Residential HVAC Design Summary
Overview of Industry Standards
System Interdependencies

- The systems within every home are interdependent
  - Structural systems
  - Mechanical systems
- They must **all** function properly to deliver home safety, durability, indoor air quality and comfort
Residential HVAC Code Reference & Beyond

- International code reference includes
  - Manuals J, S and D
  - Version is not addressed
- Additional standards and guidelines are part of the design process
- Successful equipment commissioning is dependent on the HVAC design process.
Residential HVAC System Design Resources

HVAC standards and guidelines are also interdependent

- Manual RS: System Concept
- Manual J:* Load Calculation
- Manual S: Equipment Selection
- Manual D:* Duct Design
- Manual T: Air Distribution
- Manual B: Testing, Adjusting & Balancing
- Manual Zr:* Residential Zoning
- ANSI/ACCA 5 QI:* Quality Installation Specification
  - Installation best practices
  - Capacity and performance testing
- HVAC design is a process of discovery.

* ANSI Approved Industry Standard
Comfort, Air Quality and Efficiency By Design

Manual RS - provides conceptual guidance

- Indoor air quality considerations
- Zoning considerations
- Equipment options
- Humidification / Air filtration
- Control system options
- Air system design considerations.
Manual J – Load Calculation

- Cornerstone of the design process

There have been a number of updates:
- Manual J Version 7
- Manual J Version 8

Each has delivered:
- increased sensitivities
- enhanced load accuracy
- improved modeling

Each has boundaries within which accurate loads can be produced
- It’s important that the current version be used
- Poor assumptions and self-imposed safety factors remain an issue
- Proficiency is tied to frequency of use.
Residential Load Calculation

Manual J (8th edition) process provides:

- Total heating and cooling loads
- Room by room heating and cooling loads
- Peak room loads for cooling in zoning applications.
Load Calculation Determines SHR

Manual J process provides:

- Sensible and latent cooling load
  - Sensible Heat Ratio (SHR)
  - SHR target for the cooling coil selection.

\[
SHR = \frac{\text{Sensible Cooling Load}}{\text{Total Cooling Load}}
\]
Manual J process provides equipment selection data

- Based on local climate data and operating conditions:
  - Outdoor dry bulb
  - Indoor dry bulb
  - Indoor wet bulb
- OEM data correlates equipment performance with operating conditions
- Inflated load calculations come at a price
  - Lack of confidence regarding weather extremes is a catalyst for over-sizing.

### Table 1A

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Oversizing Equipment Comes At A Price

- Increased first costs
- Reduced operating efficiency due to equipment short-cycling
  - Excessive wear / increased maintenance
  - Humidity control / IAQ
  - Temperature swings
  - Poor air circulation / hot/cold spots
  - Noise
  - Increased operating costs
- Slightly undersized equipment may actually provide greater comfort at a lower cost
  - In some cases, two-stage equipment can provide a good fit.
Manual S: Heating and Cooling Equipment Selection

- Select for cooling
- Ensure adequate blower CFM range for heating

For cooling:

- “Total cooling” data is used in conjunction with the OEM “performance data” for equipment selection
- Manual J data provides the initial cooling CFM estimate.

### Sensible Heat Ratio Versus TD Value

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<td>0.80 – 0.85</td>
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<td>Above 0.85</td>
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\[ ΔT = \text{Entering dry bulb} – \text{Leaving dry bulb} \]

\[
\text{CFM estimate} = \frac{\text{BTUH (Sensible)}}{1.08 \times \Delta T (SHR table)}
\]
Residential Equipment Selection - Cooling

Manual S: Equipment Selection
- Expanded performance data
  - CFM
  - Outdoor dry bulb
  - Indoor dry bulb
  - Indoor wet bulb
  - Total capacity
  - Sensible / latent capacity
- Stay within sizing limitations
  - Iterative process.

