# Test Project Results
# Evaluation of the Intellidyne Warm Air Furnace Control

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The Intellicon control, manufactured by Intellidyne, LLC of Plainview, N.Y. seeks to reduce energy consumption in warm air furnace heating system by adjusting the cycling pattern. The purpose of this test was to evaluate energy savings actually achieved in a field test conducted during the 2009/2010 winter heating season.

The field tests were conducted at two large office/ clinic facilities of the ACLD (Adults and Children with Learning and Developmental Disabilities, Inc.). This included the ACLD Day Services Center at 837 South Oyster Bay Road and the Executive Offices and Health Services Center at 807 South Oyster Bay Road. Both are in Bethpage, New York.

Heating and cooling for these one-story buildings is provided by a set of rooftop units which provide hot or cold air to specific zones, each with individual thermostats. The rooftop units incorporate atmospheric, gas-fired burners with fixed firing rates. In this report units are designated, for example by 7/307 which indicates rooftop unit #7 located on the building at 807 S. Oyster Bay Rd.

Intellidyne LLC installed their control systems on 6 units including 9/837; 3/837; 4/837; 7/837; 10/807; and 7/807. In addition to the control systems, Intellidyne added data acquisition equipment which monitors burner on-time as an indicator of fuel consumption. The controls operate on a one-day cycle i.e. one day they are functioning and the next they are not functioning and the furnace operates in is normal or control mode. This test duration was repeated for a nominal 60 days. The test started on 11/18/2009 and ended on 1/15/2010. Other data collected by Intellidyne included local ambient air temperature and temperature in each zone.

The basic objective of the Intellidyne measurements was to demonstrate that the furnace would require less fuel to achieve the same space temperature, corrected for changes in outdoor air temperature. The objective of the BNL work, described here was essentially to evaluate the source of energy savings and validate the Intellidyne conclusions.

To compliment the Intellidyne data, BNL added loggers to monitor flue gas exhaust temperature and the warm air discharge temperature from one of the units – 9/837. Figure 1 provides a photo of the roof with some BNL instrumentation visible.

**Results**

Instead of using Intellidyne measured local temperatures BNL us average daily values as the mean of data from Long Island Islip and JFK International airports. Figure 2 shows the trend in daily average outdoor temperature over the test period.

Figure 3 shows some interesting results for unit 9/837 flue gas temperature which illustrate the effect that the Intellidyne control has on furnace operation. With the control, the cycling rate of the burner on the furnace is much higher than with the control out of the system (not functioning or baseline case). This results in a significantly lower flue gas exhaust temperature and, as a result a higher combustion efficiency. From Figure 2, with the control off the furnace runs essentially in steady state with a flue gas temperature of 425F.

Figure 4 shows an expanded view of the exhaust gas temperature with the control on and illustrates a clear pattern – every third cycle the burner runs longer. In discussions with Intellidyne staff, they explained that this results from the programmed operation of their unit that seeks to regularly reoptimize the cycling pattern. From the pattern shown in Figure 4 the average flue gas temperature with the control on is 340F. Using a flue gas oxygen content of 10%, which is typical of atmospheric burners, the average combustion efficiency with the control on and off can be compared. With the control off, flue gas temperature of 425F and oxygen content of 10% combustion efficiency is 77.6%. With the control on, flue gas temperature of 340 and oxygen content of 10% the combustion efficiency is 80.6%. The difference in combustion efficiency is 3 percentage points. The reduction in fuel use to achieve the same heat output based on these two values of combustion efficiency is 3.7%.

With the control, the furnace warm air outlet temperature also cycles and stays in a lower average range than with the furnace on. Figures 5 and 6 provide a comparison of furnace air outlet temperature between the baseline case and the case with the control on. This temperature was measured right at the furnace air outlet.

In addition to our data, we have obtained a significant amount of run time data from Intellidyne for all of the units and this data provides a basis for correlating run time and cycling with outdoor air temperature and, in turn, estimating the impact of the control on energy use.

Figures 7 to 11 illustrate the impact that the control has on total number of burner cycles per day for 5 of the units. This analysis was done just for selected days during the test period.

For all of the sites, based on Intellidyne data, an analysis was done of the run time / average outdoor temperature correlation with the control on and off. Results are illustrated in Figures 12-17. In all cases the data was fit with a linear regression and the regression equation and correlation coefficient are included on the charts. In general the correlation is poor indicating that other factors in the building are strongly affecting the run time. These factors may include daily use pattern changes and interzonal heat flows.

For all of the units, based on the correlations, an analysis was next done of the ratio of burner on time with the control on to burner on time with the control off as a function of average outdoor temperature. Results are shown in Figure 18. To help understand the meaning of this parameter – a value of this ratio of 0.9 could be considered as an energy savings of 10%. For all of the units except 10/837 the value of this ratio converges to a level less than 1.0 as the air temperature decreases. At mild weather conditions, e.g. > 40 F the ratio diverges strongly for all units and this is likely a result of light and highly variable heating loads. We don't have an explanation for the behavior of unit 10/837.

To provide an evaluation of the potential annual energy savings based on the data collected during this test, a load profile for a typical commercial building was used. This was developed using Energy- 10, an hourly building load simulation program and the input for this was a single story, 20,000 $ft^2$ office building located in Bridgeport, Ct. This simulation was done only to generate a profile for hourly outdoor temperature variation and heating load. These results were combined with the curves from Figure 18 to determine, for each of the 6 units included, what the annual energy savings would be. Note that this analysis completely ignores interzonal heat flows and assumes that each unit essentially performs in isolation with the energy savings associated with the control as shown in Figure 18. Table 1 shows the projected annual energy savings for each unit.

Table 1. Projected Annual Fuel Use Reductions

| Unit | Reduction |
|---|---|
| 9/837 | 13.0 |
| 3/837 | -7.2 |
| 4/837 | -1.8 |
| 7/837 | 17.2 |
| 10/807 | -8.6 |
| 7/807 | 9.4 |

To combine the energy savings of the individual units into a single figure of merit, the annual savings provided by each unit was weighted by its run time or energy use. The metric used for this was the run time, with the control off with an average outdoor temperature of 42 F.  This run time at 42 F was used only as an indicator of how much load there is on each unit. The total weighted projected savings is 8.7%.  As an alternative metric an evaluation was done which also includes the nominal input rating of each of the units.  This, combined with run time at 42 F provides a measure of the contribution of each individual unit to the total fuel consumption of the 6 unit set.  This approach yields a weighted projected savings of 8.3%.

Another result of interest is provided in Figure 19.  Here we have plotted the projected annual fuel use savings vs. the daily burner run time at 42 F.  This seems to lead to the simple conclusion that the more a unit runs the greater the savings would be.

As an alternative to the methods presented above for estimating energy savings potential of this control concept, an evaluation of the total fuel use by the building, based simply  on gas meter readings and outdoor weather was done.  In this approach the total gas use in prior years, normalized for outdoor temperature was compared to gas use after the control was installed. This comparison was done only for the time period over which the test was conducted and this is roughly late November to late January.  During this period all of the rooftop units had the control in place but some of them were included in the test program. For those included in the test program, the control was working only every other day.

Table 2 shows the results of this analysis for Building 807. In this case fuel use data was available for the two years preceding the control test.  Table 3 shows the results for Building 837.   Both of these show that the fuel use, weather adjusted,  during the 2009-2010 period, where the control was in use, was significantly lower than in prior years.  These results are very encouraging but the magnitude of these results are not consistent with the all of the test results presented above. Specifically there is not a clear source for savings of this magnitude.

