

BOILER CONTROL UPGRADE REPORT

For The
Millipore Corporation & National Grid



February 2009
Revised June 2009
Prepared and Submitted by:



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1. INTRODUCTION

This study was conducted by GDS Associates under a joint agreement with Millipore Corporation and National Grid Gas Service. It is intended to provide measured energy savings of the steam process and space heating boilers in building D at Millipore's Massachusetts facilities at 80 Ashby Road in Bedford.

The information presented in this study includes an overview of activities and findings, methodologies used, historical gas usage, metered electrical data and combustion gas test data of the facilities' boilers, electricity, natural gas usage, and combustion gas.

All of the findings presented in this report are based on site visits with Millipore's Salvatore Monaco and Dave Bodwell along with additional data provided by National Grid including historical interval natural gas usage data and Millipore production input and output data. These findings are the result of what was observed at the time, along with information provided by facility staff and collected data. Every effort has been made for accuracy in this process but, as with all equipment compilations of this type, the actual quantities and locations may vary slightly.

The savings associated with boiler control upgrade included in this study are estimates based on GDS experience, analysis, data, industry standards and norms but in no way can GDS guarantee energy savings or performance. A more detailed analysis would be necessary to refine savings values prior to initiating a program or projects.

Special thanks to Sal Monaco and Dave Bodwell of Millipore for site information help and Ralph Draper from the University of New Hampshire Manchester, Engineering Technology Program for his expertise, equipment and assistance in our analysis.

This study was amended (6/11/2009) after six months of post data was collected. The 6 month results utilized regression analysis method with bin hour and heating degree days. The savings results between the bin hour and heating degree day methods were nearly identical.

The six month amended data is presented in section 4

2. OVERVIEW OF ACTIVITIES AND FINDINGS

2.1 Executive Summary

Over the course of several months GDS made six site visits to record data, install data logging metering and take photos of Millipore’s 80 Ashby, Bedford, MA - Building D steam plant. The steam plant had two 300 hp Cleaver Brooks, low pressure steam boilers fueled by natural gas. Boiler one is one of the two original boilers installed in the 1960’s (reference equipment data table below). Boiler two is similar and is a replacement Cleaver Brooks fire tube low pressure steam boiler installed in the 1990’s. Each boiler feeds a common header. The 15 PSIG steam header supplies steam to building D, C and F. Building C & F utilized the steam for Heating, Reheat and process needs. Building D is primarily space heating with a small process area also utilizing steam.

Millipore Process Boilers

Building D	Model #	Input Btu/hr	Combustion Blower HP
Boiler 1	CB 200-300	12,553,000	10
Boiler 2	CB 700 300 05	12,247,000	15

Natural Gas Consumption – 80 Ashby Rd Building D Boiler Plant

	CCF/Month				Gas Usage Savings		
	2005	2006	2007	2008	2006/2005	2007/2006	2008/2007
September		13810	14010	13790		-1%	2%
October		11990	15310	16490		-28%	-8%
November		21320	25860	21750		-21%	16%
December	33690	22980	33450	26770	32%	-46%	20%
Sum		72106	90637	80808		-26%	11%

Based on the results and many different methods of comparing both before and after installation of the boiler control and burner upgrade, GDS feels confident that good gas savings are occurring at Millipore’s Building D boiler plant. The table above show the best evidence of this with a total of 11% saved in quarter 4 (Q4) 2008 as compared to Q4 2007. When comparing Q4 2007 to Q4 2006 the trend is a typical increasing trend. Given the upward incline the savings could be great. GDS recommends a full years worth of both pre and post installation comparison to be even more conclusive. Weather and production impacts are discussed at detail in section 3.

2.2 Goals and Objectives

The goal of this project was to ascertain the potential for reduced fuel usage from boiler burner and control upgrades. The project scope of work is provided below in the bulleted list.

Several activities were conducted in completing this analysis including:

- Complete boiler tune up of both boilers, stack gas analysis readings completed before and after tune up as well as upon completion of project. Stack gas analysis readings are detailed within the report.
- Analysis of a minimum of three years worth of past natural gas usage data.
- Look for trends and correlate any consumption dips and spikes from the historical data.

- Upon completion of boiler tune up, use electrical data recording meter connected to each boiler for a minimum of two weeks to base line boiler firing and run time to gas meter consumption.
- Electrical data recorded meter conducted to each boiler for a minimum of two weeks post project completion to baseline boiler firing and run time to gas meter consumption.
- Manually record daily gas usage for duration of testing.
- Correlate boiler run time and gas consumption for process heating load and process production before and after project completion.
- Use the BIN hour method to compare gas usage and boiler run time to outdoor conditions

Each of these activities is described briefly below.

Boiler Tune up and Combustion Testing – National Grid had requested that each boiler be tested to ensure proper operation. National Grid wanted to separate any potential for additional savings from typical boiler maintenance from being tied to the boiler control upgrade. GDS performed combustion stack gas analysis testing on each boiler three times. Boiler 1 was tested on July 17th, August 20th, August 27th and September 18th, 2008. The July and August testing was prior to the control and burner upgrade. The September test was after the upgrade. Boiler 1 was tested twice prior to the upgrade because at the time of the first test the boiler was in ready mode and was not able to reach full fire for a long enough period. As a result it was retested while in lead mode on August 20th. For boiler 2 testing was performed July 17th, and twice on August 27th. The August 27th testing was performed twice in an attempt to reach higher stack temperatures. In each case the boiler load was limited. Each test conducted prior to the boiler's burner and control upgrades has shown the boilers were operating within the normal operating range¹. As a result no tune up was performed. It should be noted that Cleaver Brooks (CB) published data shows that as flue gas temperature increases the fuel to steam efficiency decreases. For the four measurements that are slightly below the published Bacharach range or 275°F - 500°F, the fuel to steam efficiency would be slightly higher. The %O₂ normal range published by Bacharach is 3%-9% while Dan Burnell at Northeast Mechanical Corp. states that a CB fire tube boiler utilizing natural gas should be in the 4% range. The test results show the %O₂ in the 2%-6% range which is lower than both Bacharach and CB average suggesting optimum operating parameters. The percent free air is the other area of interest to National Grid. The % free air should increase as the CO₂ level decreases². In each combustion test the CO₂ and % free air do not correlate directly to CB published information. This is likely attributed to the different firing levels of the boilers. In the summer it was very challenging to run the boilers on high fire longer than 4 minutes because of the reduced summer steam load.

In general, the goal of the testing and boiler tune ups was to ensure the boilers were operating in a normal range or better. Based on the test results the boilers were and are operating with a normal to slightly low stack temperature. The lower the stack temp the better the fuel to steam efficiency. If the stack temp is too low the next thing to look for is incomplete combustion. The goal for O₂ and % free air is for each to be as low as possible without compromising the combustion and draft. In each test detailed below the % O₂ and % free air look good with respect to the corresponding draft and combustion.

¹ Bacharach commercial boiler testing procedures (reference Appendix A)

² Cleaver Brooks Fire tube boiler facts, CO₂ to O₂ Conversion Chart Figure 5 page 14 (reference Appendix B)

Bacharach Test Results

Test Date	Location	CO (ppm)	O2 %	Air Free	Ambient Temp (F)	Stack		CO2	Excess Air (%)	CO (ppm)	(WC)	Notes
						(F)	Eff (%)					
Natural gas 15 psi Steam cleaver												
7/17/2008	Millipore Boiler 1	15	5.6	20	93.4	251.6	85.9	8.6	32.6	15	-0.08	brooks 300 hp Pre install - UNH-1
7/17/2008	Millipore Boiler 2	6	1.7	7	99.9	287.6	86.7	6	7.9	6	0.02	Pre Install - UNH-1
8/20/2008	Millipore Boiler 1	14	-	15	96.2	294	86.4	11.8	15	15	-0.26	Pre Install - UNH-2
8/27/2008	Millipore Boiler 2	22	6	114	71	248	85.2	8	41.9	-	0.01	Post install - UNH-2
8/27/2008	Millipore Boiler 2	129	2	14	71	249.8	86.2	10.1	12	-	0.24	Post install - UNH-2
9/18/2008	Millipore Boiler 1	26	5	34	61	252	86.1	9	28	26	-0.04	Post install - UNH-2

Historical Gas Usage and Trending – Originally GDS was not aware that hourly interval data would be available from the dedicated meter that serves the boiler room. GDS had planned to utilize Millipore’s energy management system and have Millipore staff either manually record or data trend gas usage. It was brought to GDS’s attention that National Grid had hourly interval data for meter number 52364 that is dedicated to the boiler plant. This data is more accurate than manual readings. Manual readings might not be taken at the exact same time each day and would only be daily as opposed to the National Grid supplied hourly internal data.

Weather Normalization – GDS utilized hourly weather data from the weather station in Billerica MA US Longitude 42.53, Latitude -71.22.

GDS used the local weather data and took the five minute interval data and averaged for each hour. The hourly data was then overlaid on the gas usage for the same period. This was done for the pre installation in July the post installation in late August and then again for the before period in December 2007 and the after period of December 2008. This method was used to identify the affects of weather for the daily and weekly time periods, not for the monthly. The monthly gas consumption would be less affected by weather. Statistically the longer the time period the less the variation in weather related gas consumption.

Electrical Usage and Correlation – The boiler combustion was monitored for both Boilers one and two for a minimum of two weeks. Each boiler was monitored before and after the installation of the boiler control and burner replacement. Boiler two was also monitored in the winter post control upgrade only. GDS used a statistically valid sampling of 20 minute intervals for the minimum of two weeks³. The electrical data was intended to show at what level the boilers were operating (high, low) and to indicate length of run time. In order to accomplish this GDS monitored the voltage and amperage of the feed line to the combustion boiler mounted on the front of each boiler. The feed line monitored is located in the Cleaver Brooks control panels on the side of each boiler.

