A Study of New Homes Built

For Cook Inlet Housing Authority in 2006

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COOK INLET HOUSING AUTHORITY – NEW HOME STUDY

Sunrise Energy Works, in collaboration with Arctic Energy Systems, Analysis North, Flattop Technical Services, and Alaska Building Science Network , was contracted by Cold Climate Housing Research Center (CCHRC) to provide monitoring and research on building performance of newly built Cook Inlet Housing Authority (CIHA) homes. The purpose was to identify systems that are performing well, and provide recommendations on systems or strategies that could be improved. Funding for this project is through CIHA and a grant from CCHRC providing funds and equipment from Alaska Housing Finance Corporation (AHFC).

The original proposal was to test and monitor 12 different homes, but start-up delays and an early spring meant that only 4 homes were actually studied. <u>Due to the very small sample size, it is not possible to make any general statements relating specific house characteristics and performance. Instead, this report describes the observations and measured performance in those specific homes.</u>

<u>I. Background</u>:

The original objective was to determine if new boiler homes built by CIHA and new furnace homes built by a local contractor for CIHA actually performed as designed, to meet expectations for energy efficiency, homeowner comfort, indoor air quality, and humidity control.

The original plan was to install monitoring equipment in January 2006, to monitor in the cold winter months, and to have the final report completed by June 2006. Due to a number of project delays and an early onset of spring temperatures, monitoring could not begin until the end of February and only 4 homes were able to be monitored. Two of them were CIHA-built boiler homes and two were contractor-built furnace homes. In the fall of 2006, monitoring equipment was removed and data was analyzed. This did provide an opportunity to monitor the crawlspace temperature and relative humidity during the spring and summer, when problems are more likely to occur..

<u>II. Initial Evaluation and Installation of Monitoring Equipment</u>

The first stage of this project included the following activities:

1. Installation of gas meters on gas lines coming from the street
2. Installation of data loggers:
    a. Temperature/Relative Humidity – living area, bedrooms, crawl
    b. Carbon monoxide – living
3. Runtime loggers: bath fans, crawl fan, garage heater, furnace, HRV, water heater
4. Zonal pressure tests: house to crawl, garage, attic
5. Fan flow and relative humidity readings
6. Infrared camera inspection

Observations During Installation of Monitoring Equipment

<u>Bath Fans - MV05</u>

We found no or low flow on two bath fans: downstairs hall & upstairs hall.
Screws blocked the flow on the downstairs fan damper. We were concerned that the upstairs vent might also be blocked or the outside damper iced over, but the hood is on a 2nd floor gable making it tough to check.

CIHA personnel told us that one of the exhaust hoods was unused. The mechanical contractor originally ran the laundry exhaust up with the group of exhaust hoods at the back gable end but later the dryer exhaust was rerouted and the exhaust hood was abandoned.

We checked the bath fans again after CIHA crew was supposed to have fixed them - two hoods still did not open. It also appeared that one damper did not close.

Attic Access: MV03, MV05

These 2-story houses have attic hatches nailed & screwed requiring trim removal - not the typical hatch that pushes up into the attic. This made it a major problem to place temperature/RH sensors in the attic and to inspect insulation. We were advised by CIHA to abandon that monitoring station in all the attics.

Crawl Vent: MV03, MV05

These houses have a hooded 6" round crawl vent with the damper held open by a screw behind the bug screen. We measured ~ 20 cfm air flow into the crawl adding about 1400 Btus/hour to the heat load at zero F. Closing this vent, especially in winter, would save energy and still allow the crawl exhaust fan to pull drying house air down through the crawl when the dehumidistat calls for venting. A 40% RH setting on the crawl control should be adequate. It was decided that crawlspace vents would remain closed for the study.

Garage Unit Heaters: MV03, MV05

The garage unit heaters were a different model than those that had been used for developing runtime sensors. It took several attempts to finally come up with sensors that could provide useful information.

Gas Meters: MV01, MV02, MV03, MV05, MV07, MV09

Gas meter indexes were installed at 6 houses. We initially found high counts from the meter at 517 Price. Since it was unoccupied we investigated. It appeared to be a faulty pulse indexer, the manufacturer sent a replacement and we scheduled Enstar to install a new one. After several additional tests, the replacement indexer also proved faulty. The second replacement indexer was installed and re-launched.   We were able to confirm the indexer at other locations read accurately.

Summary of commissioning items noted during initial inspection of these homes:

- HRV – dehumidistat not wired correctly
- Bath fan damper blocked with screw
- Bath fan dehumidistat didn't work
- Disconnected Duct in crawl
- Duct leakage in attic
- Furnace /plenum leakage – no air sealing per manufacturer.
- Fiberglass in rim joist – wet
- Crawlspace vent hood damper reversed
- Garage combustion air vent not needed
- Integral de-humidistat on bath fan not working

III. RESULTS
Summary

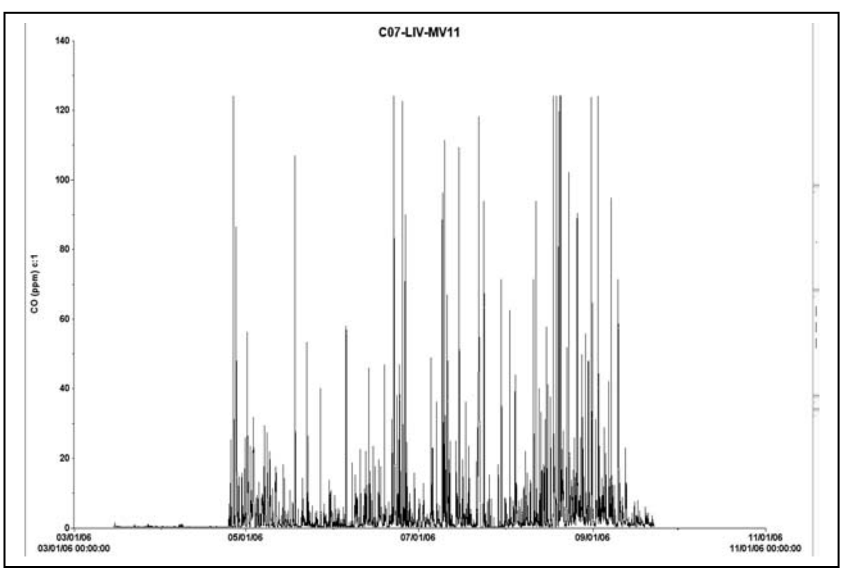
Four homes were studied in some detail. Two were 2-story homes with boilers that provided both domestic heat and hot water. The other two were 1-story homes with furnaces for domestic heat and standard domestic hot water tanks.

The following section details the data gathered from the individual homes. This includes temperature and relative humidity readings from the living area and the crawl space. Carbon monoxide levels were measured in the house and the garage. Runtimes were recorded for the furnace and water heater or for the boiler. Ventilation fan runtimes were also recorded. **We have summarized this data and noted details on specific house characteristics and performance. However, because the sample size of this study is so small, no substantive conclusions could be drawn from this study.**

A. Temperature/RH (Table 1)
Living area and bedroom temperature and relative humidity in all homes were usually within design parameters of 65-70°F and 30-50% RH. However, both of the furnace-heated homes had higher temperatures and relative humidity than the boiler homes, with an average RH of 49% and summertime RH averaging 60-70%.

Crawlspace temperature levels in all homes averaged about 65°F while relative humidity averages ranged from 39-78% . Both furnace-heated homes with passive crawlspace ventilation had higher humidity levels than boiler heated homes with crawlspace fans. Relative humidity levels were highest during the summer months, so there was little chance of condensation, but mold could become a problem with extended periods of high RH.

B. Carbon Monoxide (CO) (Table 1)
Carbon monoxide readings inside all homes indicated a background or minimum level of .2 parts per million (ppm). One home MV11, had significantly high levels of CO, with a maximum of 124.3 ppm, and an average of 4 ppm. Residents reported that no one smokes in the building and the garage was not used for parking cars. We surmise that the high levels may be related to cooking on the gas kitchen range, and we did report our concerns to both CIHA and the homeowner. Gas kitchen ranges may not be appropriate for small, tight homes. ASHRAE 62 Standard requires quieter kitchen range hoods, in an effort to encourage regular usage.



C. Ventilation (Table 2)

MV03 was the only home that was part of the intensive monitoring that was ventilated with an HRV. The HRV was operating continuously during the heating months and was off for much of the summer. The bath fans installed in this HRV home ran an average of only 2% of the time, suggesting the HRV exhaust from the bathrooms might have been sufficient if a boost timer for the HRV were installed in the bathrooms.

MV05 was also monitored for bath fan runtime. It had an upgraded bathroom fan installed in the hallway that was intended to provide the needed whole-house ventilation. Results indicate the whole-house fan was very seldom used (less than 5% of the time during the study period), and it probably would have been more effective to utilize the fan in the adjacent bathroom as both the bath and whole-house ventilation. Several of the bath fans ran for several months during the summer, suggesting the dehumidistat control for the fan was set too low for summer conditions. This is a common problem with humidity controls and homeowners understanding of how they operate. During the non-summer months, the bath fans ran about 5-10% of the time, so it is not likely that they were contributing significantly to the whole house ventilation during the winter months. Note: Many previous studies have shown that any whole-house exhaust only ventilation system runs the risk of pulling garage and crawlspace air into the home as makeup air for the exhaust fan, potentially creating indoor air quality problem. (See Appendix IV)

D. Maximum Depressurization and Zonal Pressure Tests (Table 3)

Any device that exhausts air from a tight house (exhaust fans, clothes dryers, furnace fans, furnace and water heater vents, fireplaces) can compete with the normal venting of combustion products from combustion appliances. This can lead to backdrafting and spillage. This spillage of flue gases from combustion equipment into the home is caused by depressurization (negative pressure). Flue gases can be harmful and even deadly (carbon monoxide and benzene). Depressurization can have other less dramatic, but equally important, health and comfort effects. It can speed the entrance of radon and other soil gases into the house, increase air infiltration through the building shell, and cause moisture damage.

It is generally accepted that depressurization of -5 Pascals (Pa) or more can cause problems for natural draft appliances. Continuous depressurization may be caused by forced air systems or whole-house ventilation systems. Intermittent depressurization may be caused by exhaust fans, clothes dryers, and other exhaust devices. Unlike the furnaces and tank water heaters in the contractor-built homes, the CIHA built homes with direct-vent boilers are not susceptible to these depressurization issues.

A “worst case” depressurization test can be done to determine if the exhaust fans cause unintentional depressurization in combustion air zones (CAZ). The existing fans (air handler, exhaust fans, clothes dryer, etc) are used to create the largest possible negative pressure in the area of the appliance. We can then check the CAZ(s) for the strength of the negative pressure and to see if the appliance will draft properly under these conditions. Table 4 shows the negative pressures exerted by each fan and all fans in combination. For both houses tested, the maximum negative pressure was about -14 pa. The table below shows generally accepted depressurization limits when various types of combustion appliances are in use. These limits are for cold outside temperatures and may be higher in warmer weather. Comparing this table with the Table 4 results of the homes tested, we can see that the natural draft water heater may be the largest potential problem in these homes.

CAZ Depressurization Limits

Venting Condition	Limit(Pa)
Orphan natural draft water heater (including outside chimneys)	-2
Natural draft boiler or furnace commonly vented with water heater	-3
Natural draft boiler or furnace with vent damper commonly vented with water heater	-5
Individual natural draft boiler or furnace	-5
Mechanically assisted draft boiler or furnace commonly vented with water heater	-5
Mechanically assisted draft boiler or furnace alone, or fan assisted DHW alone	-15
Exhausto chimney-top draft inducer (fan at chimney top); High static pressure flame retention head oil burner; Sealed combustion appliances	-50

Zonal pressure diagnostics (ZPDs) have become an established tool in diagnosing indirect air leakage paths in houses. ZPDs are used to identify and measure series leaks or leaks that pass through several zones of the house. For example, air leaking through the house must first move from the garage into the house and then through the house to the outside. ZPD techniques typically combine Blower Door airtightness test results with zonal pressure measurements made both before and after an opening or hole has been added to one surface of the zone being tested. ZPDs measure the pressure difference between the living space and the bordering zone (the garage) and the bordering zone and the outdoors. The techniques rely on the principle that the ratio of the pressure difference across the interior and exterior boundaries of a series leak is a direct function of their leakage area. In this study, *ZPD Calculation Utility*, a simple software program developed by The Energy Conservatory, was used to perform ZPD calculations in several of the houses. Table 4 provides those results.

The **Ratio** value provides information on the location of the primary air barrier for the monitored zone. If the **Ratio** value is between 0.0 and 0.5, the zone is better connected to the outside than it is to the inside of the house (i.e. the primary air barrier for that zone is between the house and the zone). If the **Ratio** value is between 0.5 and 1.0, the zone is better connected to the inside of the house than it is to the outside (i.e. the primary air barrier for that zone is between the zone and outside). Table 4 shows that in both cases the garage is better connected to the outside than to the inside of the house, while the crawl is “half-in, half-outside”. When attached garages are used for cars, there is the possibility of considerable spillage of car exhaust and other garage pollutants into the living zone.

It should be noted that the houses tested showed some leakage area between the crawl space and the garage and leakage area results for the living area of the house to a zone are distorted by an interconnection of adjacent zones such as the crawl space and the garage. This is important as pollutants may travel between those zones before entering the living area.

E. Furnace, Boiler, and Water Heater Use (Table 4)

The boiler-heated homes used modulating boilers, featuring AFUE efficiencies in the range of 92-93%. When used in common low temperature applications, such as heating domestic hot water, the annual efficiencies rise to 98%. They were the smallest size in their model, with about 80 million Btu input.

All four of the furnaces had AFUE efficiencies in the 80% range. MV07 was a two story house with a 64,000 Btu output furnace: the other three furnace homes had an output of 46,000 Btus.

Design Heat Load

Determining the design heat load is useful for properly sizing heating equipment. By using runtime dataloggers placed on the furnace gas valves and comparing fuel usage with outside temperatures, we were able to estimate the design heat load requirements and compare them to the AkWarm estimates and to the size of the installed heating equipment. We also looked at the normalized annual energy use from the data logging but decided not to include it in the report due to the inability to reasonably compare homes because of the various configurations of heating system type, base load uncertainly, and whether garages were included or not.

Because the boiler-heated homes had modulating boilers, we were not able to directly measure boiler usage/runtime. We did collect total gas usage from the home gas meters, and were able to estimate boiler usage for house and garage combined space heating along with an estimate for the base load (cooking, domestic water heating, dryer, and boiler standby losses).

The garage heat is included in the design heat load and energy use for boiler homes, both attached and detached garages. Runtime data on the garage heaters was not reliable enough to allow us to pull out the garage heat to more directly compare boiler houses to furnace houses. MV07 and MV09 furnace houses were measured at the gas meter; those figures include the garage and baseloads as well as furnace use.

Although we were not able to make any adjustment for occupant loads, domestic hot water energy use appears to be significantly higher for homes with stand alone water heaters. The chart below shows that in boiler homes, base fuel use, which includes cooking and clothes drying as well as heating domestic hot water, was significantly less than the measured water heater use in the furnace homes.

