BOILER BURNER UPGRADE ENERGY SAVINGS REPORT

Prepared for

Mechanical Services, Inc. for work completed at The Aroostook Medical Center

Prepared and Submitted by

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INTRODUCTION

Overview of Findings

After multiple rounds of analysis, the table below represents GDS's best estimate of verified energy savings in the two years since the new burner installation. While we did have some of the data needed to estimate savings in the third year post-install, we did not use that data in our analysis[1]. The Aroostook Medical Center (TAMC) has been undergoing renovations and expansions over the last year, which have increased their overall energy usage in the third year since the burner conversion. As shown by the table below, the energy savings in the first year after the burner installation were 10.7% and the savings in the second year were 10.1%. The figures in table 1 have been adjusted for weather. Table 2 shows the energy savings results before weather normalization in MMBtu during the same time periods.

Table 1: Weather Adjusted Energy Savings at TAMC

Time Period	MMBtu	MMBtu Savings	% Savings
Pre Burner Installation July 2010 - June 2011	54,517	na	na
Post Installation Year (1) October 2011 - September 2012	48,660	5,857	**10.7%**
Post Installation Year (2) October 2012 - September 2013	49,031	5,486	**10.1%**

Table 2: Non Weather Adjusted Energy Savings at TAMC

Time Period	MMBtu (Raw)	MMBtu Savings (Raw)	% Savings (Raw)
Pre Burner Installation July 2010 - June 2011	57,034	na	na
Post Installation Year (1) October 2011 - September 2012	52,596	4,438	**7.8%**
Post Installation Year (2) October 2012 - September 2013	51,615	5,418	**9.5%**

Please note that in both tables 1 and 2, the last five months of Post Installation Year 2 have been adjusted to account for the amount of compressed natural gas (CNG) used to heat the decompression station. The metering equipment used during this analysis was placed before the decompression station heaters, thus we needed to remove 1%[2] of the CNG use to account for this decompression station usage. The 1% estimate of heater usage was provided by XNG. We believe this to be a conservative estimate of decompression heater usage, where the actual usage by the heaters could be upwards of 2-3%. Also, please note that for the same last five months of Post Installation Year 2, an additional 2% of

[1] No supplemental oil usage was provided for post year 3

[2] 1% is provided by the CNG supplier and GDS calculated the expected vaporizer heaters with a nameplate of 140,000 Btu/h each (2 heaters) and with a 24% assumed annual load factor would match the expected 1%.

natural gas usage was removed. This reduction was taken to account for a decrease in boiler efficiency that would result from the switch in fuel burned, from Fuel Oil #2 t to Natural Gas. [3]

We are confident that our analysis represents an accurate estimate of energy savings with the information available, even though there are some variables that add to uncertainty to this analysis. Our process is discussed in more detail in the following sections, and some of the variables adding uncertainty include:

- Non Weather Related Steam Usage (number of patients served, employees etc.)
- Building Heating and Cooling Balance Points and set points
- CNG System Adjustments and Stop/Starts of CNG Usage
- Redundancy in Boilers and Boiler Operations
- Varying Efficiency of the Absorption Chiller
- Stack Issues

Each of these uncertainties are discussed more in the results section of the report.

Project Background

The Aroostook Medical Center in Presque Isle Maine had three Limpsfield burners with new Autoflame combustion controls installed on three, 250 BHP, Cleaver Brooks, fire tube, scotch marine type boilers. The burners and controls that were replaced were the originals that came with the boilers in 1973.The new burner installations began in July 2011. A new burner was first installed on boiler #1, followed by boiler #2 and boiler #3. All three burners were online by October 2011. The new burners are capable of firing with natural gas (or CNG) or fuel oil.

The new burners, while themselves an energy saving project, were part of a fuel conversion at TAMC. TAMC had used fuel oil to generate steam that was used for both heating and cooling with the existing burners. In May of 2013, a compressed natural gas (CNG) decompression station was completed which allowed for TAMC to use trucked-in compressed natural gas to fuel their steam boilers.