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| Amps| 8.2        | 8.4 | 8.6 | 9.0 | 8.7 | 8.9 | 9.2 | 9.6 |
| Hi PR| 289       | 311 | 328 | 342 | 329 | 354 | 374 | 390 |
| Lo PR| 120       | 128 | 140 | 149 | 126 | 134 | 147 | 156 |

| kW  | 2.25       | 2.29| 2.36| 2.43| 2.35| 2.40| 2.47| 2.55|
| Amps| 8.3        | 8.4 | 8.7 | 9.0 | 8.8 | 9.0 | 9.3 | 9.6 |
| Hi PR| 292       | 314 | 331 | 346 | 332 | 358 | 378 | 394 |
| Lo PR| 121       | 129 | 141 | 150 | 128 | 136 | 148 | 158 |
Residential Equipment Selection - Heating

Manual S: Equipment Selection

For heating:
- Ensure blower compatibility for heating equipment based on cooling selection
  - Sizing limitations (output capacity)
  - Exchanger $\Delta T$ range:
    - Complete a $\Delta T$ calculation:

$$\Delta T = \frac{\text{Output Capacity}}{1.08 \times \text{Heating CFM}}$$
Ensure Matched Systems Equipment Selection

- Indoor and outdoor units must be matched to deliver rated cooling performance
  - Ensures the system will:
    - deliver rated efficiency
    - balance out at the desired operating point.

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- Objectives:
  - Improve / update guidance for staged and variable speed equipment
  - Explore sizing / selection rules for
    - heat pumps
    - varied weather climates.
Manual D: Duct Design

- Equipment selection required prior to duct design
- Furnace blower data must be referenced for duct calculations
  - Design the duct system to match equipment and blower fan capabilities.
The fan will always operate where the fan and duct curves cross.

The objective is to ensure delivered CFM equals design CFM.
Fan Capacity and Pressure Limits

Total available pressure:
- Fan Blower: **0.6 inches W.C.**

Equipment pressure drop:
- Filter: 0.14”
- Coil: 0.20”

Air-side device pressure drop:
- Supply air terminals: 0.03”
- Return air terminals: 0.03”
- Dampers: 0.03”

Net blower pressure remaining: **0.17 IWC**
Room / Space CFM Requirements

Manual D Procedures:
- The design CFM requirements for each room or space must be defined
  - Use HF and CF factors.

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<th>H-CFM</th>
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<td>Bath (1)</td>
<td>1276</td>
<td>462</td>
<td>18</td>
<td>18</td>
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<tr>
<td>Bath (M)</td>
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<td>539</td>
<td>20</td>
<td>21</td>
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<tr>
<td>Bed #M</td>
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<td>156</td>
<td>4</td>
<td>6</td>
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<tr>
<td>Bsmt</td>
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<td>4568</td>
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<tr>
<td>Total</td>
<td>-------</td>
<td>------</td>
<td>850</td>
<td>850</td>
</tr>
</tbody>
</table>

Calculate CFM per BTU of Load

**Heating Factor** =
Blower CFM ÷ Manual J Heat Loss

**Cooling Factor** =
Blower CFM ÷ Manual J Sensible Heat Gain
Initial Duct Routing

Manual D Procedures:
- A reference drawing to define duct pathways must be identified
  - Register, diffuser & grille selection and location must be defined.
Manual T: Air Distribution Basics

- Room by room load data is used to select air terminal devices.
Air Terminal Device Selection

Manual T: Air Terminal Devices

- Use manufacture data to select based on:
  - Size
  - Btuh capacity
  - CFM
  - Pressure drop
  - Velocity
  - Throw
  - Spread.

<table>
<thead>
<tr>
<th>NOMINAL SIZE</th>
<th>FREE AREA SQ. IN.</th>
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<tbody>
<tr>
<td></td>
<td>Heating BTU/h</td>
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<tr>
<td></td>
<td>3045</td>
</tr>
<tr>
<td></td>
<td>40</td>
</tr>
<tr>
<td>2 1/4” x 12”</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>2 1/4” x 14”</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>4” x 10”</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- T.P. Loss
- Vert. Throw (ft.)
- Vert. Spread (ft.)
- Face Velocity
Air Terminal Device Selection

- Air terminal device selection impacts air flow patterns and coverage
  - Primary air stream
  - Secondary air stream.
Initial Duct Routing

Back to Manual D Procedures:

- Following register, diffuser & grille selection, continue with location of:
  - Equipment
  - Main Trunk
  - Branch Runs
  - Returns.
Determining Duct Size

Manual D Procedures:
- Duct is designed based on total effective length (TEL):
  - Length of straight duct
  - Equivalent length of each fitting

![Diagram of duct system]

\[\text{Equivalent Length} = 10 \text{ ft}\]
Fitting Geometry Affects Performance
Fitting Geometry Affects Performance

- Equivalent lengths for various branch fittings can be very different.