	Average Base Fuel Use (Btu/hr)	Water Heater Avg Btu /hr
MV01 - BR	1099	
MV02 - BR	2945	
MV03 – B2	3666	
MV05 – B2	3401	
MV11 - FR		5986
MV12 - FR		4062

Table 1. MONITORING RESULTS FOR TEMPERATURE, RELATIVE HUMIDITY AND CARBON MONOXIDE											
	House CO(ppm)	**House**		**Crawl**		**Master Bedroom**		**Bedroom3**		**Bedroom2**	
	Low-High (Avg)	Temp °F	RH%	Temp	RH%	Temp	RH%	Temp	RH%	Temp	RH%
MV03				(66°F)	23%-61% (39%)			68°F	23%		
MV05	.2 ppm-12 ppm (1.8 ppm)	47°F-79°F (72°F)	11%-57% (33%)			45°F-79°F (72°F)	20%-80% (35%)			61°F-82°F (70°F)	23%-49% (30%)
MV11	.2 ppm-124.3 ppm (4.0 ppm)	65°F-84°F (72°F)	12%-87% (42%)	60°F-69°F (65°F)	24%-75% (59%)						
MV12	.2 ppm-20.8 ppm (3.35 ppm)	63°F-81°F (72°F)	13%-79% (49.5%)	60°F-71°F (65°F)	24%-78% (62%)						

Table 2. FAN USAGE (CFM) – FROM RUNTIME DATALOGGERS									
	Whole house ventilation	Main Fan Flow (cfm)	On Time %	Master Bath Fan Flow	On Time %	Bath Fan 2 Flow (cfm)	On Time %	Bath Fan 3 Flow (cfm)	On Time %
MV03	HRV	60-150	64%	48	3%	60	2%	67	0%
MV05	Whole House	40	5%	42	56%	22	47%	23	3%

Table 3. MAXIMUM DEPRESSURIZATION & ZONAL PRESSURE TEST RESULTS												
Hse ID#	**MV01**	**MV02**	**MV03**	**MV04**	**MV05**	**MV06**	**MV07**	**MV08**	**MV09**	**MV10**	**MV11**	**MV12**
Stack -(Pa)			-6		-6							
Max Dep.- (Pa)			-14.4		-14							
Range ON (Pa)			-3		-3							
Dryer ON (Pa)			-1.5		-1.8							
All Bath Fans ON (Pa)			-3		-1.2							
WHF ON (Pa)			**n/a**		-0.6							
CFM50 AkWarm / Hse		1052	*1619*		1345		1490		2156		1407	1215
CFM50 Hse only		789	*1403*		1234		1169		1032		989	993
Crawl Pressure Ratio		0.579	0.474		0.661		0.671		0.656		0.663	0.579
Gar. Pressure Ratio		0.299	n/a		n/a		0.470		0.121		0.104	0.197
Eq LA hse-gar		~29sq.in.	n/a		n/a		~66sq.in.		~37sq.in.		~14sq.in.	~25sq.in.

Table 4. ALL HOUSE CHARACTERISTICS, AKWARM RESULTS & COMPARATIVE FUEL USE DATA												
House Characteristics			**Air Flow Data From**			**Heating System**		**AkWarm Calcs**			**Modeled From Study Data**	
House#	type	house size sq ft	Vent	ACH50	Garage	System Type/ Efficiency %	Size input/ output	Energy Rating/ Points	Estimated Annual energy[5]	Design heat loss Btu/hr H= house G=garage	Design fuel use Btu/hr	Modeled Data Notes
MV01	ranch	1332	hrv	2.2	attached	boiler/93% indirect dwh	80,000/ 71,000	5 Star 90.7	$1420	H –26,176 G – 6,347	35,114	1, 2
MV02	ranch	1332	hrv	2.02	attached	boiler/93% indirect dwh	80,000/ 71,000	5 Star + 92	$1379	H - 30,672 G - 5,874	38,203	1, 2
MV03	2story	1487	hrv	5.92	detached	boiler/93% indirect dwh	80,000/ 71,000	5 Star 89.4	$1521	H - 39,778 G-No data	51,133	1, 2
MV05	2story	1487	continuous no HRV	4.28	detached	boiler/93% indirect dwh	80,000/ 71,000	5 Star 90.8	$1443	H - 34,753 G- No data	46,894	1, 2
MV07	2story	1455	baths	4.16	attached	furnace/80% dwh EF .58	57,000/ 46,000	4 Star + 86.1	$1668	H - 34,496 G - 8,229	47,701	1, 2
MV09	ranch	1265	baths	4.15	attached	furnace/80% dwh EF .58	80,000/ 64,000	4 Star + 83.5	$1641	H - 28,498 G - 8,290	29,524	1, 2
MV11	ranch	1502	baths	2.97	attached	furnace/80% dwh EF .58	57,000/ 46,000	4 Star + 83.3	$1641	H - 30,383 G - 7,425	27,090	4
MV12	ranch	1265	baths	3.39	attached	furnace/80% dwh EF .58	57,000/ 46,000	4 Star + 83	$1766	H - 28,841 G - 7,776	30,803	3

1. Includes Garage Heat Load
2. Data from gas meter – house base loads may skew results: domestic hot water, cooking, dryer
3. Data Logger problems – may have affected results slightly
4. Statistical analysis marginal – poor R^2 in data
5. Estimated Annual Energy includes space heating, domestic hot water, lights and appliances. Energy costs are based on 2006 costs.

IV. CONCLUSIONS

Due to the very small sample size, it is not possible to make any general statements about performance based upon house characteristics. Instead, this report describes the observations and measured performance in specific homes.

1. Ventilation:
    a. None of the homeowners was very knowledgeable about the "hows and whys" of their ventilation systems. Some fans were left on indefinitely, others never used, and the HRV was inappropriately programmed. The separate "whole house fan" appeared to be an unnecessary extra, as the main bath fan was used much more consistently.
    b. Better commissioning of the ventilation systems at the time of installation would make sure each fan actually operates and at the design specification.
2. Mechanical Systems:
    a. Although we were not able to make any adjustment for occupant loads, domestic hot water energy use appears to be significantly higher for homes with stand-alone water heaters.
    b. The limited monitoring of fuel use and AkWarm comparisons indicate that furnace heating systems in ranch houses appear to be oversized by 50% to 117%. A smaller sized furnace may be more appropriate, especially if the installation savings could be put towards an electrically efficient furnace fan motor which has much lower electrical costs and the ability to provide optional low speed ventilation. The boilers also seem to be oversized, but because they are modulating boilers the penalty is not a significant an issue.
    c. Our attempt to monitor the gas meter on several homes did not prove to be as useful as we had hoped. Though we were able to estimate the space heating fuel use for the boiler homes, it was clearly not as accurate as being able to directly monitor the furnace homes. Monitoring fuel bills on a larger group of homes may prove to be more useful as a tool for comparing energy use for different types of homes.
3. Airborne Pollutants:
    a. The significant carbon monoxide levels in these houses is cause for further study. Of the three homes where CO monitors were installed, one home had very high CO spikes, and another had lower but still significant levels. In the home with the highest levels, the CO was attributed to a gas cook stove. It may just be that in small tight homes, electric stoves are a better option.
    b. Living area and bedroom temperature and relative humidity in all homes were usually within design parameters of 65-70°F and 30-50% RH. However, both of the furnace-heated homes had higher temperatures and relative humidity than the boiler homes, with an average RH of 49% and summertime RH averaging 60-70%.
    c. Crawlspace temperature levels in all homes averaged about 65°F while relative humidity averages ranged from 39-78% . Both furnace-heated homes with passive crawlspace ventilation had higher humidity levels than boiler heated homes with crawlspace fans.

V. RECOMMENDATIONS

1. Ventilation:
    a. Heat recovery ventilation provides a balanced, tempered air, and good distribution of air throughout the house. Smaller and simpler systems should help reduce the installation cost. As natural gas prices continue to rise, the value of heat recovery of an HRV will become a stronger incentive to utilize them. Exhaust only ventilation has been well studied in Alaska. Exhaust fans depressurize the home relative to attached garages and crawlspaces and have been found to increase pollutant transfer from garages and crawlspaces. Distribution of fresh air, especially to bedrooms has also been reported to be insufficient as well.
    b. Homeowners education as to the purpose of whole house ventilation and how to maintain their system is absolutely necessary for these systems to perform as intended.
    c. The mechanical exhaust ventilation of the crawlspaces in the CIHA homes appeared to work well at controlling relative humidity and little venting was necessary during the heating months, reducing energy costs. A heat recovery ventilator could also be used to adequately ventilate the crawlspace, thus eliminating the need for the exhaust fan.

2. Mechanical:
    a. Some of these homes had furnace duct work in the attic. This practice is not only an energy penalty, but can lead to other problems such as ice damming and is **strongly discouraged**. Leaky duct work in the crawlspace can lead to significant pressure imbalances in the home, as well. Proper specifications and commissioning on duct sealing and pressure balancing requirements would lead to better functioning forced-air heating systems. These issues are eliminated when utilizing a hydronic heating system, such as that employed on some of the homes.
    b. The practice of venting bathroom fans through the attic has the inherent problem of freezing the damper shut, making the bathroom fans inoperable. Venting bathroom fans down into the crawlspace and out of doors could alleviate this problem.
    c. The limited monitoring of fuel use and AkWarm comparisons indicate that furnace heating systems appear to be about 50% oversized; a smaller sized furnace may be more appropriate, especially if the savings could be put towards an electrically efficient furnace fan motor which has much lower electrical costs and the ability to provide low speed ventilation.

APPENDICES

I. Sample Results – Individual Home Data
II. Attached Garage/IAQ Concerns: References Commissioning Forms
III. Sample Mechanical Commissioning Form
IV. Project Study Flow Chart
V. Information To homeowners

APPENDIX I: SAMPLE RESULTS – Individual Home Data

The information provided in this section is a small sample of the data collected and analyzed for this study.

A. Boiler Home #1: MV03 Home: Boiler 2 story (517 Price)

Temperature-Relative Humidity
A. Crawl
Temperature Max: 76.6D°F, Min: 60.80°F; Avg: 66.04°F
RH Max: 61; Min: 23.40%; Avg: 38.5%
Dew Point Max 52°F; Min: 26.6°F; Avg: 39.35°F

Ventilation
HRV (Figures 1-4)
The HRV ran continuously from March through most of May, then it was off continuously June and July and intermittently used August and September, and on continuously October and November. When we retrieved the data-logger in November, the homeowner said that they had often noticed the fan noise change [when it went into boost mode] in the middle of the night and her husband had to get up and reset it. We changed the settings and gave some explanation of how it worked and why. She said they had not received previous education and she wasn't even sure what it was.

Bath Fans (Figure 5-6)
Main Bath Fan was used consistently as well, and the fan in master bathroom fan was used continuously until the data-logger became dislodged from the fan at the end of June.

Crawlspace fan ran continuously for 2 weeks in February, then was off for 4 weeks, then on again at end of March and almost continuously through October. Temperature in the crawlspace ranged from about 62-68°F throughout the period of occupancy with a high of 72°F and a low of 61°F. Relative humidity was about 25-35% before occupancy and after occupancy in mid-March, it ranged from 30-60%.

Domestic Hot Water Circulation Pump (Figures 7-8)
The domestic hot water circulation pump used an average 2,056 Btu/hr throughout the study period, with a maximum of 49,125 Btu/hr on one day in July. (Figure 7)

Figure 8 shows the daily use profile, where the circulation pump is most active in the morning hours