GDS was hired by Mechanical Services, Inc. to determine the energy savings from the new Limpsfield burners installed in 2011. Savings from the new burners were expected due to the burner's higher turndown ratios and higher combustion efficiency compared to the original burners, and it ability to finitely control the flame with parallel positioning

METHODOLOGY

Analysis Phase I

GDS first evaluated the energy savings from the new burners in 2013 prior to the conversion to CNG. At this time, GDS relied on oil deliveries to TAMC to determine energy saving. GDS also had to make some general assumptions about how the hospital was impacted by weather. GDS assumed a standard balance point of 60 degrees for heating and 65 degrees for cooling. Our initial findings showed a 10.3% annual savings from May 2012 through April 2013. In order to determine if these results were statistically valid, GDS used a linear regression analysis and assumed that a coefficient of determination

[3] Cleaver-Brooks efficiency Fact Sheet CB-7767-R1-2/96 p18 tables 8 & 9 for 250 HP at 25, 50, 75 and 100% load

(CD) of 0.75 or higher would be satisfactory. The results showed very low coefficients of determination, i.e. less than 0.45, placing into question the validity of this method given the oil delivery data on which it was based, and the assumptions of the building's balance points. The weather normalized method steps are highlighted below. GDS used hourly weather data for Presque Isle, Maine from NOAA to calculate heating degree days (HDD).

Weather Normalization Calculation

Step 1 – Determine the monthly oil deliveries for at least three years. Four years of pre-burner upgrade oil deliveries and two years of post burner upgrade oil deliveries were provided.

Step 2 – Retrieve weather data from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) web site for Presque Isle, Maine from October 2007 to March 2013.
http://www.ncdc.noaa.gov/oa/climate/climatedata.html#surface

Step 3 – Determine the season balance point temperature by graphing the outdoor temperature and the oil deliveries.

Step 4 – Utilize the season balance point temperature to determine the weather related oil deliveries. Use the hourly weather data and the season balance point temperature in order to calculate the heating degree days.
http://www.degreedays.net/

Step 5 – Use the pre and post conversion oil deliveries along with the HDD pre and post burner upgrade information to weather normalize the post burner upgrade oil deliveries. Note the HDD (pre, post and TMY3) are all at a heating balance point temperature of 60 degrees Fahrenheit (^{o}F).

$$\frac{\text{Monthly Oil Deliveries}_{\text{pre}}\ (\text{GALLONS})}{\text{Heating Degree Days}_{\text{pre}}(\text{HDD})} = \text{Weatherized Delivery Factor}_{\text{pre}}\left(\frac{\text{GALLONS}}{\text{HDD}}\right)$$

Equation 1

$$\text{Weather Normalized Oil Deliveries}_{\text{pre}} = \text{Weatherized Usage Factor}_{\text{pre}}\text{Weatherized Delivery Factor}_{\text{pre}}\ \text{x TMY3 HHD}$$

Equation 2

$$\frac{\text{Monthly Oil Deliveries}_{\text{post}}\ (\text{GALLONS})}{\text{Heating Degree Days}_{\text{post}}(\text{HDD})} = \text{Weatherized Delivery Factor}_{\text{post}}\left(\frac{\text{GALLONS}}{\text{HDD}}\right)$$

Equation 3

$$\text{Weather Normalized Oil Deliveries Usage}_{\text{post}} = \text{Weatherized Delivery Factor}_{\text{post}}\ \text{x TMY3 HHD}$$

Equation 4

Step 6 – Calculate the weather normalized oil deliveries savings or difference.

$$\left(\frac{\text{Weather Normalized Oil Deliveries}_{\text{pre}} - \text{Weather Normalized Oil Deliveries}_{\text{post}}}{\text{Weather Normalized Oil Deliveries}_{\text{pre}}}\ \text{x}\ 100\right) = \%\ \text{Difference}$$

