</td>
<td>110.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1380</td>
<td>107.5</td>
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<td>7.0</td>
<td>7.0</td>
<td>1.6</td>
<td>3.6</td>
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<td>1380</td>
<td>109.4</td>
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<tr>
<td>9.0</td>
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<td>1240</td>
<td>113.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1380</td>
<td>110.4</td>
</tr>
</tbody>
</table>

Annual Conference, December 14-16, 2021 – Nashville, TN
# St. Louis Example

## 4 Ton Full Load Performance

<table>
<thead>
<tr>
<th>EWT °F</th>
<th>Flow GPM</th>
<th>WPD PSI FT</th>
<th>Full Load Heating</th>
<th>Full Load Cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Aflow CFM</td>
<td>LAT (DB) °F</td>
<td>HC MBtuh</td>
</tr>
<tr>
<td>80</td>
<td>6.0</td>
<td>1600</td>
<td>108.4</td>
<td>66.3</td>
</tr>
<tr>
<td></td>
<td>9.0</td>
<td>1790</td>
<td>104.6</td>
<td>66.8</td>
</tr>
<tr>
<td></td>
<td>12.0</td>
<td>1800</td>
<td>110.0</td>
<td>69.1</td>
</tr>
<tr>
<td>90</td>
<td>6.0</td>
<td>1790</td>
<td>106.0</td>
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</tr>
<tr>
<td></td>
<td>9.0</td>
<td>1800</td>
<td>110.4</td>
<td>69.8</td>
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<td></td>
<td>12.0</td>
<td>1790</td>
<td>106.4</td>
<td>70.3</td>
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<tr>
<td>9.0</td>
<td>6.0</td>
<td>1800</td>
<td>112.2</td>
<td>72.8</td>
</tr>
<tr>
<td></td>
<td>9.0</td>
<td>1790</td>
<td>107.9</td>
<td>73.3</td>
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<td></td>
<td>12.0</td>
<td>1800</td>
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<td>75.8</td>
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<td></td>
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<td>1790</td>
<td>109.5</td>
<td>76.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1800</td>
<td>114.3</td>
<td>76.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1790</td>
<td>109.9</td>
<td>77.1</td>
</tr>
</tbody>
</table>

Sensible capacity > 31,451 Btuh Sens. Load
Total Capacity is slightly more than 1.2 x Tot. Load, but it is the next available size
Cannot jump to 5 ton unit to try to increase heating capacity
Minneapolis Example

- Considered a “cold winter” based upon heating/cooling degree days
- Max. sizing is Tot. Clg. Load + 15,000 Btuh*
  - $32,413 + 15,000 = 47,413$ Btuh
- Heating Load = 69,434 Btuh

*In some cases, may want to lock out full load cooling
Total capacity is more than 15,000 Btuh plus Tot. Cig. Load (32,413 Btuh)
32,413 + 15,000 = 47,413 Btuh max
May need to lock out full load cooling
(next slide)

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### 4 Ton Part Load Performance

<table>
<thead>
<tr>
<th>EWT °F</th>
<th>Flow GPM</th>
<th>WPD PSI</th>
<th>FTP</th>
<th>Part Load Heating</th>
<th>Part Load Cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>4.0</td>
<td>1.4</td>
<td>3.2</td>
<td>Aflow CFM</td>
<td>LAT (°F)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1280</td>
<td>101.0</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<td>98.1</td>
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<tr>
<td></td>
<td>6.0</td>
<td>1.8</td>
<td>4.2</td>
<td>1280</td>
<td>102.5</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td>1420</td>
<td>99.5</td>
</tr>
<tr>
<td></td>
<td>8.0</td>
<td>2.3</td>
<td>5.3</td>
<td>1280</td>
<td>103.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1420</td>
<td>100.2</td>
</tr>
<tr>
<td>80</td>
<td>4.0</td>
<td>1.4</td>
<td>3.2</td>
<td>1280</td>
<td>104.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1420</td>
<td>101.1</td>
</tr>
<tr>
<td></td>
<td>6.0</td>
<td>1.8</td>
<td>4.2</td>
<td>1280</td>
<td>106.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1420</td>
<td>102.6</td>
</tr>
<tr>
<td></td>
<td>8.0</td>
<td>2.3</td>
<td>5.2</td>
<td>1280</td>
<td>106.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1420</td>
<td>103.4</td>
</tr>
</tbody>
</table>