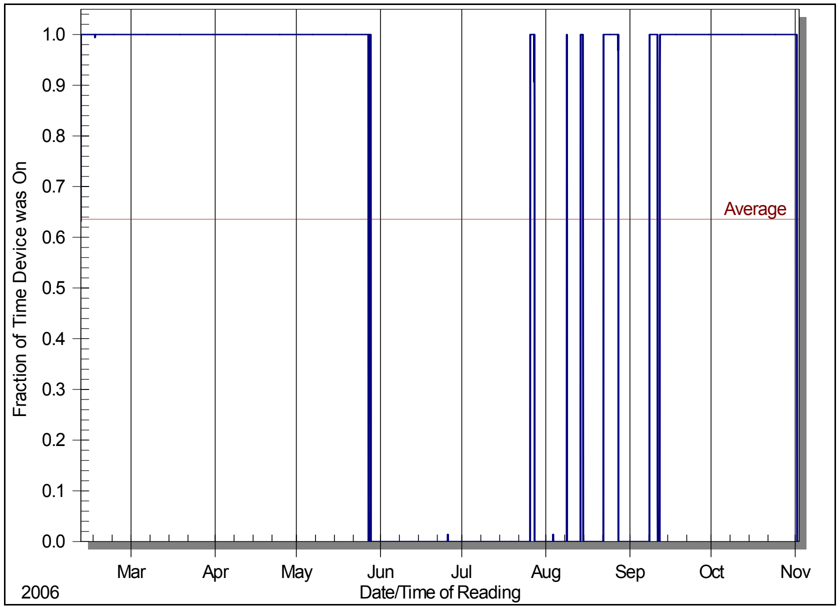


Figure 1. MV03 HRV Runtime

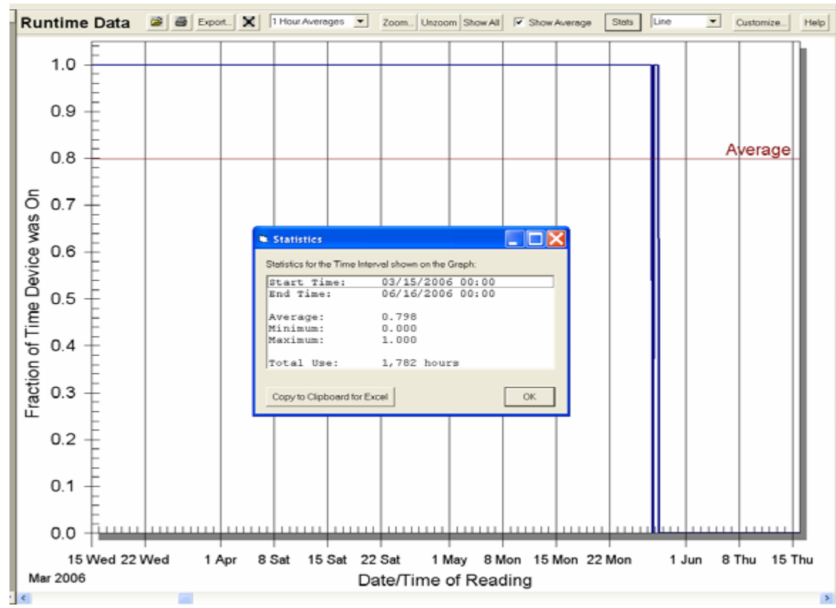


Figure 2. HRV Runtime: March 15-June 15

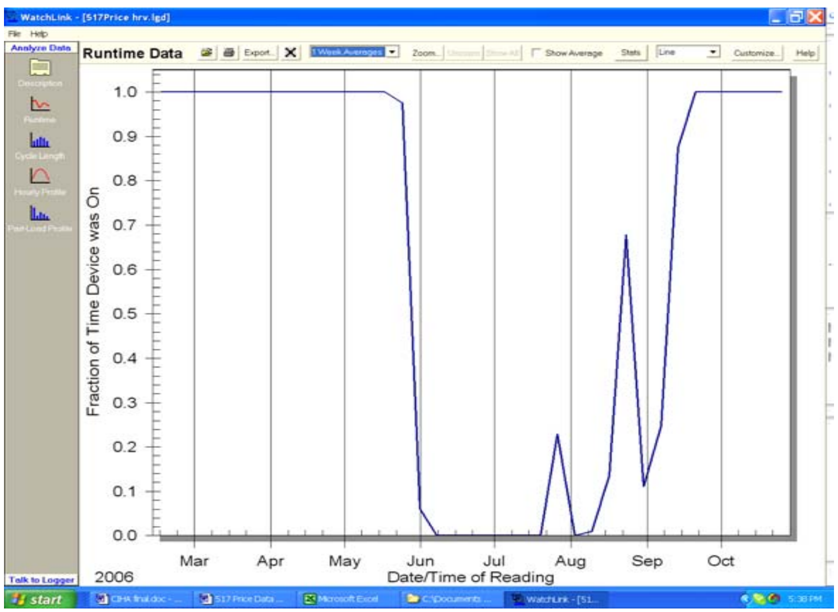


Figure 3. MV03 HRV Weekly Averages

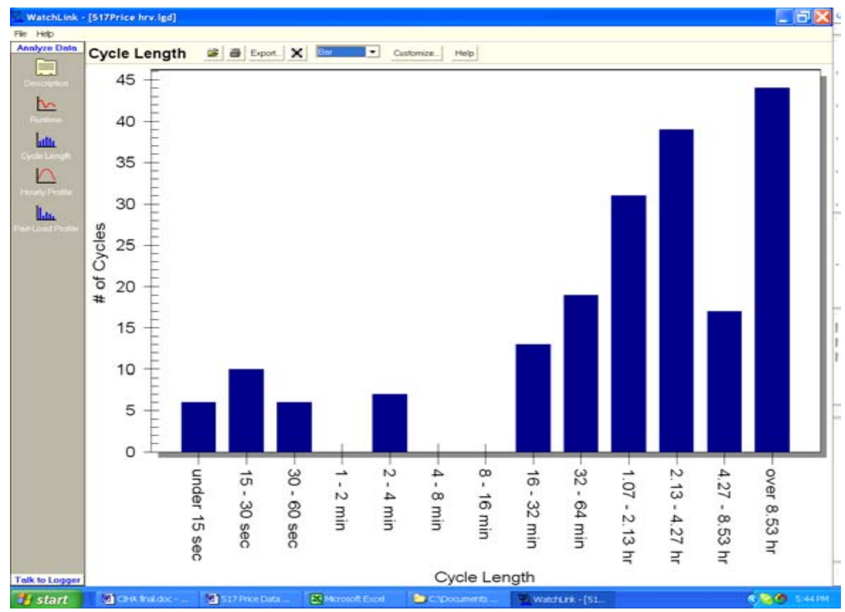


Figure 4. MV03 HRV Cycle Length Profile

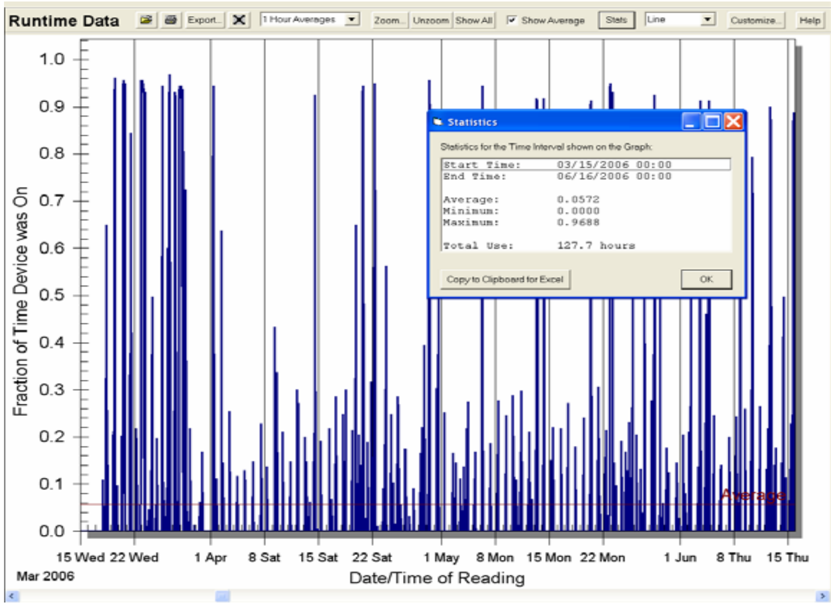


Figure 5. MVO3 Bath Fan

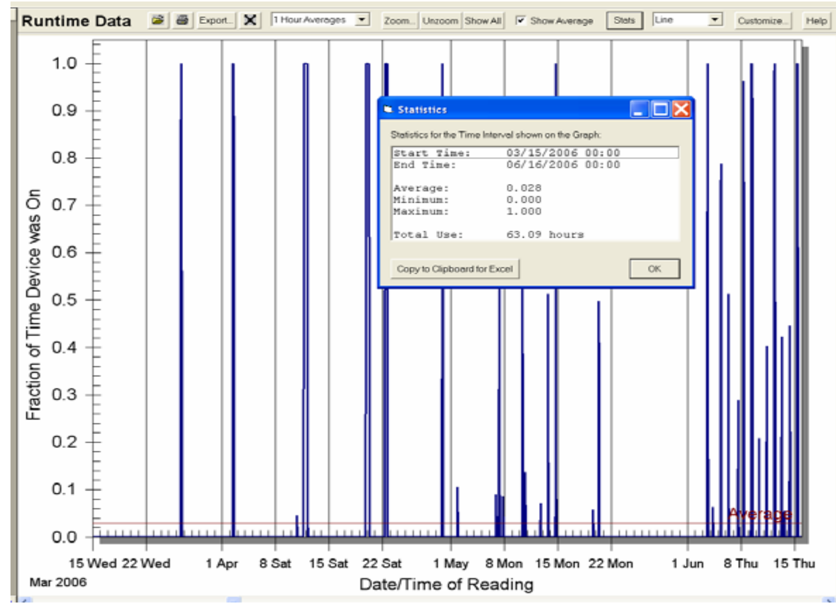


Figure 6. MV03 Bath Fan 2 Runtime

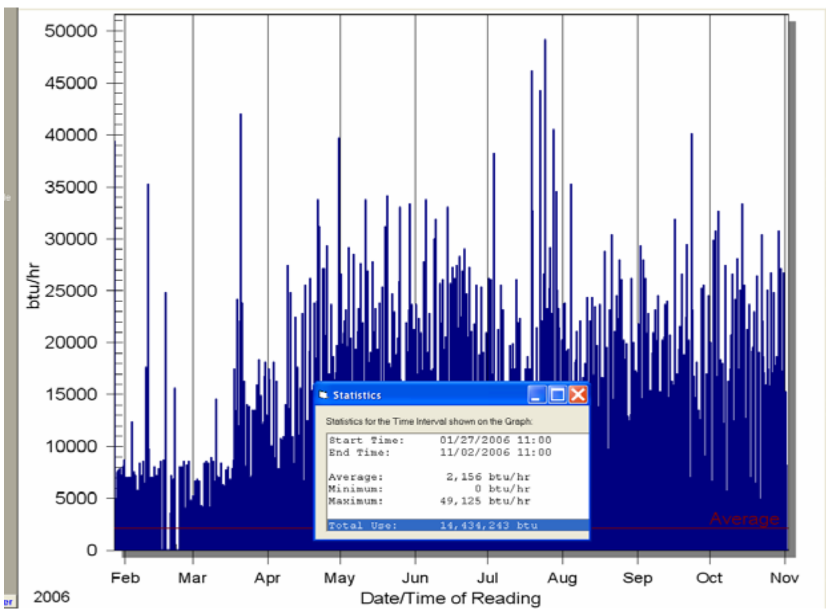


Figure 7. MV03 Domestic Water Circ Pump –Runtime Data

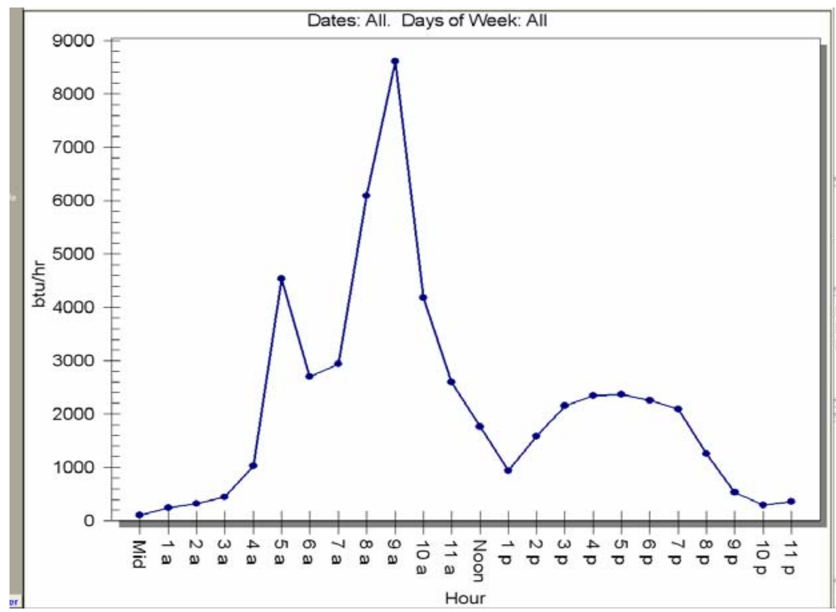


Figure 8. MV03 DWH Circ Pump Partial Load Profile

B. Boiler Home #2: MV05

Temperature/RH

The living area temperature averaged about 72°F, throughout the study time and the relative humidity ranged from 11-57%, averaging about 33%. The Master Bedroom readings were higher for both temperature and RH, maxing out at 80% RH, and averaging about 60% RH.

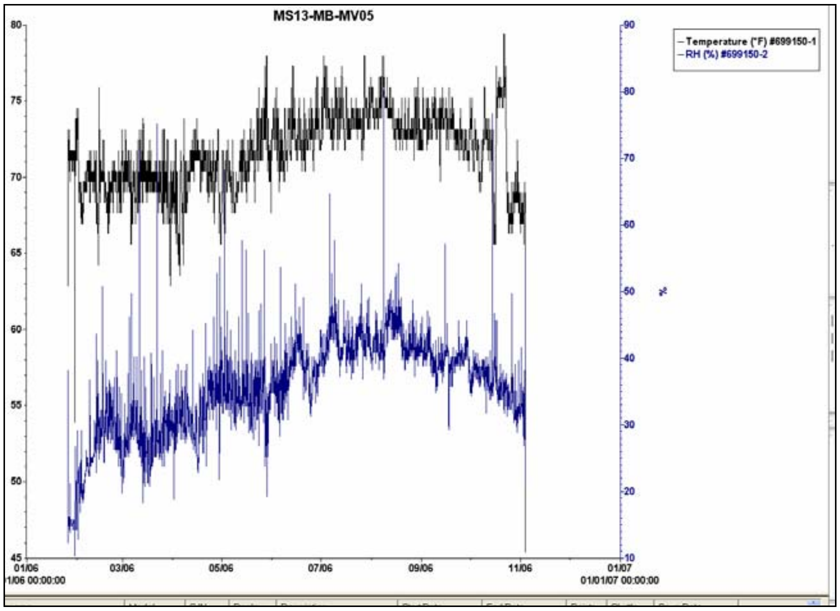


Figure 9. Master Bedroom Temperature & RH

Ventilation

Crawlspace Fan (Figures 10-11) and Temperature/RH (Figure12)

The crawlspace fan ran about 55% of the total time during the monitoring period. From the data we were able to see that the on-time varied throughout the seasons: while it barely ran in March, and in April was on 20-30% of the time, during the warmer months it was running most of the time. When the data loggers were installed we noted that the fan came on at 35% RH, even though it was set to come on at 25% RH.

Whole house fan (Figures 17-19) was used very little until June 15, but from July 15 to October 2 it ran about 20% of the time, once for two weeks straight.

Bathroom fans 2 and 3 (Figures 20-25) showed very little activity. The vent on fan 3 had been blocked at the time of installation and the fan may not yet be operating properly.

Domestic Water Heating (DWH) Circulation Pump (Figures 13-15)

The domestic hot water supply is indirectly supplied via the boiler. Figures 12-14 illustrate this, showing that during the heating season the DWH circ pump operates only about 10-12% of the time, while in the warmer summer months it is bearing the full water heating load and cycles on up to 25% of the time.

The Garage Unit Heater (Figures 26-28) averaged about 7,000 Btu/hr during the study time.

