PY 2009 Monitoring Report: Demand Control for Multifamily Central Domestic Hot Water

Prepared for Southern California Gas Company
October 30, 2009

BenningfieldGroup
400 Plaza Drive, Suite 155
Folsom, CA 95630
916.221.3110

Table of Contents

BACKGROUND 3
Gas Savings Expectations 4
Electricity Savings Expectations 4
METHODOLOGY 4
FINDINGS 5
CONCLUSIONS 10
APPENDICES 10
Appendix A: 2007-08 Energy Savings Work-paper 10
Measure Summary: 10
Gross Annual Savings: 11
Measure Cost Data: 12
Measure Description and Background 12
Load Shape 12
Energy Savings Estimation Methodologies (Electric and Natural Gas) 12
Measure Costs 16
Incremental Measure and Installed Costs 16
References and Citations 16
Appendix B: On Demand Efficiency Program Rationale 16
Appendix C: Monitoring Equipment Details 18

Table of Figures

Figure 1: Monitored Gas Savings 6
Figure 2: Monitored Electricity Savings 9

Background

This report provides the results of the monitoring that was completed by September of 2009 on PY2008 and PY2009 installations of demand pumps within the On-Demand Efficiency (ODE) Program. We monitored 12 PY2008 sites and 23 PY2009 sites, though the amount of data per site that we collected in 2009 was much greater than on the PY2008 sites. Once the Benningfield Group and Sempra reviewed the preliminary results from the 12 PY2008 sites, we found a tremendous variance in savings across individual installations. In an attempt to better understand why this variance occurred, we increased the amount of building and system descriptive data in 2009. We analyzed the variances in gas savings by building size, CDHW system storage capacity, number of apartments, and other potentially relevant factors.

The monitoring that is the subject of this report stems from the following paragraph in the original proposal and the resulting contract:

"For a total of four buildings (changed to 10%-15% of installations in the contract documents) with installed controls, we will meter the boiler's gas consumption over a two-week period before the demand controller is installed and for two weeks after the controller is installed. We will use portable data loggers that monitor and record the current draw through the boiler's gas valve solenoid on the burner ignition module. This data logging configuration will not require any invasive procedures (cutting or splicing) into the existing equipment or wiring. The difference in gas consumption between the two observation periods provides confirmation that the system is working as designed. We will also install a non-intrusive portable data logger that monitors the recirculation pump on/off status to verify that the controller influences the pump motor operating time."

In order to make the data collection more efficient, we modified the monitoring protocols somewhat. For instance, instead of collecting data for two weeks *before* installation of the demand controlled pump, and another two weeks *after* installation, we alternated weeks with the demand control activated and deactivated. This reduced the possibility of any significant bias from changes in occupancy coincidental with the two week periods. It had additional benefits of (a) reducing the cost of plumbers' time, (b) reducing the potential for quality issues from repeated removal and replacement of the pump, and (c) reduced tenant issues that would have arisen if the DHW system had had to be shut off repeatedly. Also, we achieved a higher level of accuracy relying on in-line flow meters for gas and water. The balance of the monitoring methodology is described in Section 2, below.

The Program provides a method of decreasing natural gas consumption in central domestic hot water (CDHW) systems with recirculation loops in multifamily buildings, while improving occupant satisfaction with the hot water delivery. Demand controls on hot water recirculation systems turn off the recirculation pump when it is not needed, thereby reducing heat loss from the loop, reducing the boiler fire time, and thus reducing natural gas consumption. Because it shuts the pump off when not needed, it also saves on electricity.

Gas Savings Expectations

The Program had an initial PY2008 goal to save 134,555 gross therms of natural gas annually (107,644 net therms) by installing 85 CDHW systems in existing multifamily building in The Gas Company's service territory. The goal was expanded in late 2008 by forty installations and 63,283 gross therms (50,626 net therms) by a contract amendment. The new goals for PY2008 were 125 installations and 197,838 gross therms (158,270 net therms).[1] The PY2009 goal was 277025 gross therms from the installation of 175 demand pumps in existing multifamily buildings. The total PY2008/09 goal was nearly 475,000 therms (approximately 380,000 net therms). This resulted from an estimate of 1583 gross therms of annual savings per installed demand control pump.

This measure is not listed in the CPUC Database for Energy Efficiency Resources (DEER), so in 2007 the Benningfield Group developed a methodology specifically for estimating savings due to this Program. The methodology and the estimate are described in Appendix A: 2007-08 Energy Savings . This is the work-paper that the Benningfield Group submitted with the original Program proposal with minor changes as noted in the text and footnotes. The assumed savings per unit was 1583 therms, based on previous research by the Heschong Mahone Group, the Davis Energy Group, and Architectural Energy Corporation (formerly Eley Associates).

Electricity Savings Expectations

In the 2007 work-paper, the Benningfield Group also provided an estimate of electricity savings that should result from the dramatic reduction in pump run-time. Although neither the Program nor Southern California Gas Company are credited with these savings, it is appropriate to include the estimate here and compare the monitored results to them. Based on the same sources as the gas savings estimates, the Benningfield Group estimated that demand pumps would save an average of 327 kWh per year per controller. The 300 installations in PY2008/09 should, therefore have resulted in annual savings of 98,100 kWh.

Methodology

With guidance and support from the Benningfield Group, Enovative Group carried out monitoring of demand controlled pumps installed by plumbers and other installers. We purchased utility grade gas meters, thermistors, water flow meters, and data loggers sufficient to monitor many sites at a time. Details on the monitoring equipment employed are in Appendix C.

The protocol involves monitoring of temperature of hot water supply (HWS) and hot water return (HWR) lines, pump run times, and gas usage on all monitored sites, and water flow and ambient temperature on a subset of sites. The data loggers record temperature data on 15-second intervals and aggregate the data over 15-minute periods. They record pump run time by logging actual off and on times to the second. Gas usage is recorded as cubic feet on a "pulse" basis, logged on the same 15-minute increments.

[1] The assumed net-to-gross ratio for this program in PY2008/09 was 0.80.

The HWS and HWR thermistors are placed against the copper pipe and isolated from ambient temperature with ~1" of standard pipe insulation. To reduce the prospect of conduction through the copper pipe interfering with an accurate measurement of the temperature of the water within the HWS and HWR lines, the thermistors are generally located as far from the storage tank as possible within the confines of the boiler room and given the limitations of the length of the lead wires.