Part load satisfies the Manual J requirement without being oversized by more than 15,000 Btuh
Variable Speed Equipment

• May allow for greater heating capacity via ...
  • Manual S allows up to 1.3 x total cooling capacity
  • Some models, by design have higher heating capacity compressors

• Still need to conscious of over sizing (more later) for cooling
• Must consider any impacts on loop sizing
Sizing considerations

• Under sizing
• Over sizing
• Utility / state / provincial program requirements
• Ductwork limitations (retrofits)
• “Goldilocks”
Under Sizing

• Comfort issues in summer (unable to satisfy thermostat)
• Excessive use of backup heat in winter
  • High bill complaints
• Potential for cold loops in the winter / hot loops in the summer
  • Equipment could lock-out on safeties
  • Could shorten equipment life
• Unhappy customers / bad perception for the industry
  • Bad news always travels faster than good news
Over Sizing

• Potential for poor dehumidification in summer due to short cycling
  • Comfort issues, possibly even health issues if severe enough
  • High humidity could damage building materials

• Higher installation costs
  • Won’t be competitive vs. another geo dealer, and especially vs. a traditional system
  • Higher airflow if water-to-air system
    • Is the ductwork sufficient for a retrofit?
Utility / State / Provincial Requirements

• Watch for programs that may require sizing that does not comply with ACCA Manual S / C448 / IRC
  • Example: Must size for 100% of heating load
  • Example: May not include electric backup heat
  • Example: May not include fossil fuel backup heat
  • Example: Requires gas or propane back up heat (dual fuel)

• Considerations will have to be made
  • Look at two-stage or variable speed equipment
  • Look at combining geo with other systems
Ductwork Limitations (Retrofits)

• Northern climates may have ductwork sized for cooling
  • Minneapolis example heat loss/gain earlier in the presentation
    • If this were a retrofit, it could have a 2-1/2 ton air conditioner and a 90,000 Btuh furnace
      • Likely about 1000 to 1200 CFM
    • Will there be enough ductwork for a 4 ton geo?
    • Should a dual fuel system be considered with a split systems?

• Inadequate ductwork could lead to ...
  • Noisy system
  • “Cold blow”
  • Premature compressor failure (low airflow in heating / high head)
  • Coil freeze up in cooling
Goldilocks

• Proper load calculation
• Sizing per ACCA Manual S (U.S.) or C448 (Canada)
  • With consideration to utility/state/provincial requirements
• Consideration of retrofit challenges (e.g. ductwork)
• Competitively sized system → Sale for the contractor & happy customer
Design and installation of ground source heat pump systems for commercial and residential buildings

ANSI/CSA/IGSHPA C448 Standard
Why Is the Standard Important?

• Standard provides unified / consistent requirements
  • Minimizes / removes differences
  • Provides / simplifies referencing for regulators → improves enforcement
  • Provides framework for practitioners in the industry to adhere to
  • Provides confidence for consumers
  • With each new edition, validation and inclusion of new advancements
  • Helps industry to explain the benefits of GSHPs to policy makers and the public

• The 2016 edition had a lot of input from IGSHPA and NGWA (used in Canada since 1992)
• Gives the industry a single resource for training development / personnel certification
• Bi-National (Canada/U.S.) provides consistency of design/installation in North America*
• An accredited process provides further legitimacy to the Geothermal industry
• Consensus process ensures that all stakeholders are considered
• Can facilitate trade / job creation
• Sets the course for real growth of the GSHP Industry via a performance-based Standard that delivers true end-user value with all market stakeholders

*Referenced in building code in Canada / IMC and IRC in U.S.
The Latest ICC Developments!

2021 IMC

Example tables (IRC & IMC):