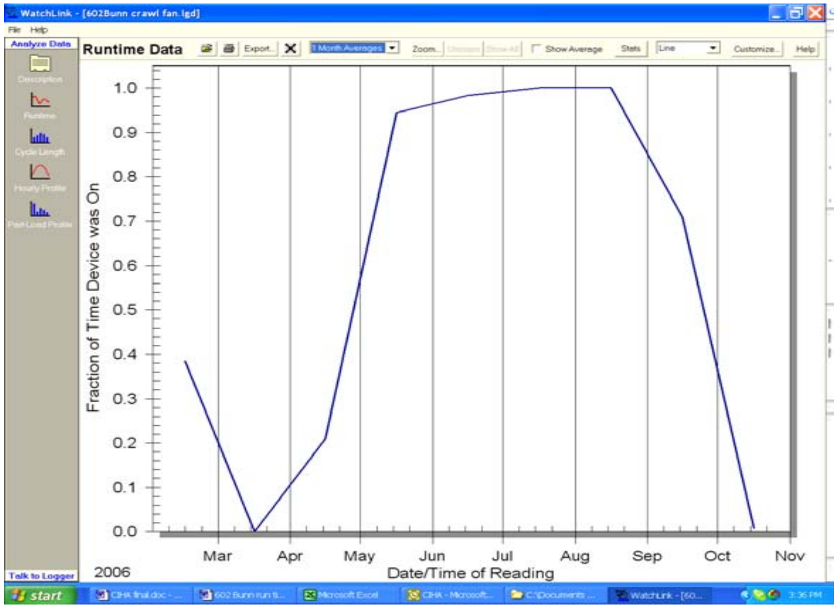


Figure 10. MV05 Crawl Fan Run time

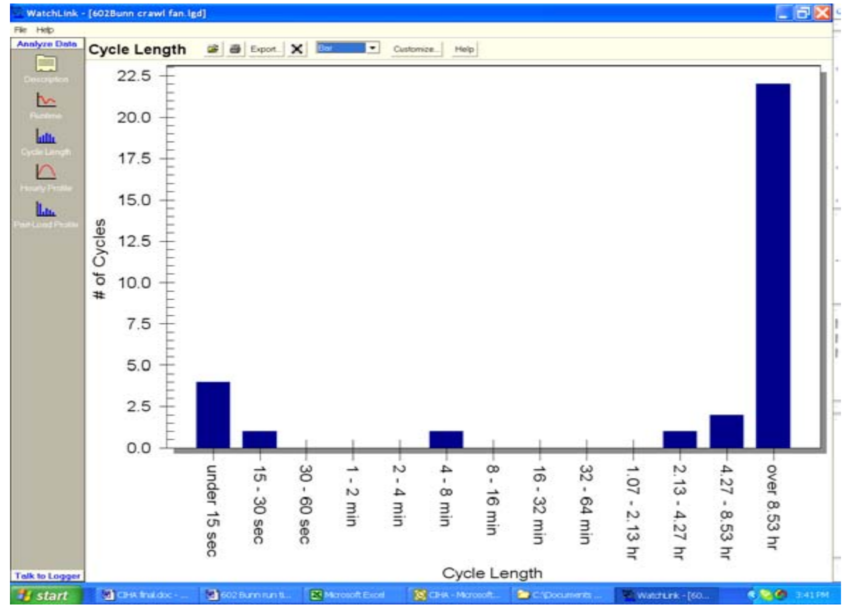


Figure 11. MV05 Crawl Fan Cycle Length

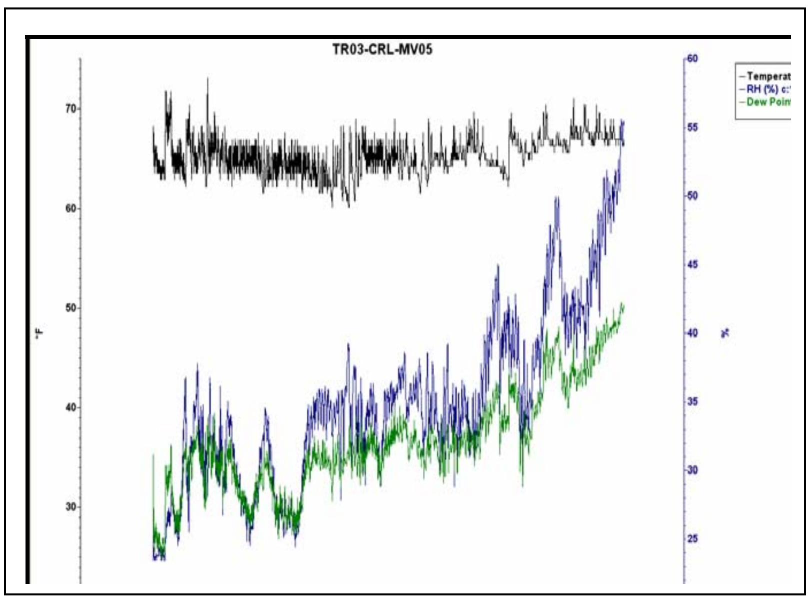


Figure 12. MVO5 Temperature-Relative Humidity

Temperature in the crawl was consistently between 60-70°F throughout the study time. Relative humidity averaged 35%, but ranged from a minimum of 23% in the winter to a high of 56% in the summer.