³ ISO New England FCM measurement and verification protocol, April 2008

3. Data Analysis

This section of the report provides detailed information regarding the pre and post boiler control and burner upgrade gas usage as provided by National Grid for the boiler plant. Hourly interval data was used for the analysis. Each boiler was metered for electrical consumption of the combustion air blower as an indicator of boiler run time and firing level. A Dent Elite Pro data logger was used to record the electrical data (Serial number E5107) The Dent meter was used in combination with Dent CT's (CON0500 500 Amp). Five minute weather data was used to compare the potential impact of weather on the steam load. Millipore provided production output information that relates to the time period and process areas under this process load. Both Paul Lukitsch and Sal Monaco from Millipore stated that on several occasions, and after the metering, the production equipment was being operated on a 24-7 basis. In order to rule out the potential for reduced weekend and holiday operations, GDS only considered normal work days or non holiday week days when looking at the daily and weekly comparisons. For the monthly comparisons the entire month was taken into consideration.

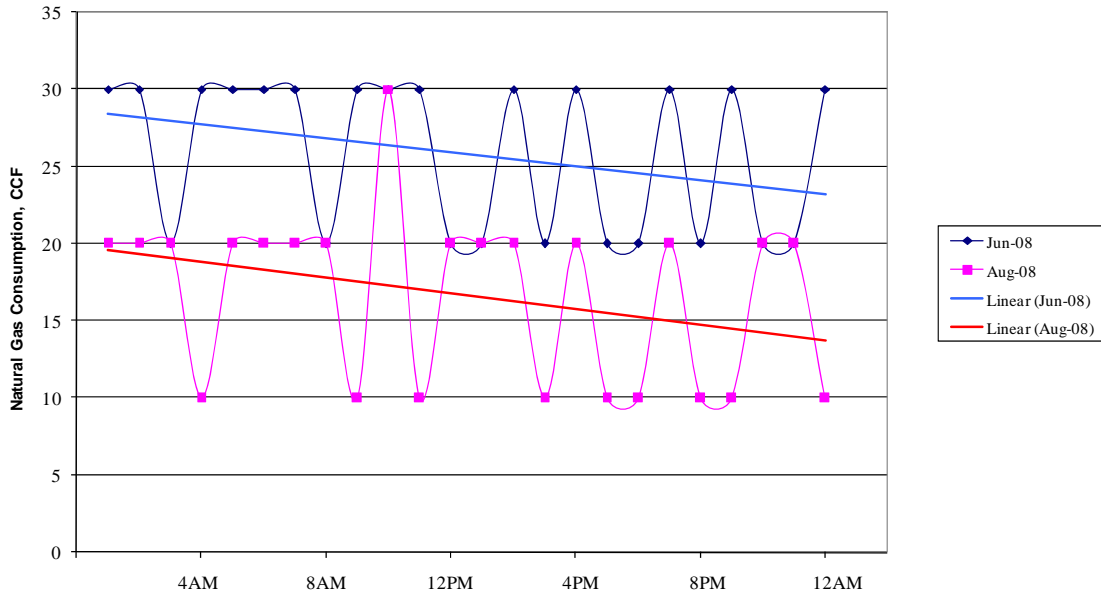
GDS's approach was to first compare the gas usage both pre and post installation of the boiler control and burner system. Then GDS added the outdoor air temperature for the time period being described. Production was then taken into consideration for the appropriate time period. The production data was supplied on a daily basis. The pre scrap production volume was used for comparison of gas consumption pre and post boiler control upgrade installation. While GDS is not able to identify exactly how far the scrap, if any, made it through the process this will need to be a consideration when using the production data in comparison to the energy usage data. GDS is not able to draw direct conclusions of the steam demand of each product line. For this report each product is assumed to have equal steam load demand.

While recording data for this project and testing each boiler it was noted that the summer load was very light on the boilers. As a result and to ensure accurate analysis GDS also monitored and compared winter gas usage and looked at the potential impact of weather. No electrical data was taken in December of 2007 as this was prior to GDS' involvement with the project. Electrical data in December 2008 was logged and utilized.

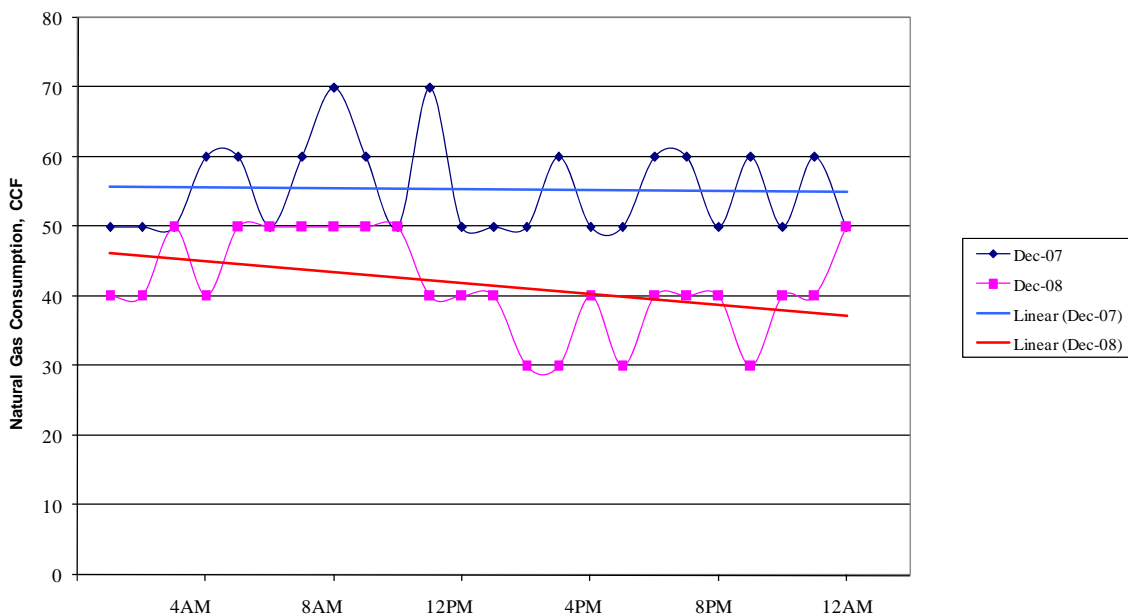
3.1 Daily Comparison Figures:

Gas Usage (Daily): The following two figures show the gas usage for a day in the summer both before and after the installation of the boiler controls and burner. The first graph shows a decrease in usage. Weather and production were not taken into consideration in these graphs. The second figure looks at winter day comparisons.