Equation 5

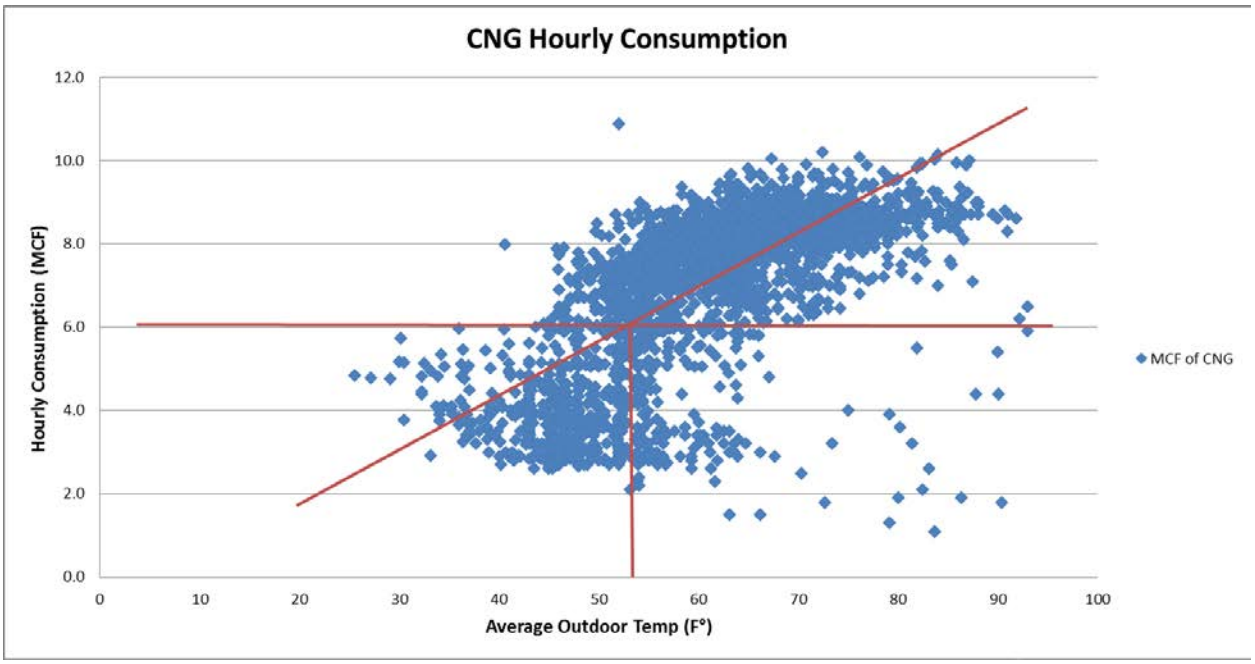
After meeting with TAMC to review the initial findings, it was decided that in order to better identify the building's balance points, GDS would use hourly interval data collected by the new CNG system, which was already online and operational. This interval data could be matched with hourly weather data and would hopefully result in a more accurate and statically significant balance point for the building.

Analysis Phase II

GDS received hourly interval data from May 16th 2013 through September 22nd 2013. This data collection had two distinct purposes:

- The first was to gather data that related to actual building fuel consumption, rather than fuel oil deliveries, as deliveries been had the only data available prior to the switch from fuel oil to compressed natural gas.
- This data was to be used to find a more accurate balance point for the building.