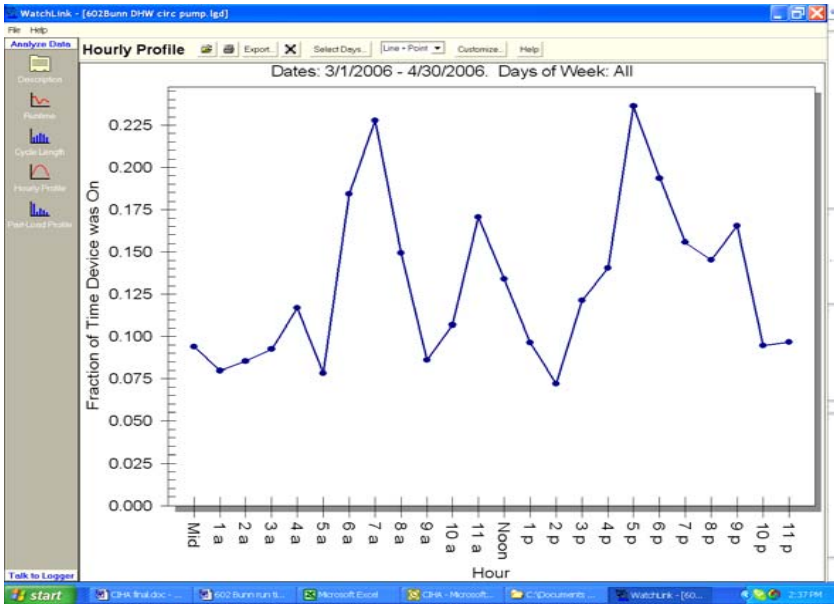


Figure 13. MVO5 DWH Runtime: June-July

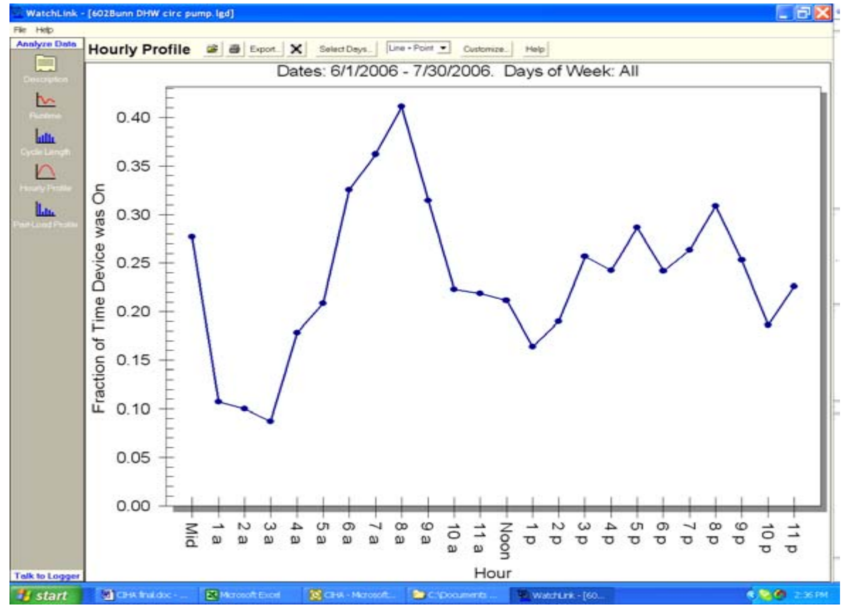


Figure 14. MV05 DWH Runtime: Feb-Mar

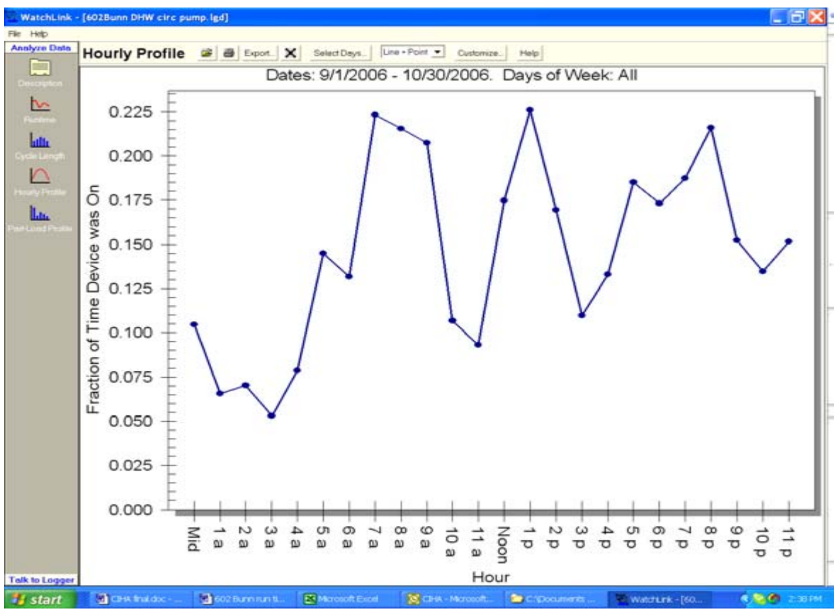


Figure 15. MV05 DWH Runtime: Sept-Oct

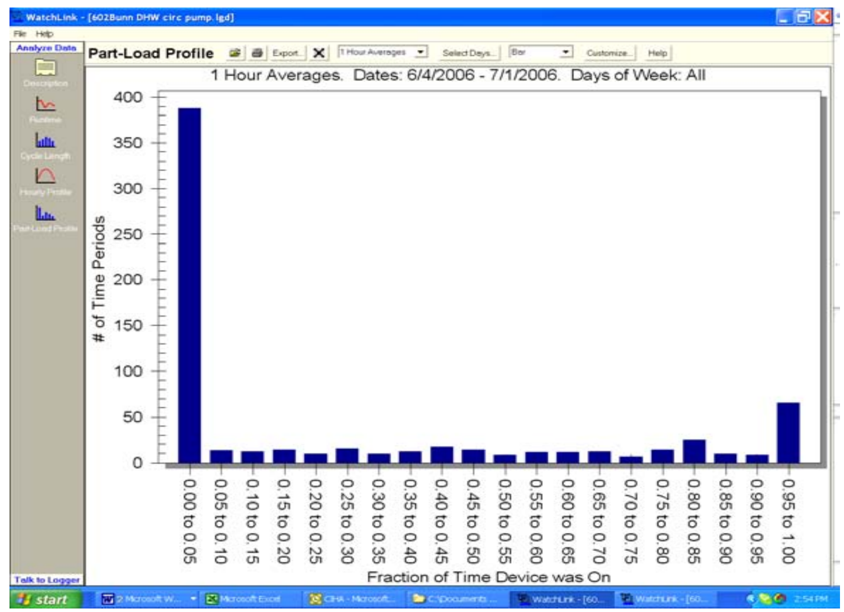


Figure 16. MV05 DWH Part Load Profile: One Hour Averages

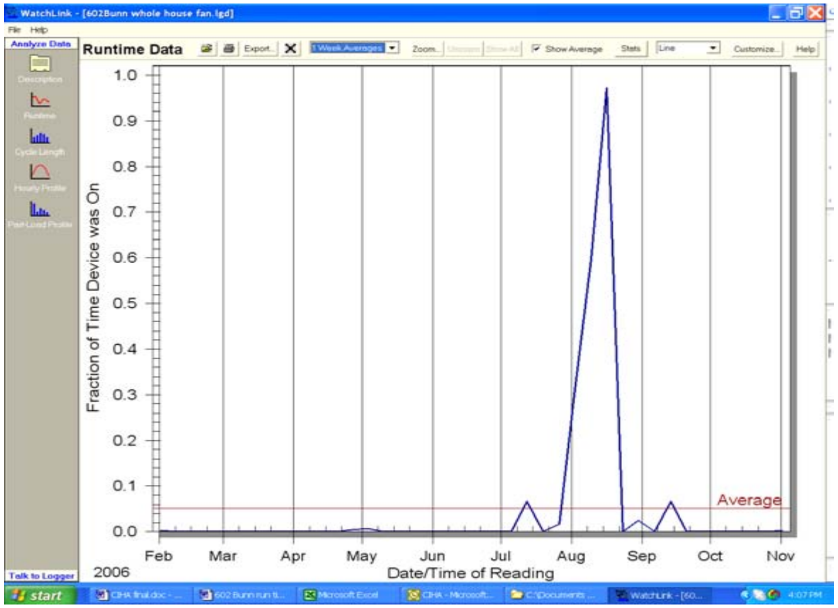


Figure 17. MV05 Whole house fan run time – weekly average

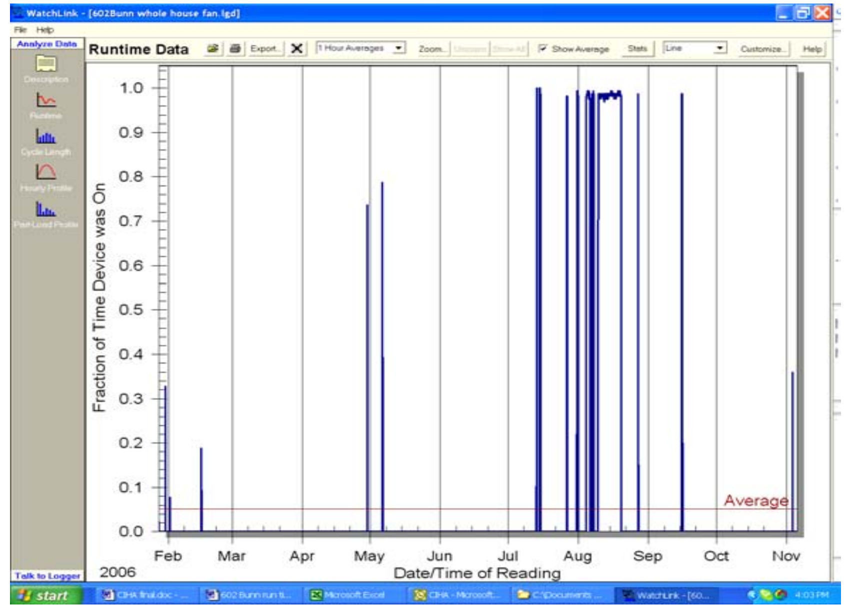


Figure 18. MV05 Whole House Fan run time - 1 hour average

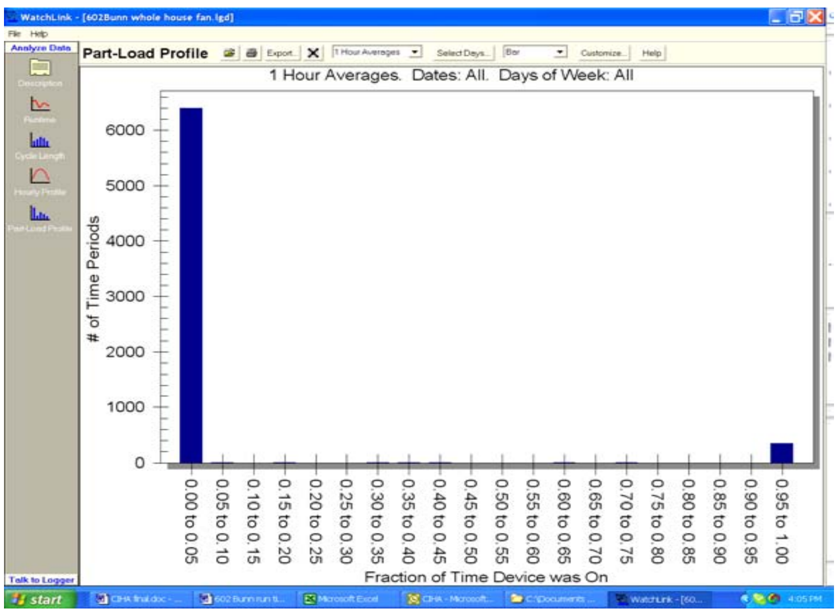


Figure 19. MV05 Whole House Fan Partial Load Profile

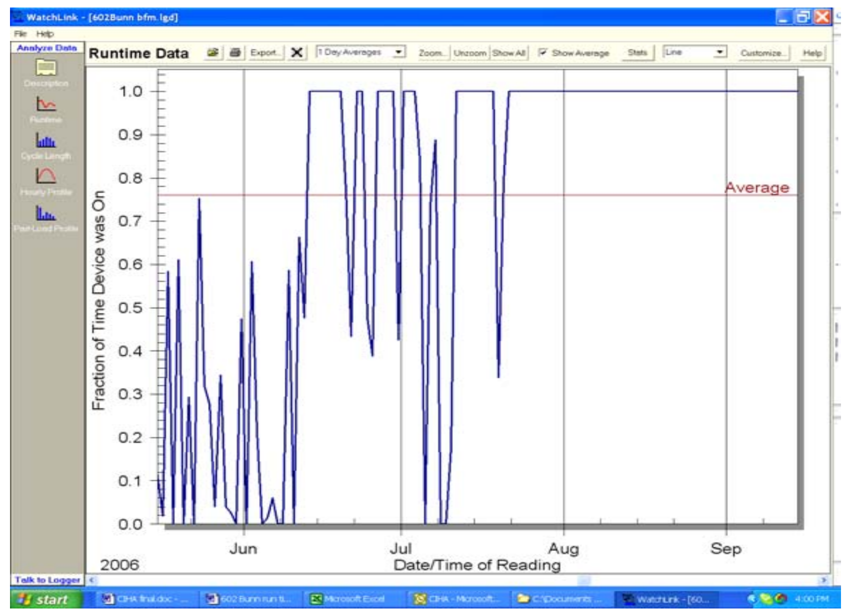


Figure 20. MV05 BFM Runtime - 1 Day Averages

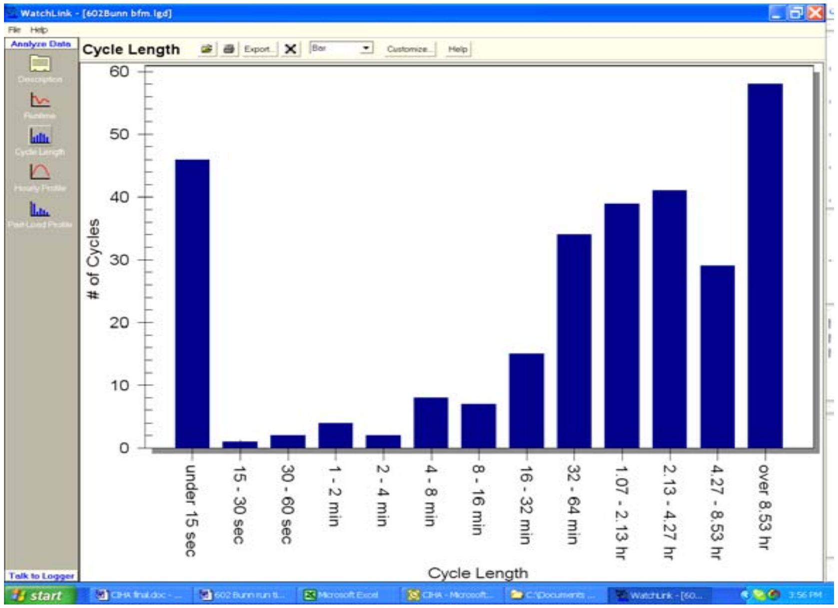


Figure 21. MV05 BFM Cycle Length

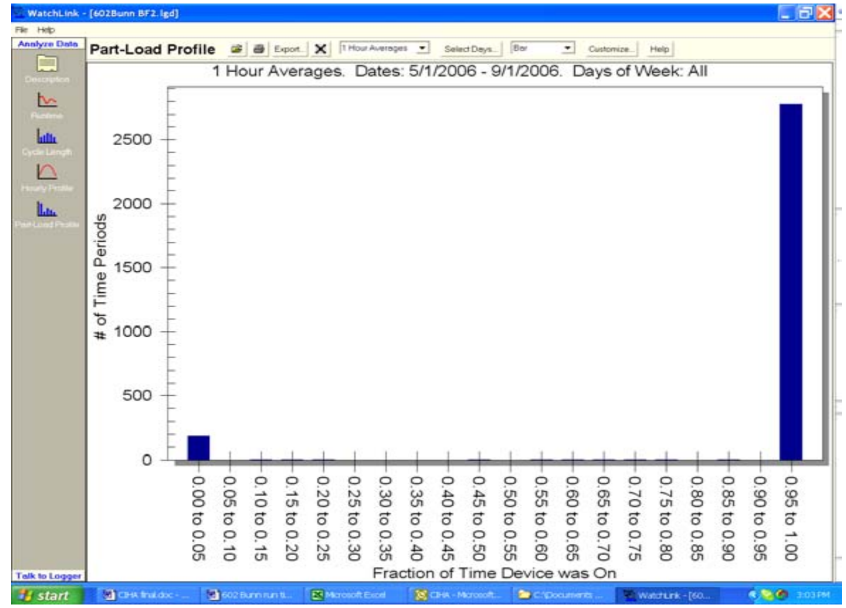


Figure 22. MV05 BF2 Fan Run Time

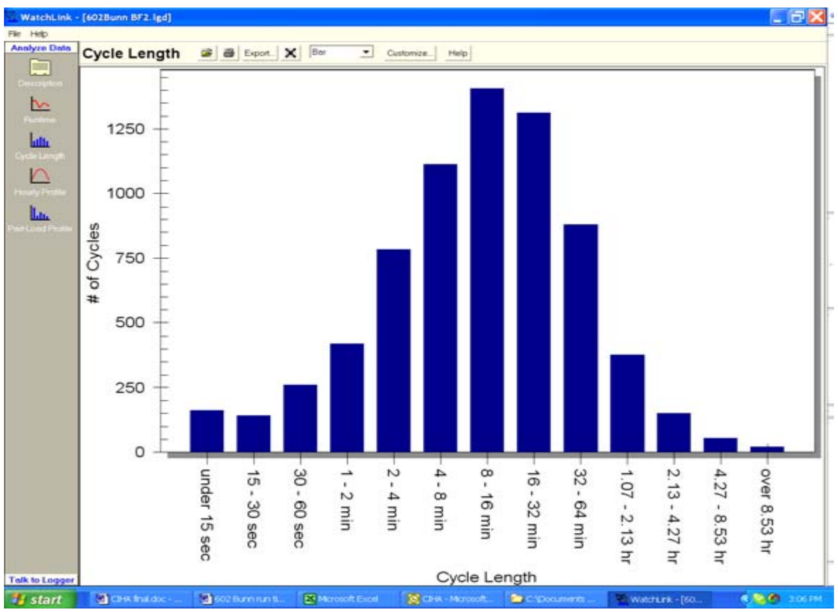


Figure 23. MV05 BF3 Cycle Length

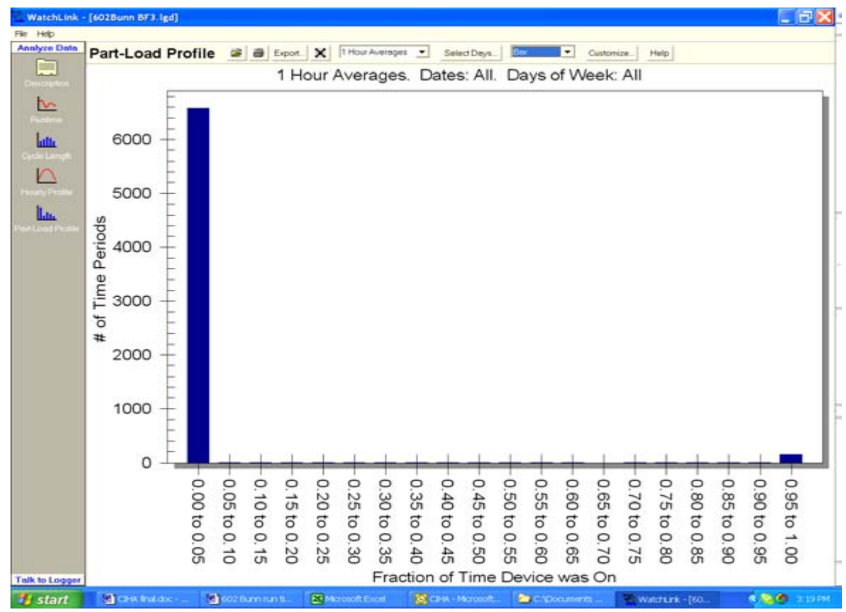


Figure 24. MV05 BF3 Runtime – 1 Hour Average

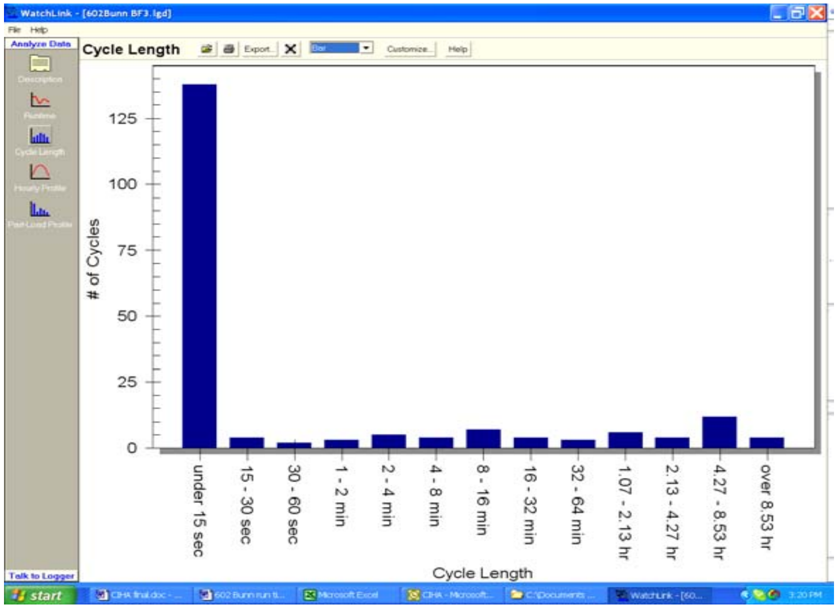


Figure 25. MV05 BF3 Cycle Length

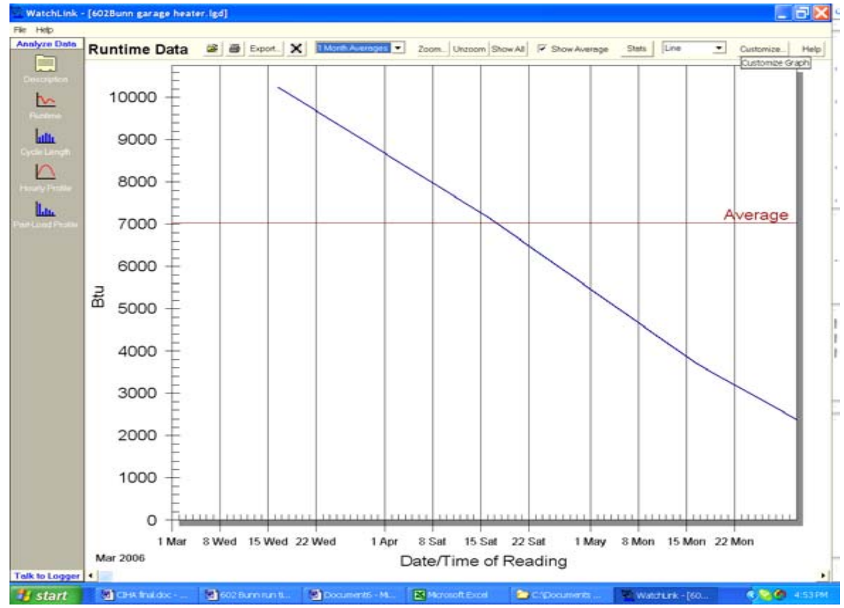


Figure 26. MV05 Garage Unit Heater Runtime - 1-Month Averages

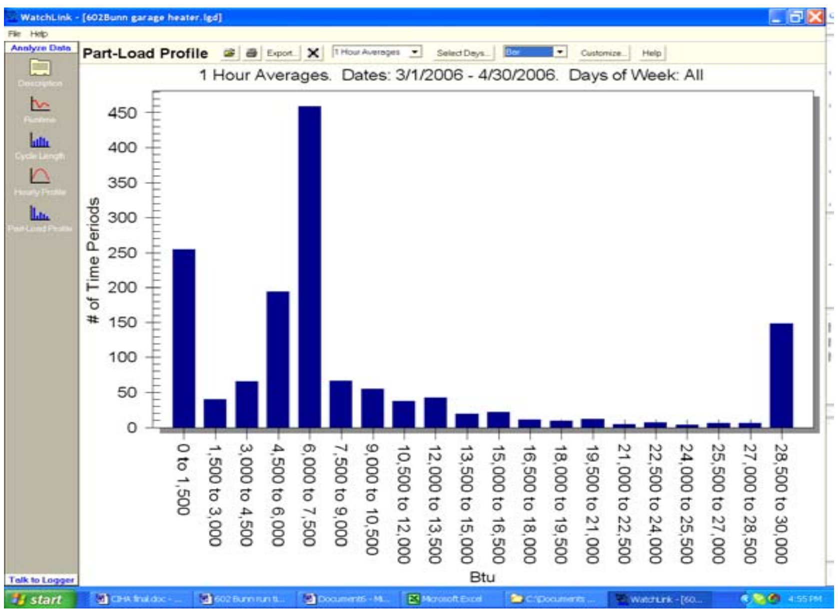


Figure 27. MV05 Garage Unit Heater Part Load Profile Mar-April

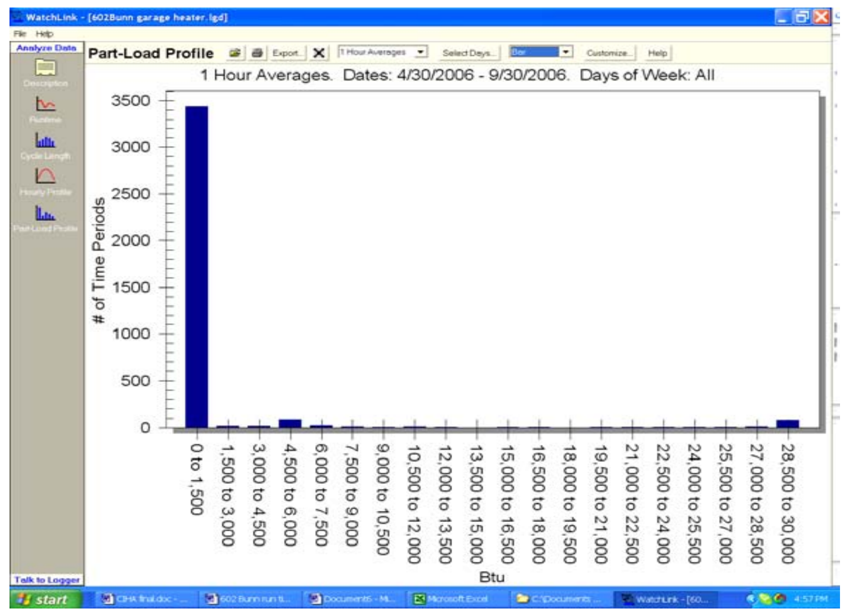


Figure 28. MV05 Garage Unit Heater Part Load Profile May- September

C. Furnace Home #1: MV11 Ranch style w/furnace, attached garage and fan ventilation

CO Living Area: Installed March 15, 2006 and until April 27 the average reading was .2 parts per million (ppm). On April 27 CO peaked at 87.6 ppm at 8:30 AM, and remained above 10 ppm for much of the day. Thereafter rates rose and fell continuously, with a maximum value of 124.3. A post-test return to the building determined that the garage was not being used for any vehicles and none of the occupants claimed to smoke in the home. There are quite a few people living in the home who seem to do a significant amount of cooking. An untested hypothesis is that the high CO levels are connected to the gas-fired kitchen cook stove, but the figure below shows the peak day, with high CO levels most of the day. **The CO levels are significant enough that we recommend a follow-up CO monitoring to try to pinpoint the problem(s).**