**Hourly Boiler Usage in the Old Boiler Plant
for Wed. June 25, 2008 versus Wed. August 27, 2008**

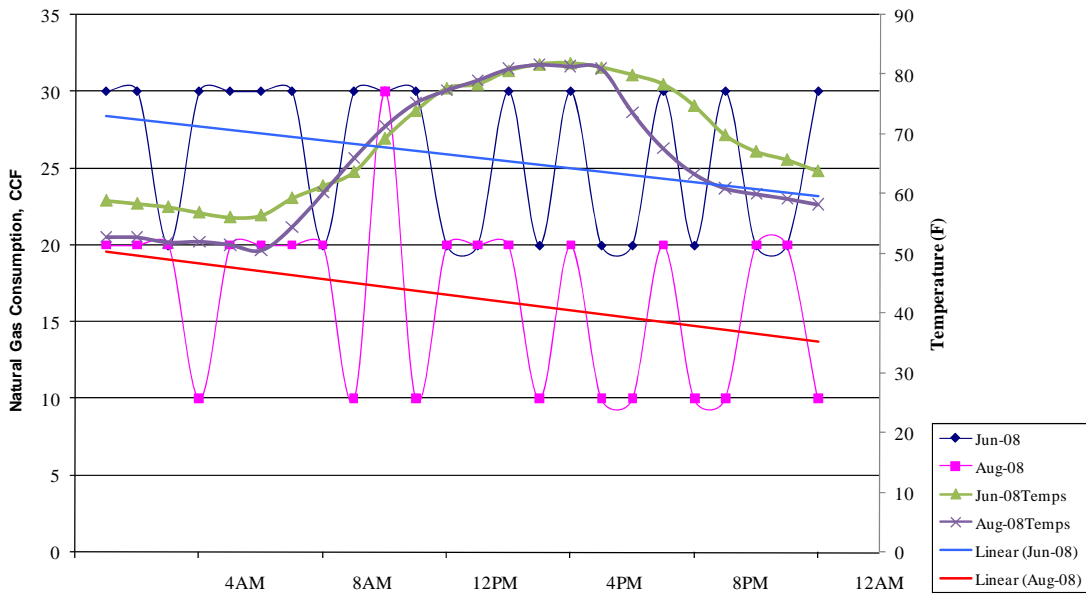


**Hourly Boiler Usage in the Old Boiler Plant
for Wed. December 5, 2007 versus Wed. December 3, 2008**



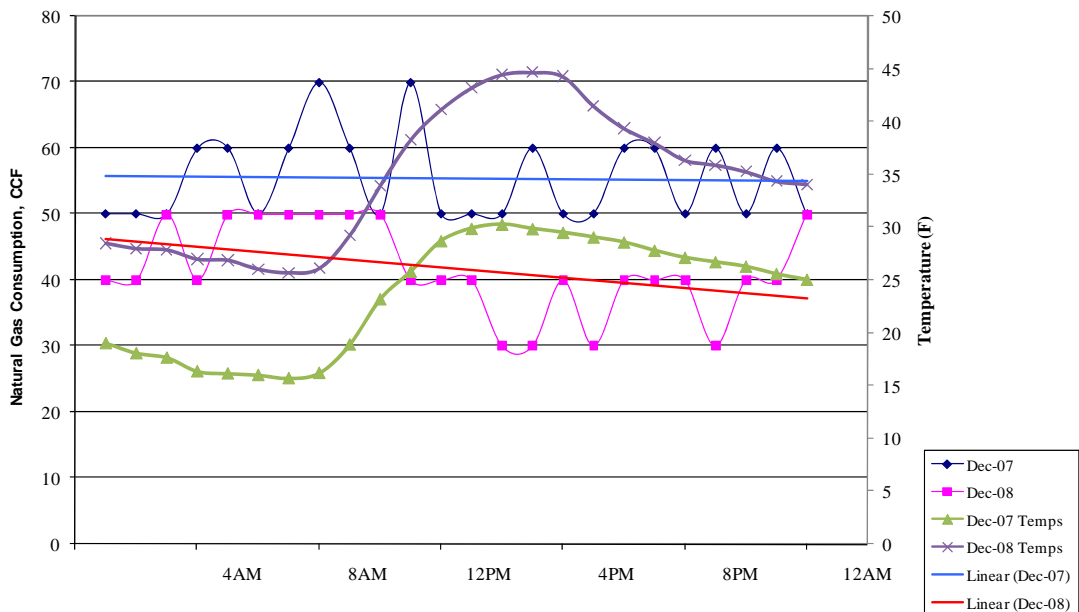
Gas Usage with Weather Data (Daily): The following two figures show the same daily gas usage as above with the time specific weather data overlaid to help show the impact of the weather on the gas usage. The summer data figure shows no potential impact from weather for good reason. The summer steam load should be tied to the process load. Weather data was nearly identical.

**Hourly Boiler Usage in the Old Boiler Plant and Outside Temperatures
for Wed. June 25, 2008 versus Wed. August 27, 2008**



The following figure shows the gas usage and weather data. In this figure the weather could very well have had an effect on the reduced gas usage. The outdoor temperature in 2008 as compared to the same time in 2007 was higher. The gas usage in 2008 is less and could be tied to or influenced by the outdoor air temperature.

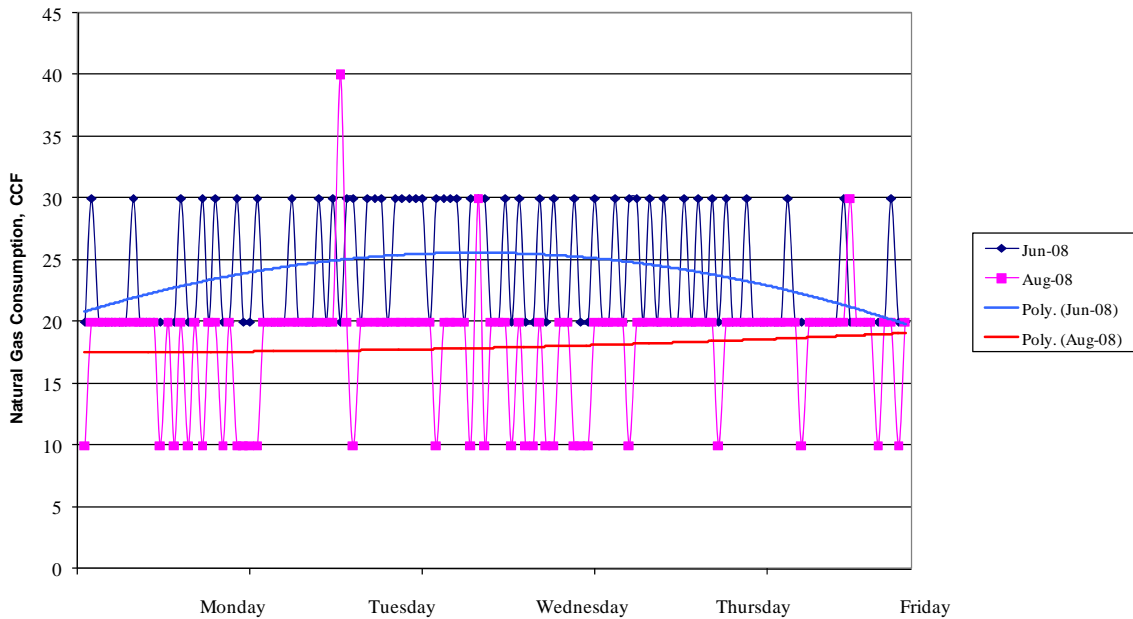
**Hourly Boiler Usage in the Old Boiler Plant and Outside Temperatures
for Wed. December 5, 2007 versus Wed. December 3, 2008**



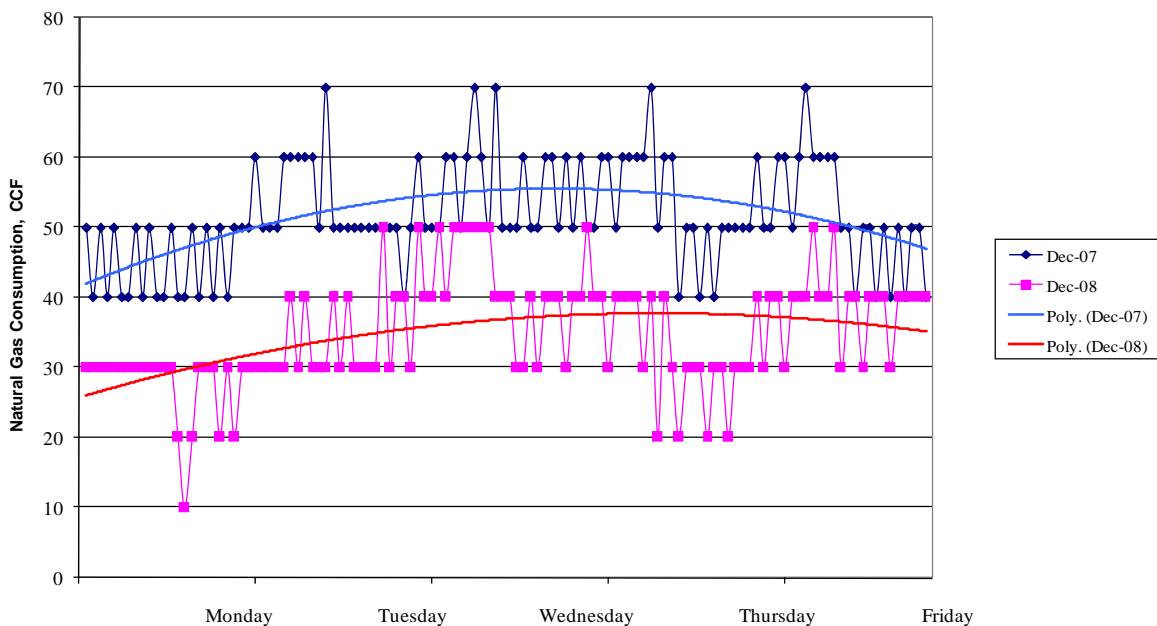
3.2 Weekly Comparison Figures:

Gas Usage (Weekly): The following two figures show the gas usage for a week in the summer and winter and before after the installation of the boiler controls and burner. The first graph shows a decrease in usage. Weather and production were not taken into consideration in these graphs.