Enovative Group gathers the stored data on one week cycles, switching between demand control and continuous pumping until they have at least two weeks of data from both conditions.[2] At each visit, Enovative Group staff downloads the data onto a laptop, resets the data loggers, and corrects any problems (e.g., a thermistor lead that became detached). Compared to gathering two solid weeks of data in the continuous pumping mode followed by two weeks of data in the demand controlled mode, alternating weeks helps to minimize any potential impact of changes in weather, vacations, vacancies, or other occupancy changes that might occur during the data collection period.

In 2008, the water flow meters worked for only a very few sites before the meters developed problematic leaks. Although Enovative Group contacted the meter manufacturer and followed their instructions on repairing the meters, they quickly developed leaks again. We stopped using them because they were too unreliable. In PY2009, we obtained new flow meters and monitored several of the CDHW systems for water usage.

Findings

The estimated natural gas and electricity savings from the 35 monitored sites are presented in the following tables. The ex post estimate of gas savings from the monitored sites is slightly lower than the ex ante estimate in our work-papers. The ex ante estimate was 1583 therms per control, and our monitored results show 1526 therms per control; 96% of the expected savings. This result is based on a sample of 35 sites out of 125 installations in 2008 and 175 installations in 2009.

Extending the average savings from the 35 completed monitoring sites to the full 300 installations for PY2008/09, we estimate that the Program saved 457,800 therms of natural gas. This compares well with the ex ante estimate of 474,900 therms.

These 35 monitored sites comprised 1540 apartments. Average gas savings per dwelling unit across the monitored sites is 35 therms/apt. The range of savings was from 17.8 therms/apt to 95.7 therms/apt.

[2] Note that in most cases, Enovative collected three weeks of data for the demand control condidtion.

Project	# of apts per loop	Therms/yr Savings	Therms/yr Per Apt
A	50	1107	22.1
B	46	885	19.2
C	39	810	20.8
D	20	1324	66.2
E	24	1043	43.5
F	32	2127	66.5
G	39	943	24.2
H	40	1087	27.2
I	29	2211	76.2
J	39	2579	66.1
K	43	1404	32.7
L	133	1788	13.4
M	189	2321	12.3
N	32	1587	49.6
O	49	1878	38.3
P	49	1878	38.3
Q	39	993	25.5
R	43	1242	28.9
S	50	1960	39.2
T	40	1396	34.9
U	38	1951	51.3
V	36	1544	42.9
W	20	1191	59.6
X	30	631	21.0
Y	30	799	26.6
Z	28	498	17.8
AA	30	1099	36.6
BB	28	1302	46.5
CC	49	1110	22.7
DD	32	2605	81.4
EE	42	1931	46.0
FF	50	907	18.1
GG	30	2870	95.7
HH	23	1942	84.4
II	49	2455	50.1
Total for 35 Sites	1540	53,398	
Average	44	**1526**	**therms**
Average Per Aparment		34.7	therms
Controls in PY2008/09 Program		300	
Estd. PY2008/09 Savings		**457,697**	**therms**

Figure 1: Monitored Gas Savings

We present the data in terms of savings per apartment because that seems like a logical way to look at it, and it is one of the two bases upon which the utilities provide a variable incentive within the Multifamily Retrofit Rebate Program (the other criteria being vintage

of the building). However, the data only mildly support number of apartments as a major determining factor in savings expectations. As the graph in Figure 2 shows, only about 59% of the variance can be explained by looking at the number of apartments on the controlled CDHW loop. It is worth noting that the vintage of the building has virtually no effect on the savings expectation. For vintage, the R^2 was less than 0.10, meaning that it could only explain less than ten percent of the variation.

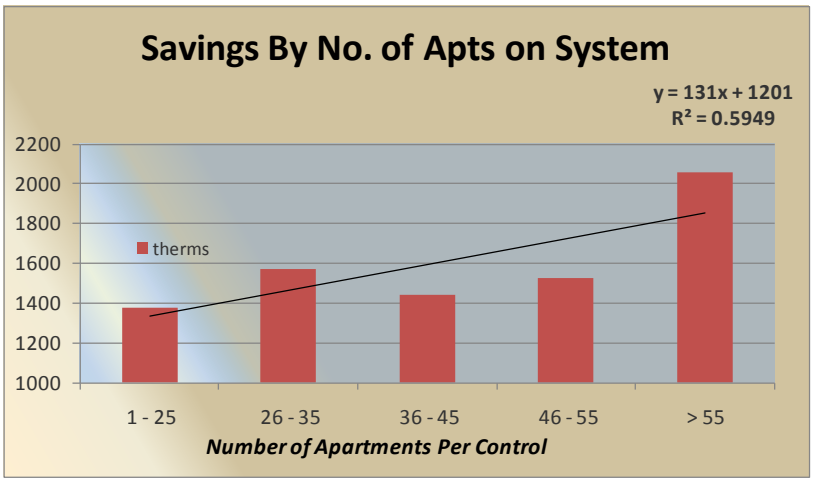


Figure 2: Savings as a Function of Number of Apartments

However, we found a few other factors with which savings expectations show a higher and/or more certain correlation. For example, the number of stories in the building served shows a strong correlation. As the graph in Figure 5 shows, the number of stories appears to explain over 80% of the variation in savings. This is not surprising since there will obviously be greater pipe length in taller buildings and the primary gas savings from the demand control result from reduced losses in the loop; the longer the loop, the greater the savings ought to be.

