Ductless Hydronic Distribution Systems

Welcome to the Webinar! We will start at 1:00 PM Eastern Time

Be sure that you are also dialed into the telephone conference call:

Dial-in number: 800-779-8694; Pass code: 2506667

Download the presentation at: www.buildingamerica.gov/meetings.html

Date: November 8, 2011
Introduction to Building America

- Reduce energy use in new and existing residential buildings
- Promote building science and systems engineering / integration approach
- “Do no harm”: Ensure safety, health and durability are maintained or improved
- Accelerate adoption of high performance technologies

www.buildingamerica.gov
Building America Industry Consortia
Industry Research Teams

NorthernSTAR Building America Partnership

Habitat Cost Effective Energy Retrofit Program

Building Energy Efficient Homes for America (BeeHa)
Today’s Speakers

David Springer is co-founder and current president of Davis Energy Group (DEG), and has led DEG’s work in the Building America program since 2002. He participates in a variety of projects involving building energy efficiency and renewable energy systems, including HVAC design, performance monitoring and evaluation, technology development, and codes and standards development.

Bill Dakin, P.E., Engineering Manager, has served on the DEG staff since 1993, overseeing DEG’s design consulting and building energy analysis services. He is a skilled building energy analyst and also manages utility and government sponsored research and design projects, and provides critical design and analysis support for Building America. Mr. Dakin is a LEED Accredited Professional and is the technical advisor for DEG’s LEED-Homes program.

Christine Backman is a Staff Engineer at DEG focusing on energy modeling, performance analysis, and evaluation and optimization of energy efficient technologies in buildings. She is a skilled user of modeling programs including BEopt, EQuest, EnergyPro, Energy Gauge, and TRNSYS. A self-described “Excel Ranger”, she applied her statistical abilities to evaluate utility bill data and produce one of the few Building America community closeout studies completed.
Building America Webinar:

*Ductless Hydronic Distribution*

November 14, 2011
The ARBI Team

...plus multiple industry partners
Webinar Objectives

• Review research gaps in distribution systems identified through the Building America process
• Review current knowledge on distribution system characteristics and design options
• **Summarize results of analyses conducted on hydronic vs. ducted distribution**
• Identify future research needs and opportunities
Building America Strategy

• Standing Technical Committees identify gaps and barriers in specific areas:
  – Building enclosures
  – Space conditioning (HVAC)
  – Water heating
  – Home energy management
  – Test methods
  – Implementation

• STC’s develop strategic plans
• Teams coordinate to conduct targeted research
Gaps Identified by HVAC STC

• Heating & Cooling Equipment
  – Lack of availability of small capacity heating & cooling systems
  – Excessive fan energy use

• Distribution
  – Low cost space conditioning distribution strategies for low load homes
  – Effectiveness of zoned systems
Primary HVAC Issues

- Ducts in non-conditioned spaces (esp. attics) have a low distribution efficiency and alternatives are costly:
  - Creating non-vented, conditioned attics or interior chases for ducts
  - Multi-split variable refrigerant flow systems
- Most conventional equipment is oversized for houses with small loads
  - Cycling losses
  - Poor humidity control in humid climates
- Forced air zoning is problematic
  - Systems cannot vary airflow capacity with the number of zones calling for heating or cooling
  - Duct over-sizing, dump zones, and/or bypass dampers compromise efficiency
Alternatives to Ducts in Attic

• Non-vented attics
• Ducts in conditioned space
• Mini/Multi split heat pumps
• Ductless Hydronic
  – Definition – What is ductless hydronic distribution?
  – All Electric
  – Gas/Electric
Non-Vented Attics

• Sealing and insulation at roof line is costly
• Moisture problems have been identified
• Area of insulated roof/ceiling is increased
Duct Chases

- Affect architecture
- Requires two trips by drywall installer
- Limited space for furnace or air handler
Modified “Plenum” Trusses

- Can limit location of diffusers
- Limited space for furnace or air handler
- Added cost to create air & thermal barriers
Multi-Split Heat Pumps