**TABLE 1210.4**
GROUND-SOURCE LOOP PIPE

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>STANDARD (see Chapter 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorinated polyvinyl chloride (CPVC)</td>
<td>ASTM D2846; ASTM F441; ASTM F442</td>
</tr>
<tr>
<td>Cross-linked polyethylene (PEX)</td>
<td>ASTM F876; CSA B137.5; CSA C448; NSF 358-3</td>
</tr>
<tr>
<td>Polyethylene/aluminum/polyethylene (PE-AL-PE) pressure pipe</td>
<td>ASTM F1282; CSA B137.9</td>
</tr>
<tr>
<td>High-density polyethylene (HDPE)</td>
<td>ASTM D2737; ASTM D3035; ASTM F714; AWWA C901; CSA B137.1; CSA C448; NSF 358-1</td>
</tr>
<tr>
<td>Polypropylene (PP-R)</td>
<td>ASTM F2389; CSA B137.11; NSF 358-2</td>
</tr>
<tr>
<td>Polyvinyl chloride (PVC)</td>
<td>ASTM D1785; ASTM D2241</td>
</tr>
<tr>
<td>Raised temperature polyethylene (PE-RT)</td>
<td>ASTM F2623; ASTM F2769; CSA B137.18; CSA C448; NSF 358-4</td>
</tr>
</tbody>
</table>

**TABLE 1210.5**
GROUND-SOURCE LOOP PIPE FITTINGS

<table>
<thead>
<tr>
<th>PIPE MATERIAL</th>
<th>STANDARD (see Chapter 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorinated polyvinyl chloride (CPVC)</td>
<td>ASTM D2846; ASTM F437; ASTM F438; ASTM F439; CSA B137.6</td>
</tr>
<tr>
<td>Cross-linked polyethylene (PEX)</td>
<td>ASTM F877; ASTM F1807; ASTM F1960; ASTM F2080; ASTM F2159; ASTM F2434; CSA B137.5; CSA C448; NSF 358-3</td>
</tr>
</tbody>
</table>
C448 Guidance

• Standard provides references for design guidance
  • Heat Loss/Gain: Use ACCA Manual J for U.S. / CSA F280 for Canada
  • Equipment Sizing:
    • Use ACCA Manual S for U.S. / C448 verbiage for Canada
    • Annex D has heating sizing calculations (next slide provides more detail)
  • Loop temperatures (part II presentation)
  • Antifreeze types/concentration
  • Loop flushing/purging
  • Ductwork guidelines (ACCA Manual D in U.S. / HRAI in Canada)
  • Piping materials
  • Flow Centers
  • Startup/commissioning
C448 Heating Sizing Guidance

• Annex D provides heating sizing guidelines based upon heating correction factor (Cd)
  • Amount of heat gain the structure experiences, the annual heating requirement of the structure (annual degree days), the ability of a building to retain internal heat due to construction quality, and the building heat loss

• Cd is a target of 95% of heat loss (remainder with backup heat)

• Typical Cd is about 0.65 to about 0.75

• IMPORTANT: Heat Pump capacity must be chosen at min. EWT

• Annex E discusses bin method, used by most heat pump manufacturers’ software programs

• IMPORTANT: Sizing is an iterative process (next slide)
Iterative Process

• Heating equipment selection should be compared to ...
  • ACCA Manual S (U.S.) or C448 requirements (Canada) of 105% heating / 125% cooling
  • Utility / State / Provincial requirements
  • Ductwork limitations

• Systems with dominant cooling load (cooling load is about the same or more than the heating load) almost always have enough heating capacity if sized per ACCA Manual S
ANSI/CSA/IGSHPA C448 Availability

• $155 at CSA or ANSI websites (hard copy or PDF)
• $100 (PDF copy) for IGSHPA members at igshpa.org
• Free view access:
  • Go to igshpa.org/standards and click on the view access link
  • Create a free account at CSA Communities
Duct Design Considerations

• Typical design is 400 CFM per ton of nominal cooling capacity
• Most residential units have ECM motor
• PSC motor available in some single speed models
• Maintain ACCA Manual D velocities to provide quiet system (next slide)
## Maximum Velocities

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<th>Supply Side</th>
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Size for Throw: Refer to the installation guide for specific requirements.
Hydronic Design Considerations
Hydronic Design Considerations*

• Most flexible of all geothermal systems
  • Radiant floor heating
  • Forced air heating and/or cooling (fan coil) – ducted or ductless
  • Full condensing DHW (some models)

• Limitations
  • Maximum water temperature may be too low for baseboard or radiators (review compressor operating envelope)
  • Controls can get complicated
  • Typically, more labor intensive
  • Most water-to-water units require a buffer tank

*More in part IV workshop
Questions?
Thank You!

Limitations of residential load calculations, ACCA Manual S requirements, ANSI/CSA/IGSHPA C448 guidelines, and other topics that help put residential equipment selection into perspective

Jeff Hammond
Executive Director, IGSHPA