Conclusions

- All of the test results clearly demonstrate that the control tested increases the cycling rate dramatically and this leads to an average reduction in the exhaust gas temperature. This reduction leads to an increase in efficiency and a clear reduction in fuel use of 3.7%.
- Attempts to correlate fuel use, based on burner run time, with control on or off during the test period showed a very large degree of scatter in the data. Analysis of this data, even with the large scatter, showed reductions in fuel use with the control in some buildings and increases in others, dependent on weather conditions. Under the coldest conditions, 5 of the 6 units tested converged to an energy use reduction with the control on the order of 10%.

- To evaluate annual energy savings potential, an hourly heating load simulation was run for a typical local commerical building using Energy 10 software. This provided the magnitude of expected savings and again results were positive for some units and negative for others.
- Results of all units when averaged, weighted based on total unit fuel use, yielded an annual savings of 8.3%.
- Analysis of total fuel use in each of the two test buildings, based on meter readings, was done to provide another measure of potential savings. This yielded savings in the 20% range, which is not supported by the day on/ day off tests and for which a mechanism of savings is not apparent.

**Figure 1. Photo of the roof of test building during installation of controls and test equipment**

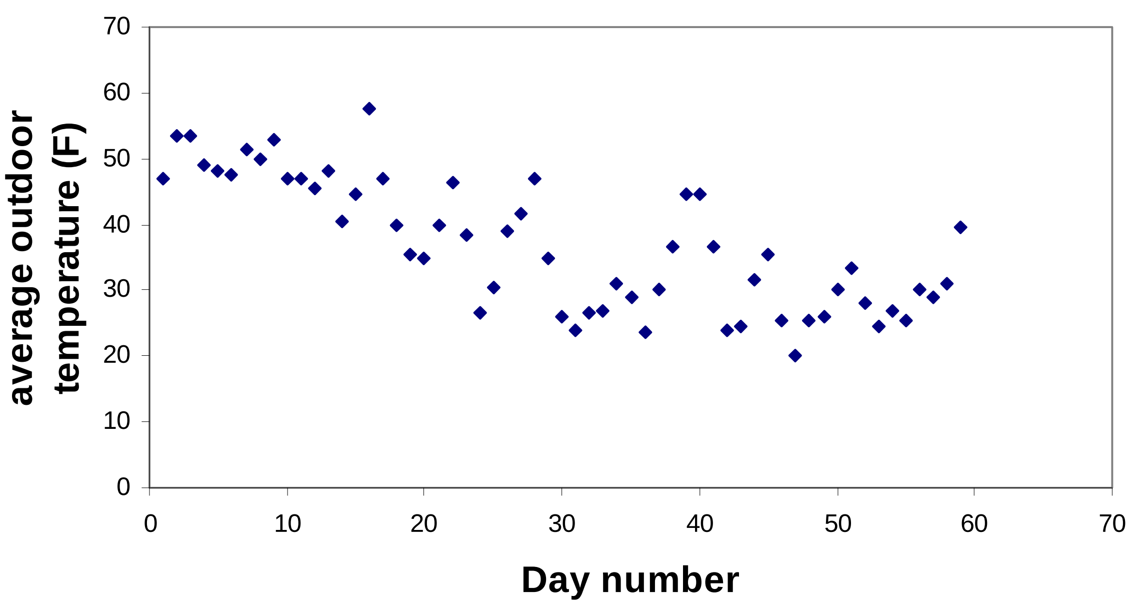


