LEARNING OBJECTIVES

1. Understand what typical central hot water loop losses are for small and large buildings.

2. Understand operating efficiency of the inverter driven Daikin Altherma for central hot water heating and how it compares to other air source heat pump water heaters.

3. The relative merits of three different hot water temperature maintenance systems for small apartment buildings.


Earn x CPHC CEUs
Self-report link: www.phiplus.org/cphc/self-report
AGENDA

- Multifamily Hot Water Load
- Temperature Maintenance Systems
- Pilot Study
- Why Recirculation Flow Measures are Limited.
- High Performance Hot Water Systems
Based on billing analysis of 10 Multi-family Buildings in Seattle

Median Energy Use Index (EUI): 39 kBTU/sf/yr

DHW EUI ~ 10 kbtu/sf/yr
APARTMENT - ANNUAL HOT WATER HEATING LOAD

Multi-Family Hot Water EUI (kbtu/sf/yr)

- Temperature Maintenance: 4
- Hot Water Load: 6
- Other Loads: 30

Heating Water + Temperature Maintenance / Losses
CENTRAL HOT WATER SYSTEM

Parts of a Central Hot Water System

- Central Plant
- Primary Supply
- Risers
- Balancing
- Temperature Maintenance System
TEMPERATURE MAINTENANCE SYSTEMS

Making Hot Water Available in 20-30 Seconds in a Central Hot Water System

Three Different Approaches

1. Traditional Circulation System
2. Pipe in a Pipe Circulation System
3. Electric Heat Trace and No Circulation

"OK, there! I don't want to hear anyone whining about how long it takes for the water to get hot!"
TRADITIONAL CIRCULATION LOOP

- Connects a Return line and Hot Water Circulation Pump to the end of the supply line and circulates hot water to keep supply pipe hot.

- Uses 100-200’ of extra piping and insulation to bring recirc line back.

- Balancing can be tedious

- Pinhole leaks can occur in copper recirculation systems after 20+ years
PIPE IN A PIPE CIRCULATION LOOP

Similar to traditional hot water circulation, except return piping is located inside of supply riser.

Reduced surface area results in less heat loss.

Can still get COP on recirculation load.

Reduced insulation costs trades off with copper risers.

Cost Effective
Electric controller set to maintain temp

Results in reduced piping length and elimination of pumping energy *(24/7 typ)*

Advantage is it is simpler and neutral cost increment over traditional

Disadvantage is no COP on reheating

20 year life, need to locate primary lines in common spaces
Temperature Maintenance Pilot Study

**Building A**  
*Traditional Recirculation Loop*  
12 Units ~ 1450 SF each, 2 Bedroom

**Building B**  
*Electric Heat Trace*  
12 Units ~ 1450 SF each, 2 Bedroom

**Building D**  
*Pipe in a Pipe Recirculation Loop*  
13 Units ~ 1450 SF each, 2 Bedroom
Temperature Maintenance Pilot Study Objectives

Compare Performance of 3 Different Temperature Maintenance Systems in 3 Similar 12 Unit Multi Family Buildings

Use Hydronic Inverter Driven Heat Pump To Heat Water in a Central Plant.

Compare Recirculated Systems with Non-Circulated Systems. Heat Pump Impact

Comparisons with other heat pump buildings

All Buildings used good insulation 2” thick wall for garage and 2x6 cavity, dense pack for risers (R-11)
PILOT STUDY HEAT PLANTS
### Hot Water Usage

**Grow Building A**

<table>
<thead>
<tr>
<th>Building</th>
<th># Occupants</th>
<th>Mean DHW (Gal/Day)</th>
<th>Hot Water pp/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>18</td>
<td>250</td>
<td>13.9</td>
</tr>
</tbody>
</table>

![Building A Diagram](image)
HOT WATER USAGE
GROW BUILDING B
12 UNITS

<table>
<thead>
<tr>
<th>Building</th>
<th>Occupants</th>
<th>Mean DHW/Day</th>
<th>Hot Water /pp/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>30</td>
<td>490</td>
<td>16.3</td>
</tr>
</tbody>
</table>
FINDINGS
PRELIMINARY FINDINGS

Grow Bainbridge: Temperature Maintenance Losses by Recirc Strategy

Maintenance Losses (watts)

- Trad Recirc: 2500 watts
- Heat Trace: 750 watts
- Pipe in Pipe: 1500 watts

Building/Recirc Strategy
- BuildingA: Classic Recirc
- BuildingB: Heat Trace
- BuildingD: Pipe-in-a-Pipe
Slope Indicates that in the summer less energy is needed for heating as the city water is 20-30 degrees warmer.