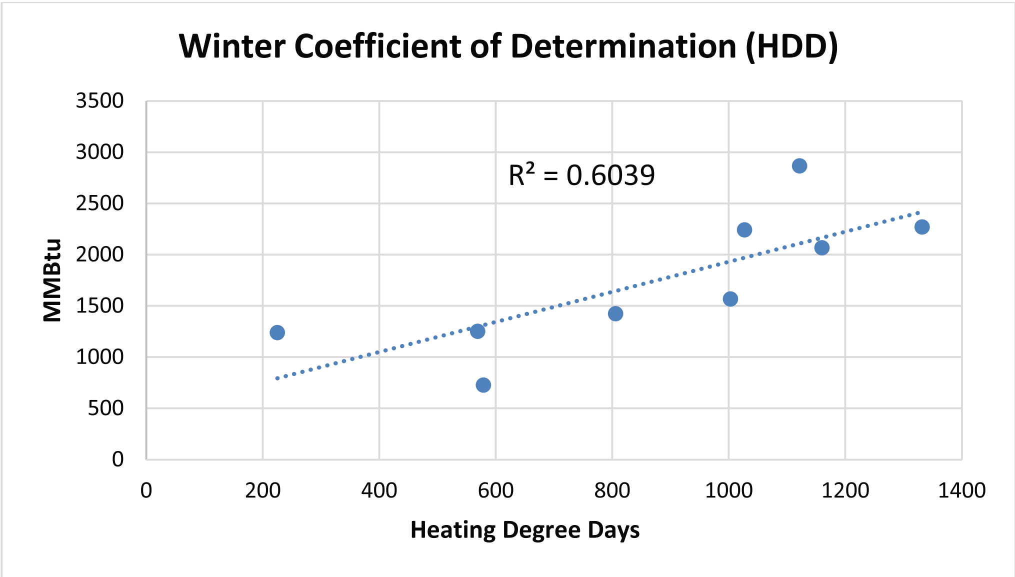
The following graph was created using hourly average CNG meter data and the corresponding outside temperature. Looking at the data, the summer balance point appears to be at 55ºF. Interval data for the winter months was not available at the time of our most recent round of analysis.

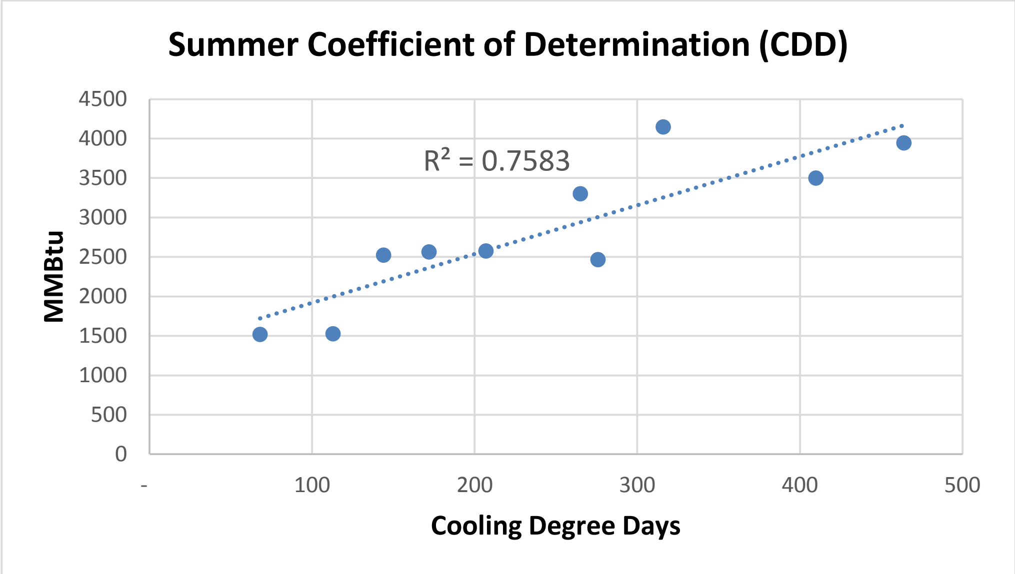


Once the new balance point was determined, GDS calculated the actual CDDs for all the summer periods for which GDS had oil delivery data and CNG usage records. While GDS has records of oil data going back to 2008, to get the best estimate of energy savings GDS used a one year period prior to the burner conversion and a two year period after the burner conversion in the savings analysis.