**Figure 2. Profile in outdoor temperature during the test period**

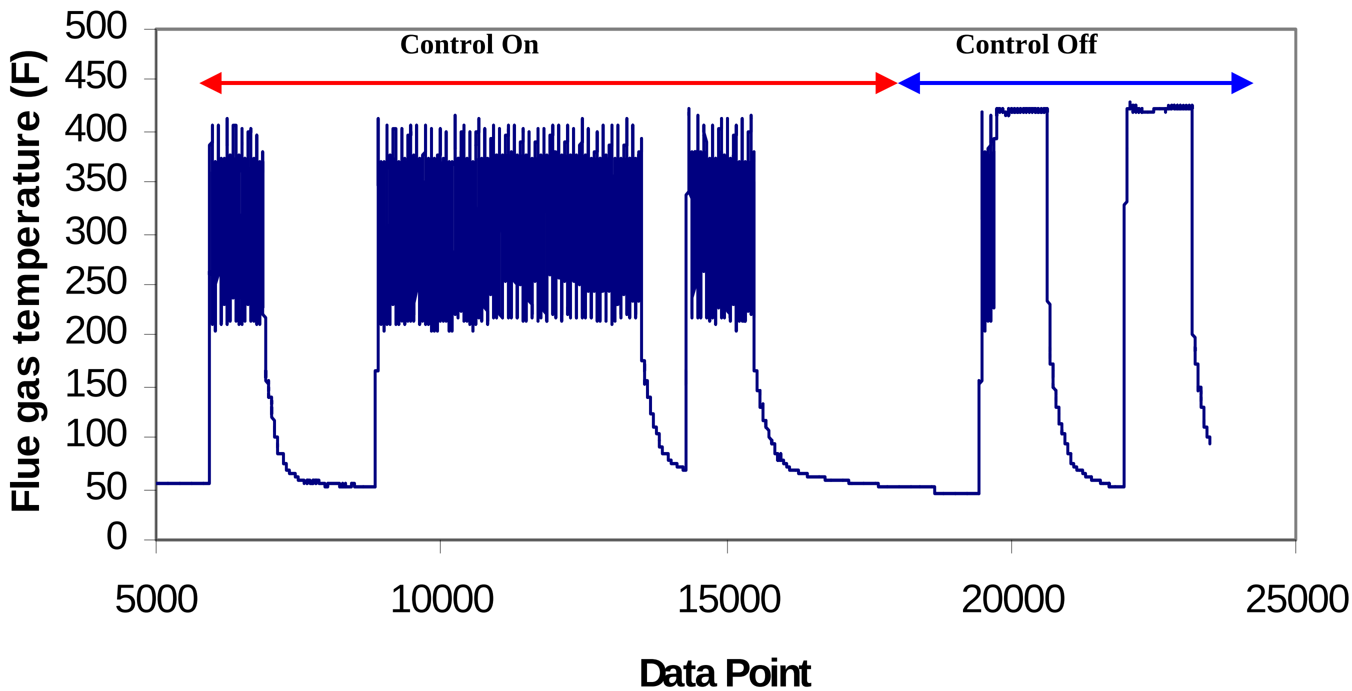


**Figure 3. Flue gas temperature with control on and off**

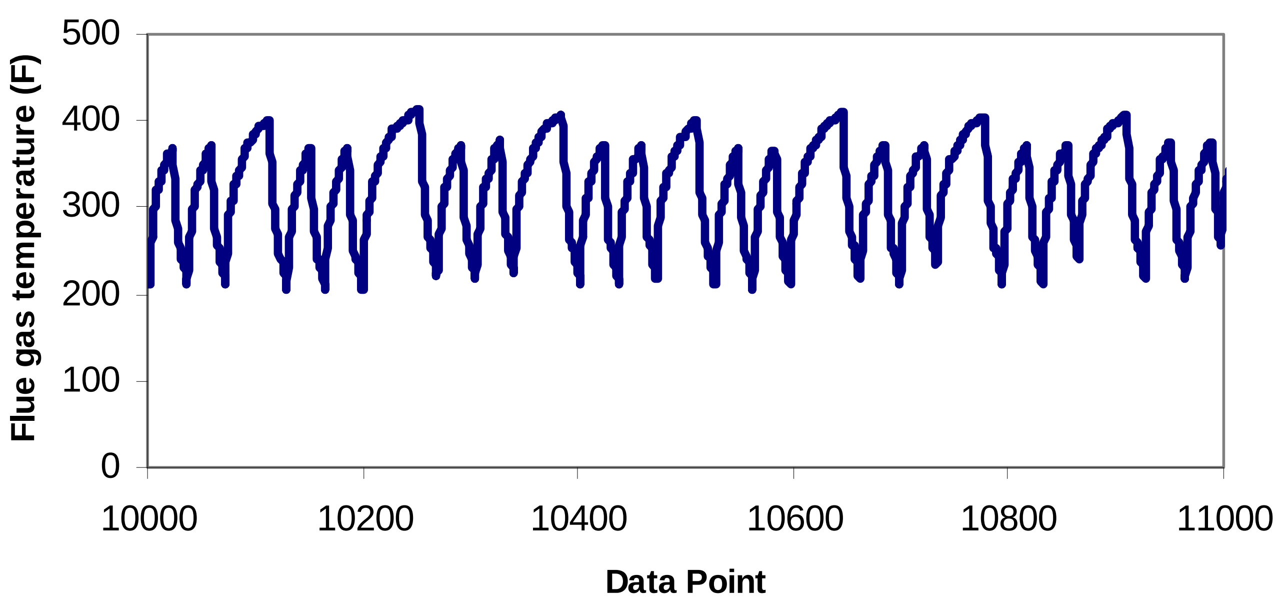


**Figure 4. Flue gas temperature with control on , expanded scale**

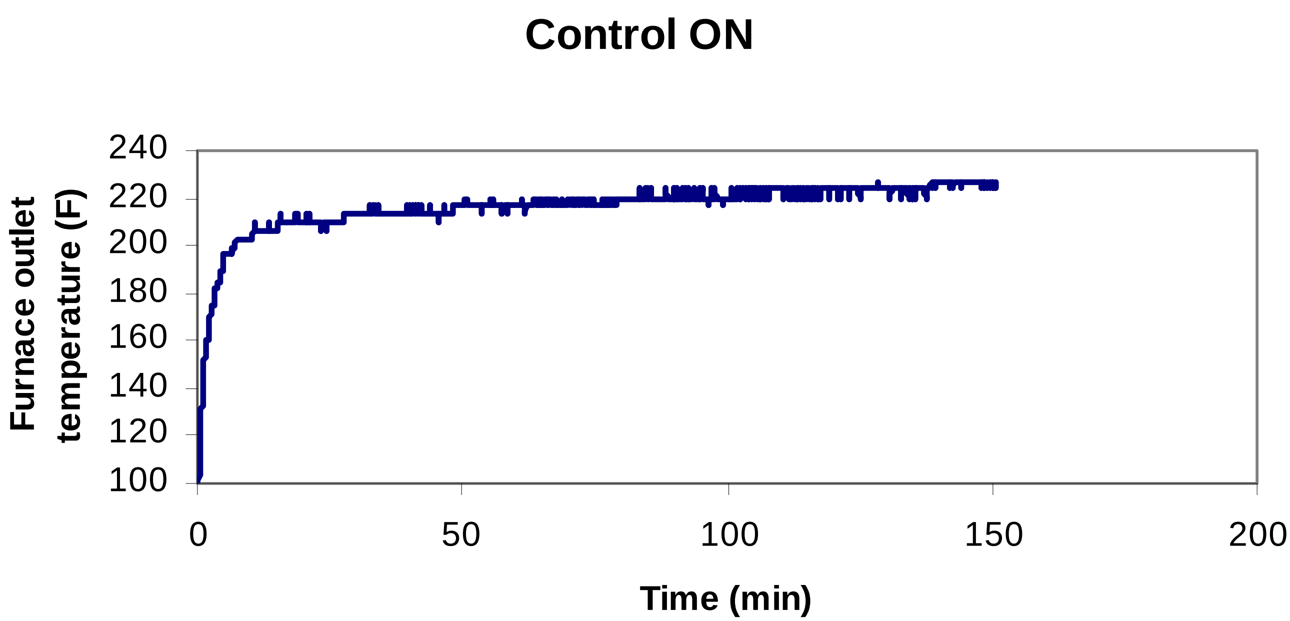


**Figure 5. Air outlet temperature with the control off**

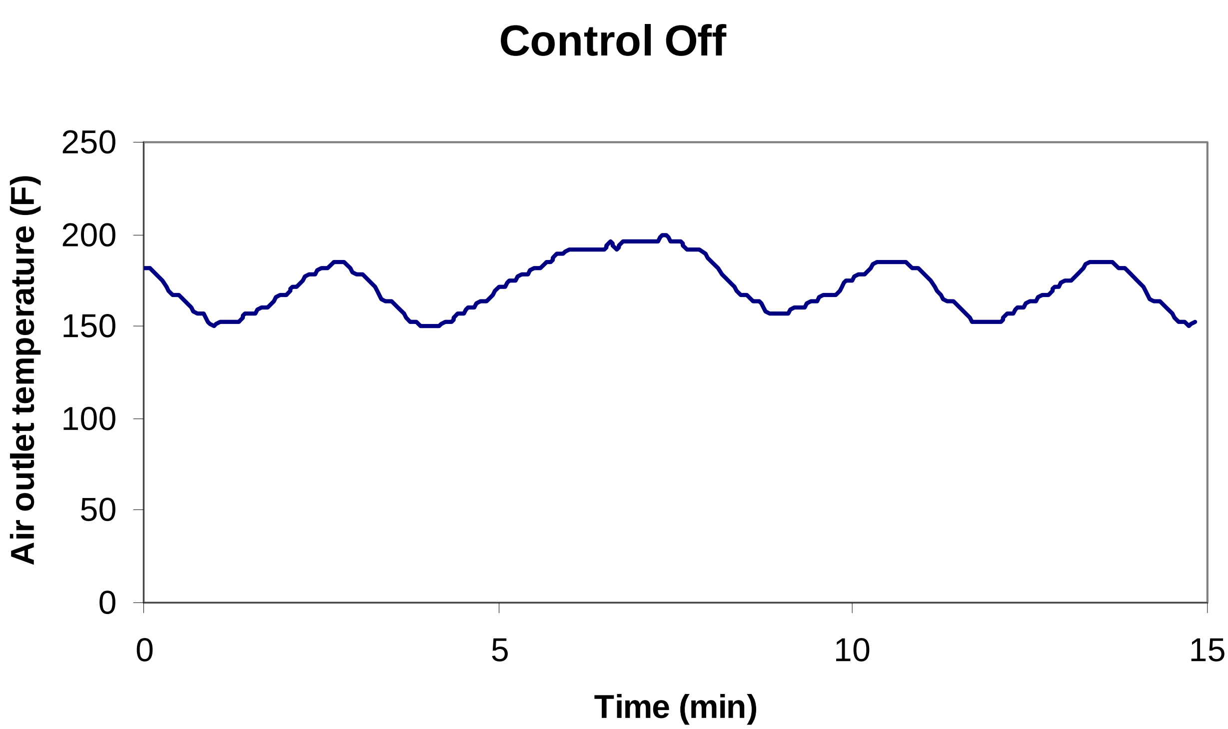


**Figure 6. Air outlet temperature with the control on**

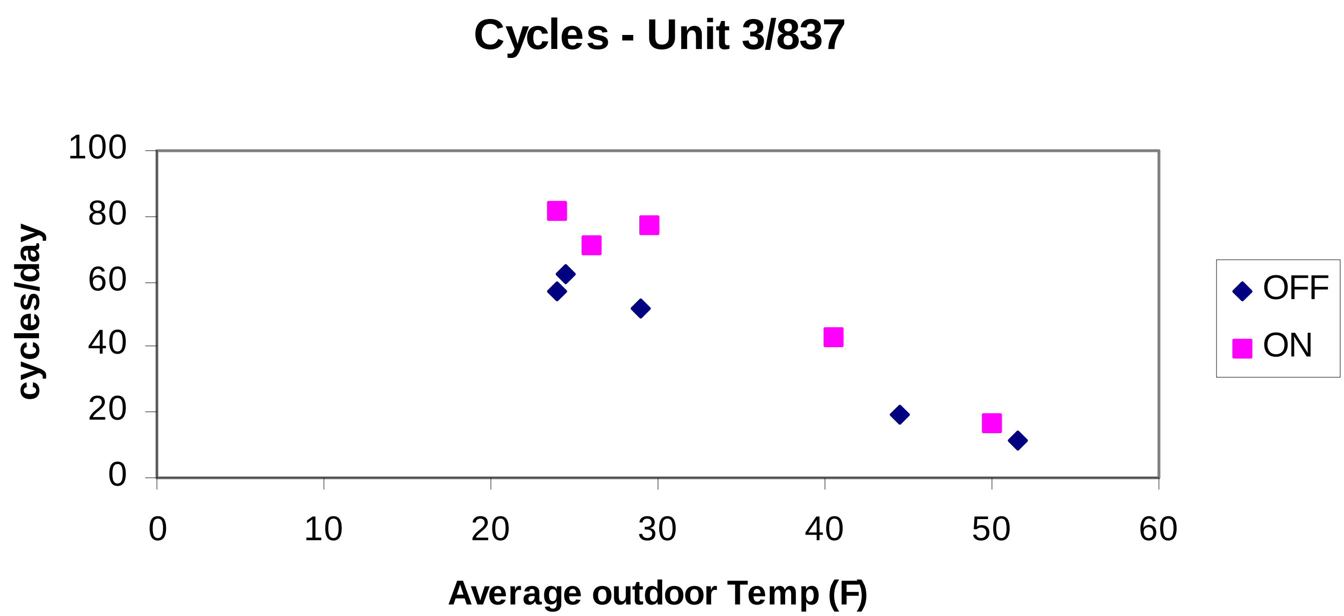


**Figure 7 Cycles per day – Unit 3/837 Control on and off**

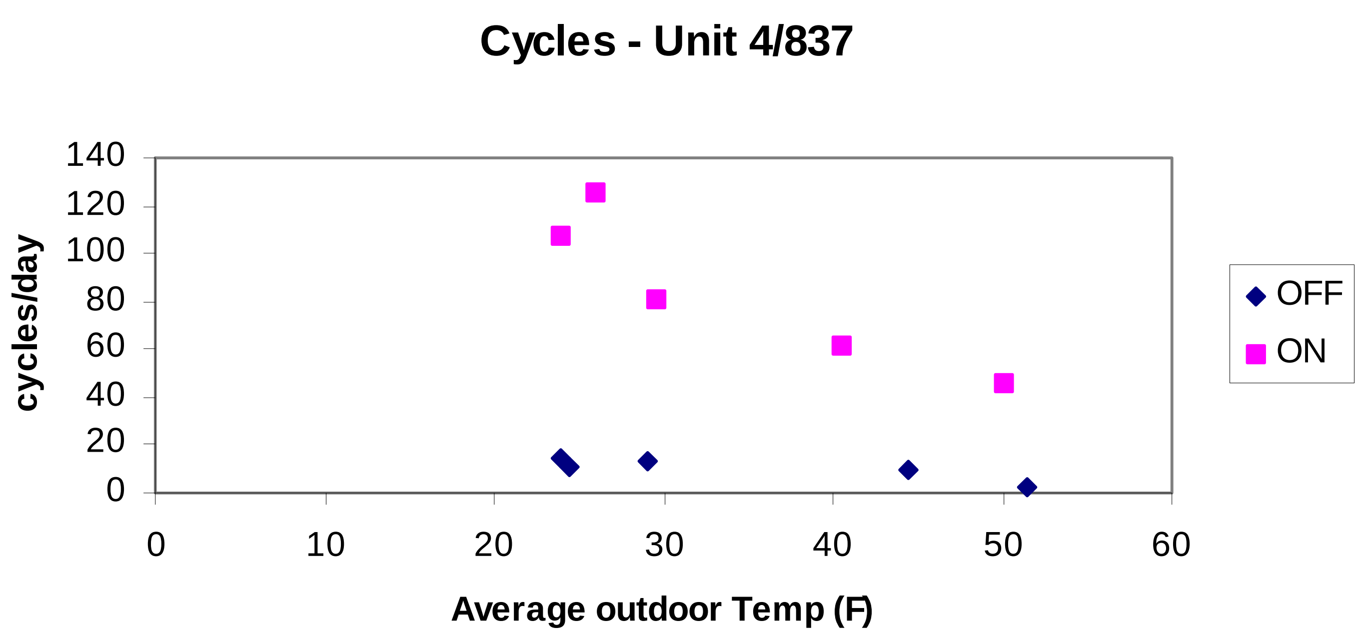


**Figure 8 Cycles per day – Unit 4/837 Control on and off**

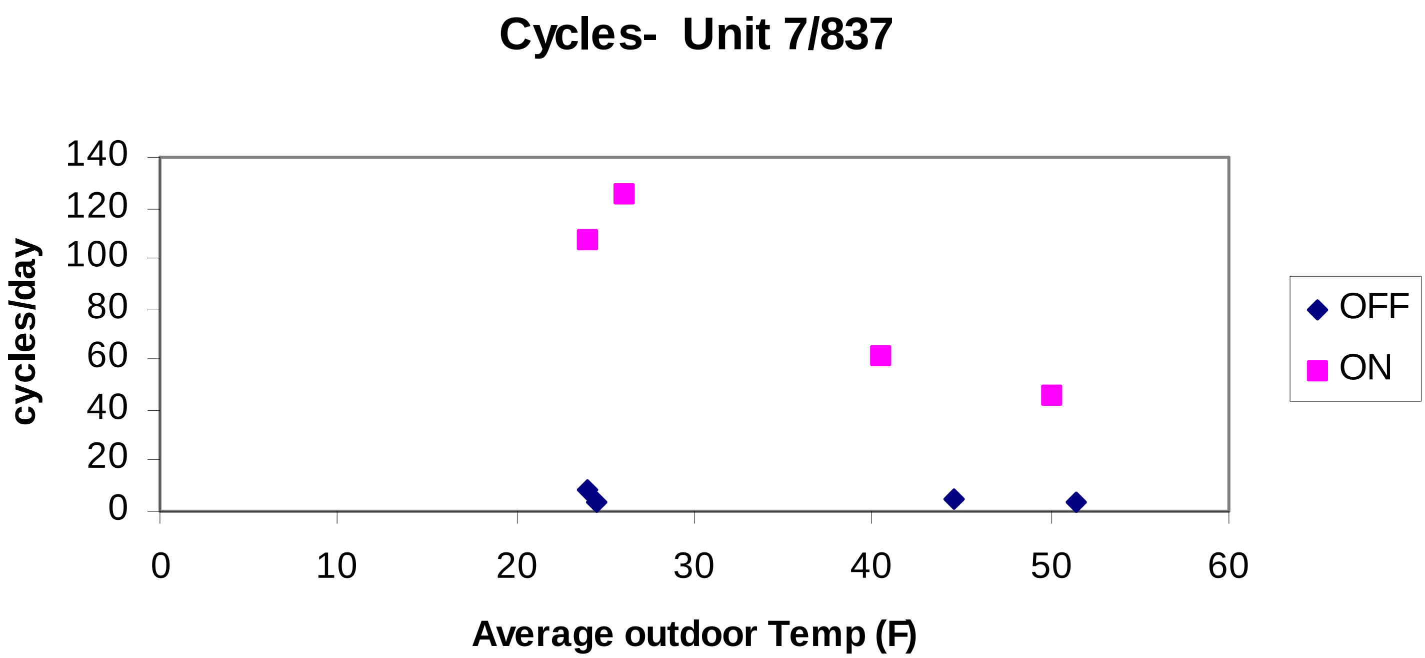


