Estimating Potential Savings from Demand Controlled Pumping Systems

1. Executive Summary

The performance of a **demand controlled pumping system** in a typical residential water heating installation was analyzed. Demand controlled pumping is a method of bringing water quickly to fixtures far from the water heater in order to minimize the waste of water running down the drain while waiting for hot water to arrive. As of January, 2006, there are three companies selling products that do this: ACT Inc., Metlund Systems (www.gothotwater.com), TACO (www.taco-hvac.com) and Uponor Wirsbo (www.wirsbo.com). These products and their application are the subject of this analysis.

An analysis was performed to quantify the potential enhancement of water heater energy factor due to the use of a demand controlled pumping system under a range of conditions expected to be encountered in typical residential settings. A set of linked steady-state energy balance equations was solved in a spreadsheet-based simulation to predict the **energy factor (EF) enhancement** of a 40-gallon gas tank water heater, a 52-gallon electric tank water heater, (the most-commonly-encountered sizes for storage water heaters) and for gas and electric tankless water heaters.

Based on this analysis, it is reasonable to assign the following energy factor enhancement coefficients when using demand controlled pumping systems:

Trunk and Branch
The savings due to a conservative 15% reduction in water consumption results in energy factor enhancement coefficients ranging from 1.12 to 1.17 for the range of water heaters that were evaluated (See Table 5).

Structured Plumbing
The savings due to a conservative 20% reduction in water consumption plus an additional savings equivalent to another 10% reduction in water use due to insulation, result in energy factor enhancement coefficients ranging from 1.27 to 1.42 for the range of water heaters that were evaluated (See Table 5).

In order to obtain the highest combination of water and energy efficiency, the energy factor enhancement for Structured Plumbing needs to be aligned with the top tier for Hot Water Distribution Systems in LEED-H or similar green building programs.

Retrofitting Existing Recirculation Systems
The savings here are energy, not water related as in the first two applications. Retrofitting a demand controlled pump will reduce the energy needed to operate the pump and keep the circulation loop hot by up to 98 percent (286 therms or 6,388 kWh per year) and is proportional to the run time of the existing system.

Literature Survey

There are four studies that taken together document the energy savings potential of demand pumping systems. In 1999, on behalf of the American Water Works Association Research Foundation (AWWARF)[1], Aquacraft conducted research in many parts of the country as part of the Residential End Uses of Water Study (REUWS). In 2002, Oak Ridge National Laboratory (ORNL)[2] conducted a study in conjunction with the City of Palo Alto that examined the use of demand pumping systems in retrofit applications. In 2003, the Davis Energy Group (DEG)[3] conducted a study as part of their work for the Building America program on new construction that showed that the use of a demand pumping system saves energy compared to standard recirculation techniques. In 2005, the California Energy Commission[4] conducted a study conducted to better understand hot water distribution systems.

Aquacraft's REUWS took data from 1200 homes in 12 metropolitan areas in the U.S. and Canada. Although the vast majority of the effort was focused on total water consumption, in some of these locations hot water use was measured separately. Table 1 shows data from two of these studies and from the REUWS. The range of hot water use in the REUWS is estimated based on the rounded off percentages from the EBMUD and Seattle studies.

Table 1 Estimated Hot Water Consumption in the United States

	EBMUD	Seattle	REUWS
Water Use (gallons/capita/day)			
Hot Water	21.1	25.1	21 to 28
Total Indoor Water	70.9	62.2	69.3
Percent	29.8	39.6	30 to 40
Number of People	2.5	2.6	2.8
Hot Water Use (gallons/household)			
Daily	52.75	65.26	58.8 to 78.4
Monthly	1,582	1,958	1,764 to 2,352
Annually	18,990	23,494	21,168 to 28,224

[1] **Residential End Uses of Water Study (REUWS)**, American Water Works Association Research Foundation, 1999.

[2] **Water and Energy Savings using Demand Hot Water Recirculating Systems in Residential Homes: A Case Study of Five Homes in Palo Alto, California**, Moonis Ally and John Tomlinson, Oak Ridge National Laboratory, September 2002.

[3] **Progress Report on Building America Residential Water Heating Research**, Davis Energy Group, November 2003, cited with permission of David Springer.