The coefficient of determination (CD) of the above graph is less than 0.45, indicating that weather is not a great predictor of overall CNG usage at TAMC. Rather than weather normalizing the entire consumption for the pre burner conversion and post burner conversion data, GDS examined the usage in the shoulder seasons. GDS assumed this to be a good indicator of the building's base consumption or non-weather dependent energy usage and removed the base fuel consumption from the heating and cooling months. After the base consumption was removed, GDS ran another regression analysis, plotting

Energy Use (MMBtu) v. Degree Days. For the summer months, MMBtu (consumption) was plotted against Cooling Degree Days, and for the winter months MMBtu (consumption) was plotted against the Heating Degree Days. The following two charts show the relationship between weather and usage in the summer and winter.





A Coefficient of Determination 0.75 or higher would indicate a satisfactory relationship between the variables. The results show low coefficients of determination during the heating season (R^2=0.60), and an acceptable coefficient of determination during the cooling season (R^2=0.76). The low coefficient of performance indicates that the winter use has a very weak weather related correlation. Due to stronger correlation between weather and summer usage, the summer consumption (above the base consumption) was weather normalized using CDD, which was calculated using a balance point of 55°F. No weather normalization was done for the heating months due to the low R^2. Raw deliveries were compared in the pre and post conversion periods for these months. The R^2 values for the summer and winter were calculated using XNG's reported consumption data collected after the Natural Gas conversion.

RESULTS

Table 3: Detailed Weather Adjusted Energy Savings at TAMC

TAMC Pre-Post Burner Analysis						
	2009/2010	2010/2011	2011/2012	2012/2013		
Month	**Partial Baseline Year (MMBtu)**	**Partial Baseline Year (MMBtu)**	**Post Year 1 (MMBtu)**	**Post Year 2 (MMBtu)**	**Savings Year 1 (MMBtu)**	**Savings Year 2 (MMBtu)**
October	-	3,206	2,560	**3,172**	646	34
November	-	3,990	3,902	3,561	88	429
December	-	4,018	3,869	4,255	149	(237)
January	-	3,978	5,174	5,464	(1,195)	(1,486)
February	-	3,959	3,875	3,559	83	399
March	-	5,310	3,864	3,282	1,446	2,028
April	-	2,589	2,575	2,308	14	281
May	-	**4,222**	**3,749**	**3,242**	474	980
June	-	**6,912**	**3,603**	**5,221**	3,309	1,691
July	**5,266**	**5,761**	**5,292**	**5,068**	(26)	198
August	**6,928**	**7,346**	**5,245**	**5,827**	1,683	1,102
September	**4,138**	**3,293**	**4,952**	**4,071**	(814)	67
Total		**54,517**	**48,660**	**49,031**	**5,857**	**5,486**
Percent (%) MMBtu Savings (Compared to Baseline Year)					**10.7%**	**10.1%**

Cooling Equipment Operation Records for 2012 indicate TAMC had cooling equipment on for the entire month of October 2012, thus a CDD analysis was used to normalize the data.

Key	
	Burner Installation - not used in analysis
	Weather Normalized (CDD)
	Raw Consumption (MMBtu)

Table 3 above shows the Year 1 and Year 2 energy savings at TAMC. "Post burner upgrade Year 1" data consists of all fuel oil deliveries. These deliveries, reported in gallons, were converted to MMBtu using a standard conversion factor of 0.139 MMBtu per gallon. Starting in May 2013 during "Post Year 2," the CNG decompression station was completed, allowing TAMC to use either natural gas or fuel oil. In cases where each fuel was used in a particular month, we converted the gallon of fuel and volume of CNG into MMBtu. The Btu content of the monthly volume of CNG was collected from the supply company XNG, which tracks this data for billing purposes. They verified that the Btu content can vary (from about 1.01 to 1.05 MMBtu/MSCF of gas) based on the dominant gas in the pipeline when the gas is extracted. The months of May 2013 through September 2013 represent mostly natural gas consumption with some supplemental fuel oil consumption. It is also important to note a 1% reduction in the CNG deliveries removed since the metering equipment is placed before the decompression heaters which are running on CNG. This adjustment only effects CNG consumption in the months of May through September in the second year post burner install. We also applied a 2% factor to the five post months with CNG usage to account for the fuel switch from oil to CNG[4].