**Figure 9 Cycles per day – Unit 7/837 Control on and off**

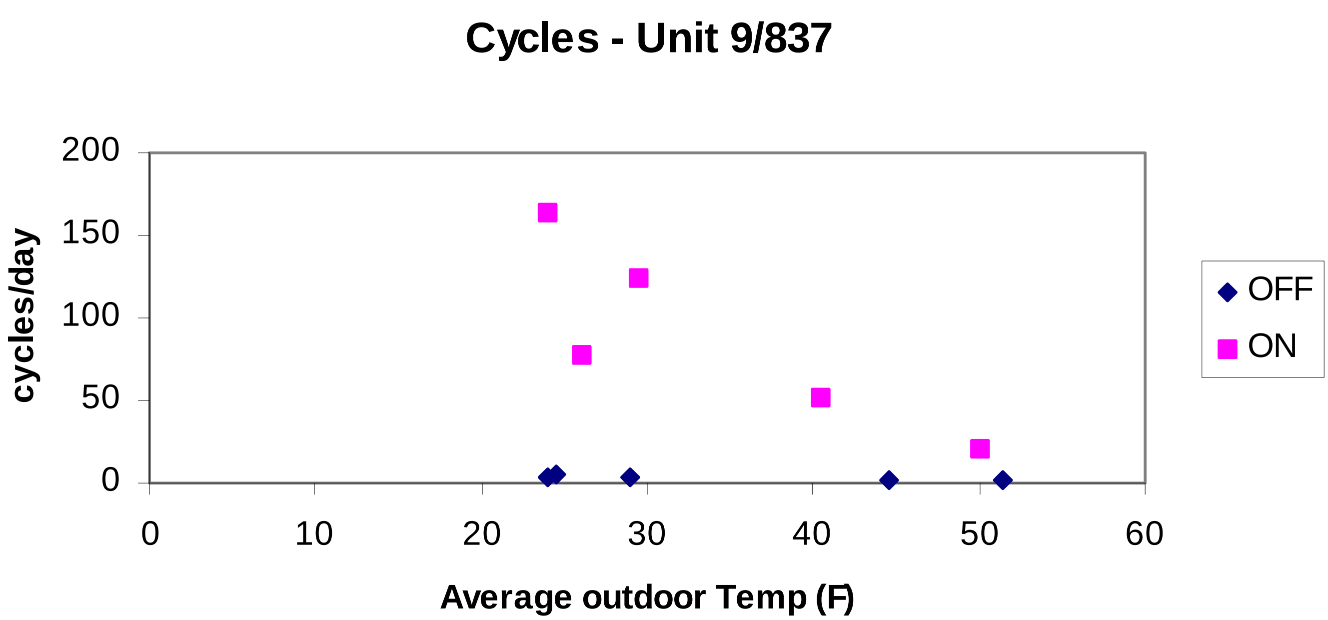


**Figure 10 Cycles per day – Unit 9/837 Control on and off**

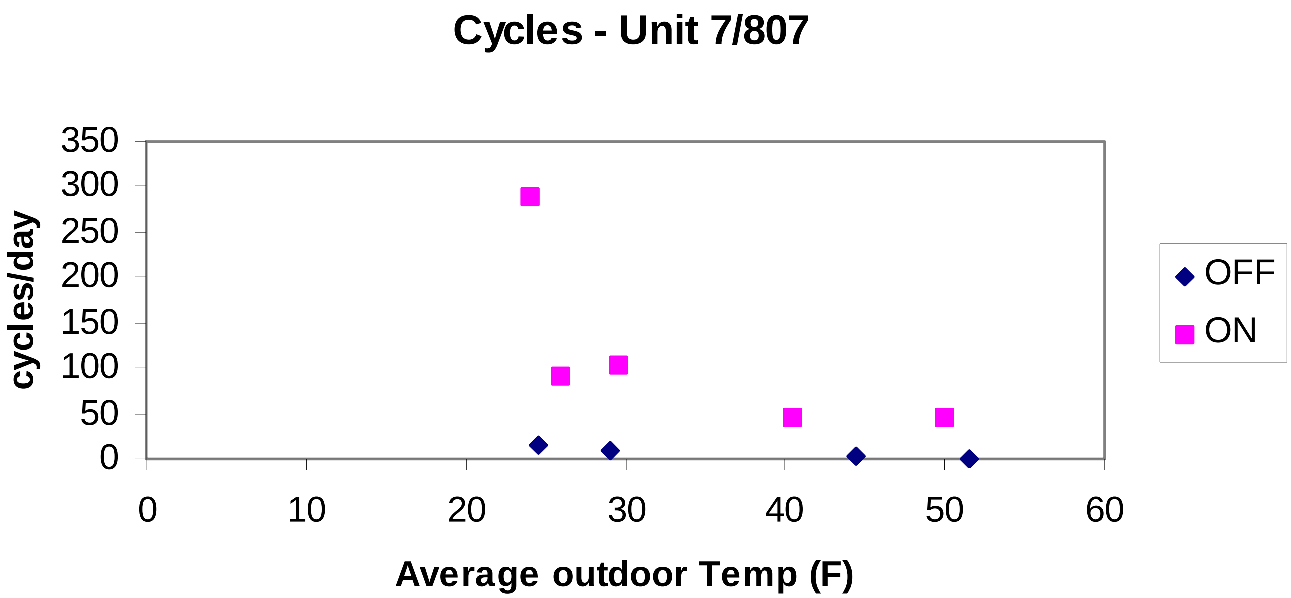


**Figure 11 Cycles per day – Unit 7/807 Control on and off**

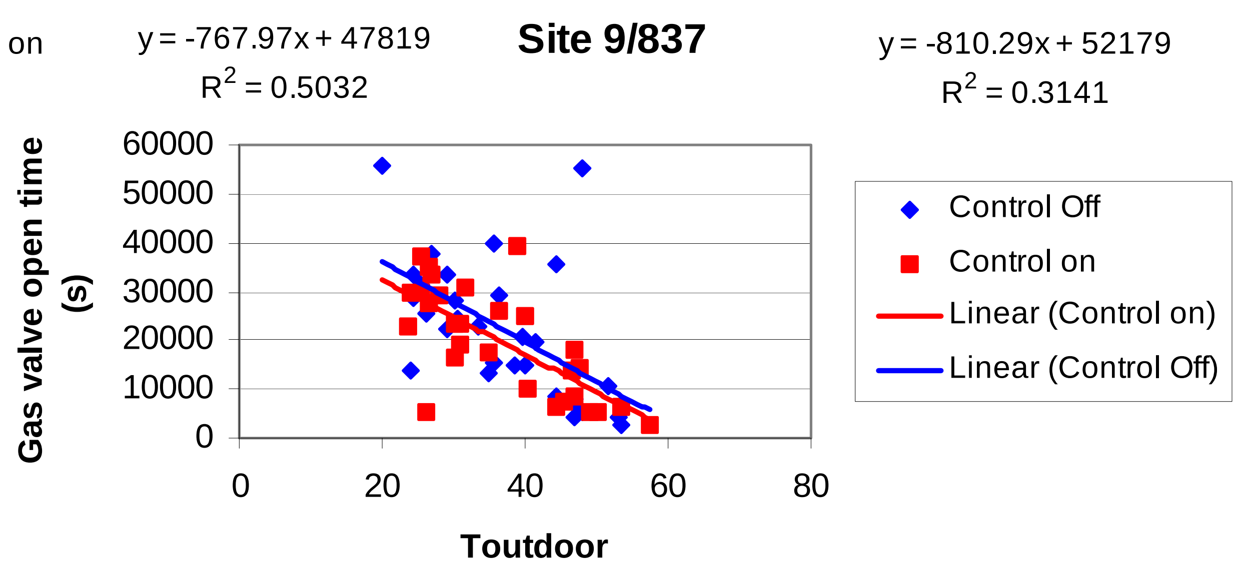


**Figure 12 Burner run time – Unit 9/837 – Control on and off**

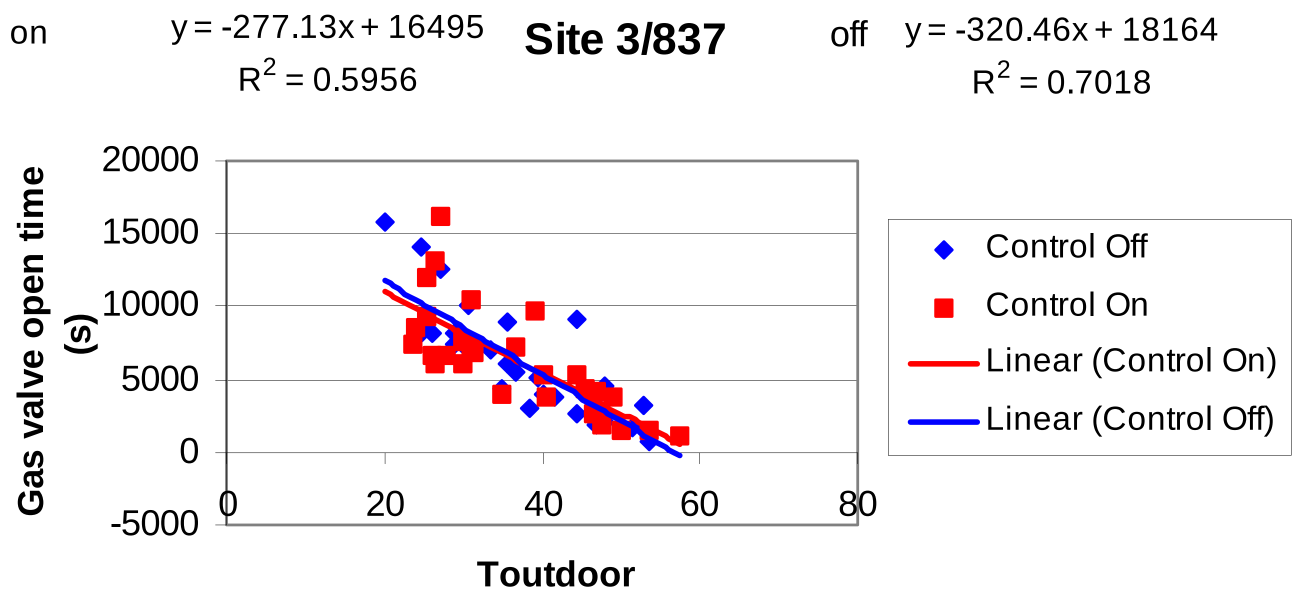


**Figure 13 Burner run time – Unit 3/837 – Control on and off**

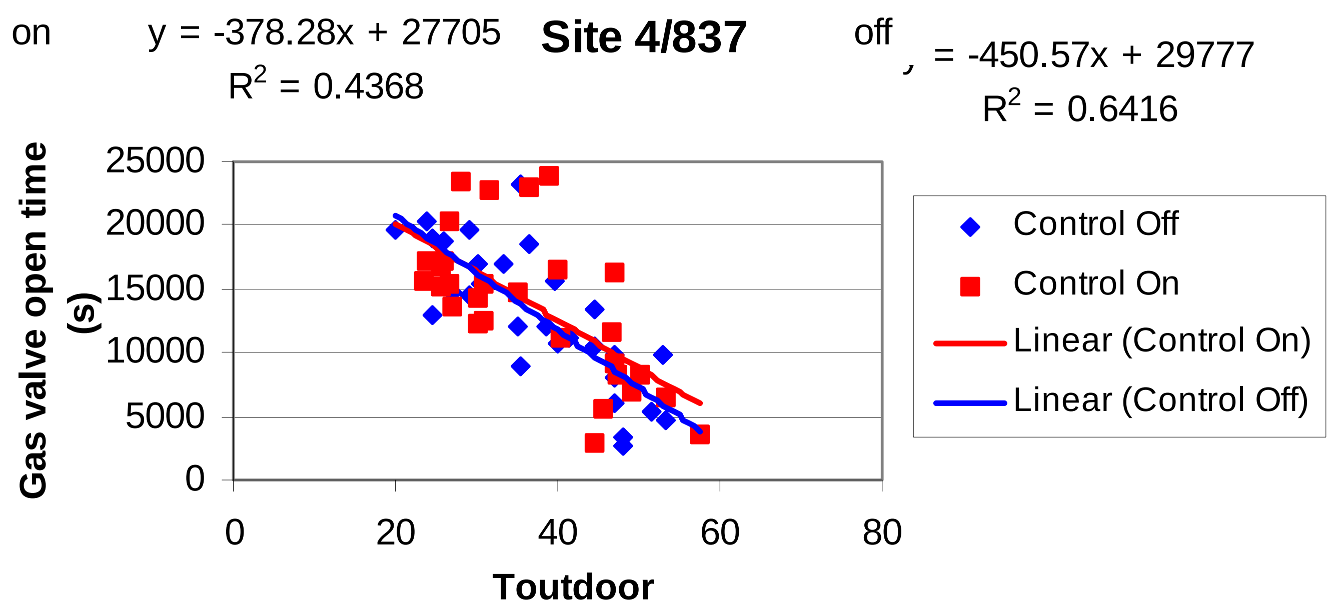


**Figure 14 Burner run time – Unit 4/837 – Control on and off**

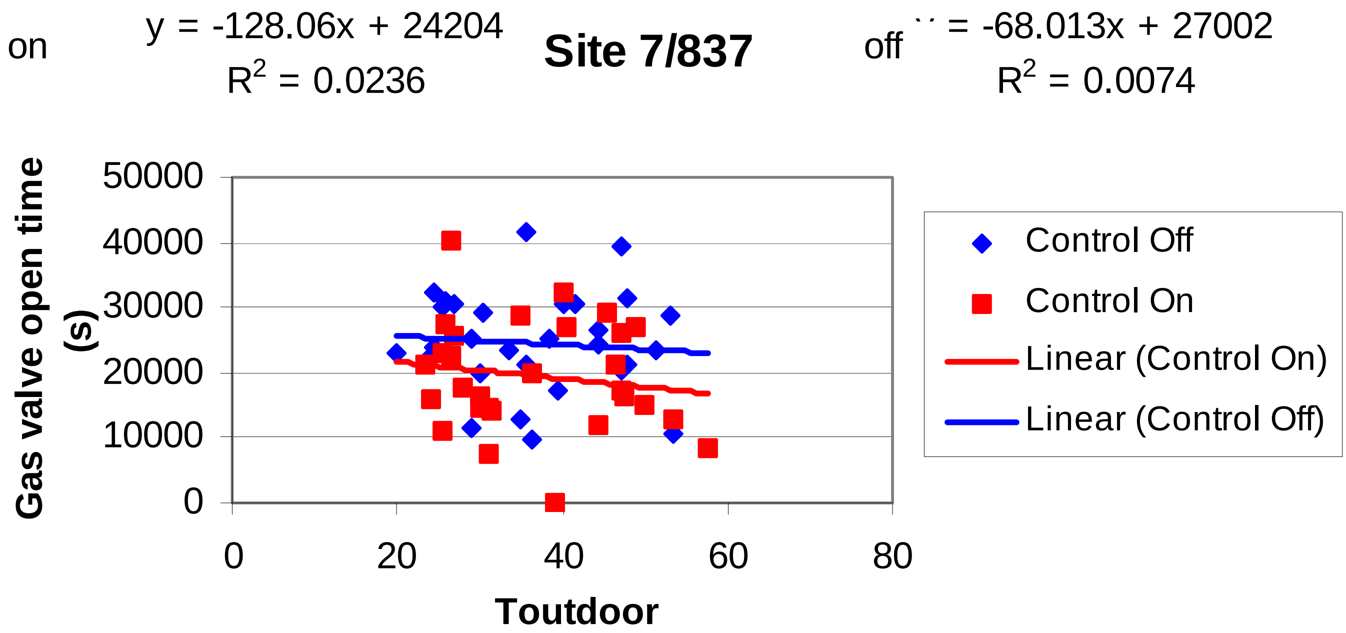


**Figure 15 Burner run time – Unit 7/837 – Control on and off**

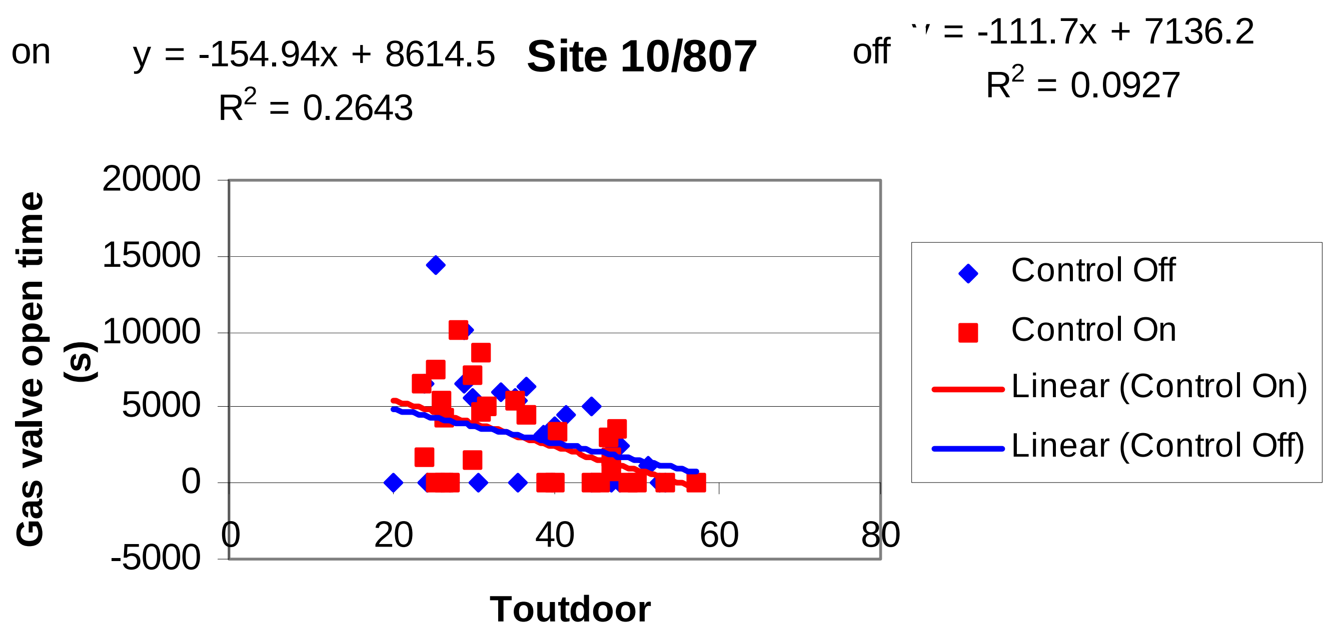


**Figure 16Burner run time – Unit 10/801 – Control on and off**

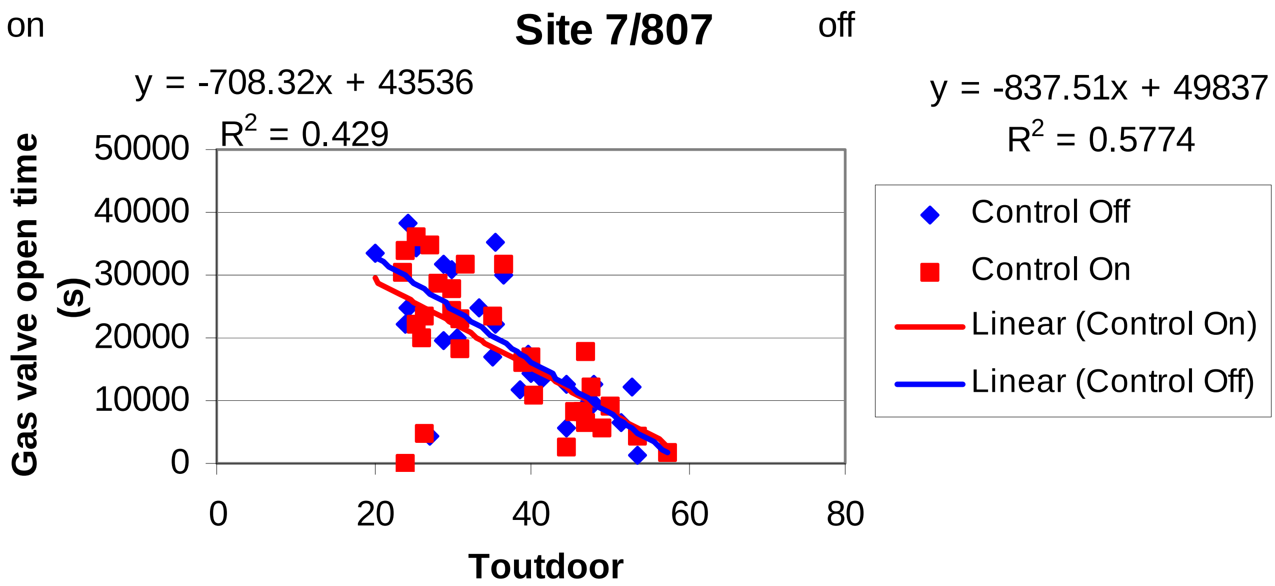