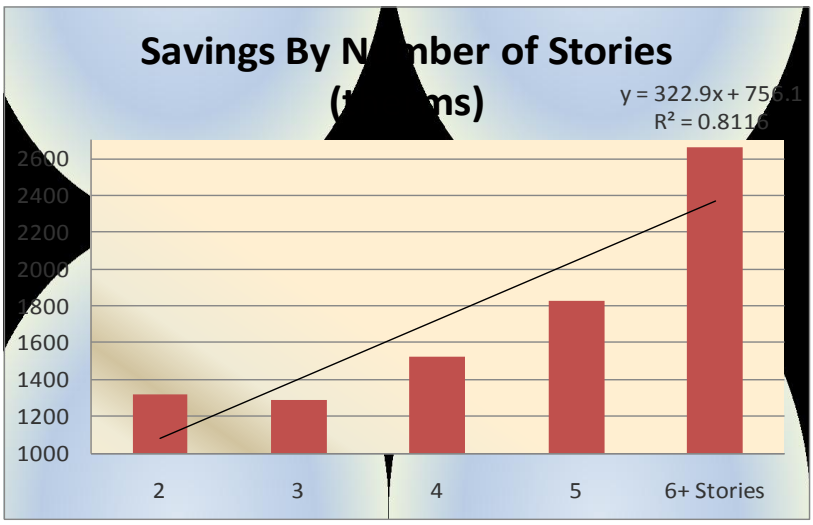


Figure 3: Therm Savings as a Function of Number of Stories

The most certain relationship between a building or CDHW system feature and total therm savings however, appears to be for total hot water storage capacity. The larger the

storage tank, the greater the savings from installation of a demand pump. The likely reason for this is that with greater storage capacity and a continuously operating pump, the boiler needs to fire almost as often as if there were little hot water storage capacity. The continuously operating circulation pump acts to continuously mix the temperature in the tank with cooled water from the loop. When we replace the continuous pump with a demand pump, the water in a large tank can stratify during periods of low demand (periods wherein the pump will be mostly controlled off), and still provide enough hot water from the top of the tank meet intermittent needs without turning the pump on. With a much smaller tank, the demand control pump will likely cycle on every time there is any demand during periods of low demand.

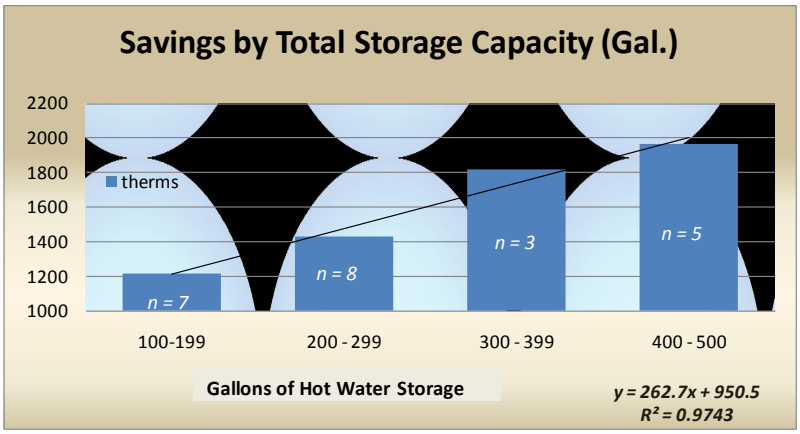


Figure 4: Therms Savings as a Function of Hot Water Storage Capacity

ELECTRICITY In addition to the gas savings, the Program produces electricity savings. On a subset of the monitored sites (29 of the 35 sites), we also collected pump run time data. On 32 of the 35 monitored sites, we were also able to verify the wattage of the pump that was replaced.[3] The existing pumps at these sites had all been in continuous operation (e.g., no timers or other operational controllers). The new demand pumps ran an average of 1.81 hours per day during the monitored period. From this data, we estimate annual electricity savings at approximately 1236 kWh/year per controller, or roughly four times the original expectation. To develop this estimate, we

- multiplied the original pump wattage by 24 hours
- multiplied the D'Mand pump wattage (165 Watts) by the logged runtime per day
- subtracted the D'Mand Pump daily kWh from the original pump daily kWh
- multiplied the result by 365 days

The table in Figure 5 shows the data and the averages across the monitored sites.

[3] At the other three sites, the plumbers removed and recycled the old pump before we had the opportunity to note the wattage.

Site Number	Pre-existing Pump Wattage	kWh/day with Original Pump	Monitored D'Mand Pump Run Time (hrs)	kWh/day with D'Mand Pump	KWh/yr Savings
1	85	2.04	1.43	0.236	658
2	85	2.04	2.7	0.446	582
3	205	4.92	1.86	0.307	1684
4	135	3.24	0.67	0.111	1142
5	165	3.96	0.438	0.072	1419
6	90	2.16	0.58	0.096	753
7	205	4.92	6.02	0.993	1433
8	215	5.16	2.3	0.380	1745
9	185	4.44	1.87	0.309	1508
10	185	4.44	1.11	0.183	1554
11	85	2.04	0.4	0.066	721
13	215	5.16	7.8	1.287	1414
15	205	4.92	1.1	0.182	1730
16	87	2.088	2.18	0.360	631
18	90	2.16	0.15	0.025	779
19	85	2.04	0.74	0.122	700
20	205	4.92	2.74	0.452	1631
21	180	4.32	0.15	0.025	1568
22	85	2.04	0.1	0.017	739
23	165	3.96	0.56	0.092	1412
24	165	3.96	0.56	0.092	1412
26	135	3.24	0.23	0.038	1169
27	215	5.16	1.4	0.231	1799
28	85	2.04	1.22	0.201	671
29	215	5.16	3.85	0.635	1652
30	245	5.88			0
31	85	2.04			0
32		0			0
33	180	4.32	3.5	0.578	1366
34		0			0
35	205	4.92	2.24	0.370	1661
36	205	4.92	1.9	0.314	1681
37	215	5.16			0
38		0			0
39	92	2.208	2.9	0.479	631
Average	**156**	**3.75**	**1.817**	**0.30**	**1236**

Figure 5: Monitored Electricity Savings

Extending the average savings of 1236 kWh/yr per pump to the 300 sites where ODE installed demand pumps in 2008/09, we estimate that the Program saved 370,800 kWh of electricity. Based on the 1336 dwelling units served by the CDHW systems at the 29 sites where we had enough data to calculate savings, the average kWh savings per apartment is 30.1 kWh/unit.

WATER It was our intent in the PY2009 monitoring report to provide an estimate of water savings due to use of demand controls. In 2008 we difficulties with the water

meters available for monitoring ODE sites. They proved to be unreliable. In 2009, we used new water flow meters to monitor water usage on a sample of sites but were not able to begin that monitoring at the outset of 2009 due to an equipment delivery delay. We also collected total site water usage data from the water utility's site water meter at each weekly visit to about half of the PY2009 sites.