20 degree F seasonal swing in the garage

Grow Bainbridge: Garage Temp by Building

Building/Recirc Strategy
- BuildingA: Classic Recirc
- BuildingB: Heat Trace
- BuildingD: Pipe-in-a-Pipe
Resistance Heat Triggered As Daikin HP Errored out due to voltage fluctuation in grid.

Notice that in the summer less energy is needed for heating as the city water is 20-30 degrees warmer.

Building D Still Not Fully Occupied
60 Degree Air Entering Heat Pump Produces COP 2.9

45 degree Air Entering Heat Pump Produces COP 2.2

COP ~ 2.5 for DHW in BG Parking Garage
Lower COP in Building D due to both warmer return water with pipe in a pipe as well as close proximity to garage entry, the latter is likely a greater contributor.
## Tabled Comparison (6 Buildings)

<table>
<thead>
<tr>
<th>Temperature Maintenance (units)</th>
<th>Total Hot Water Use/day (gal/day)</th>
<th>Hot Water Use (kwh/day)</th>
<th>Daily Hot Water Usage Load/Unit (kwh/day)</th>
<th>Total Temp Maint. Heat Loss Rate (watts)</th>
<th>Daily Temp Maint. Load (kwh/day)</th>
<th>Temp Maint. (kwh/day/unit)</th>
<th>% Temp Maint. To Hot Water Use Load</th>
<th>% Temp Maint. over Total DHW Load</th>
<th>TM Heat Loss Rate (Watts/unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A (Electric Tank In Unit)</td>
<td>18</td>
<td>3</td>
<td>3</td>
<td>60/unit</td>
<td>1.44</td>
<td>1.44</td>
<td>47%</td>
<td>32%</td>
<td>60</td>
</tr>
<tr>
<td>A-Traditional HWC</td>
<td>250</td>
<td>43</td>
<td>4</td>
<td>2500</td>
<td>60</td>
<td>5.00</td>
<td>141%</td>
<td>59%</td>
<td>208</td>
</tr>
<tr>
<td>D-Pipe in Pipe Recirc</td>
<td>260</td>
<td>44</td>
<td>3</td>
<td>1500</td>
<td>36</td>
<td>2.77</td>
<td>81%</td>
<td>45%</td>
<td>115</td>
</tr>
<tr>
<td>B-Heat Trace</td>
<td>490</td>
<td>83</td>
<td>7</td>
<td>750</td>
<td>18</td>
<td>1.50</td>
<td>22%</td>
<td>18%</td>
<td>63</td>
</tr>
<tr>
<td>Traditional HWC (92)</td>
<td>1530</td>
<td>260</td>
<td>3</td>
<td>8500</td>
<td>204</td>
<td>2.22</td>
<td>78%</td>
<td>44%</td>
<td>92</td>
</tr>
<tr>
<td>Traditional HWC (118)</td>
<td>2640</td>
<td>449</td>
<td>4</td>
<td>7500</td>
<td>180</td>
<td>1.53</td>
<td>40%</td>
<td>29%</td>
<td>64</td>
</tr>
</tbody>
</table>
**DAILY DHW ENERGY/UNIT WITH COP**

*(ACTUAL USAGE AND LOSS/UNIT (NOT NORMALIZED)*

![Bar chart showing daily kwh/unit for different systems]*

- **Tank In Unit**: Assumes Electric Resistance (ER) Tank in Unit, Approximate Losses, “Base-Case”
- **A-Traditional Recirc**: Grow A, Traditional Recirc, Daikin Primary Water Heat to 120F, Electric Trim Included but hardly needed, 24/7 HWC Pump for TM. Losses are hidden when heat pump COP is applied. Low Hot Water Usage makes TM a larger fraction of the total load.
- **D-Pipe In a Pipe Recirc**: Grow D, Pipe in a Pipe Recirc, Daikin Primary Water Heat to 120F, Electric Trim Included but only used if Daikin has Error, 24/7 HWC Pump for TM. 45% Savings in Pipe in a Pipe for this install includes the garage horizontal runs (60%)
- **B-Heat Trace**: Grow B. High Hot Water Usage compared to other buildings, Only a supply pipe used and heat trace under insulation.
- **Midrise (SE)**: 92 Unit 6 story apartment in Seattle with a garage located Colmac Heat Pump Water Heating System, Traditional Recirc
- **Midrise (SU)**: 118 Unit 6 story apartment in Seattle with a garage located Colmac Heat Pump Water Heating System, Traditional Recirc
DAILY HOT WATER ENERGY (KWH/UNIT) 
NORMALIZED TO EQUAL WATER USAGE