**Hourly Boiler Usage in the Old Boiler Plant
for late June 2008 versus late August 2008**

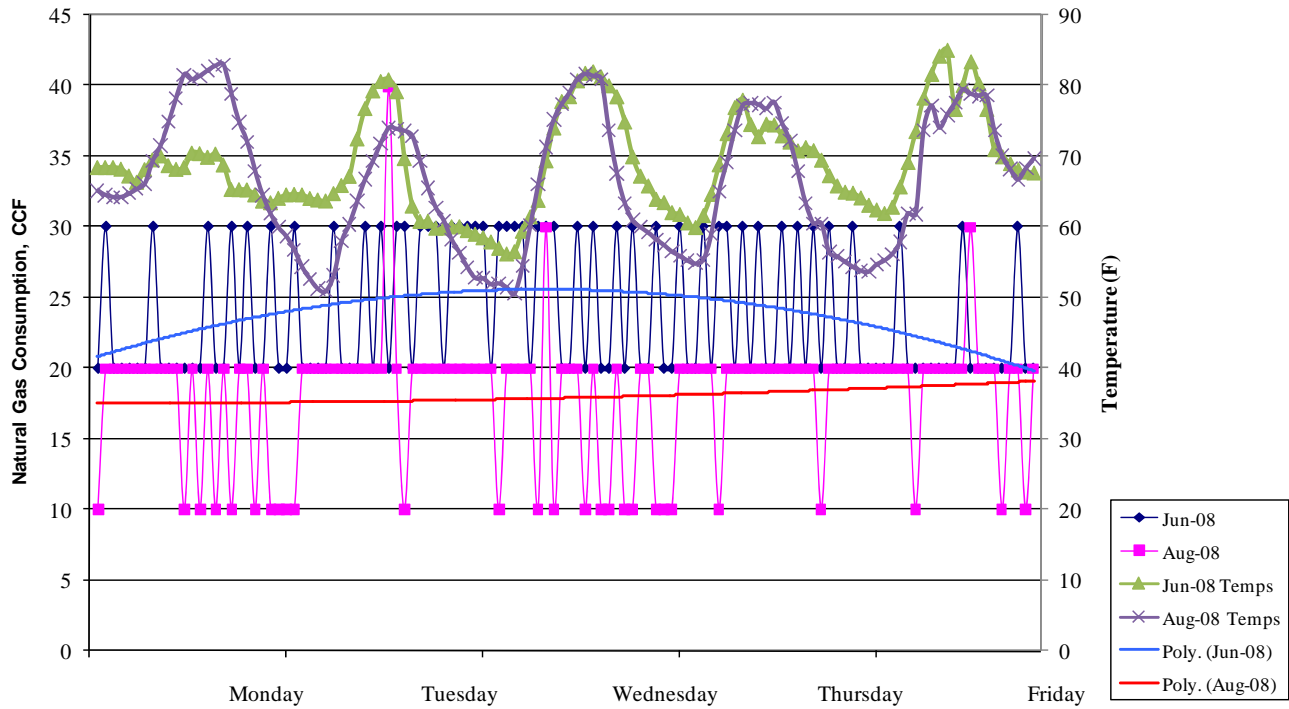


**Hourly Boiler Usage in the Old Boiler Plant
for early December 2007 versus early December 2008**



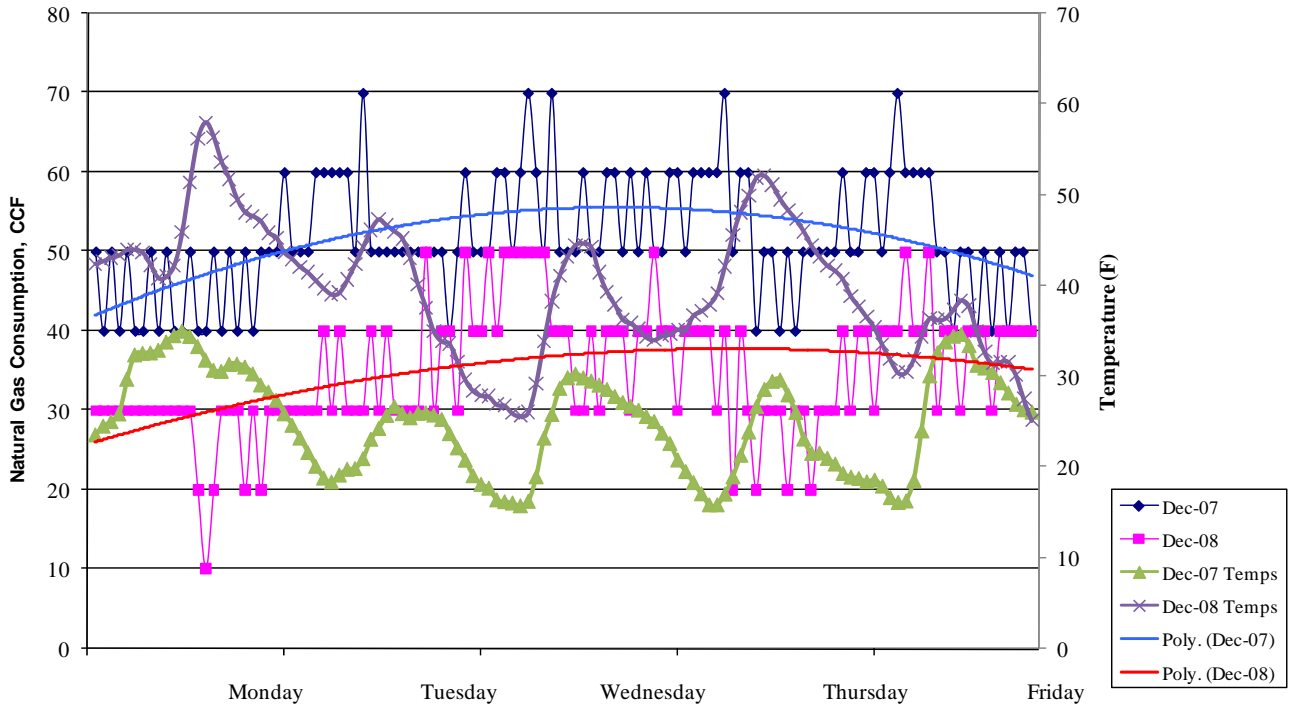
Gas Usage with Weather Data (Weekly): The following two figures show the same weekly gas usage as above with the time specific weather data overlaid to help show the impact of the weather on the gas usage. Again, the summer data shows no impact from weather for good reason as the summer steam load should be tied to the process load. There is the potential for summer reheat but the weather data shows no significant impact on the gas usage in the summer.

**Hourly Boiler Usage in the Old Boiler Plant
and Outside Temperatures for late June 2008 versus late August 2008**



The following figure shows the gas usage and weather data in winter conditions. In this figure the weather could very well have had an effect on the reduced gas usage. The outdoor temperature in 2008 as compared to the same time in 2007 was higher. The gas use is less and could be tied to or influenced by the outdoor air temperature. The graph doesn't show any variation with the outdoor temperature. While this is not conclusive, it is possible that the winter steam load could be primarily process driven. The summer load is much less than the winter load, 10-20% of boiler name plate (300 HP) in the summer and 50-75% in the winter.

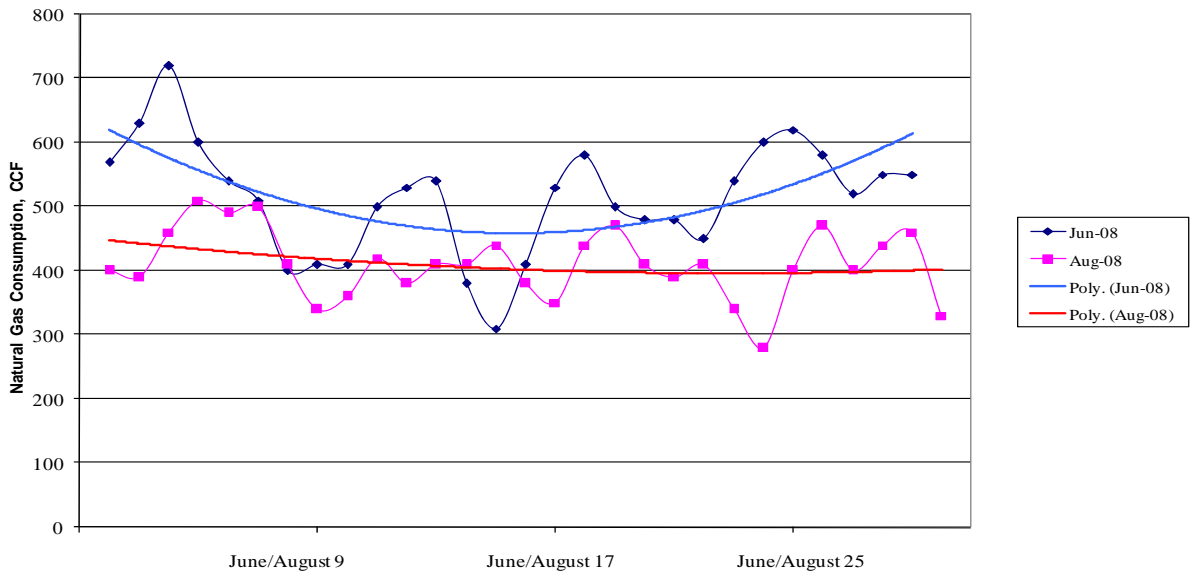
**Hourly Boiler Usage in the Old Boiler Plant and Outside Temperatures
for early December 2007 versus early December 2008**



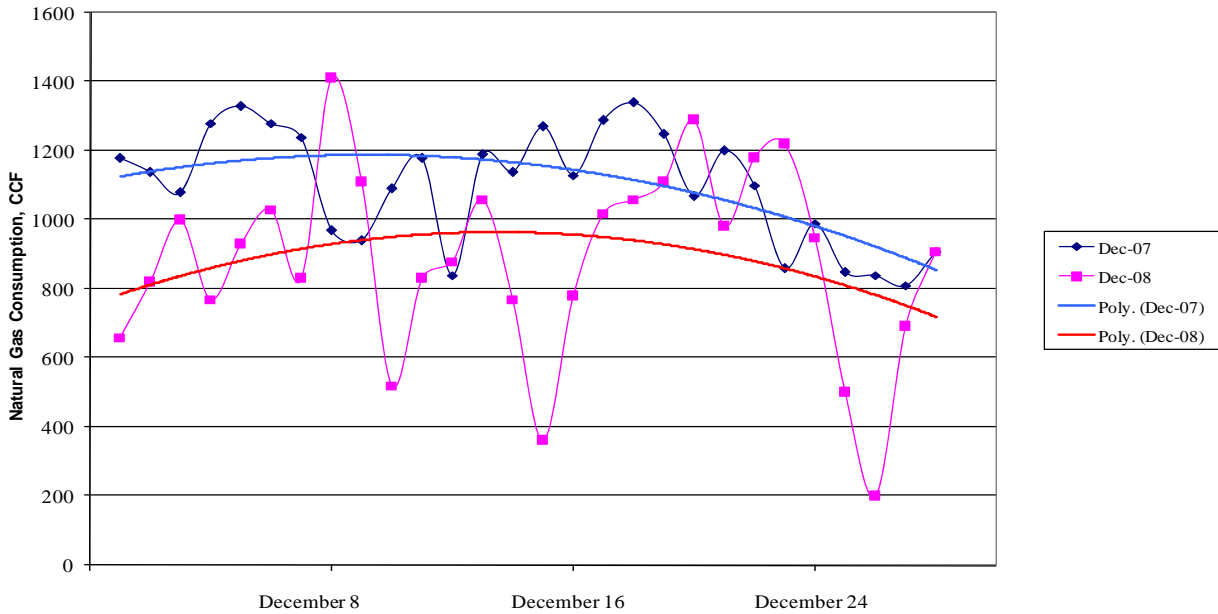
3.3 Monthly Comparison Figures:

Gas Usage (Monthly): The following two figures show the gas usage for a Month in the summer and then the winter and before and after the installation of the boiler controls and burner and again in the winter. The first graph shows a decrease in usage. Weather and production was not taken into consideration in these graphs. The second figure looks at winter day comparisons.

