Compact DHW Distribution in Single Family New Construction Homes
2016 ACEEE Hot Water Forum

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Yanda Zhang (ZYD Energy)
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Overview

• **Background**
  – Scope and goals
  – Status quo and California’s Title 24

• **Methodology and Findings**
  – Performance analysis
  – Workshops and interviews

• **Next steps**
  – Preliminary measure selections
  – Lab and field demonstrations
Scope for Compact Distribution Design

• Inform programs, design guidelines, and code (Title 24)
  – Designs to reduce water, energy, and time wasted
  – Improve end-user satisfaction
  – Consider cost effectiveness

• Hot water distribution (e.g. pipe diameter, fixture locations)
  – Related elements are considered (e.g., water heater type, insulation)

• New construction, single family residential
  – Not multifamily or nonresidential

• Our role
  – Performance analysis
  – Engagement
  – Measure development
  – Demonstration

Source: https://buildingsfieldtest.nrel.gov/hot_water_distribution
Literature Review

• Current Practices
  – PEX piping
  – Trunk and branch
  – Water heater located in garage
  – Direct paths often avoided (DEG, 2012)

• Research
  – Water Usage: 17 gpd-person of hot water, though there is significant variation (Lutz, 2011) (Henderson, 2015)
  – Water Waste:
    • 1.8 gal of warmup waste per shower (1.1 gal is behavioral).
    • 9-25% of water is wasted (Sherman, 2014) (Henderson, 2015)
    • Based on limited field studies and detailed modeling
A Big Part of Title 24’s Standard Budget

[Graph showing DHW Budget as a % of Total Compliance Budget and Estimated % of SF Housing Starts]

DHW Low % of total compliance budget

DHW High % of total compliance
Title 24 Compact DHW Req’s

• Prescriptive requirements - 150.1(c)8A
  – Path A: tankless
  – Path B: Storage water heaters
    • Floor Area Served is defined per water heater
    • HERS field verified piping length

<table>
<thead>
<tr>
<th>Floor Area Served (ft²)</th>
<th>Maximum Measured Water Heater To Use Point Distance (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1000</td>
<td>28’</td>
</tr>
<tr>
<td>1001 – 1600</td>
<td>43’</td>
</tr>
<tr>
<td>1601 – 2200</td>
<td>53’</td>
</tr>
<tr>
<td>2201 – 2800</td>
<td>62’</td>
</tr>
<tr>
<td>&gt;2800</td>
<td>68’</td>
</tr>
</tbody>
</table>

• Performance paths
  – Credits and penalties for alternate distribution methods
Methodology and Findings
Characterizing Fixtures with Polygons

\[
\frac{\text{Polygon Area}}{\text{Conditioned Floor Area}} = \text{Polygon \%}
\]

\[\rightarrow \frac{1,170}{3,253} = 36\%\]
Architectural Compactness Variation
Varying Designs for Volume Estimates

Trunk and branch
4 zones

Home run
10 zones

Circulation
1 zone
Not Yet Analyzed, but Promising

Source: http://www.gothotwater.com/
Varied WH Location and Distribution

- Used standard draw schedules/events

<table>
<thead>
<tr>
<th>1-Story Floorplan</th>
<th>2-Story Floorplan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case, T&amp;B, WH in garage</td>
<td>Base case, T&amp;B, WH in garage</td>
</tr>
<tr>
<td>T&amp;B, WH central in garage</td>
<td>-</td>
</tr>
<tr>
<td>T&amp;B, WH central in attic</td>
<td>-</td>
</tr>
<tr>
<td>T&amp;B, WH in pantry</td>
<td>T&amp;B, WH in pantry</td>
</tr>
<tr>
<td>-</td>
<td>T&amp;B, 2x WH</td>
</tr>
<tr>
<td>HR, WH in pantry</td>
<td>HR, WH in pantry</td>
</tr>
<tr>
<td>HR, WH central in attic</td>
<td>-</td>
</tr>
<tr>
<td>Circulation</td>
<td>Circulation</td>
</tr>
<tr>
<td>-</td>
<td>Circulation, 2 zones</td>
</tr>
</tbody>
</table>

WH = Water Heater, T&B = Trunk and Branch, HR = Home Run
Condensed Results

<table>
<thead>
<tr>
<th>Description</th>
<th>Wasted Gallons/Day</th>
<th>% of Base Case</th>
<th>Avg Wait Time (s)</th>
<th>% of Base Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case, T&amp;B, WH in garage</td>
<td>4.9</td>
<td>100%</td>
<td>38</td>
<td>100%</td>
</tr>
<tr>
<td>T&amp;B, WH ext wall of pantry</td>
<td>3.7</td>
<td>75%</td>
<td>25</td>
<td>67%</td>
</tr>
<tr>
<td>HR, WH ext wall of pantry</td>
<td>3.0</td>
<td>62%</td>
<td>15</td>
<td>39%</td>
</tr>
<tr>
<td>Circulation</td>
<td>0.6</td>
<td>12%</td>
<td>4</td>
<td>9%</td>
</tr>
</tbody>
</table>

- Moving WH centrally saves water and time
- Home run system seems to improve performance over T&B
- Circulation saves the most water and time
- Investigating implications for energy waste
How Long Should We Wait?