There weren't enough data on water usage from enough sites to provide a solid estimate of the impact of demand control pumps on water use. On some sites there appeared to be small water savings and on others, small increases in water use. Future monitoring should include more sites and employ very strict data collection protocols to overcome some of the uncertainties that still exist in the impact of demand controlled pumps on water usage.

Conclusions

We feel that the sample size represented in this study is large enough to verify the value of the Program and the demand pumps, and is appropriate for use as a reference in a workpaper on the D'Mand Pump and the On Demand Efficiency Program. However, the data set is too small to justify placing demand pumps in the DEER with deemed savings. It might justify changes to the IOUs' MF retrofit programs, in particular by adding demand pumps as an eligible measure. Comparing the data from these 35 sites to those from the 139 sites with temperature modulation controls in the Southern California Gas Company study conducted by KEMA in 2007/08, indications are that the demand controlled pump may be the most reliable, cost-effective means of achieving gas savings in multifamily properties. The data support our 2007 ex ante estimate of gas savings at the 96% realization rate.4 The results show that the Program could also claim significant electricity savings; a result not possible with the temperature modulation controls since they require re-circulations pumps to run constantly.

Appendices

Appendix A: 2007-08 Energy Savings Work-paper

Please note that the information provided below on the work-paper is historical and is meant to be background information only. With the monitoring results collected on the PY2008/09 installations, we intend to provide a new work-paper for the PY2010/12 iteration of the program. The workpaper should contain better estimates of gas and electricity savings based on data from the 35 monitored sites in 2008 and 2009.

Measure Summary

Measure Name: Demand Control for Multifamily Central Domestic Hot Water

End Use: Multifamily Domestic Hot Water

[4] Realization rates on other controls for CDHW systems in Itron's 2006 MF Retrofit Program evaluation, and KEMA's 2008 evaluation were 12.5% and 25%, respectively.

Effective Useful Life: 15 years, per SoCalGas E3 Calculator: Water Heater Controls, for Retrofit and Replace on Burnout

Net-to-Gross Ratio: Affordable Housing: 100%; Market Rate MF: 80%; per SoCalGas E3 Calculator: Advanced Water Heating Systems and the PY2009 DEER5

Gross Annual Savings

Unit of Measure: pump

Building Type: Multifamily residential

Building Vintage: Built before 2005

Climate Zones: All of SoCalGas service territory: 5-Santa Maria, 6-Long Beach, 8-El Toro, 9-Burbank, 10-Riverside, 14-China Lake, 15-El Centro

Peak kW annual savings: 0 (negligible)

kWh annual savings: 327 per unit

Therm annual savings: 1,583 per unit

[5] In the original work-paper, this was 100% for all cases based on fixed values in the SoCal Gas E3 Calculator.

Measure Cost Data

Unit of Measure: Pump

Program Strategy: Retrofit

Base Equipment Cost: $400 (circulation pump with no controls)

Measure Equipment Cost: $1,500 6

Incremental Cost: $1,100

Labor Cost: $500

Installed Cost: $2,000

Measure Description and Background

Measure Description: Demand controls on hot water recirculation systems turn off the recirculation pump when it is not needed, thereby reducing unnecessary heat loss from the loop, reducing the boiler fire time, and thus reducing the natural gas consumption.

Related DEER measure: no DEER measures are identical or even closely related to this measure.

Base case for savings estimate: continuous pumping (no controls) or timeclock installation that has been bypassed.

Load Shape

Not applicable as the demand savings are negligible.

Energy Savings Estimation Methodologies (Electric and Natural Gas)

Through marketing efforts and direct rebates, this program will save 197,875 therms and 40,875 kWh every year by impacting 125 multifamily building central domestic hot water (CDHW) systems in the existing building market.7 All the realized savings occur from installations in 2008. The program is scaleable and has a greater energy savings potential than that predicted.

This particular measure is not listed in the CPUC Database for Energy Efficiency Resources (DEER). Therefore, to determine the impacts of this program, we conducted a literature search and reviewed the applicable publications. Three publications are directly applicable to this program, as they describe savings estimates for installing a demand controller, using either a timeclock control or no control (continuous pumping) as the

---

[6] In the original work-paper, these costs were listed as $2000 for Measure Equipment Cost, $1600 for Incremental Cost, $300 for Labor Cost, and $2300 for Installed Cost. These data were based on conversations with Mark Franklin of Saves You Energy, since SYE was to be the vendor for ODE. In spring of 2008, with approval from SCG, the Benningfield Group switched to Enovative Group as the vendor for the demand pumps. The new costs are based on Enovative's experience.

[7] This sentence was modified from the original to account for the larger number of installations (125 vs. 100) required by the contract plus contract amendment.

baseline case. Eley Associates prepared two of these publications in support of the 2005 Title 24 Building Energy Efficiency Standards. In their report (p. 38) to the California Energy Commission (CEC) entitled "Measure Analysis and Life Cycle Cost, Part 1,"8 the heat loss from a CDHW recirculation loop is reported for various types of controls. For the scenario of no control (continuous pumping), the heat loss through the recirculation loop is reported as 137.3 therms per year. With a demand control installed to command the recirculation pump, the reported heat loss is only 39.8 therms per year, yielding an annual savings of 97.5 therms between the demand control and no control scenarios. Scaling up from the report's 3,080 sf prototype to a 50,000 sf multifamily building (1,000 sf x 50 units) yields an annual savings of 1,583 therms. We use a direct linear scalar in this case, as the distribution loss as a percentage of recovery load increases with floor area up to 2,000 sf, then remains constant through the largest building under study (3,080 sf). The appropriate baseline condition is no control installed (continuous pumping) as we will target existing buildings (no new construction). The vast majority of these systems will have no pump control. On occasion, the system will have a timeclock installed, but the vast majority of the timeclocks will be inoperative due to human intervention or self failure.