**Hourly Boiler Usage in the Old Boiler Plant
for June 2008 versus August 2008**

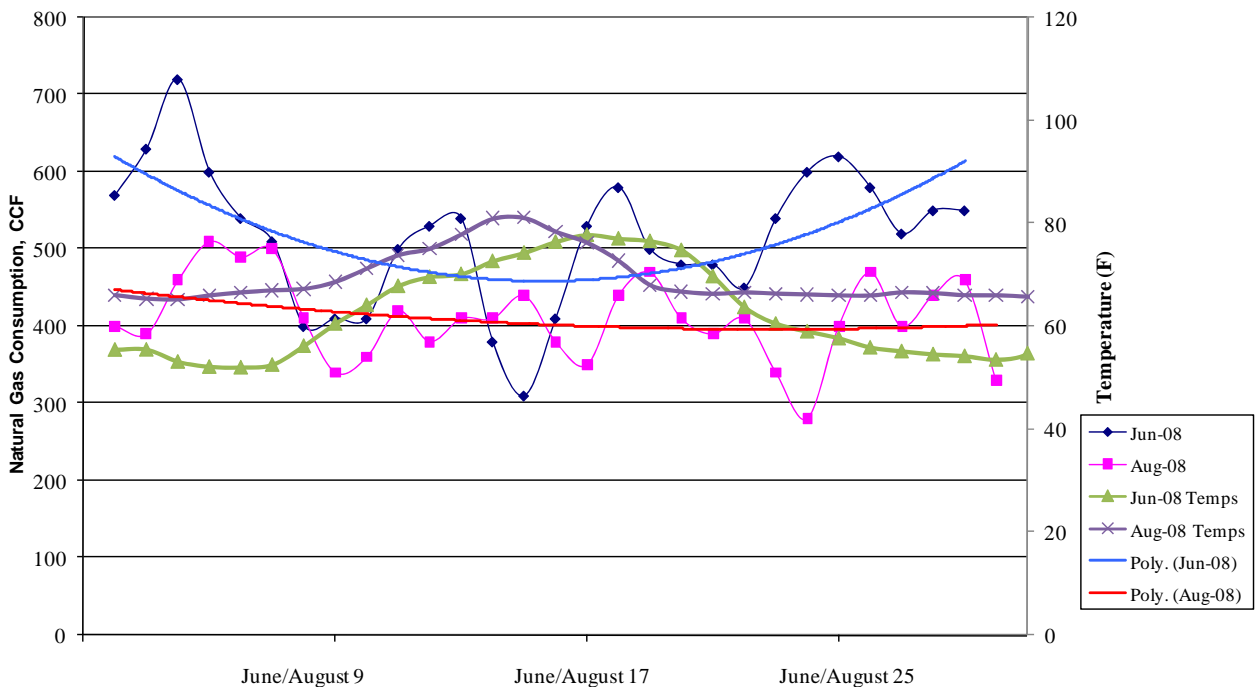


**Hourly Boiler Usage in the Old Boiler Plant
for December 2007 versus December 2008**



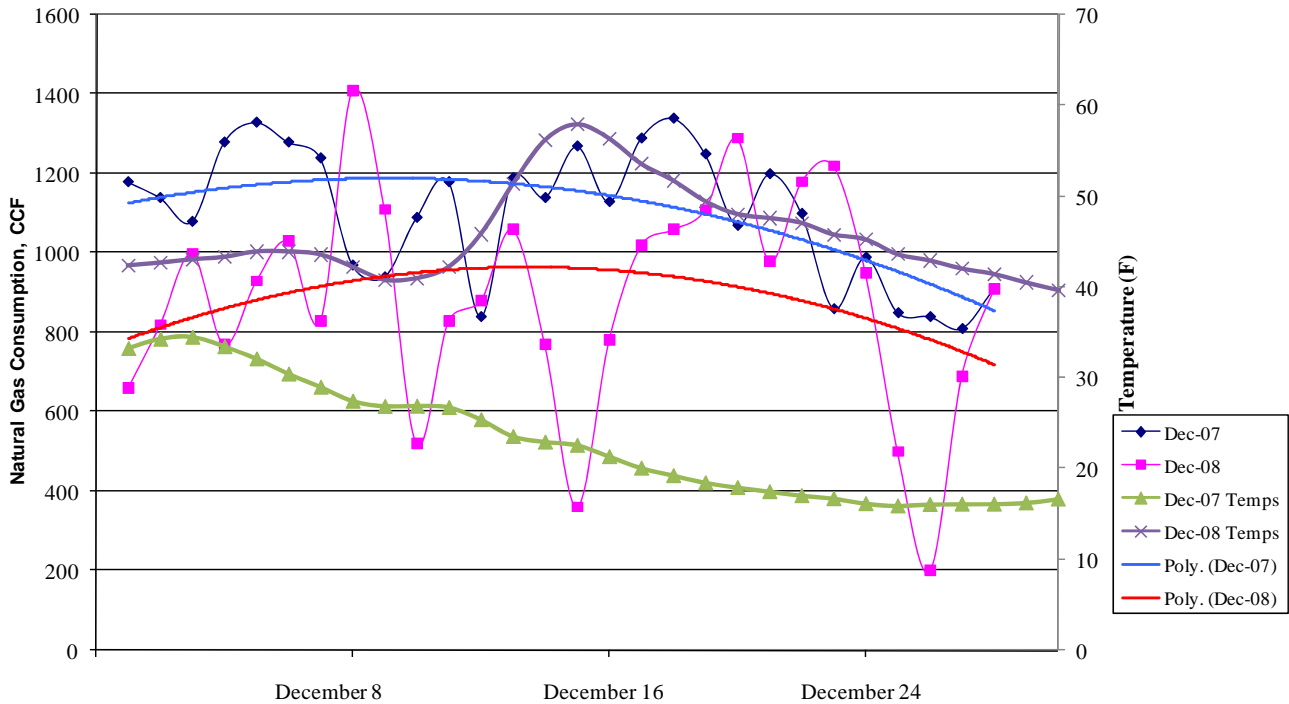
Gas Usage with Weather Data (Monthly): The following two figures show the same monthly gas usage as above with the time specific weather data overlaid to help show the impact of the weather on the gas usage. The summer data figure shows no potential impact from weather for good reason. The summer steam load should be tied to the process load. No space heating is required in the summer. There is the potential for summer reheat but the weather data shows no significant impact on the gas usage in the summer.

**Hourly Boiler Usage in the Old Boiler Plant
and Outside Temperatures for June 2008 versus August 2008**



The following figure shows the gas usage and weather data. In this figure the weather could very well have had an effect on the reduced gas usage. The outdoor temperature in 2008 as compared to the same time in 2007 was higher. The gas use is less and could be tied to or influenced by the outdoor air temperature. The graph doesn't show any a variation with the outdoor temperature. While this is not conclusive it is possible that the winter steam load could be primarily process driven.

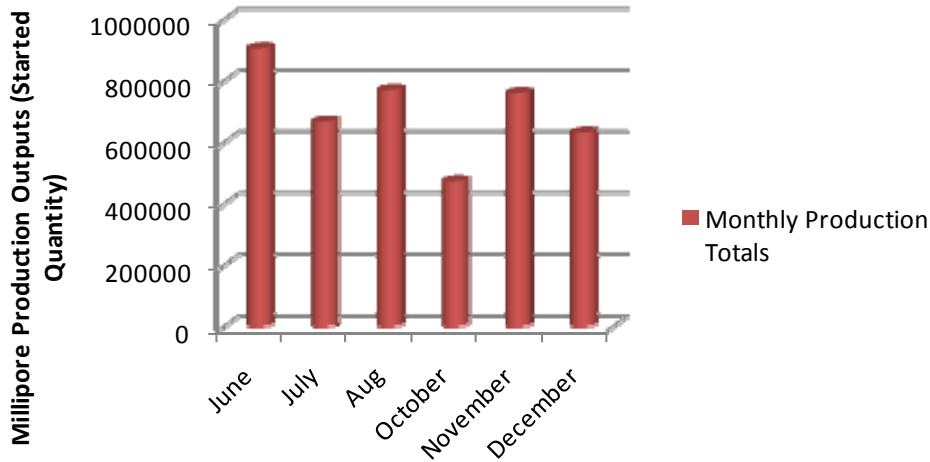
**Hourly Boiler Usage in the Old Boiler Plant
and Outside Temperatures
for December 2007 versus December 2008**



3.4 Millipore Production Throughput:

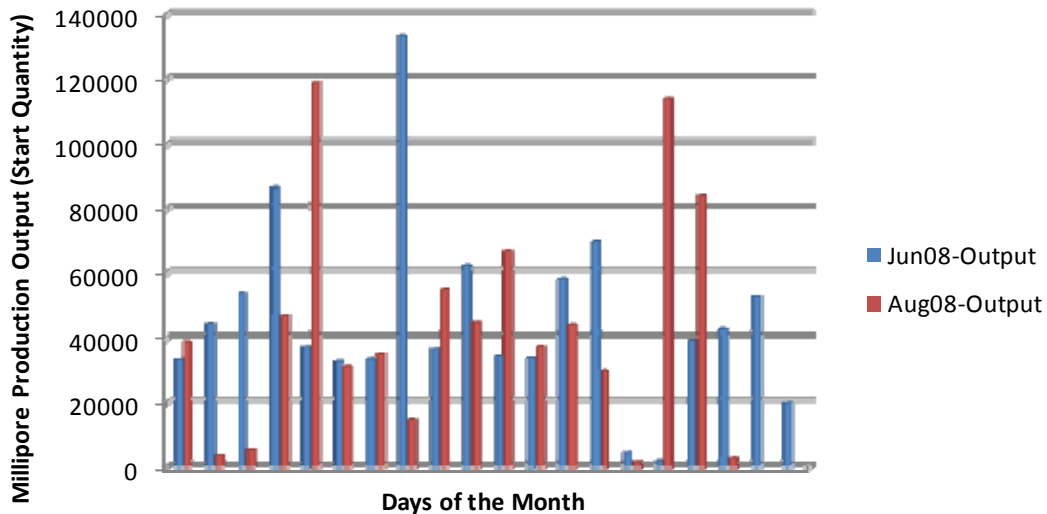
GDS received daily production output data from Millipore. This information was used to help identify any major changes in production and then attempt to correlate to changes in process steam loads. GDS used the work started as a metric for production. While not a significant factor (less than 10%) scrap is product that still requires process steam. While it is not know at what stage in production the scrap was it was assumed to have required process steam. As was reported several times by Millipore staff and is shown in the figure below.