<table>
<thead>
<tr>
<th>Component</th>
<th>Daily Hot Water Load/Unit (kwh/day)</th>
<th>Temp Maintenance (kwh/day/unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank in Unit</td>
<td>4.0</td>
<td>1.4</td>
</tr>
<tr>
<td>A-Traditional Recirc</td>
<td>2.0</td>
<td>1.6</td>
</tr>
<tr>
<td>D-Pipe in Pipe Recirc</td>
<td>1.1</td>
<td>1.6</td>
</tr>
<tr>
<td>B-Heat Trace</td>
<td>1.5</td>
<td>1.6</td>
</tr>
<tr>
<td>Midrise (SE)</td>
<td>1.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Midrise (SU)</td>
<td>0.7</td>
<td>1.8</td>
</tr>
</tbody>
</table>
TEMPERATURE MAINTENANCE HEAT LOSS COMPARISONS

WATTS/UNIT

- Tank in Unit: 60
- A-Trad Recirc: 208
- D-Pipe in Pipe: 115
- B-Heat Trace: 63
- Midrise (92): 92
- Midrise (118): 64
TEMPERATURE MAINTENANCE CONSIDERATIONS

• Recirculation Systems and Heat Pumps Can be Tricky, don’t underestimate simple.

• Heat Trace is a 20 year life will likely need to be replaced, integrate replacement planning into design.

• Hot water recirculation systems built out of copper do develop pinhole leaks due to constant circulation and abrasive forces of water.

• Single Pass heat pump systems should consider heat trace and extra insulation as these systems work best without warm return water.

• Multi-pass heat pump systems should consider pipe in a pipe technology over traditional recirculation, cost effective and qualifies for Utility Incentives
Multi-Family Central DHW Measurement Projects: Odds of No Flow Occurring
Meter Resolution 1gal at Grow, 10gal at Sunset/Stream

Total Hours with No Measured Flow:
Grow A 14.6%
Grow B 12.3%
Stream Uptown 3.7%
Sunset Electric 3.4%

Building
- **Red**: Grow A: 12 Units
- **Green**: Grow B: 12 Units
- **Blue**: Stream Uptown: 118 Units
- **Purple**: Sunset Electric: 92 Units

HWC PUMP CONTROL MEASURES ARE LIMITED, BEWARE..
DESIGN APPROACH TO HIGH PERFORMANCE HOT WATER SYSTEMS
DESIGN CONSIDERATIONS
PROGRAMMING AND DESIGN

- Back to back bathrooms sharing a single stack reduces UA by factor of 2

- Locate hot water storage and primary distribution in heated space to capture losses for $\frac{1}{2}$ the year

- Plan for super-insulated hot water piping runs, Risers- 2x8 studbays, provide for adequate room for insulated pipe clamps

- Consider Distributed Plants versus Single Central Plant. (closer to use, smaller piping, less heat loss)

- Use heat pumps when heating with utility provided power, lowest carbon
DESIGN CONSIDERATIONS
CONTINUOUS INSULATION — 2-3” THICK WALL, W/VB
DESIGN CONSIDERATIONS
FULL PIPING INSULATION MOUNTS
DESIGN CONSIDERATIONS
INSULATION JACKETS ON TANKS AND VALVES
Delta T of 50-70 degrees year round
We insulate houses to R-20 and 30 for 1 week of 47F delta T
Pipe Insulation is Cost Effective, Need More Market Forces for R-18 to 25
Every Building with a central hot water system is wasting 10% of its energy annually
PASSIVLOOP

Super-Insulated Hot Water Storage and Distribution System that reduces losses from 75 Watts to 15 watts per unit. Increase U value of entire hot water plant by a factor of 5.

PassivLoop

- R-25 Insulation on central hot water piping
- R-25 jackets around storage tanks
- Eliminate Thermal Bridging on Pipe Mounts and Penetrations
- Hot Water Storage Tanks located inside heated space
- Insulated Valves and Pumps.
- 1 hot water stack per 2 back to back apartment stacks (1/2 UA)
- Smaller Distributed Single Pass DHW Systems (Sanden)
- No Recirculation Systems (Use Heat Trace)

- Targeted losses are less than 15 Watts/apartment.
REMINDER

SELF-REPORT C PHC CEUs

Self-report link:
www.phius.org/cphc/self-report
Enter verification code: 61704