EL: Equivalent Length

<table>
<thead>
<tr>
<th>Fitting</th>
<th>EL</th>
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<tr>
<td>4-A</td>
<td>30</td>
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<tr>
<td>4-B</td>
<td>35</td>
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<tr>
<td>4-C</td>
<td>60</td>
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<td>4-D</td>
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<td>4-E</td>
<td>70</td>
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<td>4-F</td>
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<td>4-G</td>
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<td>4-H</td>
<td>50</td>
</tr>
<tr>
<td>4-I</td>
<td>10</td>
</tr>
<tr>
<td>4-J</td>
<td>30</td>
</tr>
<tr>
<td>4-K</td>
<td>30</td>
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<tr>
<td>4-L</td>
<td>80</td>
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<tr>
<td>4-M</td>
<td>20</td>
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<tr>
<td>4-N</td>
<td>45</td>
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<tr>
<td>4-O</td>
<td>20</td>
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<tr>
<td>4-Q</td>
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<td>4-R</td>
<td>20</td>
</tr>
<tr>
<td>4-S</td>
<td>20</td>
</tr>
<tr>
<td>4-T</td>
<td>20</td>
</tr>
<tr>
<td>4-U</td>
<td>20</td>
</tr>
<tr>
<td>4-V</td>
<td>60</td>
</tr>
</tbody>
</table>

4-G: EL = 80

4-J: EL = 30
Fitting Impact on Equivalent Length

Comparison of furnace plenum geometry:

- 45 ft
- 20 ft
- 85 ft
- 120 ft
- 60 ft
- 45 ft
Duct size and performance is affected by:
- floor plan
- equipment location
Duct Total Effective Length

Manual D Procedures:
- Determine the total effective length for the longest supply and return run combination

45 ft actual
500+ ft equivalent length
**Equivalent Length & Duct Friction Rate**

- Adjust net blower pressure based on design total effective length.

**Total available pressure:**
- Fan Blower: **0.6 inches W.C.**

**Equipment pressure drop:**
- Filter: **0.14”**
- Coil: **0.20”**

**Air-side device pressure drop:**
- Supply air terminals: **0.03”**
- Return air terminals: **0.03”**
- Dampers: **0.03”**

Net blower pressure remaining: **0.17 IWC**

**Friction Rate:** Defined as friction per 100 ‘ of duct

\[
\text{Friction Rate} = \frac{0.17 \times 100}{500} = 0.034
\]
Residential Duct Design

Manual D Procedures:

- Size the trunk and branch ducts for:
  - CFM
  - Friction Rate
  - Velocity
Next – Fabrication, Installation & Start-up

- Installation
- Seal the duct system
- Start-up.
Next – Balance The Duct System

Manual B: Testing, Adjusting and Balancing

- Duct system must be balanced following installation.
NEW - ACCA Manual Zr Residential Zoning

- Manual Zr: Residential Zoning
  - Released January 2012
  - Generic guidance and solutions for residential zoning

- Goals:
  - Protect the HVAC equipment
  - Improve comfort and temperature control
  - Maximize customer satisfaction

- Zoning Requires:
  - Accurate load calculations
  - Properly size equipment
  - Accurate duct design
  - Air balancing

- Zoning Rules:
  - Don’t zone to resolve design, construction or installation problems.
ANSI/ACCA 5 QI: Quality Installation Specification

- Road map for quality installation
- Consistent with manufacturer’s installation instructions
- Opportunity to improve installation processes
  - Design
  - Equipment Installation
  - Air Distribution
  - System Documentation
  - Owner Education

The only way to confirm capacity, efficiency and performance:
- Test!
Routine AC System Problems

- Dirty evaporator
- Electrical burn out (compressor)
- Dirty filter
- Dirty condenser
- Dirty blower motor
- Low air flow
- Wrong wire size
- Moisture in the system
- Damaged coil surfaces
- Incorrect refrigerant charge
- Air in the system
- Contaminants/acids in the system
- Low voltage or voltage drop
- Valve damage
- Plugged metering device
- Control wiring problems
- Lose wire/connection
- Refrigerant piping errors
- Refrigerant leaks
- Mismatched system
- Improperly sized unit
- Wrong size installed metering device
- Age
- Lightning / Mother Nature
- Condenser Not Level
- Oil Loss
- Kinked refrigerant Line
- Compressor stuck/not performing
- Wrong refrigerant
- Bypassed control (jumpers)
The systems within every home are interdependent

- Structural systems
- Mechanical systems

Interdependencies within the HVAC design process must be addressed

Industry standards and guidelines provide the roadmap for quality in the design, installation and commissioning process

- Where these fit within building codes will continue to evolve.
Enjoy the rest of the conference!