Comparing the Energy Requirements of Hot Water Circulation System Control Strategies: Preliminary Results

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Learning Objectives

1. Understand the control strategies for hot water circulation systems
2. Learn about a test setup that is being used to compare the water, energy and time performance of the control strategies.
3. Examine the patterns in the data coming from this test.
4. Begin the comparison of the energy performance of several of the control strategies.
The Test House – 2-story, 3,200 sf
Water Heater, Circulation Pump and Controls – as installed
Circulation Pump and Controls – as Installed
Water Heater, Circulation Pump and Controls – as of April 2014
Test Stand for Circulation Pumps and Control Strategies
The Theory
Hot Water Circulation Systems

There are six types of circulation systems:

• Thermosyphon (gravity convection with no pump),
• Continuously pumped systems,
• Timer controlled,
• Temperature controlled,
• Time and temperature controlled, and
• Demand controlled.

Given the same plumbing layout, all of these systems will waste the same amount of water at the beginning of a hot water event.

The difference in these systems is in the energy it takes to keep the trunk line primed with hot water.
Operating Costs of Circulation Loops

• Pump
• Heat loss in the loop
• Maintenance
  – Failure of the pump
  – Incorrect control settings
  – Pipe leaks
• What percent of the energy costs are due to the pump? To the losses in the loop?
Determination of Heat Loss in Circulation Loops

• You could measure the pipe lengths, diameters, insulation and environmental conditions and calculate the heat loss, if you can get to all of it!

• Or you could measure flow rate and the difference in temperature between the water leaving from, and returning to the water heater.
Heat Loss in Circulation Loops –
Calculation for Loop Losses Only

Sample Calculation: 1 gpm and 1°F temperature drop

- Energy = m * c_p * (T_{hot} - T_{return}) = Btu
- 1 gpm * 8.33 pounds per gallon * 1 * 60 minutes per hour * 1°F = 500 Btu/hour/°F

Natural Gas Water Heater

- 500 ÷ 0.75 efficiency = 667 Btu/hour/°F
- 667 ÷ 100,000 Btu/Therm = 0.00667 Therm/hour/°F
- 0.00667 * $1.00/Therm = $0.00667/hour/°F

Electric Water Heater

- 500 ÷ 0.98 efficiency = 510 Btu/hour/°F
- 510 ÷ 3,412 Btu/kWh = 0.15 kWh/hour/°F
- 0.15 * $0.10/kWh = $0.015/hour/°F
Annual **Energy Use** for a Circulation System Attached to a Gas Water Heater (Therms)

<table>
<thead>
<tr>
<th>Continuous Pumping at 1 Gallon Per Minute</th>
<th>Temperature Drop in °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0.16</td>
</tr>
<tr>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>365</td>
<td>58</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pump Flow Rate in Gallons Per Minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
</tr>
</tbody>
</table>

Steady state heat transfer efficiency is assumed to be 75%.

Electrical energy to operate the pump is additional.
Annual **Energy Use** for a Circulation System Attached to an Electric Water Heater (kWh)

<table>
<thead>
<tr>
<th>Days</th>
<th>Temperature Drop in °F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>3.60</td>
</tr>
<tr>
<td>30</td>
<td>105</td>
</tr>
<tr>
<td>365</td>
<td>1,278</td>
</tr>
</tbody>
</table>

<table>
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<th>Pump Flow Rate in Gallons Per Minute</th>
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<td>5</td>
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<tr>
<td>10</td>
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</tbody>
</table>

Steady state heat transfer efficiency is assumed to be 98%.

Electrical energy to operate the pump is additional.
When Do You Not Want to Operate a Hot Water Circulation Pump?

- When you don’t need hot water
  - When you aren’t there
  - When you are sleeping or doing something else

- When you are using hot water

The only time you want to operate the pump is just before you need hot water.

Use Demand Controlled Circulation

- The pump will run less than ½ hour per day
- The most energy efficient option.
Energy to Operate a Circulation Loop

<table>
<thead>
<tr>
<th>Loop Heat Losses</th>
<th>Recirculation</th>
<th>Demand Controlled Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daily Hours of Operation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24 12 8 6 4 2</td>
<td>0.25</td>
</tr>
<tr>
<td>Natural Gas (therms)</td>
<td>292 146 97 73 49 24</td>
<td>3</td>
</tr>
<tr>
<td>Electric (kWh)</td>
<td>6,388 3,194 2,129 1,597 1,065 532</td>
<td>67</td>
</tr>
<tr>
<td>Pump Energy(kWh)</td>
<td>438 219 146 110 73 37</td>
<td>8</td>
</tr>
</tbody>
</table>

Loop is assumed to be 100 feet long.
50 feet supply, 50 feet return

Recirculation:
Flow rate is 1 gpm
Temperature drop is 5F
50 watt pump

Demand Controlled Priming:
85 watt pump
The Practice
Control Strategies Being Tested

The intent is to determine the energy it takes to provide hot water quickly anywhere, anytime, regardless of changing schedules

- Continuous Circulation
- Aquastat – Low, Medium and High Speed
  - 85-105F, 105-115F
- Intermittent Pulsed Timer
- Demand Controlled
- Other – Aquastat and Timer, Memory
Continuous Circulation: Low Speed
Continuous Circulation: Low Speed
Continuous Circulation: Medium Speed
Continuous Circulation: Medium Speed
Intermittent Pulsed Timer
Intermittent Pulsed Timer
Aquastat: 85-105F, Medium Speed
Aquastat: 85-105F, Medium Speed
Aquastat: 85-105F, High Speed
Aquastat: 85-105F, High Speed
Aquastat: 105-115F, Medium Speed
Aquastat: 105-115F, Medium Speed
Aquastat: 105-115F, High Speed
Aquastat: 105-115F, High Speed

sMAP 2.0 Plotting Engine

Reading Time (America/Los_Angeles)

now | reset  Select Streams  Plot  Clear

Stack  Autoupdate  Zoom  Hover

[csv] HWDS_h18 (beagle20) :: /hwds_test/0x327d/tempA
[csv] HWDS_h18 (beagle20) :: /hwds_test/0x3468/tempA
Given human nature, it is our job to provide the infrastructure that supports efficient behaviors.
Thank You!

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