• Allow supply terminals to be distributed without the need for ducting
• Require costly variable refrigerant flow compressors
• Limited allowable vertical and total refrigeration line length
• Installation quality is critical
Can be used to define distribution efficiency for ducted systems

Hydronic chapter is undergoing revision

Will provide a means of comparing distribution alternatives (except mini & multi-splits)
Project Hypothesis

• Hydronic distribution offers a better value proposition than ducts:
  – Lower heat losses from conduits (pipes vs. ducts)
  – Less energy required to move fluid (pumps vs. fans)
  – Easier to seal against leakage
  – Pipes can be routed under attic insulation or through framing without modifying the structure
  – Easier to transport and install pipes than ducts
  – Easier to zone
  – Potential for off-peak storage and integration with solar and heat recovery
Duct vs. Pipe Heat Loss

• Assume 5,000 Btuh of cooling delivery
• Ducted Air Delivery
  – 167 cfm 8”Ø duct = 12.8 Btuh thermal loss

• Hydronic Chilled Water Delivery
  – 0.7 gpm 1/2”Ø pipe = 4.6 Btuh thermal loss (64% Savings)
Fan vs. Pump Energy

@ 1,000 cfm & 365 W/ 1000 cfm
= 365 W

135 W + 164 W ≈ 300 W
Fan vs. Pump Energy

Measured Cooling Fan Power – Ducted Systems

2010 Study (Wilcox, Chitwood, Proctor)
Fan vs. Pump Energy

@ 1,000 cfm & 0.50 in w.c.
= 590 W

135 W + 164 W ≈ 300 W
## Terminal Delivery Options

<table>
<thead>
<tr>
<th>Delivery Options</th>
<th>Load Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Pancake&quot; fan coil or ceiling cassette</td>
<td>Heating or Cooling</td>
</tr>
<tr>
<td>Baseboard Convector</td>
<td>Heating Only</td>
</tr>
<tr>
<td>Wall Radiators</td>
<td>Heating Only</td>
</tr>
<tr>
<td>Ceiling Panels</td>
<td>Heating or Cooling</td>
</tr>
<tr>
<td>Slab-on-Grade Radiant Floor</td>
<td>Heating or Cooling*</td>
</tr>
<tr>
<td>Raised Foundation Radiant Floor</td>
<td>Heating Only</td>
</tr>
<tr>
<td>Valence</td>
<td>Heating or Cooling</td>
</tr>
</tbody>
</table>

*Dry climates with exposed concrete or tile floors only
Delivery Systems - Piping

- Pipes vs. Ducts
  - Piping is easier to transport & install than ducting
  - Reduced thermal losses
  - Relative costs
    - 8” R-8 duct - $2.51/ft
    - ½” R-5 PEX - $2.13/ft

- Home Run Piping
  - Route piping direct from heat source to terminal (no branching)
  - Reduced water volume
  - Reduced thermal losses
Hot-Chilled Water Sources

- Heating Only - Gas
  - Dedicated boiler
  - Two-function boiler/water heater
  - Combined system (with or without heat exchanger)
Hot-Chilled Water Sources

- Heating & Cooling – Electric
  - Air-to-water heat pump
  - Three function heat pump
- Heating & Cooling – Gas/Electric
  - Boiler or water heater
  - Chiller (air conditioner with refrigerant-to-water heat exchanger)
Current Research Projects

La Mirada Homes – Tucson Arizona

Cana House – Chico California
Mixed Mode Distribution in Hot-Dry Climates
Basic Modeling Approach

- Used TRNSYS to model forced air and hydronic distribution systems
- 2400 ft² house, design based on Building America Simulation Protocols
- Sizing based on ACCA Manual J & D and standard methods for hydronic systems
- Hydronic system assumes forced-air distribution using ceiling-mounted cassettes (appropriate for all climates and building types)
- Similar 13 SEER heat pumps used in both cases
Hydronic vs. Duct Layouts

Ducted Forced Air

Ductless Hydronic

Kitchen
Dining
Bed 2
Bed 3
Bed 4
Bath 2
Pdr
Laundry
Master Bedroom
Master Bath
Great Room
Garage