The other applicable publication by Eley Associates (relying heavily on work by the Heschong Mahone Group9) useful for this program is their Codes and Standards Enhancement (CASE) Initiative, a 2005 Title 24 code change proposal for multifamily water heating.10 This report presents the results of DOE2.2 energy simulation modeling of multifamily buildings ranging from 32,027 sf (54 units) to 122,783 sf (92 units). Their results for Climate Zone 9 are listed in the following table:

HMG's CASE Report: CDHW recirculation loop heat loss and annual gas savings associated with pump controls

[8] California Energy Commission. April 2002. "Part I: Measure Analysis and Life-Cycle Cost" *2005 California Building Energy Efficiency Standards*. PDF Version of document downloaded on June 11, 2007 from http://cacx.org/title24/2005standards/archive/rulemaking/documents/document_list.html

[9] Although this report was written, and the research behind it was conducted by the Heschong Mahone Group, it is incorrectly attributed to the Davis Energy Group and Eley Associates within the CEC docket and other records of the 2005 Title 24 update process.

[10] California Energy Commission. May 2002. "Code Change Proposal for Multifamily Water Heating" *2005 California Building Energy Efficiency Standards*. PDF Version of document downloaded on June 11, 2007 from http://cacx.org/title24/2005standards/archive/rulemaking/documents/document_list.html

	Bldg 1	Bldg 2	Bldg 3
Floor area, sf	91,350	32,027	122,783
# units	88	54	92
Avg sf/unit	1,038	593	1,335
Heat loss, no control, MMBtu	677	320	1,498
Heat loss, timeclock, MMBtu	501	256	981
Timeclock savings, therms	1,760	640	5,170
Timeclock savings, baseline is no controls, normalized to 50,000 sf	963	999	2,105
Demand savings, baseline is no controls, normalized to 50,000 sf	**1,804**	**1,840**	**2,946**

This report analyzes the control scenario of timeclocks but not demand controls. The previous report we discussed (Eley's Measure Analysis report) presents distribution loop heat loss estimates for timeclocks and demand controls, in addition to other control strategies. The incremental savings gained by upgrading from a timeclock to a demand control is 841 therms/year (50,000 sf building). The table above shows the savings realized by installing a functional timeclock control instead of continuous pumping (no control). Adding the 841 therms/year additional savings realized by upgrading from a timeclock to a demand control yields the last line in the table: Demand savings.

The third publication of interest to this program is also the most recent of the three, published by Heschong Mahone Group (HMG) in June 2006 in support of the 2008 California Building Energy Efficiency Standards.11 This paper presents the results of their CEC-funded research on multifamily CDHW systems and associated pump controls. It concludes that the CEC should establish a new prescriptive requirement for the 2008 standards, which will likely take effect in Fall 2009, that CDHW recirculation systems in multifamily buildings use either temperature modulation controls or recirculation pump demand controls. Our proposed program compliments their new construction code change proposal as we will target existing buildings that are appropriate for installing a demand control as a retrofit.

HMG conducted three months of field testing at three different multifamily buildings for this research and concluded that demand controls save 250 to 4,500 therms/year (normalized to a 50,000 sf building). They also concluded that temperature modulation controls save from 0 to 3,600 therms/year. We decided against temperature modulation controls for this program due to the higher gas savings achievable with demand control. One author of the proposal (Matthew Tyler) actually served as the HMG project manager

[11] Heschong Mahone Group. June 2006. "Measure Information Template—Central Hot Water Distribution Systems in Multifamily Buildings" *2008 California Building Energy Efficiency Standards*. PDF Version of document downloaded on June 11, 2007 from http://www.energy.ca.gov/title24/2008standards/documents/2006-07-12_workshop/reviewdocs/

for almost the complete duration of this research project before leaving to join Benningfield Group. Thus, we have extensive first-hand knowledge of the demand control installation, operation, and gas savings.

HMG reports a very large range of potential savings, from 250 to 4,500 therms/year; the average of this range is 2,400 therms/year. This compares with the results of Eley's Measure Analysis report of 1,583 therms/year and the average of the three buildings reported in their CASE report of 2,200 therms/year. For this program, we accept the most conservative annual savings number of 1,583 therms. Multiplied by the 100 control systems that the program will install yields a total annual savings of 158,300 therms.

Table 1. Summary of demand control annual therm savings reported by others

Savings from Eley's CASE report, Bldg 1	**1,804**
Savings from Eley's CASE report, Bldg 2	**1,840**
Savings from Eley's CASE report, Bldg 3	**2,946**
Average savings from HMG's reported range of savings	**2,400**
Savings from Eley's Measure Analysis Report	**1,583**
Proposed savings for this Demand Conti for Multifamily CDHW program (minimur of the savings numbers listed above)	**1,583**

The annual recirculation pump energy for various pump control scenarios is published in Eley's Measure Analysis report. Continuous pumping uses 350 kWh/year, while demand control reduces the pump energy to only 23 kWh/year, an annual savings of 327 kWh. Multiplied by the 100 control systems that the program will install yields a total annual savings of 32,700 kWh.

Peak Demand Reduction Estimation Methodologies (Electric)

Any peak demand reduction is negligible for this measure.

Base Case Costs

The base case is simply a circulation pump with no controls that runs continuously. The base equipment cost is $400 plus an additional $500 in labor for installation, for a total installed cost of $900.

Measure Costs

The measure is an On-Demand Intelligent Pump that costs $1,500 plus an additional $500 in labor for installation, for a total installed cost of $2,000. Installation is identical to the base case as the measure equipment is very similar to the base case equipment with the addition of on-board control panel.

Incremental Measure and Installed Costs

The incremental cost for this measure is $1,100 ($1,500 demand pump - $400 continuous pump). The installation cost is $500 for the base case and also for the measure.

References and Citations

California Department of Finance, Demographic Research Unit. County/State Population and Housing Estimates.

California Energy Commission. April 2002. "Part I: Measure Analysis and Life-Cycle Cost" 2005 California Building Energy Efficiency Standards. PDF Version of document downloaded on June 11, 2007 from http://cacx.org/title24/2005standards/archive/rulemaking/documents/document_list.html

California Energy Commission. May 2002. "Code Change Proposal for Multifamily Water Heating" 2005 California Building Energy Efficiency Standards. PDF Version of document downloaded on June 11, 2007 from http://cacx.org/title24/2005standards/archive/rulemaking/documents/document_list.html

Heschong Mahone Group. June 2006. "Measure Information Template—Central Hot Water Distribution Systems in Multifamily Buildings" 2008 California Building Energy Efficiency Standards. PDF Version of document downloaded on June 11, 2007 from http://www.energy.ca.gov/title24/2008standards/documents/2006-07-12_workshop/reviewdocs/

Personal communication with Mark Franklin, President of Saves You Energy, LLC, a demand control provider.