Millipore Monthly Production Outputs



The daily production shows more variation and is difficult to draw comparisons of each product type and the specific process steam load demand.

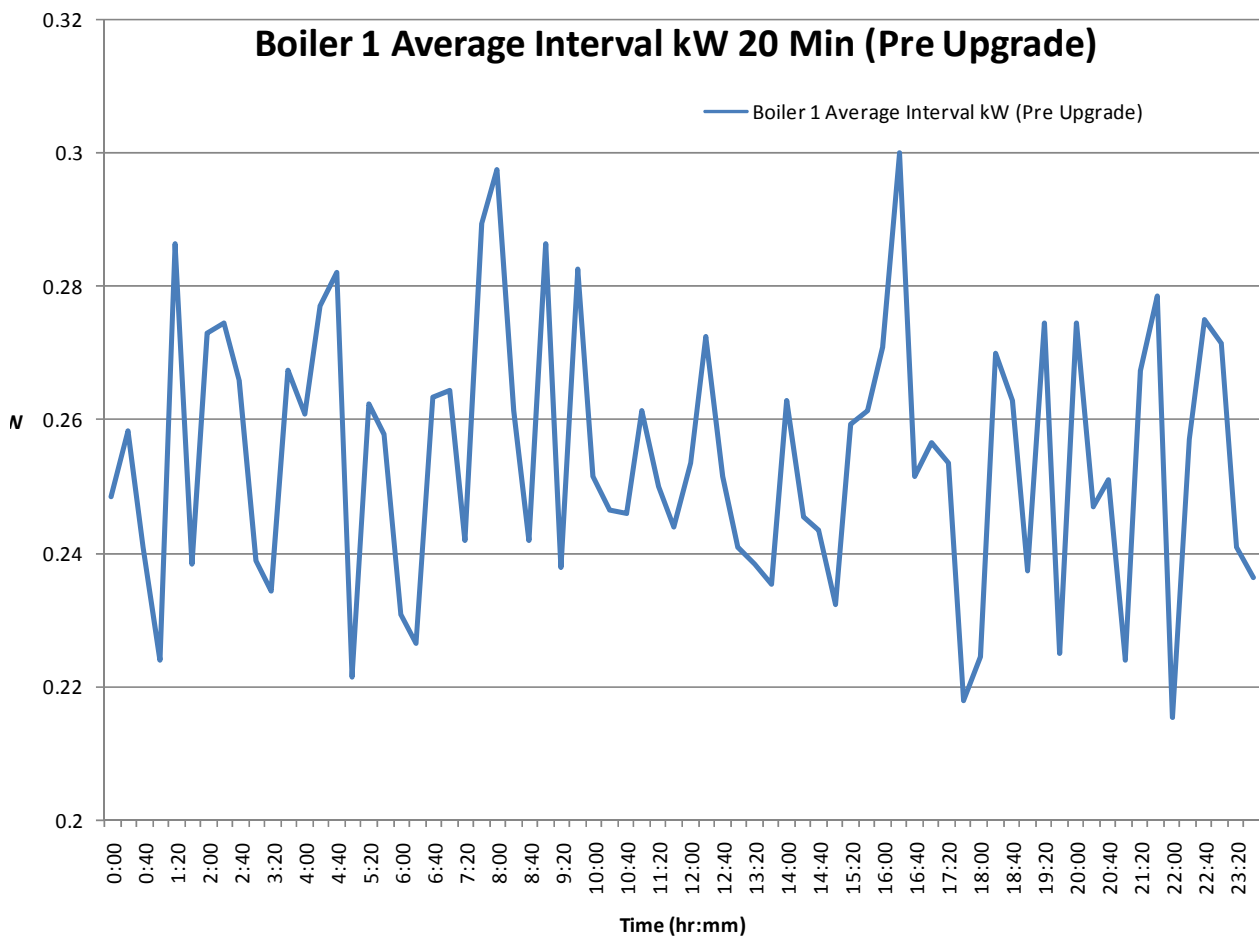
Millipore Daily Production Output for June and August 2008



3.5 Combustion Boiler Electrical Data:

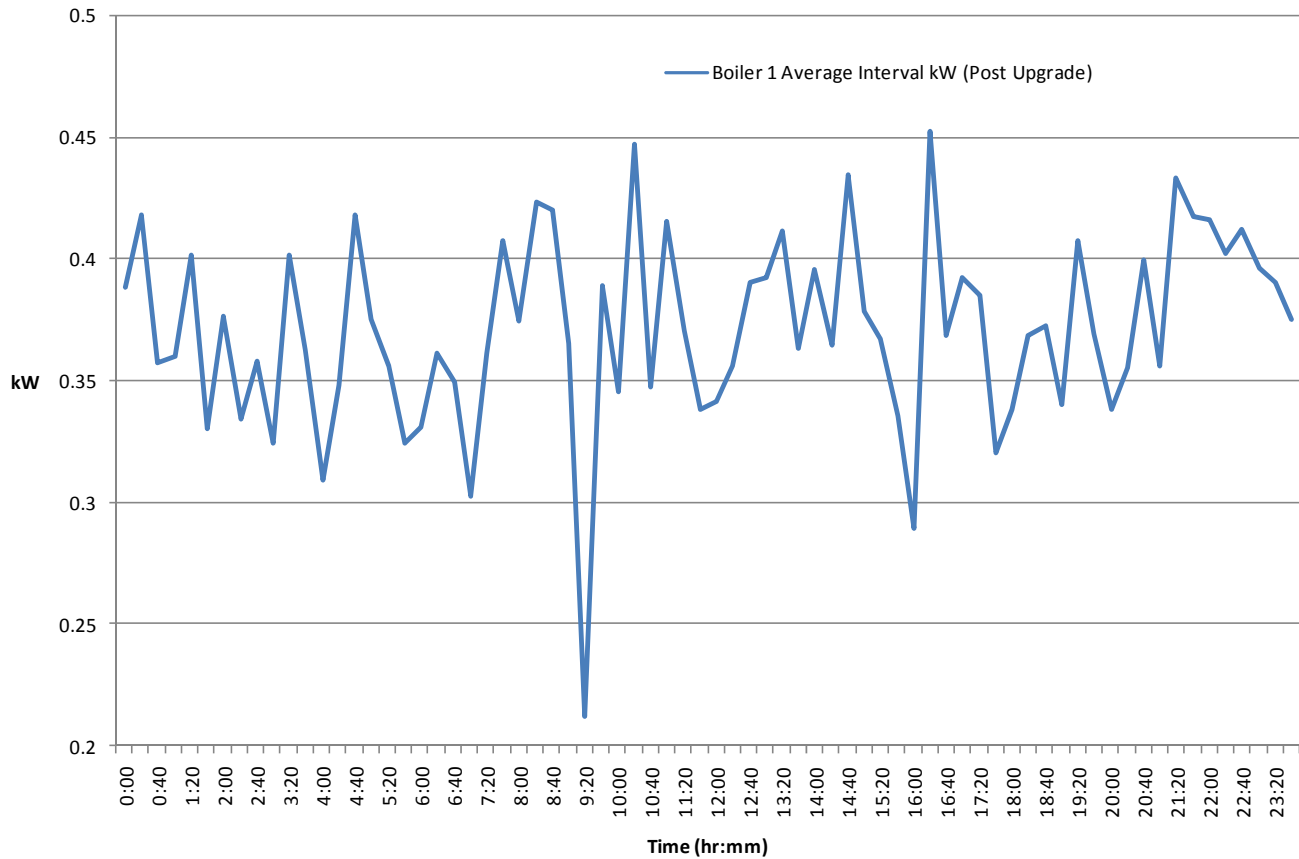
GDS utilized a Dent Elite Pro power quality and data logging meter (Serial number E5107, GDS 3) to record the electrical usage and demand of the combustion blower on each of the boilers. The combustion blowers operate at varying levels based on the boiler demands. Each boiler had Variable Frequency Drives (VFD) on the boiler's combustion blowers. The blowers operate at varying speeds depending on boiler demand. Boiler 1 had a 10 HP blower and Boiler 2 had a 15 HP blower. Boiler 1 was 208 Volts and Boiler 2 was 480 Volts. What we had hoped to discern was some clear usage pattern that might show the effects pre and post upgrade.

The figure below shows the 20 minute demand for boiler one combustion blower prior to the installation of new boiler controls and burner.