Kitchen
Dining
Bed 2
Bed 3
Bed 4
Bath 2
Pdr
Laundry
Master Bedroom
Master Bath
Great Room
Garage

C病毒感染的临床表现

1. 发热：患者通常会出现发热症状，体温可能升高至38°C以上。
2. 全身肌肉酸痛：患者可能会感到全身肌肉酸痛，尤其是四肢肌肉。
3. 咳嗽：干咳、湿咳或伴有痰的咳嗽。
4. 呼吸道症状：患者可能会出现咽痛、喉咙痛以及声音嘶哑。
5. 呼吸困难：少数情况下，患者可能会出现呼吸困难。

预防和治疗

1. 预防：避免与感染者密切接触，佩戴口罩，勤洗手，保持良好的个人卫生。
2. 治疗：早期使用抗病毒药物，如奥司他韦。

注意：以上内容仅供参考，具体治疗方案应根据医生的建议进行。
TRNSYS Model

- **Base Case**
  - Forced air ducted system
  - Single zone
    - 1 thermostat
  - Air to air heat pump
  - Blower Fan
    - 900 CFM
    - 327 W
Energy Use Comparison - Methods

TRNSYS Model

- Ductless Hydronic
  - 4 Ceiling Cassettes
    - Airdale Model
      - 250 CFM/room
      - 0.14 CFM/Watt
    - Single zone
      - 1 thermostat
    - Air to-water heat pump
      - Altherma specs
Energy Use Comparison - Results

Annual Electricity Use (kWh/yr)

- Ducted Forced Air System (Ducts in Attic): 8,844 kWh/yr
- Ducted Forced Air System (Ducts in Zone): 7,316 kWh/yr
- Ductless Ceiling Cassette (Single Zone): 5,376 kWh/yr

- Annual Fan and Pump (kWh/yr)
- Annual Cooling (kWh/yr)
- Annual Heating (kWh/yr)
# Delivery Efficiency

<table>
<thead>
<tr>
<th>Distribution Energy Savings</th>
<th>Delivered Energy by Heat Pump (MBtu/yr)</th>
<th>Fan and Pump Energy (kWh/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ducts in Attic</td>
<td>56.0</td>
<td>972.8</td>
</tr>
<tr>
<td>Ductless</td>
<td>47.7</td>
<td>714.9</td>
</tr>
<tr>
<td>% Savings</td>
<td>15%</td>
<td>27%</td>
</tr>
</tbody>
</table>
## Zoning Impacts

<table>
<thead>
<tr>
<th>System Type</th>
<th>Annual Heat Pump (kWh/yr)</th>
<th>Annual Pump (kWh/yr)</th>
<th>Annual Fan (kWh/yr)</th>
<th>Total (kWh/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ductless-Single Zone</td>
<td>4661</td>
<td>193</td>
<td>522</td>
<td>5376</td>
</tr>
<tr>
<td>Ductless-4 Zones</td>
<td>4724</td>
<td>188</td>
<td>657</td>
<td>5570</td>
</tr>
<tr>
<td>Savings</td>
<td>-63</td>
<td>5</td>
<td>-136</td>
<td>-194</td>
</tr>
<tr>
<td>% Savings</td>
<td>-1%</td>
<td>3%</td>
<td>-26%</td>
<td>-4%</td>
</tr>
</tbody>
</table>

### Energy Use Comparison - Results

The table above shows the energy use comparison for different system types under Zoning Impacts. The data includes annual heat pump, pump, and fan usage, leading to total energy consumption. The savings and percentage savings are also calculated for each category.

![Graph showing energy use over time](image-url)

The graphs illustrate the energy use over different hours of the simulation, highlighting the impact of zoning on energy consumption.

**Hour of the Simulation**

- **TLiv**: Living space energy use
- **TBdrm**: Bedroom energy use
- **TKitchen**: Kitchen energy use
- **TMbdrm**: Bathrooms energy use

- The top graph shows energy use from 1390 to 1420.
- The bottom graph shows energy use from 1395 to 1415.