Appendix B: On Demand Efficiency Program Rationale

This program saves energy by improving the market penetration of an advanced technology for central water heaters in multifamily buildings. This program provides an incentive of $1600 for installation of a hot water demand control system that controls the pump on a CDHW system recirculation loop. In a continuous pumping system, the pump operates nonstop to circulate hot water through the loop. The recirculation loop loses heat continuously and the boiler must fire to replenish the lost heat. A timeclock is sometimes installed to control the pump, but they are often broken, overridden, removed, or mis-set (especially due to power failures)12. Other kinds of controls either (a) respond to changing conditions in a way that masks CDHW system component failures, (b) don't respond quickly enough to changes to avoid tenant complaints on holidays, or (c) do not

[12] Personal correspondence with California Energy Commission staff and Heschong Mahone Group.

respond at all and therefore require sub-optimal settings to avoid complaints. A demand control system switches on the recirculation pump only when there is demand for hot water and the hot water return temperature is below a certain setpoint. This scenario minimizes the opportunity for heat loss through the recirculation loop and thus reduces gas consumption.

In a CDHW system with no controls, the pump continuously circulates hot water through the recirculation loop without stopping, even during periods of no hot water usage. In this scenario, the recirculation loop is continuously losing heat to the surrounding environment. A demand control system commands the pump on only when there is hot water demand and the hot water return temperature is below a setpoint temperature.

When a timeclock is used to control a recirculation pump, the installer needs to guess when hot water is needed. They have direct control of the hours per day of pump operation. This decision directly impacts the boiler gas consumption, yet no logic is readily available to optimize the timeclock program with respect to minimal gas consumption. In fact, the programming decision is usually biased toward minimizing tenant complaints, which means shutting off the pump only in the middle of the night when they hope no one needs hot water. Tenant behavior and hot water usage can be unpredictable and spontaneous, so tenants can experience a very long wait for hot water, especially when a tenant works during the day and is awake late at night. Timeclocks are often disabled within a few months of installation due to tenant dissatisfaction and complaints about hot water availability. The pump then runs continuously, eliminating any energy conservation benefits. Unlike the operation of the demand pump, when a re-circulation pump is deactivated by a time-clock, a large volume of water may need to be dumped down the drain before tenants' receive satisfactorily hot water.

Aquastats have a high temperature setpoint (when the temperature of the water in the return loop reaches this temperature the pump shuts off) and a low temperature setpoint (when the temperature of the water in the return loop drops below this temperature the pump turns on). In concept the average daily temperature of the loop is lowered a few degrees. In reality, the high temperature setpoint is set at the same temperature as the water in the storage tank. Of course as the water travels through the building it loses heat and by the time it comes back to the boiler it will be at least 15º F cooler. For example, if the high temperature setpoint is 135º F, the low temperature setpoint is 110º F, and the boiler temperature is set for 135º F, the return temperature in a very efficient system might be as high as 120º F. It will never reach the Aquastat's high temperature setpoint and therefore the pump will never shut off, thereby eliminating any energy conservation benefits.

Temperature modulation controls are proven energy conservation technologies when they are installed correctly (which is usually the case) and maintained by trained technicians (which is rarely the case for two of the three main brands). Trained technicians who install the system understand how it works and have an understanding of the monitoring and control features. However, the site maintenance staff is typically under-trained and unprepared to properly maintain the system.

After installation temperature modulation controllers remain in a passive mode for a period of time, simply monitoring hot water demand. Based on the learned pattern of

usage, the controller algorithm adjusts the water temperature in the storage tank based on anticipated needs, increasing the temperature to meet higher demand. The water temperature in the storage tank determines when the boiler will fire – lower set-point temperatures during off-peak usage periods means the boilers will remain off for longer periods of time. Under normal circumstances this may be a sound strategy. However on some occasions such as a holiday, forecasting hot water demand based on the previous 7 days can result in lack of hot water and a complaint call to management.

Additionally, when something else in the CDHW system fails, the controller can incorrectly "learn" that higher temperature water is needed. One temperature modulation control manufacturer overcomes this limitation by setting the temperature ramp up and ramp down periods manually and continuously monitoring system performance. They can tell when apparent usage outside the historical range results from a component failure, rather than intermittent schedule changes, and they notify site staff that the system needs attention. Still, real-time response to actual increased demand cannot be handled, so the temperatures and timing of ramp-up and ramp-down must be programmed to meet the worst cases expected. This means that significant potential energy savings are still left on the table.

The D'mand Pumps use a water flow sensor and an adjustable temperature sensor to monitor real-time events. In order for the pump to come on there must be a demand for hot water and the temperature of the return line must be lower than a certain temperature setpoint. When hot water is needed, the controller turns the pump on and it moves water through the recirculation loop at approximately 26 gpm, which is 5 to 10 times faster than a standard pump. When there is no demand, the hot water stays in the insulated storage tank, which is much more efficient at retaining heat than the copper recirculation line. In order to maximize energy efficiency, today's technologies must react in real-time and in a manner that continues to provide a high level of service. If a technology cannot meet these requirements they will often be disabled shortly after installation, or they must be set at significantly lower than maximum efficiency.

Appendix C: Monitoring Equipment Details

Gas meters

The ODE team has five gas meters of various sizes. The size used for any particular CDHW system depends upon the Btu input of the boiler or water heater. Using a smaller meter on a system with a large Btu input requirement may create an unacceptable pressure drop. Since the cost of a meter increases as the size of the meter increases, we have a range of sizes instead of all large meters. The range of gas meters the team uses include a Dresser Roots Meter model number 8C15 at the large capacity end, to the American Meter Company AC-250 at the lower capacity end.