<table>
<thead>
<tr>
<th>Volume in the Pipe (ounces)</th>
<th>Minimum Time-to-Tap (seconds) at Selected Flow Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.25 gpm</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>16</td>
<td>30</td>
</tr>
<tr>
<td>24</td>
<td>45</td>
</tr>
<tr>
<td>32</td>
<td>60</td>
</tr>
<tr>
<td>64</td>
<td>120</td>
</tr>
<tr>
<td>128</td>
<td>240</td>
</tr>
</tbody>
</table>

ASPE Time-to-Tap Performance Criteria

- Acceptable Performance: 1 – 10 seconds
- Marginal Performance: 11 – 30 seconds
- Unacceptable Performance: 31+ seconds

Workshop for Interim Feedback

- Attendees included builders, plumbing engineers, and policymakers
- 15 seconds time-to-tap may be marketable
- Barriers to relocating WH indoors (leaks, $$$)
- Considering fixture layout in floorplans is
  - Most economical
  - Least palatable
- Code should consider reducing minimum DHW pipe diameter req’s
- Survey builders (next slide)
Builder Survey Feedback

• Interviewed 2 plumbers and 7 builders

• Builders commonly received wait time complaints
  – Longest wait times commonly exceed 60 seconds
  – Some pre-plumb homes to be compatible with circulation

• Demand circulation systems
  – Heavily penalized in Title 24
  – Passed up by homebuyers

• Builders prefer circulation loop to an under-sink system because of reduced wait time at all fixtures
• Opposite results from workshop – most preferred:
  – Locating WH closer to use points
  – Designing homes more compactly
• Home run systems discontinued due to high costs, no perceived improvement in efficiency

<table>
<thead>
<tr>
<th>No. of Data Points</th>
<th>Base Cost</th>
<th>Incremental Costs for Compact Design Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>T&amp;B, WH in garage</td>
<td>5</td>
<td>Demand recirculation 6</td>
</tr>
<tr>
<td>Home run</td>
<td>2</td>
<td>WH location inside 4</td>
</tr>
<tr>
<td>Under-sink circulation</td>
<td>4</td>
<td>2 water heaters 2</td>
</tr>
<tr>
<td>Average</td>
<td>$3,840</td>
<td>$1,280</td>
</tr>
<tr>
<td></td>
<td>$250</td>
<td>$1,120</td>
</tr>
<tr>
<td></td>
<td>$860</td>
<td>$2,380</td>
</tr>
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Next Steps
Researching Compact Measures

• Water savings are important, but:
  – Homebuyers value cost savings and time savings more
  – Title 24 values energy savings more

• Measures that save time, energy, and are likely cost effective
  1. Water heater close to hot water fixtures (attic or kitchen exterior walls)
  2. Optimized two-zone design (trunks)
  3. Under-sink circulation priming (under-sink pumping)

• Does not preclude other measures
Research Methods to Refine Measures

• Energy savings performance model
  – TRNSYS a black box

• Field demonstrations of measures
  – 6 installations, each with a conventional baseline
  – Measuring entrained volume and time-to-tap

• Lab Testing at the Applied Technology Services (ATS)
  – Attain data to validate energy savings model
  – Collect pressure drop vs. flow rate data
  – Demo measure savings
Thank You!

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## Competing priorities

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Priority #1</th>
<th>Priority #2</th>
<th>Priority #3</th>
<th>Priority #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homeowner</td>
<td>Time savings and convenience</td>
<td>Reliability</td>
<td>Low incremental cost</td>
<td>Water savings</td>
</tr>
<tr>
<td>Builder</td>
<td>Minimize homeowner complaints</td>
<td>High value (T24 credits) compared to incremental cost</td>
<td>Reliability</td>
<td></td>
</tr>
<tr>
<td>Plumber</td>
<td>Minimize homeowner complaints</td>
<td>Low installation cost, easy implementation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Title 24</td>
<td>Energy savings</td>
<td>Water savings</td>
<td>Cost effectiveness</td>
<td>Reliability</td>
</tr>
</tbody>
</table>
# Assessment of Compact Solutions

<table>
<thead>
<tr>
<th>Solution</th>
<th>Time</th>
<th>Energy</th>
<th>Cost</th>
<th>Reliability</th>
<th>Water</th>
<th>Marketability</th>
<th>Key Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central WH Location</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Market acceptance</td>
</tr>
<tr>
<td>Central Fixtures</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>High; same as status quo</td>
<td>Medium</td>
<td>Low</td>
<td>Market acceptance</td>
</tr>
<tr>
<td>Multiple WHs</td>
<td>Medium</td>
<td>Medium; penalty with storage</td>
<td>High</td>
<td>Medium; more maintenance</td>
<td>Medium</td>
<td>High</td>
<td>Market acceptance</td>
</tr>
<tr>
<td>Circulation</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Costs, energy penalty</td>
</tr>
<tr>
<td>Home Run</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Costs</td>
</tr>
</tbody>
</table>