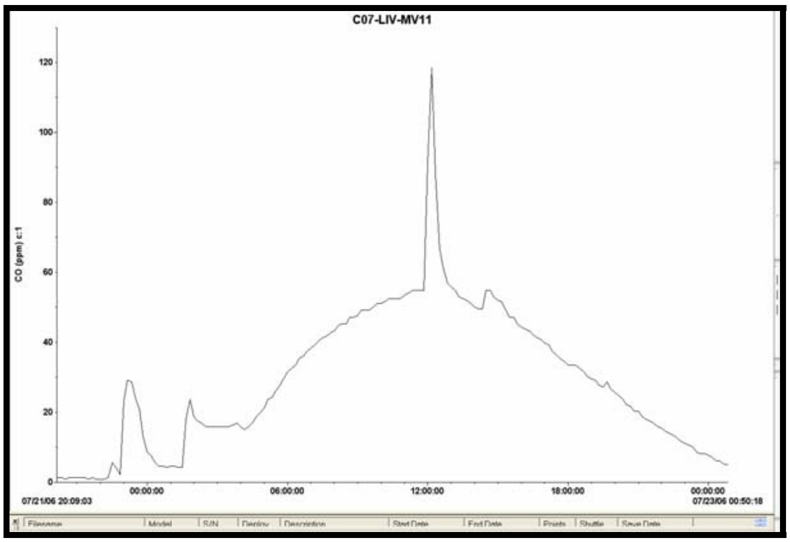


Figure 29. MV11 Living Area CO Levels

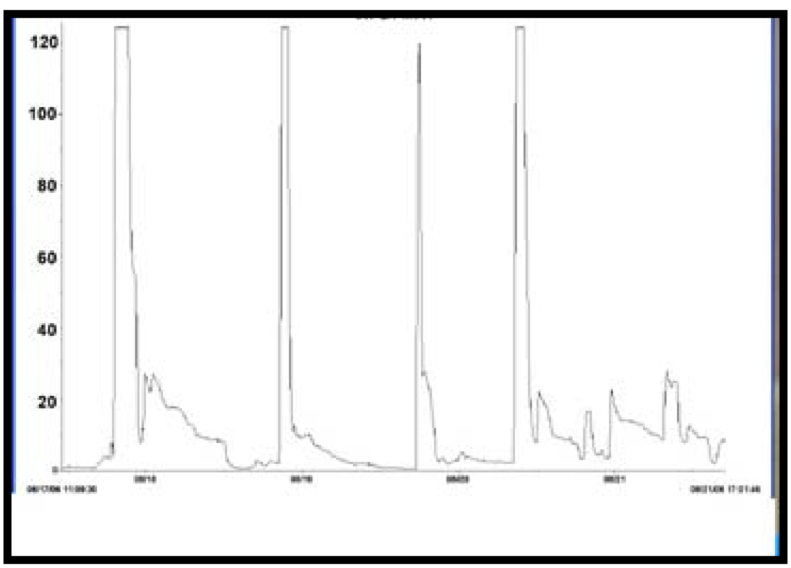


Figure 30. MV11 CO Worst Peaks

Temperature/RH Crawl
Temperature Max: 69.71°F, Min: 60.80°F; Avg: 64.36°F
RH Max: 74.8%; Min: 24.00%; Avg: 58.65%
Dew Point Max 59.60°F; Min: 29.04°F; Avg: 48.90°F

Furnace (Figures 31-32): During the cold December 3-5, 2005 the furnace ran about 40% of the time. During that time, the furnace cycles were less than 5 minutes. The furnace runtime data-logger was not installed during the full study period.

Domestic Water Heater (Figure 33): During the time of occupancy between May and November 2005, the water heater used about 6000 Btus/hr, and in most 1 hour periods, about 4,000 Btus/hr were consumed.

Garage Unit Heater (Figure 34):
During the cold days of December 3-5, 2005, the garage unit heater ran about 33% of the time and averaged about 19,000 Btu/hr. This high use may have been related to construction activities, as the home was not occupied at the time. The garage heater runtime data-logger was not installed for the full study period.

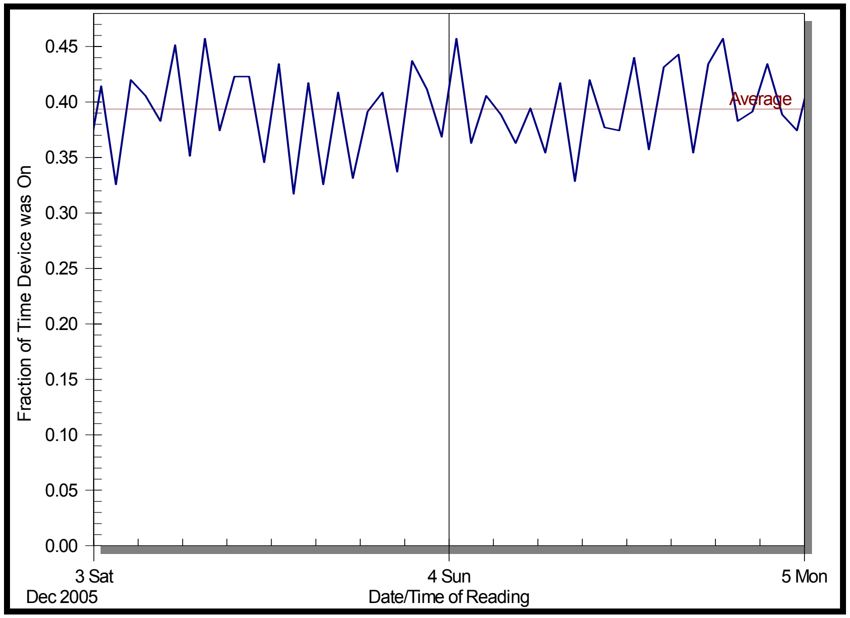


Figure 31. MV11 Furnace Runtime: Fraction of Time Running

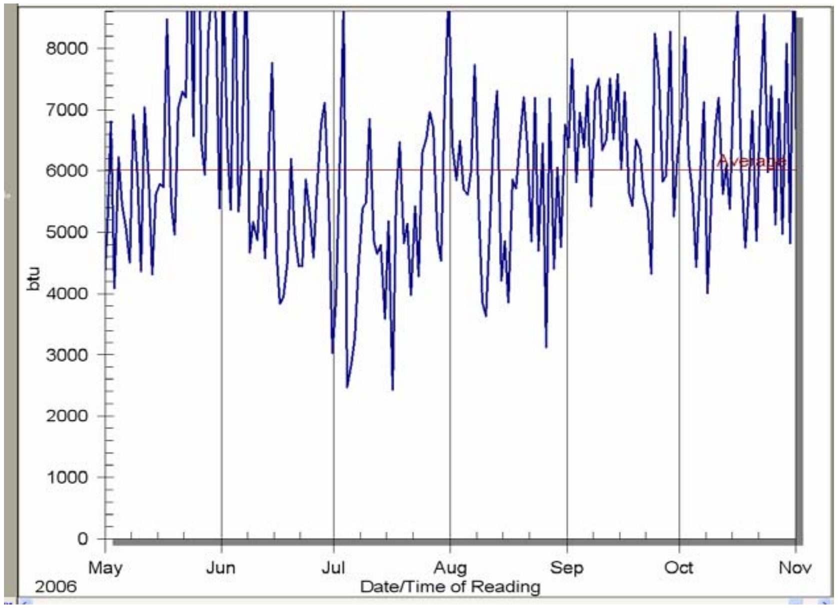


Figure 32. MV11 DWH Runtime

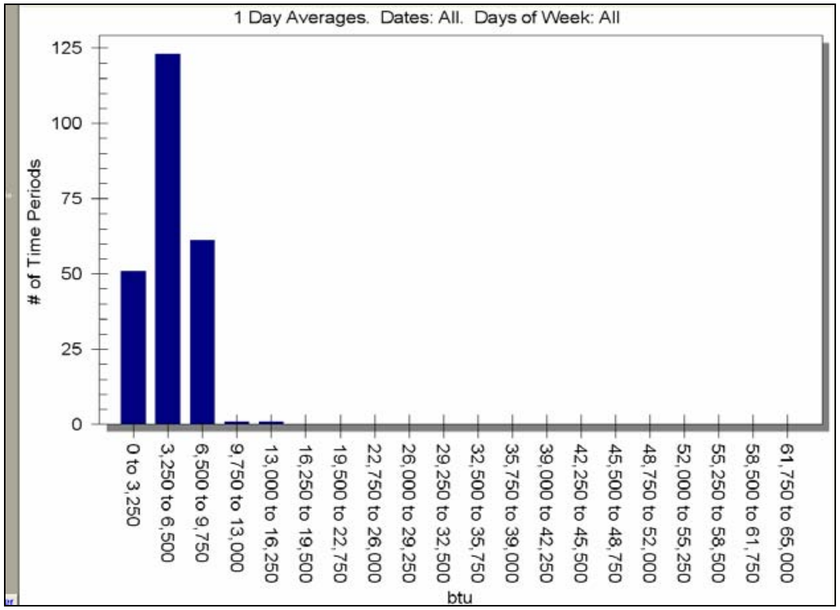


Figure 33. MV11 Furnace Cycle Time

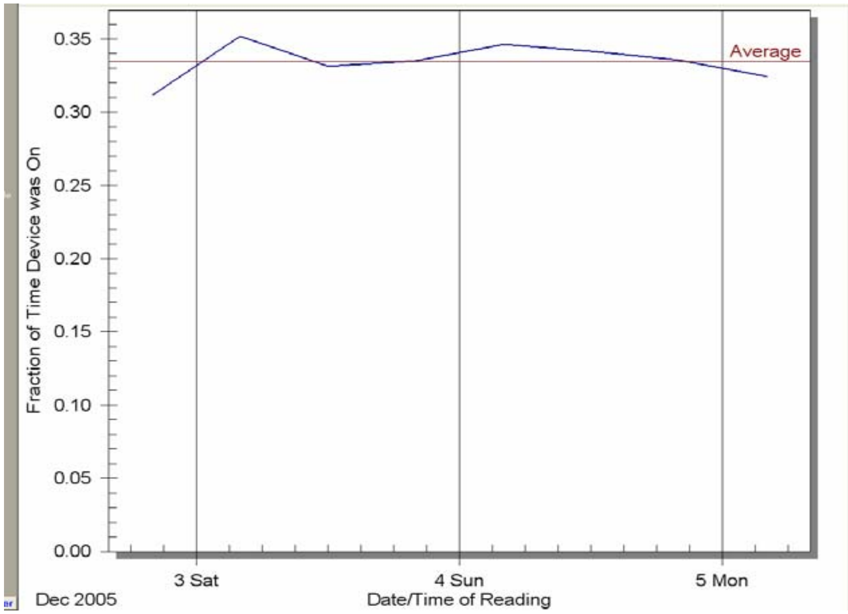


Figure 34. MV11 Garage Heater Runtime- Dec 3-5, 2005

D. Furnace Home #2: MV12: ranch style w/ furnace, attached garage and fan ventilation

Furnace (Figures 37-39): This home had a furnace with 57K input / 46K heat capacity, with an 80% AFUE. The runtime data logger indicates that between March 12 and September 17 this furnace used 33,854,200 Btu of fuel, while averaging 7,463 Btu/hr, maxing out at 28,224 Btu/hr in March. During the summer months, between June 1 and August 31, it averaged about 2,158 Btu/hr. It would be more useful to monitor during a longer cold period to get a better picture of annual fuel use.

Garage Unit Heater (Figure 40):
The garage unit heater ran about 38% of the time during the cold days of December 3-5, 2005.

Water Heater (Figures 41-44):
The standard natural draft, tank-type domestic water heater used a daily average of about 4,000 Btu/hr throughout the study period, and the monthly average was about 42000 Btu/hr, with peak times in June and July. Daily use appeared to be consistent for each month of the study period. (Figure 44)

Carbon Monoxide (CO) Monitoring (Figure 35-36)
Although CO levels in this home averaged only 3.35 ppm throughout the study period, they peaked at 20.8 ppm, and there were a significant number of unhealthy peaks. This home has an attached garage and some of the peaks may be associated with automobile use, but there were also a number of times when peaks occurred later in the day, such as in the example shown below for May 6, 2005. We recommend further evaluation of the carbon monoxide levels in this home by monitoring the garage and living space simultaneously and doing more assessment of occupant activities.

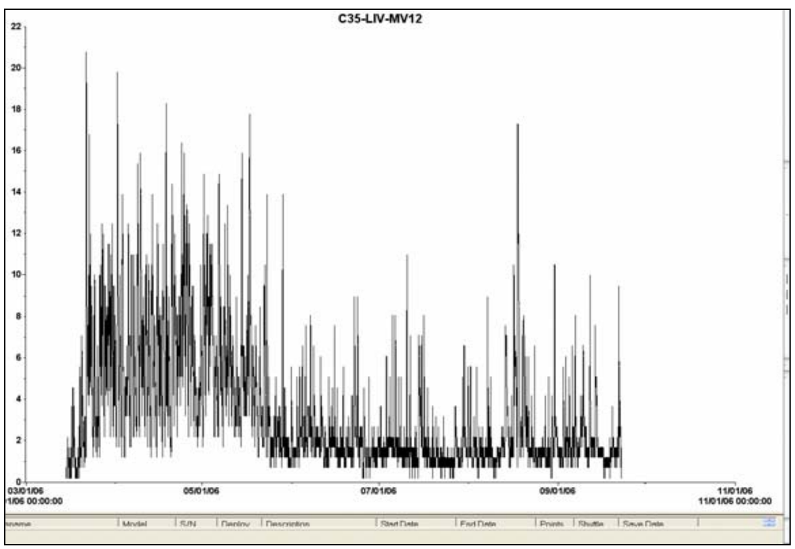


Figure 35. MV12 Living Area CO Levels

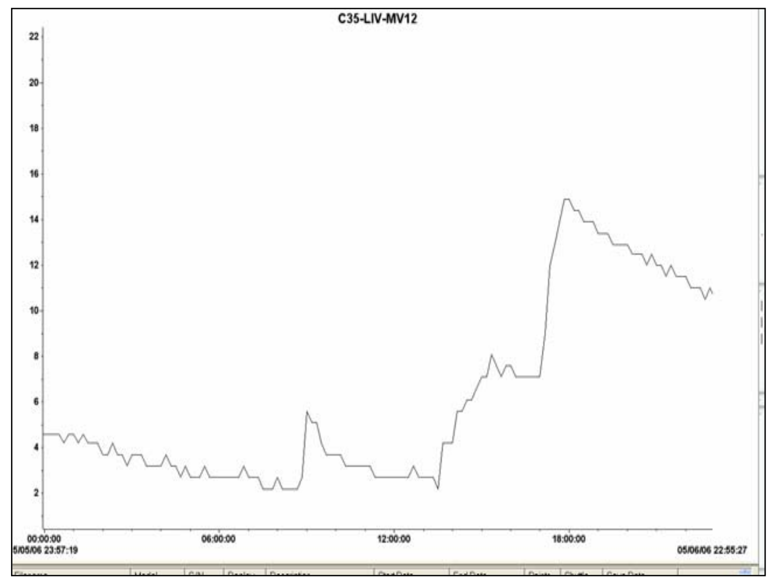


Figure 36. MV12 1-Day Sample CO Levels

MV12 Furnace –
The runtime data logger indicates that between March 12 and September 17 this furnace used 33,854,200 Btu of fuel, while averaging 7,463 Btu/hr, maxing out at 28,224 Btu/hr in March. It would be more useful to monitor this furnace during the colder seasons.