As previously discussed, the coefficient of determination for the winter was not strong enough to warrant weather normalization. For these periods (shown green in the Table3) the raw MMBtu energy consumption was compared to the baseline year.

The summer consumption was normalized based on weather after removing the base consumption. This base consumption was added back in after the weather sensitive consumption was normalized. These values are shown in Table 3 as blue.

The three months during the burner conversion, July through September 2011, were not used in either the baseline period or in the Year 1 or Year 2 post period. To replace these three months, GDS used the previous year's summer period July through September 2010.

Energy savings of 10.7% were found in the first year after the burner conversion. In the second year after the burner conversion, 10.1 % energy savings were found.

Uncertainties

The GDS analysis indicates that in each of the two years after the burner installation, the energy savings slightly exceeded the expectations of Mechanical Services, Inc. and TAMC. The burners were estimated to produce 9.47% energy savings. While the savings targets have been met, there are several factors that could have influenced the energy savings findings, resulting in actual savings that are greater than our estimates:

- Non Weather Related Steam Usage – TAMC is believed to use the steam boilers for many other purposes such as laundry and sterilization, which are not tracked. In our analysis, we removed an estimated "base load" to account for this non weather related usage, which is quite high, supporting our hypothesis that a large portion of TAMC's oil and CNG use is not weather dependent. The base-load was not weather normalized and was added back into the total consumption as shown in Tables 1-3. These loads could also be variable based on the demands

[4] Cleaver-Brooks efficiency Fact Sheet CB-7767-R1-2/96 p18 tables 8 & 9 for 250 HP at 25, 50, 75 and 100% load

of the hospital but number of patients served, what type of services and the number of employees.

- Building Balance Points – The balance point was first estimated at a standard 60^{o}F for heating and 65^{o}F for cooling. After the CNG system was installed, hourly consumption was plotted against outdoor temperature during the summer months to establish a better cooling balance point. We found a balance point of 55^{o}F, and used this as the pre and post cooling balance point for our analysis. Since no hourly interval data was collected during the heating season, we could only estimate a possible heating balance point. Previously the oil deliveries where used to try and determine the balance point and the data was inconclusive.
- CNG System Adjustments and Stop/Starts of CNG Usage – The use of the CNG decompression station and firing of natural gas for the steam boilers began in the second year after the installation of the burners. During this time, there were several stops in the CNG system and usage where fuel oil had to be substituted to fire the boilers. This stop/starting might have impacted the burner's ability to operate at peak efficiencies during those times, resulting in decreased savings.
- Redundancy in Boilers and Boiler Operation (Integrated Boiler Management Strategy) – It was reported that at times TAMC was running two boilers simultaneously when the building's load could have been supported by one boiler, thus needlessly increasing energy usage. The bottom blow down procedure to reduce the water level in the non-firing boiler is also a potential cause of efficiency losses.
- Efficiency of Absorption Chiller – Absorption chillers are not good load following chillers, so to prevent costly maintenance repairs these types of chillers are not used for night time set back and changes on the load side, and as a result there is some uncertainty related to the summer analysis without having meter steam use for the chillers.
- Stack Issues – The stack is believed to be originally designed for #6 heavy oil. The combustion gases are typically higher and can require more draft. This can cause more heat being pulled out of the boiler. There where dampers installed to help limit this effect when the burners where upgraded but the true impact over a range of operating characteristics can vary.