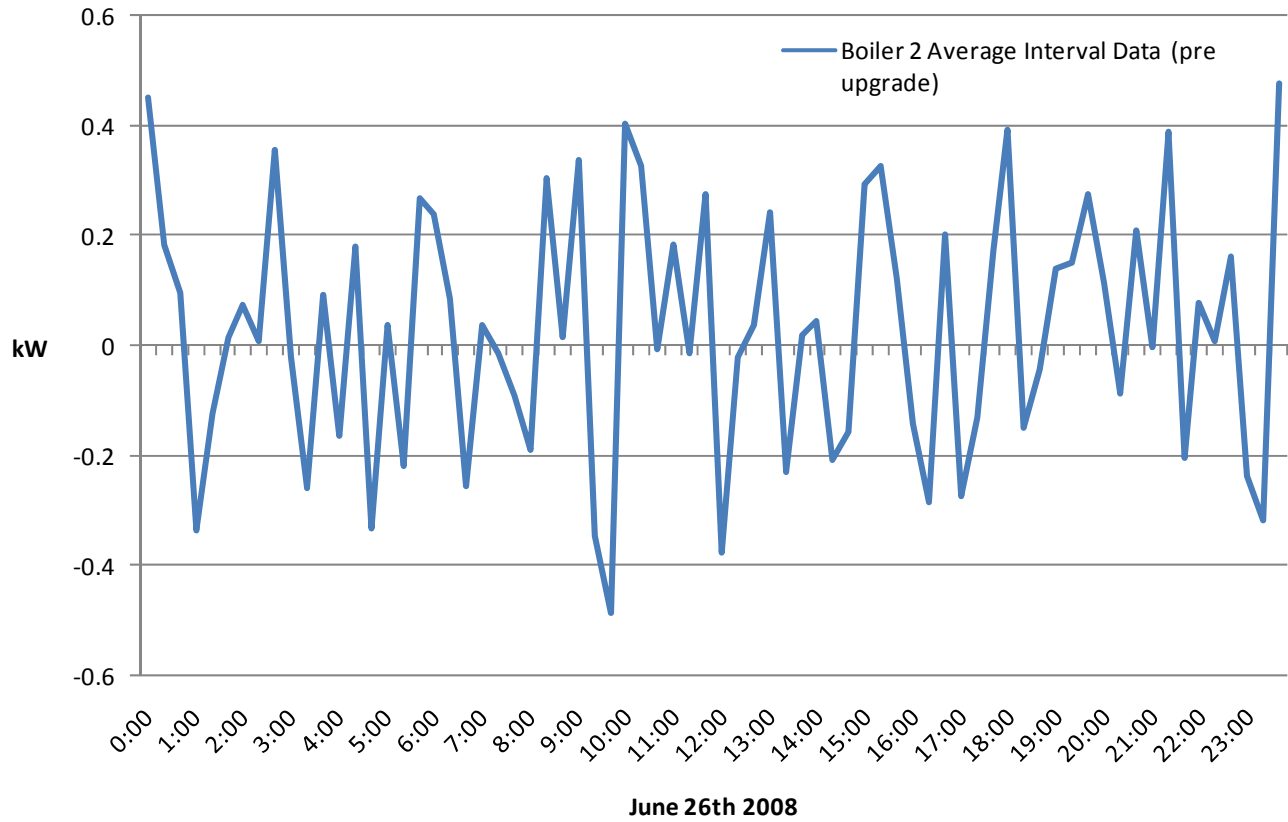
The following figure shows combustion air blower demand post installation of new boiler controls and burner on boiler one. Noting the dip at 9:20 AM this was a disruption in boiler operation and could be for a number of reasons but mostly likely from maintenance. Each day at 9:20 AM the boilers switches lead lag operations.

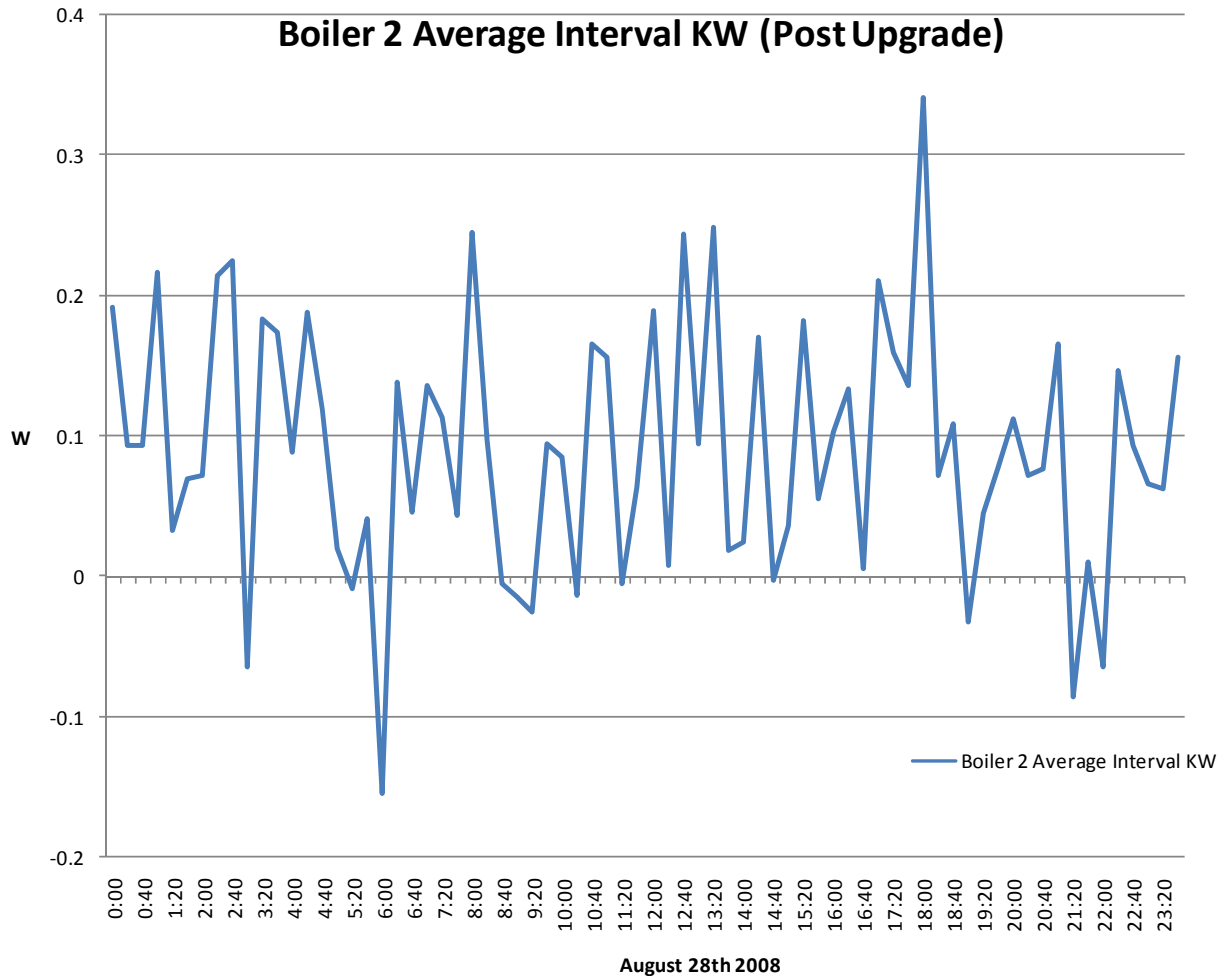
Boiler 1 Average 20 Min Interval kW (Post Upgrade)



The figure below shows combustion air blower demand at 20 minute intervals for boiler 1 prior to the installation of new boiler controls and burner for boiler two.

Boiler 2 Average 20 Min Interval Data (pre upgrade)





Electrical Data Summary: Based on the data collected each boiler had a unique electrical usage pattern. For boiler 1 the usage prior to the installation was typically in a band between 0.1 and 0.4 kW. Boiler one was fed with 208 volts, 3 phase power. The name plate motor horse power (HP) was 10 HP. Based on standard engineering calculations and a measured average power factor of 73% and a NEMA motor efficiency of 80%, the motor is operating at less than ¼ HP. When the new controls and burner were added the motor operation demand increased but was only at ¼ HP. This is likely caused by an increase in combustion air flow. The electrical data had no other obvious patterns dips and evidence that one control system ran significantly different. Boiler 2 had similar results with a few differences. The electrical data on boiler 2 was 480 Volts, the motor was 15 HP and the electrical data recorded showed negative data at times. This was likely caused from the motor still spinning and potentially feeding power back through the lines when the controls called for motor speed reduction or stoppage. This data of back feeding power is strong evidence of why filters and reactors on VFD’s should be standard practice. In both cases (boiler 1 & 2) the electrical demand went up slightly.

3.6 Natural Gas Usage Development – 80 Ashby Rd Boiler Plant

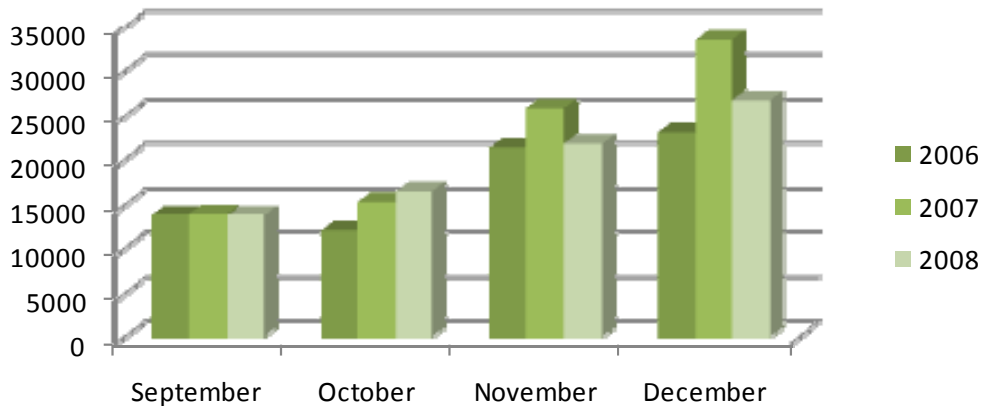
3 Year Analysis: December 2005 – December 2008

The gas usage below take all loads on the boiler into consideration and compares month to month two years prior to the boiler control upgrade and the four months after. While not conclusive the evidence is strong that the trend for usage was on the increase, with the addition of the boiler control and burner replacement have helped to reduce gas usage. Weather and production data was taken into consideration (reference sections above).