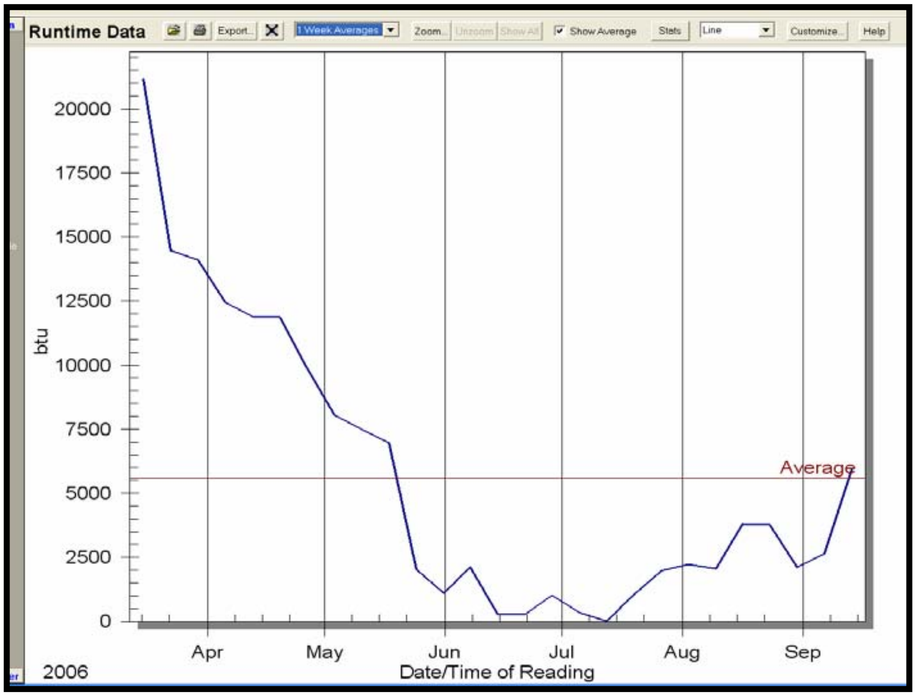


Figure 37. MV12 Furnace Runtime Data Weekly Averages

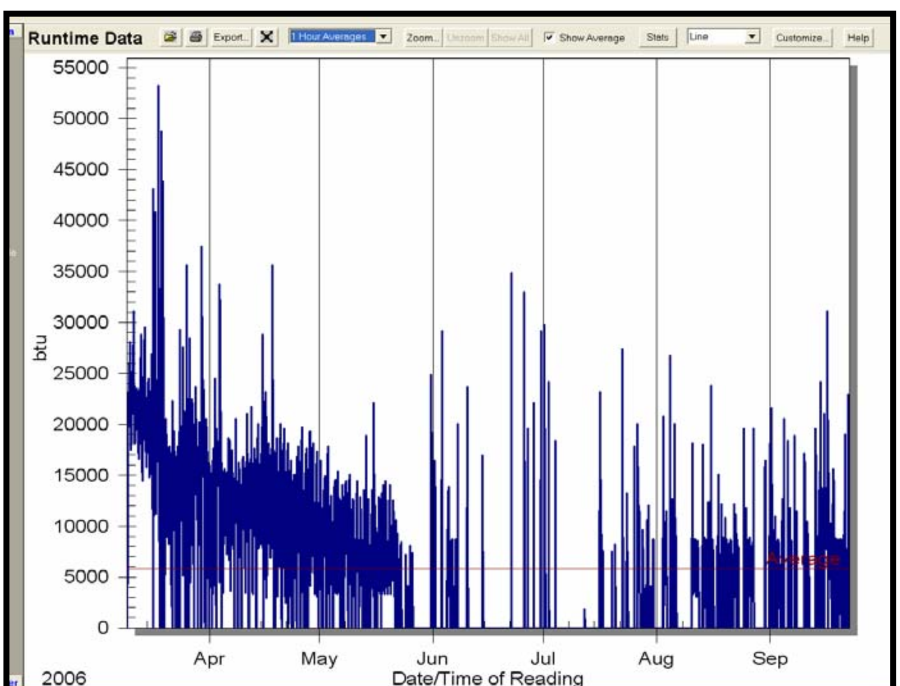


Figure 38. MV12 Furnace Runtime Data – 1 Hour Averages

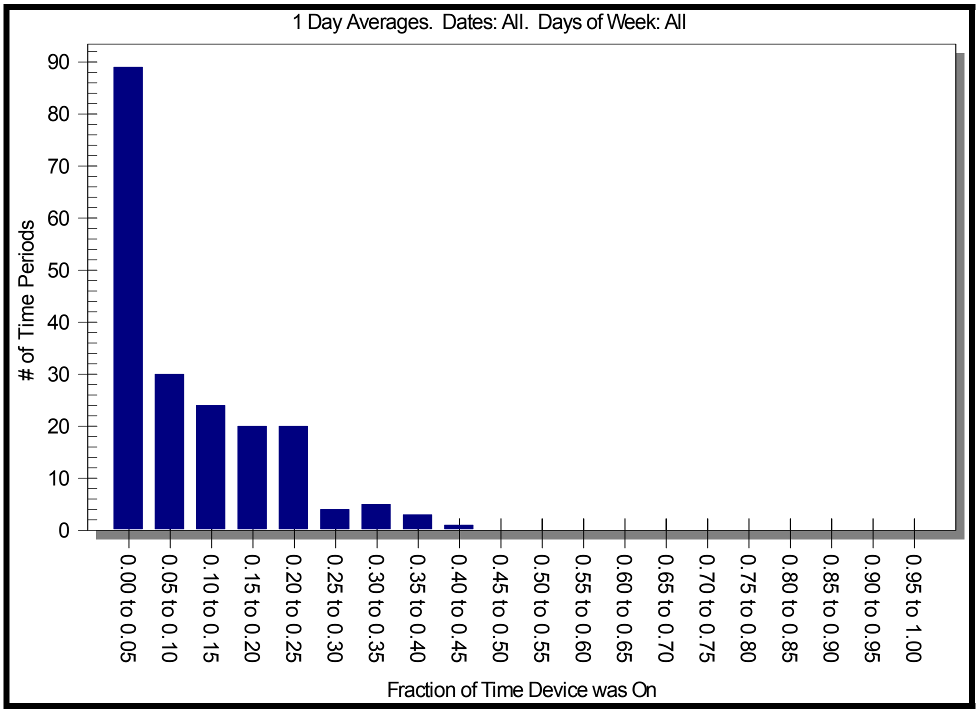


Figure 39. MV12 Furnace Runtime Fraction

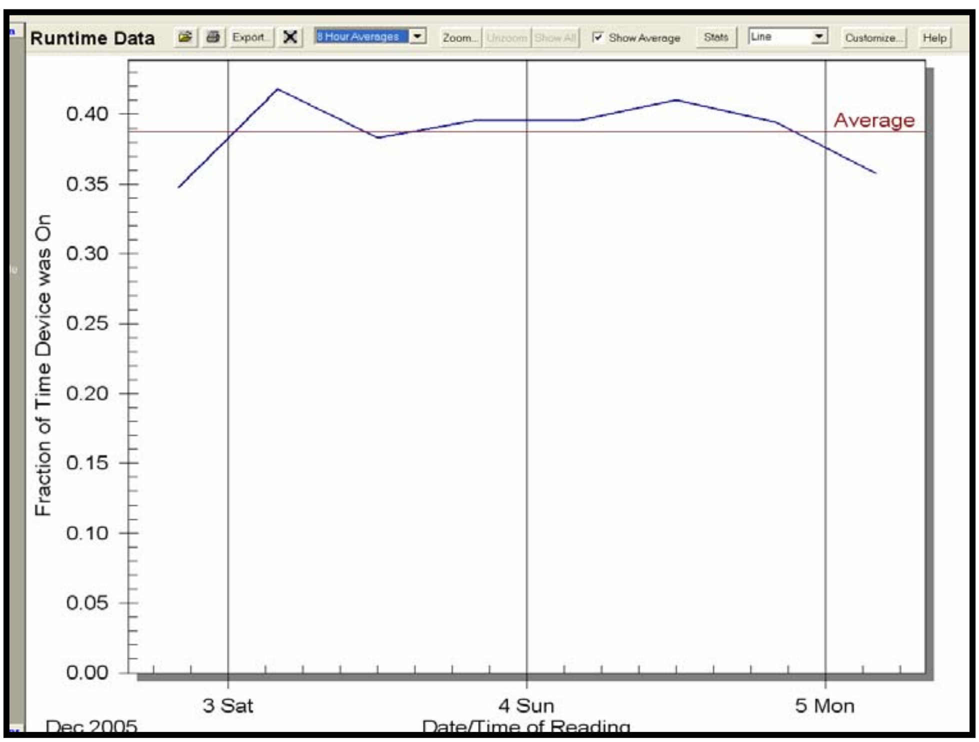


Figure 40. MV12 Garage Unit Heater Runtime Data of Tim Running

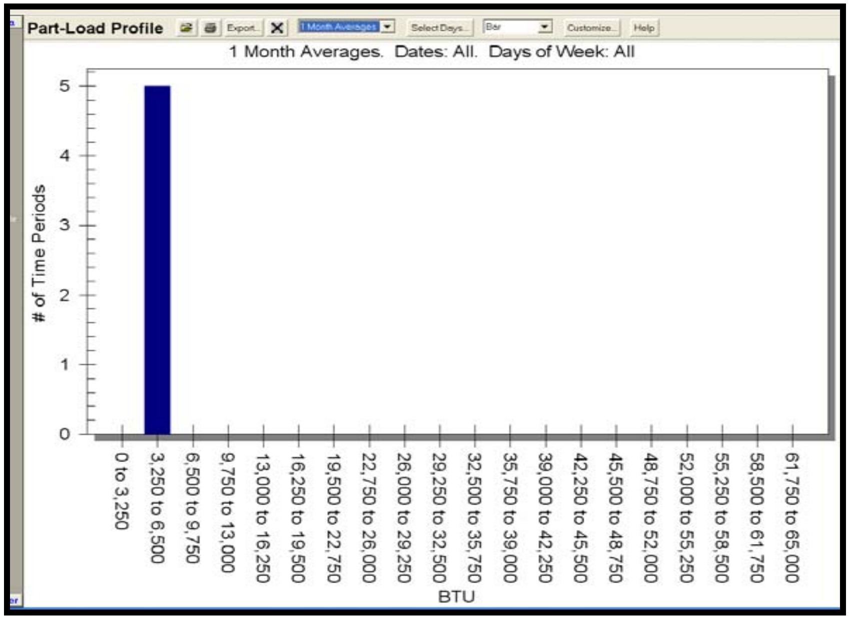


Figure 41. MV12 Water Heater Average Daily Use

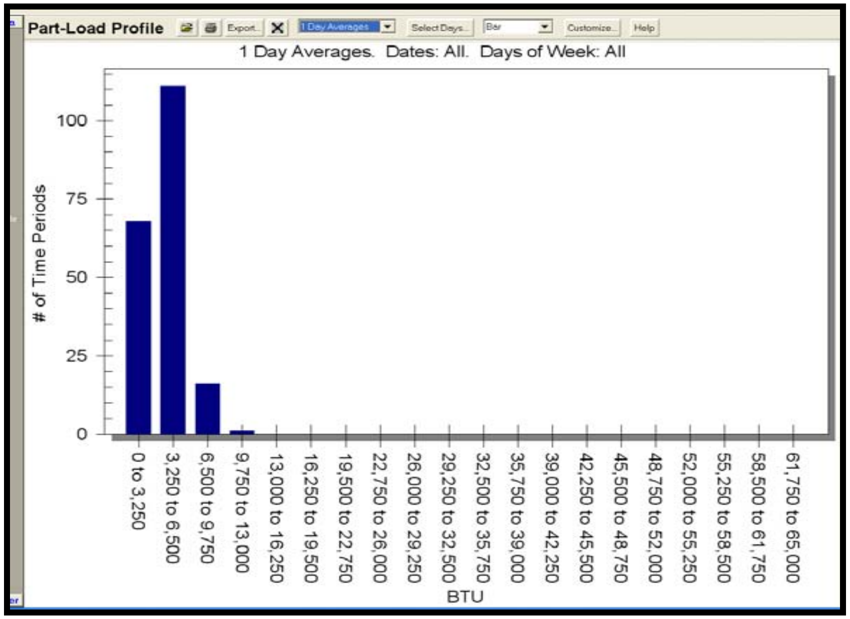


Figure 42. MV12 Water Heater Monthly Average

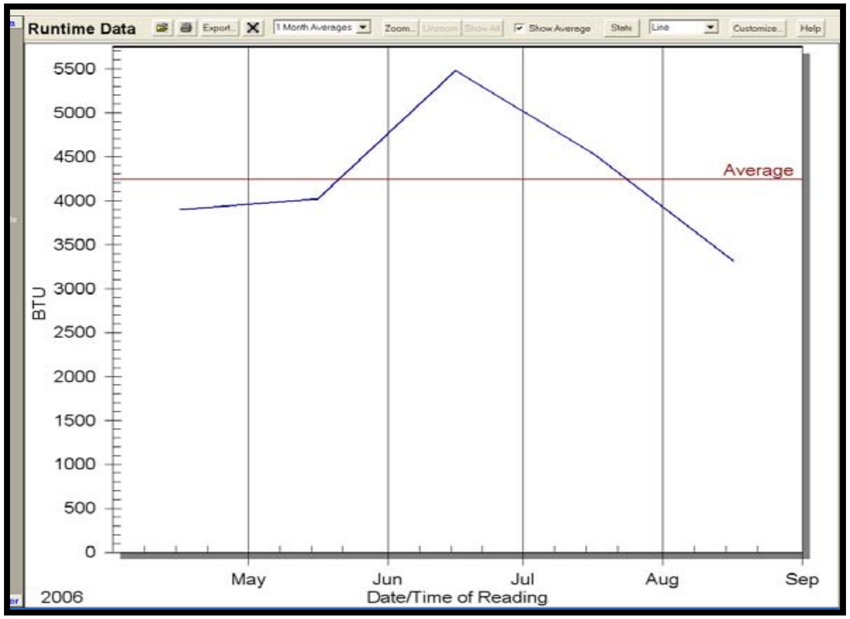


Figure 43. MV12 Water Heater Monthly Runtime Data

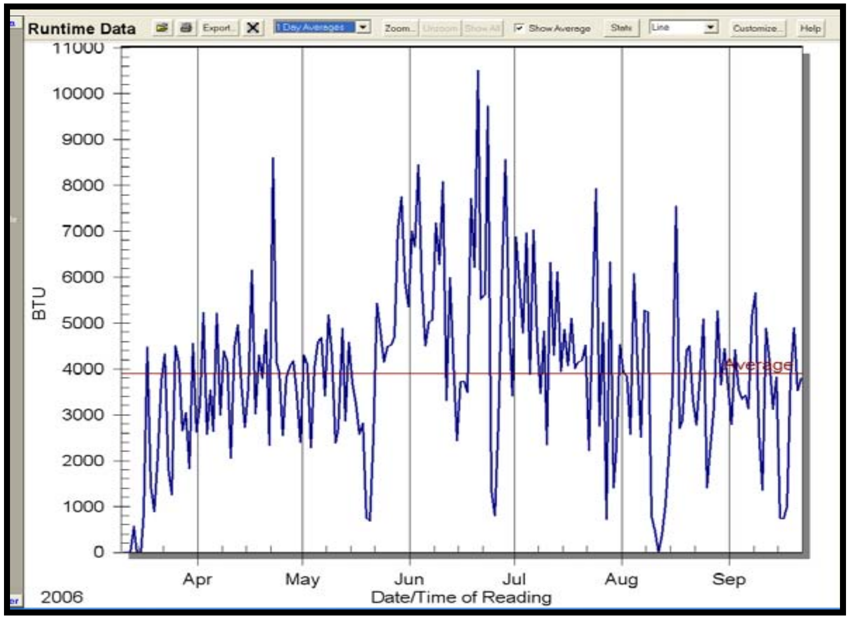


Figure 44. MV12 Water Heater Runtime Data - Daily Averages: 4000 Btus/hr

Temperature & Relative Humidity

In the living area of this home the temperature averaged about 72°F and the average relative humidity was 50%, ranging from 13-79% RH.

The crawlspace temperature averaged about 65°F and the relative humidity averaged 62%, ranging from 24-78% RH. This crawlspace had no exhaust fans so relative humidity was high most of the time.

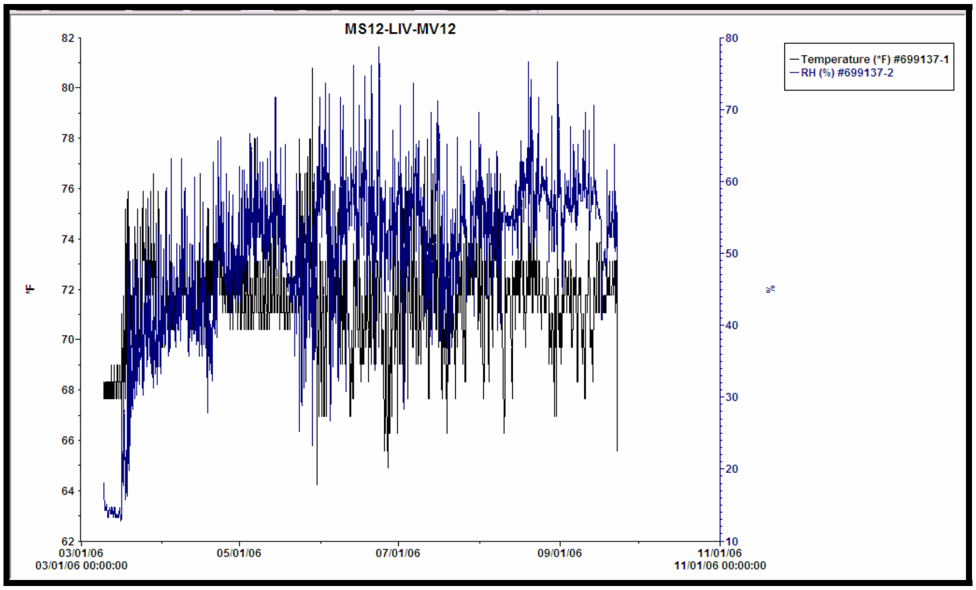


Figure 45. MV12 Living Area Temperature and RH

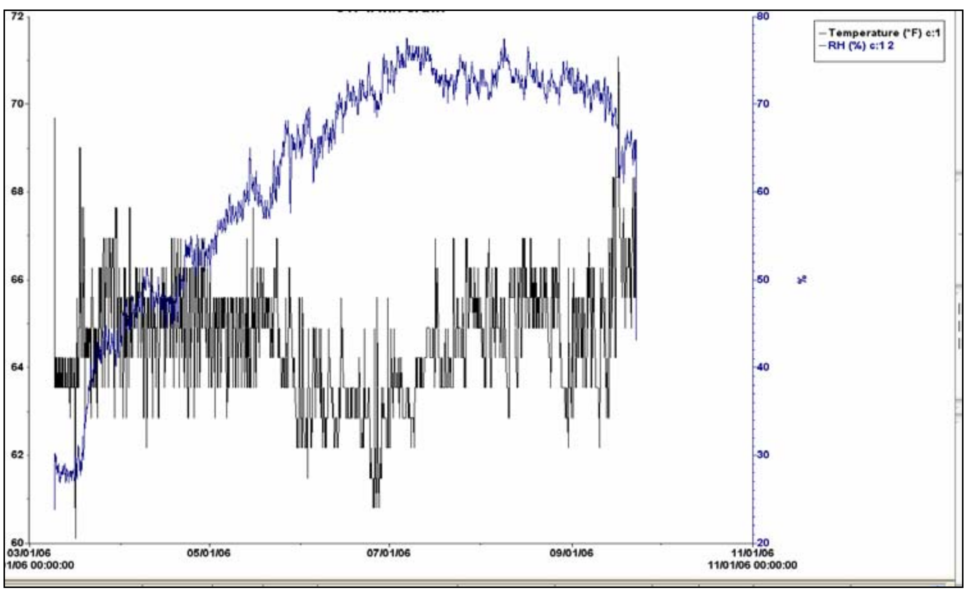


Figure 46. MV12 Crawlspace Temperature and RH

APPENDIX II. ATTACHED GARAGE/IAQ CONCERNS: REFERENCES

Alaskan Studies and Reports

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APPENDIX III. SAMPLE COMMISSIONING FORM: MECHANICAL EQUIPMENT

1. Boilers:

Clock gas meter: _____seconds/cf   Repeat: _____seconds/cf

Confirm T-Stats & zone valves are working   _____ downstairs   _____ upstairs

Boiler Water Pressure: _______ lbs

DHW Tank Temperature _______ deg. F

_____ Boiler responds to DHW call - 180 deg. temp.

____ No observable leaks

2. Furnaces:

_______________ Location of Furnace

Clock gas meter: _____seconds/cf ,   Repeat: _____seconds/cf

______ Return Air Temp.

______ Supply Air Temp.

______ Return Static Pressure in wc

______ Supply Static Pressure in wc

______ Observe several cycles to assure not operating on high limit switch

______ Clean new filter

______   Plenum and ducts air sealed

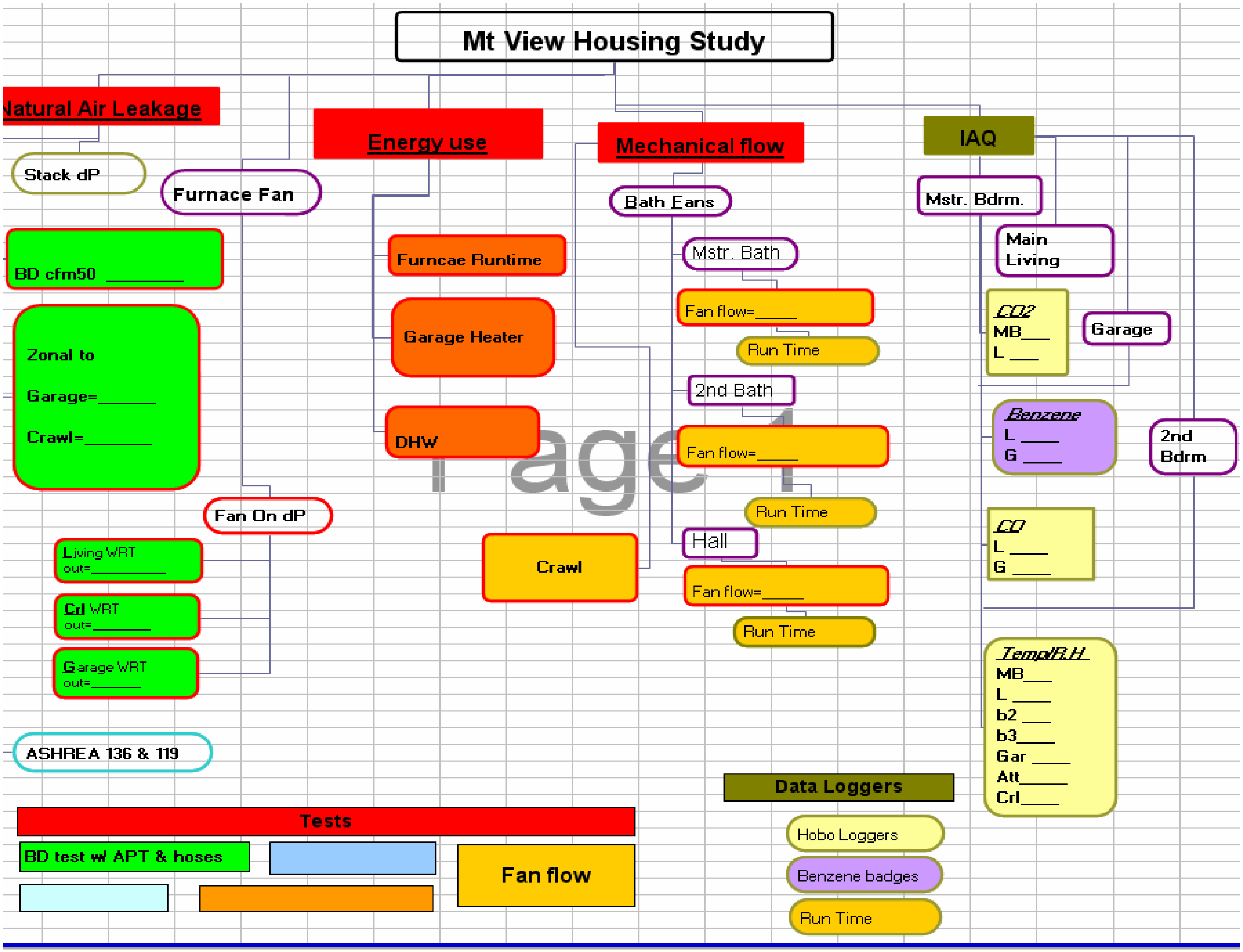
_______ Location of ducts   (crawl)   (attic)

Garage Unit Heater:

Clock gas meter: ____ sec./cf   Repeat: ______sec/cf

_____   Observe several cycles for proper operation

APPENDIX IV. HOUSING STUDY FORMAT



APPENDIX V. HOMEOWNER INFORMATION

COOK INLET HOUSING AUTHORITY - NEW HOME STUDY

Dear New Homeowner,

Congratulations on your purchase of a fine new home from Cook Inlet Housing Authority! We hope you will enjoy it for many years to come.

We have been contracted by Cook Inlet Housing Authority to provide some technical assistance on how their new houses are operating with regard to energy efficiency, ventilation, indoor air quality and occupant comfort.

To help us in this evaluation, we will be temporarily installing some monitoring instruments in various locations in your house. Our goal is to get one month's worth of data before removing the instruments. We will try to be as unobtrusive as possible and hope not to inconvenience you in any way.