The data indicates that zoning can significantly affect energy consumption, with potential savings and efficiency improvements.
Further Modeling Objectives

• Generic Air-to-Water Heat Pump model
• Delivery Methods-Radiant Floor or Ceiling Panels
• Climate Zone Impacts
• Building Load Impacts
## Estimated Savings

<table>
<thead>
<tr>
<th>System Type</th>
<th>Annual Heating (kWh/yr)</th>
<th>Annual Cooling (kWh/yr)</th>
<th>Annual Fan and Pump (kWh/yr)</th>
<th>Total (kWh/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ducted Forced Air System (Ducts in Attic)</td>
<td>6,967</td>
<td>944</td>
<td>933</td>
<td>8,844</td>
</tr>
<tr>
<td>Ductless Ceiling Cassette (Single Zone)</td>
<td>4,139</td>
<td>522</td>
<td>715</td>
<td>5,376</td>
</tr>
</tbody>
</table>

Estimated Annual Savings: **3,468**

Estimated Annual Cost Savings: **$390**

Cost savings based on $0.113/kWh (National Avg. Electricity Rate)
Comparative Costs

- Costs based on heat pump systems for layouts shown
- Approximate incremental costs only included for Aqua Products heat exchanger package (heat pump costs assumed equal)
- Labor costs included only for distribution duct and hydronic piping
- Incremental cost = $7414
- Air handlers are 67% of hydronic system cost

### BASE HEAT PUMP COSTS

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP Air Handler &amp; coil</td>
<td>$872</td>
</tr>
<tr>
<td>Diffusers</td>
<td>$49</td>
</tr>
<tr>
<td>Return Grilles</td>
<td>$19</td>
</tr>
<tr>
<td>Ducts</td>
<td>$745</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$1,685</strong></td>
</tr>
</tbody>
</table>

### HYDRONIC SYSTEM COSTS

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manifolds</td>
<td>$53</td>
</tr>
<tr>
<td>Piping</td>
<td>$357</td>
</tr>
<tr>
<td>Airdale air handlers (3)</td>
<td>$6,103</td>
</tr>
<tr>
<td>MagicAire air handler</td>
<td>$400</td>
</tr>
<tr>
<td>Heat pump heat exchanger</td>
<td>$1,200</td>
</tr>
<tr>
<td>Diffusers</td>
<td>$23</td>
</tr>
<tr>
<td>Return Grille</td>
<td>$5</td>
</tr>
<tr>
<td>Buffer Tank (50 gal)</td>
<td>$407</td>
</tr>
<tr>
<td>Pumps, heat pump &amp; zone</td>
<td>$371</td>
</tr>
<tr>
<td>Air separator</td>
<td>$103</td>
</tr>
<tr>
<td>Expansion tank</td>
<td>$29</td>
</tr>
<tr>
<td>Switching relay</td>
<td>$48</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$9,099</strong></td>
</tr>
</tbody>
</table>
Neutral Cost Analysis

- Savings would support an incremental cost of $5421
- High cost of terminal units is the greatest cost component
- Use of small, distributed air handlers would result in a positive cash flow

<table>
<thead>
<tr>
<th>CASH FLOW</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Cost Savings</td>
<td>$390</td>
</tr>
<tr>
<td>Incremental Cost for Hydronic Distribution</td>
<td>$7,414</td>
</tr>
<tr>
<td>Amortized Incremental Cost (6%, 30 years)</td>
<td>$533</td>
</tr>
<tr>
<td>Annual Positive Cash Flow</td>
<td>-$143</td>
</tr>
</tbody>
</table>
Summary

• Simulations show significant energy savings relative to ducted systems
• Additional savings may result from zoning
• Equipment gap: inexpensive, ceiling-mounted forced air terminal units
• Radiant floor distribution would likely cost less than the specified forced air units
• Additional product offerings and increased volume would improve market viability
• Trades would need to adapt to provide both plumbing and HVAC services
Next Steps

- Evaluate for different climates
- Comparative field test of systems
  - Radiant floor distribution (in process)
  - Forced air distribution
- Work with TESS on TRNSYS model verification
- Develop performance maps for air-to-water heat pumps