**Figure 17 Burner run time – Unit 7/807-Control on and off**

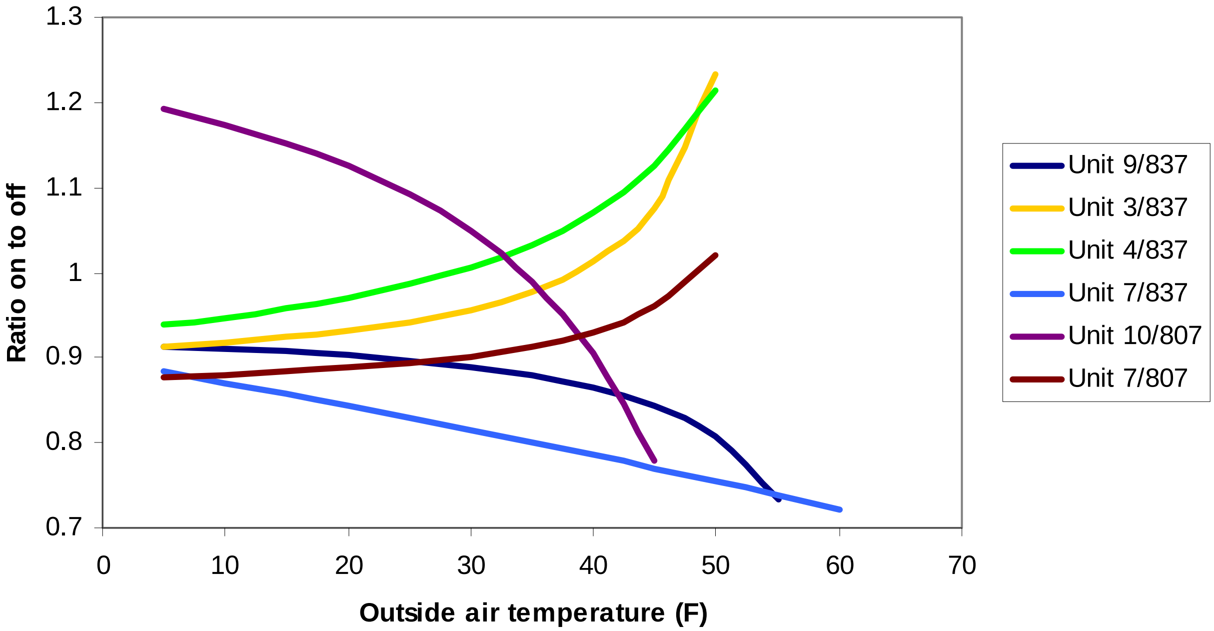


**Figure 18 All units – ratio of burner on to off times as a function of outdoor air temperature**

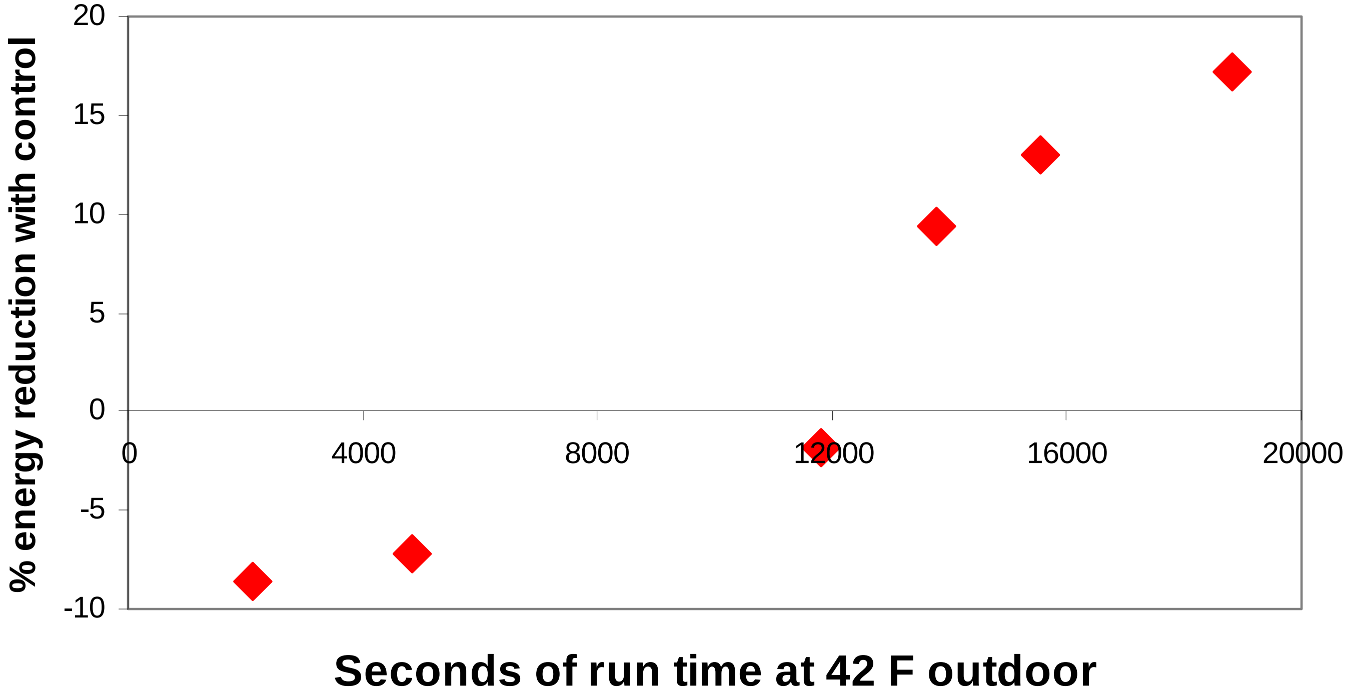


**Figure 19 Projected annual savings as a function of the load on each unit**

Table 2. Results of fuel use analysis, based on meter readings for Building 807

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| **Building 807** | | | | | | |
| 2007-2008 | **Before installation of controls** | | | | | |
| Start Date | End Date | Therms | Degree Days | Therms/Degree Day | | |
| 11/28/2007 | 12/28/2007 | 1909 | 822 | 2.322384 | | |
| 12/28/2007 | 1/31/2008 | 1961 | 1039 | 1.887392 | | |