Model 5C15 & 8C15 ROOTS® Meter

Features:

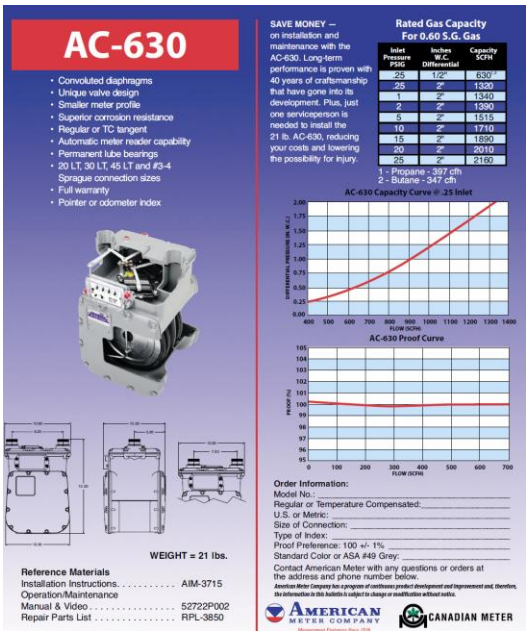
- Small, Compact Size
- No Lubrication Needed
- Dial or Odometer Index
- Seal or Vented Index
- Top or Bottom Inlet

Series Z Compact Meters

Aesthetically pleasing 5C15 (500 acfh) and 8C15 (800 acfh) compact line-mounted meters are ideal for small commercial loads at pressures up to 15 PSIG (1 Bar). Series Z meters provide excellent measurement accuracy starting at "pilot loads" and continuing throughout the range of the meter. A dial face index is standard. An odometer-type index is available upon request.

Specifications

	5C15	8C15
Base Rating (Q Max)	500 cfh (14.2 m^3/h)	800 cfh (22.6 m^3/h)
Diff on Air Q Max	< 0.5 in. w.c.	< 0.9 in. w.c.
Weight	7 lbs. (3.2 kg)	7 lbs. (3.2 kg)
Size	8.375" x 6.625" x 4.95"	8.375" x 6.625" x 4.95"
MAOP	15 psig (103 kPa)	15 psig (103 kPa)
Start Rate	2.3 cfh	2.3 cfh
Stop Rate	1.75 cfh	1.75 cfh
Lubrication	Lubed for Life	Lubed for Life
Temperature Rating	-40°F to 140°F (-40°C to 60°C)	-40°F to 140°F (-40°C to 60°C)
Accessory Options	Dial or Odometer Index	Dial or Odometer Index
Index Box Options	Sealed or Vented	Sealed or Vented
Inlet Options	Top or Bottom	Top or Bottom
Connections (std)®	Sprague #4	Sprague #4
Accuracy	±1%	±1%



AC-630

- Convoluted diaphragms
- Unique valve design
- Smaller meter profile
- Superior corrosion resistance
- Regular or TC tangent
- Automatic meter reader capability
- Permanent lube bearings
- 20 LT, 30 LT, 45 LT and #3-4 Sprague connection sizes
- Full warranty
- Pointer or odometer index

SAVE MONEY — on installation and maintenance with the AC-630. Long-term performance is proven with 40 years of craftsmanship that have gone into its development. Plus, just one serviceperson is needed to install the 21 lb. AC-630, reducing your costs and lowering the possibility for injury.

Rated Gas Capacity For 0.60 S.G. Gas

Inlet Pressure PSIG	Inches W.C. Differential	Capacity SCFH
.25	1/2"	630
.25	2"	1320
1	2"	1340
2	2"	1390
5	2"	1515
10	2"	1710
15	2"	1890
20	2"	2010
25	2"	2160

1 - Propane - 397 cfh
2 - Butane - 347 cfh

AC-630 Capacity Curve @ .25 Inlet

AC-630 Proof Curve

WEIGHT = 21 lbs.

Reference Materials
Installation Instructions AIM-3715
Operation/Maintenance Manual & Video 52722P002
Repair Parts List RPL-3850

Order Information:
Model No.:
Regular or Temperature Compensated:
U.S. or Metric:
Size of Connection:
Type of Index:
Proof Preference: 100 +/- 1%
Standard Color or ASA #49 Grey:

Contact American Meter with any questions or orders at the address and phone number below.

American Meter Company has a program of continuous product development and improvement and, therefore, the information in this bulletin is subject to change or modification without notice.

AMERICAN METER COMPANY
CANADIAN METER

These meters can be connected to the data loggers so that consumption data can be aggregated over set time periods (ten minutes in our case) and time stamped for correlation to other data.

Water flow meters

We have three water flow meters, though two did not operate well during the course of the monitoring. Enovative worked with the manufacturer to identify the problems and repair them, but they still proved to be unreliable. Consequently, we have water usage on only a subset of the monitored sites. The meters are in 1.5" and 2" sizes. All of the water flow meters were manufactured by Assured Automation. The picture below illustrates these meters.

WM Series

Water Flow Meter

The WM Series water meters are multi-jet (inferential) impeller meters. They measure total flow in gallons. The impeller and magnet are the only moving parts in the measuring chamber. The chamber is located in a strainer basket, which allows for high amounts of impurities to be passed through the meter without affecting its operation. The impeller movement is transferred by a magnetic coupling to the hermetically sealed register.

FEATURES

- Proven multi-jet water meter design.
- Hermetically sealed dry dial protected from the elements, won't discolor or fade.
- Integral strainer in measuring chamber protects measuring components from foreign debris.
- Tempered glass lens for continued readability.
- Hinged lens cover to protect lens and register from damage.
- Magnetic drive to eliminate potential leak point.
- Easy to read register display with large clear digits.
- Odometer measures in gallons up to 9,999,999 (99,999,999 for WM150/200).
- Needle displays 10 gallons per rotation in 1/10th gallon increments with full gallon numbers. (100 gallons per rotation in 1 gallon increments with 10 gallon numbers for WM150/200)
- Low flow indicator.
- Frost resistant forged bronze body.
- Horizontal or vertical installation.
- Connections are external non-tapered meter threading (comes with Male NPT thread adapters).

WM SERIES MODEL NUMBERING

Model Number: WM X X

Body x Connection Size:
50 = 5/8" x 1/2"
75 = 5/8" x 3/4"
7575 = 3/4" x 3/4"
100 = 1" x 1"
150 = 1-1/2" x 1-1/2"
200 = 2" x 2"

Optional:
Output:
PO = Dry Contact Reed Switch Pulse Output*

* Not available on WM75, use WM7575.

MAXIMUM PRESSURE
150 PSI

TEMPERATURE RANGE
Up to 122°F

MATERIALS OF CONSTRUCTION
Housing:
Epoxy coated forged bronze.

SPECIFICATIONS
Accuracy:
± 1.5%.