The instruments that you may notice placed throughout your house include:

> Living Area and Master Bedroom: basket includes instruments for recording temperature, relative humidity, carbon monoxide and carbon dioxide.
>
> Other Bedrooms, crawlspace and attic: temperature and relative humidity instrument.
>
> Garage: carbon monoxide, temperature and relative humidity sensors, and heater run-time data logger.
>
> Ventilation fans – run-time data logger.
>
> Heating system and water heater – run-time data logger.
>
> Outdoor gas meter – gas use data logger (six study homes only).

We would appreciate it if you would leave these instruments in place and not interfere with their operation. If a problem arises, please contact us at the phone number listed below.

To get the most useful information on how your home works for you, we hope you will ignore all of these instruments and lead your life as normal, doing your day-to-day activities as routinely as possible. We have enclosed a short questionnaire that we will pick up at the end of the month, where you can let us know if there have been any problems.

Thank you very much for being willing to participate in this study. We look forward to sharing with you any useful results.

COOK INLET HOUSING AUTHORITY NEW HOME STUDY - HOMEOWNER QUESTIONAIRE

House Location: ______________________________________Owner:__________________________
Dates of Study: Beginning Date:_________________________ Ending Date:_______________________
Number of occupants: ________Adults _______Children under 10 _______Teens________

1.	During the time of this study, was your home not occupied for longer than one day? (Circle one) If yes, can you tell us when and for how many days?			Y	N
2.	Was your home operating in a normal manner during the time of this study? If not, describe the problem:			Y	N
3.	Did you find all areas of your home warm and comfortable? If not, describe the problem:			Y	N
4.	How often did you: Use the cook stove? Wash clothes? Use the clothes dryer? Shower? Take a bath?	Minutes/Day	Minutes/Week		
5.	Was your car kept in the garage each night during the study?			Y	N
6.	Comments or concerns?				

LETTER OF AUTHORIZATION

The Cook Inlet New Homes Energy Study includes a comparison of each home's gas and electric bills for the month of the study. In order to obtain that information from your utility we need your signature of authorization. If you would rather supply us with the utility bills for that time period, that is okay.

Release

I hereby authorize the following fuel and electric suppliers to release to Sunrise Energy Works the energy use data for my home located at the address below:

Enstar Natural Gas Account No.(If available)___________________

Anchorage Municipal Light and Power Account No. (If available)___________________

I hereby authorize you to release information on my fuel bills for the purpose stated above. I agree that a photocopy of this release may be used. I understand that this information will be used only to provide data for the above-named agency, and no information obtained through this release shall be made public in such a manner that the dwelling or occupants can be identified.

Fuel Customer Name	Street Address/Mailing Address
Signature	Date