Natural Gas Consumption – 80 Ashby Rd Building D Boiler Plant

	CCF/Month				Gas Usage Savings		
	2005	2006	2007	2008	2006/2005	2007/2006	2008/2007
September		13810	14010	13790		-1%	2%
October		11990	15310	16490		-28%	-8%
November		21320	25860	21750		-21%	16%
December	33690	22980	33450	26770	32%	-46%	20%
Sum		72106	90637	80808		-26%	11%

Millipore Building D Boiler Plant Gas Usage



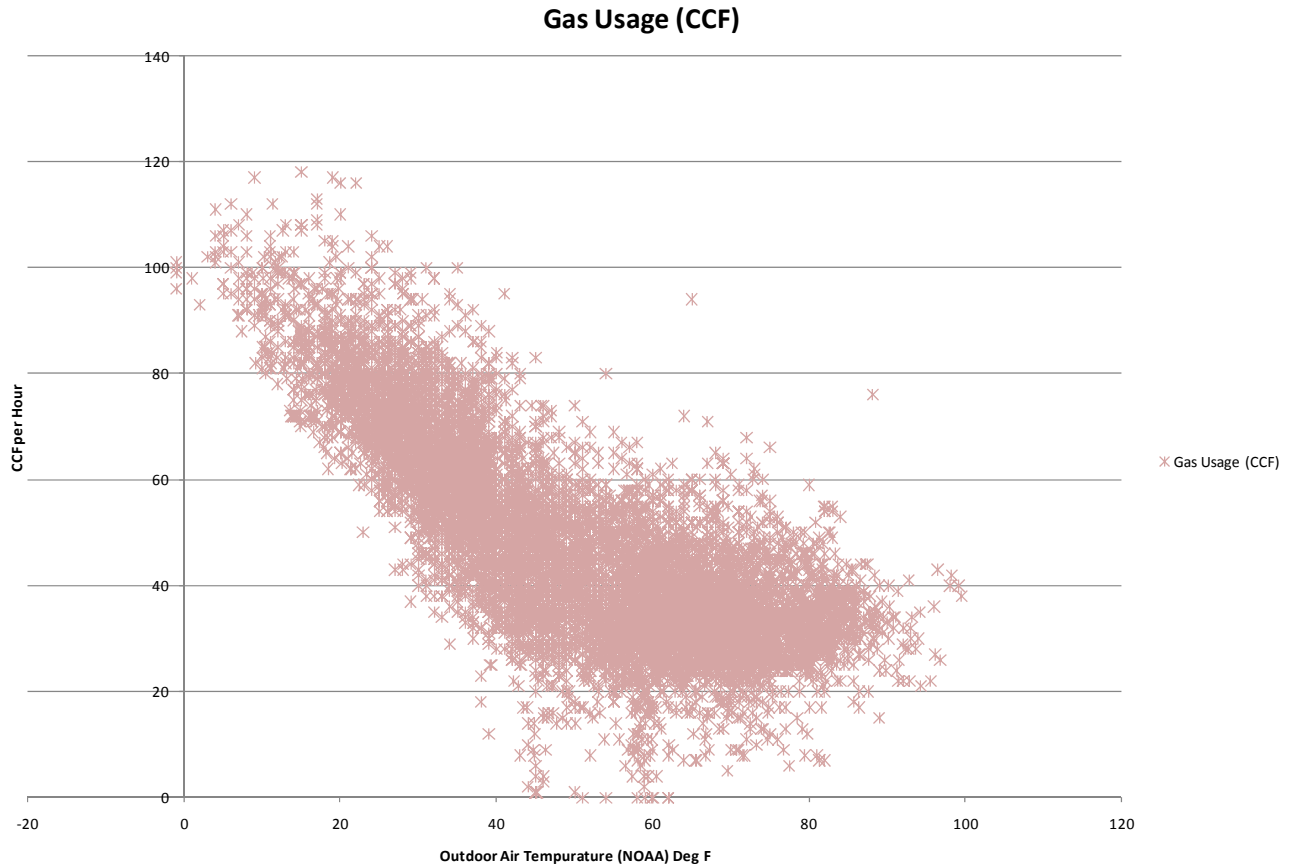
4. Six Month Data Analysis

The original scope of work for this project was to analyze gas usage data pre and post installation. Since the original installation in the summer of 2008, Millipore Corporation has requested a 6 month and one full year data analysis to verify the estimated savings for the boiler control upgrade.

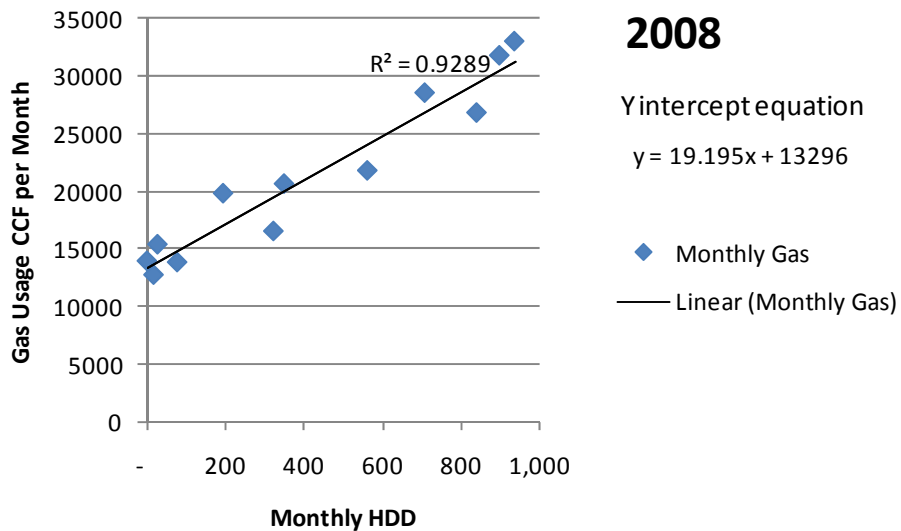
The six month data analysis utilized hourly interval gas data from 2006 to present for the Millipore Boiler plant. The only gas consuming equipment in that building are the twin 300 HP gas fired 15PSI steam boilers. Hourly weather observation data was retrieved from NOAA. The Heating Degree Days (HDD) were retrieved from underground weather.

Millipore Building D Boiler Plant with 59 deg F balnce point HDD								
	2006		2007		2008		2009	
	HDD	CCF	HDD	CCF	HDD	CCF	HDD	CCF
January		35350	928	30680	936	32970	1,190	37380
February		35390	1,013	35370	898	31740	820	29190
March		31400	741	27640	708	28500	706	19310
April		23710	477	20180	350	20600	340	15140
May	195	20680	172	19000	195	19770		
June	35	15420	47	16340	28	15340		
July	4	13650	15	13160	1	13900		
August	31	16760	22	13700	18	12700		
September	104	13810	86	14010	78	13790		
October	302	11990	199	15310	323	16490		
November	421	21320	610	25860	562	21750		
December	674	22980	960	33450	840	26770		

A balance point of 59°F was derived for the Millipore buildings served from the boiler plant. The balance point was derived by graphing the usage (CCF per day) on the y axis and the corresponding outdoor temperature (NOAA). The non temperature sensitive consumption is horizontal and the temperature sensitive consumption (usage) rises at the outdoor temperature decreases. The balance point is the point at which horizontal and incline meet. For Millipore’s boiler plant this point was 59°F.

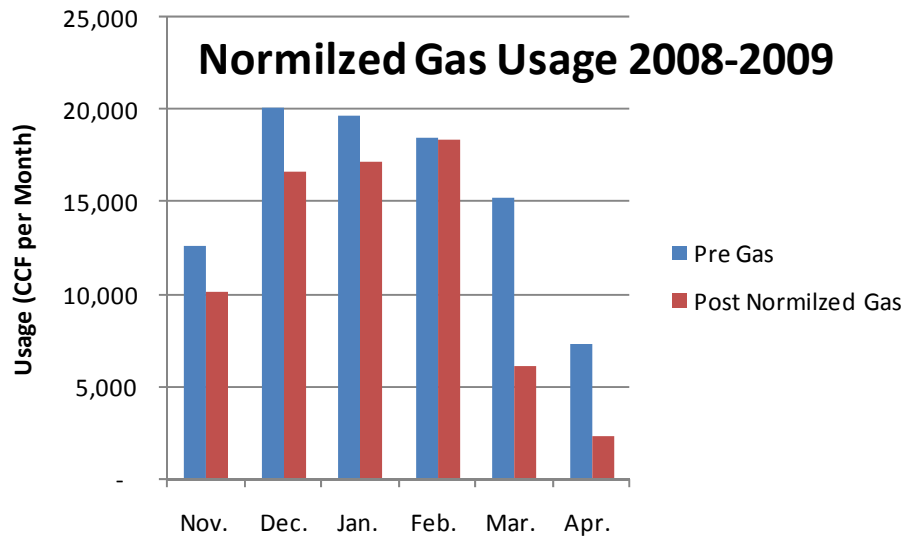


Then the non weather related gas usage was derived using both bin hours and HDD monthly totals and gas usage monthly totals for 2006 thru the present. The Y axis intercept was used to determine what exactly was process load related and what was weather related.



Once the weather related gas usage was normalized the resulting gas usage and sequential savings was graphed.

Normalized 6 Month Savings			
Method	Gas Saved		% of original
HDD	22,689	CCF	31%
Bins	22,963	CCF	31%



The remaining pieces to the puzzle are to account for any potential production load variation. Production data for part of 2007 most of 2008 had been made available. There are five more months of production data that are needed

Appendix A

Bacharach Commercial Boiler – Combustion Testing Procedures

Appendix B

Cleaver Brooks Boiler Efficiency Facts