[4] **Hot Water Distribution System Research – Phase I Final Report**, Carl Hiller, Applied Energy Technology for the California Energy Commission, March 2005.

Based on the large sample studied, it would appear that typical residential hot water consumption is between 50 and 80 gallons per household per day. A percentage of this is wasted due to inefficient hot water distribution systems.

The ORNL study on five existing homes showed that a demand pumping system saves both water and energy in retrofit. Following typical practice in retrofit, they installed a demand pumping system under a sink in the hot water location furthest from the water heater. Even though there were multiple hot water locations served by the trunk line going to the last fixture, only one activation mechanism was provided for each system. They presented estimates of water and energy savings as shown in Table 2. The daily water savings have been calculated from the annual savings.

Table 2 Water and Energy Savings in Existing Homes

Number of Hot Water Use Points	Daily Water Savings (gallons)	Annual Water Savings (gallons)	Annual Energy Savings (kWh)
1	2.5 to 8.2	900-3,000	200-400
4	10 to 32.8	3,600-12,000	800-1,600

ORNL measured the savings from the one hot water use point that was served by the demand pumping system and projected the savings presented for a house with four hot water use points. ORNL determined that the waste of water and energy were due to both technical and behavioral factors. One very interesting result was that when using the on-demand circulation pump, less water came out of the pipe before water was hot enough to use. They determined empirically that the ratio of water wasted at slow flow to the water wasted at circulation pump flow was 1.29:1.

The Davis Energy Group conducted a study as part of their work for the Building America program on new construction that showed that the use of a demand pumping system saves energy compared to standard recirculation techniques. In this 3080 square foot single story house with a very large recirculation system, DEG tested six combinations of pump and controls to determine which one performed best. Table 3 shows that the demand pumping system (Modes 3 and 4) ran the fewest minutes per gallon of hot water used. It ran one-fifth as long as the next best option and one-seventieth as long as uncontrolled recirculation.

Table 3 Recirculation Pump Operating Time

Parameter	Pump Minutes / Gallon of Hot Water Used
Uncontrolled Recirculation	57.6
Timer control (16 hours/day)	38.4
Mode 1- Wattstopper system	6.4
Mode 2- add return line temp sensor	4.3
Mode 3- Metlund demand system	0.80
Mode 4- "3" w/ 2 sensors shielded	0.88

According to the report, run time could have been reduced by eliminating the false signals, which due to the activation method chosen for the experiment, were 70 percent of the total number of signals sent to the pump. Run times could have been around 0.24 minutes per gallon of hot water used. With improved activation, they estimated that the energy to run the properly configured system would have been 25 therms.

All of the other circulation pump control strategies DEG tested used significantly more energy than that used by the demand controlled system. In addition, all recirculation systems except demand recirculation systems use more energy than is associated with the water running down the drain and therefore are energy inefficient. They have been installed for customer convenience, not energy efficiency.

The energy consumed to operate the demand circulation system in this house with a long, high volume circulation system is comparable to the energy that runs down the drain if only 5 gallons per day is wasted while waiting for hot water to arrive, half that at 10 gallons per day and one fourth at 20 gallons per day. This means that it takes less energy to operate the house with the demand pump than it would to operate it without any circulation system at all. The branch piping in this house was not intentionally configured to minimize the volume of water between the fixtures and the circulation loop. In an intentional Structured Plumbing system it would be possible to reduce the waste and wait by an additional 50 percent, while using no more energy than would have been wasted letting 5 gallons per day run down the drain.

The California Energy Commission study looked at water and energy waste in three parts of a hot water event as shown in Figure 1. They conducted a series of parametric tests in a laboratory on ½ and ¾ inch copper and PEX-A (two layers of cross linked polyethylene with a film of aluminum between them as an oxygen barrier). The tests were done on bare pipe and on pipe with ½ and ¾ wall thickness insulation.

Ideally, the delivery phase is short (seconds), the use phase is however long is required and the cool down phase is what happens between events. The water heater temperature must be hot enough to overcome the losses in the hot water distribution system and provide water that is hot enough to mix with some amount of cold water to get the desired temperature. The useful hot water temperature varies with activity; for example, washing hands may be done at a different temperature than taking a shower.