| | | | | | | |
| 11/28/2007 | 1/31/2008 | 3870 | 1861 | 2.079527 | | |
| | | | | | | |
| 2008-2009 | **Before installation of controls** | | | | | |
| Start Date | End Date | Therms | Degree Days | Therms/Degree Day | | |
| 11/22/2008 | 12/27/2008 | 1924 | 989 | 1.945399 | | |
| 12/27/2008 | 1/29/2009 | 2366 | 1219 | 1.940935 | | |
| | | | | | | |
| 11/22/2008 | 1/29/2009 | 4290 | 2208 | 1.942935 | | |
| | | | | | | |
| | | | | | | |
| 2009-2010 | **After installation of controls** | | | | | |
| Start Date | End Date | Therms | Degree Days | Therms/Degree Day | | **% reduction from prior year** |
| 11/25/2009 | 1/27/2010 | 2889 | 1925 | 1.500779 | | **22.76%** |

Table 3. Results of fuel use analysis, based on meter readings for Building 837

| | | | | | | |
|---|---|---|---|---|---|---|
| **Building 837** | | | | | | |
| | | | | | | |
| 2008-2009 | **Before installation of controls** | | | | | |
| Start Date | End Date | Therms | Degree Days | Therms/Degree Day | | |
| 11/22/2008 | 12/27/2008 | 2269 | 989 | 2.294237 | | |
| 12/27/2008 | 1/29/2009 | 2803 | 1219 | 2.299426 | | |
| | | | | | | |
| 11/22/2008 | 1/29/2009 | 5072 | 2208 | 2.297101 | | |
| | | | | | | |
| | | | | | | |
| 2009-2010 | **After installation of controls** | | | | | |
| Start Date | End Date | Therms | Degree Days | Therms/Degree Day | | |
| 11/25/2009 | 12/29/2009 | 1675 | 953 | 1.757608 | | |
| 12/28/2009 | 1/27/2010 | 1826 | 972 | 1.878601 | | |
| | | | | | | **% reduction from prior year** |
| 11/25/2009 | 1/27/2010 | 3501 | 1925 | 1.818701 | | **20.83%** |