Data loggers and related equipment

We also employed five DataPro data loggers, four SmartLoggers, several current transformers and thermistors. This equipment all came from Dent Instruments and was designed for ease of interface.

SMARTloggers™

Technical Information

GENERAL SPECIFICATIONS	
Logger Types	**LIGHTING**: Internal Photo Sensor **MAG**: Internal Magnetic Field Sensor **CT**: External Current Transformer **CONTACT**: External Switch or Relay
Display	5-digit LCD showing Total On-Time, Percent On, On/Off Annunciator
Time Stamps	Month, Day, Year and Hour, Minute, Second
Time Resolution	One second
Sampling Rate	One per second (1 Hz)
Data Analysis	Statistics, summaries, graphs and data export using **SMART**ware™
Memory	8,000 records, ring memory plus Separate On-Time Totalizer
Sensitivity	**LIGHTING**Logger™: Adjustable **MAG**logger™: 40 mGauss min **CT**logger™: 0.25 amp min **CONTACT**logger™: Dry contacts

COMMUNICATION SPECIFICATIONS	
Communication	USB with **SMART**logger™ communications cable
MECHANICAL SPECIFICATIONS	
Operating Temperature	0° to 60°C (32° to 140°F)
Operating Humidity	5% to 95% non-condensing
Battery Life	5 years
Internal Clock	Real-Time, Crystal controlled, true calendar, 20 ppm accuracy (~1 min/month)
Weight	40 gm (1.3 oz)
Dimensions	6.3 x 3.8 x 1.9 cm (2.5" x 1.5" x .75")
Mounting	Magnets, Velcro®, or Mounting Hole
Warranty	Three Years

SMARTware™: Data Analysis Made Easy

- All **SMART**loggers™ use **SMART**ware™ Windows®-based software that makes it easy to analyze and visually present recorded data
- Monitor usage trends with the click of a mouse
- Pre-programmed graphs and analysis functions make understanding your data simple
- Easily export usage data into other popular spreadsheet and database programs
- Extremely flexible to accommodate a wide range of measurement needs

Need Answers to Energy Questions?

The **SMART**logger™ TOU series of instruments are designed to monitor the On-Off status, Time-of-Use operating schedule, and Total On-Time for energy consuming devices and systems. Models are available for Lighting systems, Motors, Relays and Switches, and virtually any electric load. The non-contact monitoring makes installation simple. Each of these small, robust instruments provide powerful data for superior energy management.

Four **SMART**logger™ Models Available

CTlogger
External Current Transformer

LIGHTINGlogger
Internal Photo Sensor

MAGlogger
Internal Magnetic Sensor

CONTACTlogger
External Switch or Relay

Contact Information

DENT INSTRUMENTS
DENT Instruments, Inc
Energy & Power
Measurement Solutions
64 NW Franklin Avenue
Bend, Oregon 97701 USA
541 388 4774
800 388 0770
fax 541 385 9333
www.DENTinstruments.com

DISTRIBUTOR
PLACE CONTACT INFO HERE

SMARTware
SMARTware™ 2008

DATApro™

Multi-Purpose 4-Channel Data Logger

- Accepts 4 channels of current, pulse count, temperature and DC voltage.
- Measures True RMS (current only).
- User-defined recording intervals of 3, 15, 30 seconds or 1, 2, 5, 10, 15, 20, 30 minutes or 1, 12, or 24 hours and the ability to select maximum, minimum, average, instantaneous or all parameters.
- Expandable memory from 25,000 records standard to 100,000 records with the high-memory option), allows for weeks to months of recording time.
- Better than 1% accuracy (<0.5% typical).
- Communications via direct RS232 connection, internal modem or wired/wireless LAN systems.
- ELOG™ Windows-based software package for programming, set-up, communicating, data retrieval and analysis. Easy data exporting to almost any analysis program like Excel®.
- Installs in minutes and is equipped with strong magnetic strips for securing within panels.
- Made of heavy plastic, only 8 x 15 x 6 cm (3.2" x 5.9" x 2.4") and just 340 gm (12 ounces) to easily fit inside panels for safety and convenience.
- Available weather-tight enclosure for outdoor or harsh environments.
- UL Listed for USA, Canada & Mexico and CE Compliant for Europe.

DATApro
4-Channel
Recording Meter
DENT

Software

The software employed in the monitoring was also from Dent Instruments. The software is called ELOG and Smartware, both of which were designed to work with the DataPro loggers and related equipment. The software resides on a laptop and allows the user to download data from the loggers, control the loggers (e.g., adjust sensitivity), clear logger memory after downloading data, graph the data, perform other analyses, export the data to another program (e.g., Excel), print reports from the data, and perform several other functions. Some of the analyses that the SmartWare enables the user to perform include: summary statistics, load profiles, multiple logger file aggregation, analysis of TOU rate periods, and run-time graphs.

ELOG™ Software

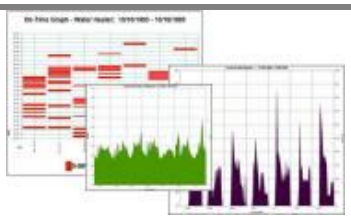
For use with the **ELITE*pro*** and the **DATA*pro*** series of instruments.

The **ELOG** software is used with the **ELITE*pro*** or **DATA*pro*** instruments. This Windows™-based software allows user defined recording intervals of 3, 15, 30 seconds, 1, 2, 5, 10,15, 30 minutes, and 1, 12, and 24 hours with the ability to select maximum, minimum, average, instantaneous, or all parameters.

It graphically displays recorded data, performs analyses and allows automatic, remote data collection and alarm capability to detect and display selected values once predetermined high or low points are met within any measurement parameter. Data is also easily exported to popular spreadsheets and databases for special analyses.

SMARTware™ Software

For use with **SMART*loggers*** series of instruments.



All **SMART*loggers*** use SMART***ware***™ software that makes it easy to analyze and visually present monitored data.

The **SMART*ware***™ software provides a number of 'one-touch' analyses including Summary Statistics, Transition & Time Series Data Points, Multiple Logger file aggregation, Analysis by TOU rate periods such as Rate Schedule Analysis, Run-Time, Time Series, On-Time & Load Profile graphs, and exporting capabilities to popular spreadsheets and databases such as Excel® and Access®.