EtaPro Project – Heat Rate

Introduction

The goal of this project was to find an effective cost savings project within the facility. This was attempted by investigating ways to lower the facilities heat rate using EtaPro to collect and analyze data. The first part of this project investigates which situation will result in a lower heat rate: using Steam Turbine extraction, or the Supplementary Process Steam Generators (SPSG's) to provide steam to the steam host while the facility is online. The heat rate differences were analyzed and a cost analysis was completed to illustrate the potential savings in dollars per hour ($/hr) of run time.

Each day the facility was dispatched, the operators made a decision to either use Steam Turbine Extraction or to run the SPSG's for process steam flow. During each day, EtaPro was used to capture data including Net MW, Ambient Temperature, Heat Rate, and Fuel usage from 9:00 am through 10:00 pm. The timeline was chosen to help ensure that the facility was at a relatively steady state after startup. A data point for each parameter was captured every five minutes throughout the timeline. EtaPro does not account for fuel flow to the SPSG's, therefore the Historian program was used to get this information. These values were then added to the EtaPro results. The data shown in the following sections are averaged values for the entire day. In other words, each day was summarized by an average temperature, average MW output, etc. This data was then split into days when the SPSG's were online and when Steam Turbine Extraction was used. Data has been collected from June 2, 2010 through July 15, 2010. The data was presented in this manner due to the many variables that determine how the facility is loaded on a day to day basis (AGC, ambient temperature, weekend vs weekday dispatches, etc.) Overall, the results summarize a "big picture" outlook.

In addition to data collected over a time basis, a steady load analysis was also completed. The plant was held to a constant mega-watt output and data was taken while using both process steam supply points. This data was analyzed and the results shown in the following sections.

Design Data

The first step in the project is to determine how well the facility is performing (in terms of heat rate), when compared to the design data. The following design data that was provided in the ABB manuals and can be seen in Figure 1.

Design Output Data: Base Load on ST Extraction			
Ambient Temp (^oF)	Total Net Output (MW)	Fuel Usage (Lower Heating Value) (MMBtu/hr)	Heat Rate (Btu/KWh)
0	399	3027	7580
59	357	2670	7490
100	316	2408	7624

Figure 1 - Base Load Design Data

The above design data shows three different base load conditions. All three conditions assume that the facility is on Steam Turbine extraction with 150 KPPH to the steam host. Applying a curve fit to the design data allows for the design heat rate to be determined at different MW settings. This curve fit and corresponding polynomial equation can be seen in Figure 2.

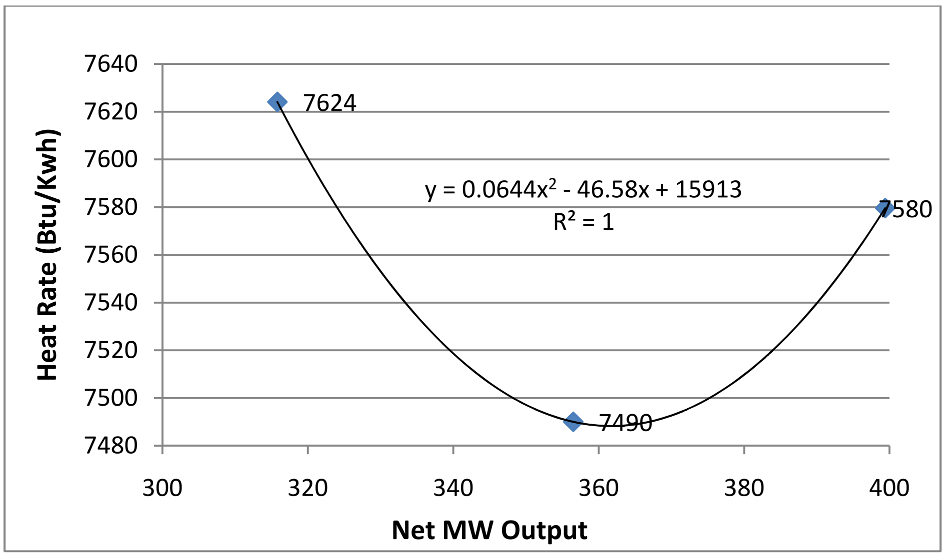

Figure 2 - Base Load Design Heat Rate

EtaPro Data

The following data is represented in ascending order of MW, not by date. Figure 3 shows the EtaPro data collected when the SPSG was used for process steam.

SUMMARY OF AVERAGE DATA - SPSG to Process				
DATE	AMB TEMP (F)	MW	HEAT RATE (Btu/KW hr)	FUEL USE (MMbtu)
6/22/2010	93.3	212.2	8317.7	1765.4
6/23/2010	93.1	258.1	8250.5	2129.6
6/30/2010	79.8	278.1	8324.1	2314.9

7/3/2010	84.0	278.2	8462.4	2354.4
7/4/2010	91.4	281.9	8319.1	2345.2
7/2/2010	82.6	287.2	8328.1	2391.6
6/12/2010	84.4	291.5	8219.7	2395.9
6/19/2010	88.8	294.0	8083.0	2376.6
6/21/2010	91.3	306.3	8025.8	2458.4
6/26/2010	89.7	306.7	8092.0	2481.5
6/20/2010	92.0	307.2	8082.8	2482.8
6/4/2010	85.4	307.2	8054.0	2474.5
6/14/2010	90.0	308.2	8068.9	2486.5
7/5/2010	93.7	308.9	8113.4	2506.3
6/24/2010	96.0	311.8	8049.5	2510.1
6/11/2010	86.0	312.7	8016.8	2507.2
6/5/2010	90.2	313.0	7998.4	2503.7
6/25/2010	89.5	313.4	8040.2	2520.1
6/27/2010	95.7	318.8	7972.8	2541.7
6/13/2010	90.8	319.0	7981.2	2545.6
7/7/2010 B	101.3	328.0	7933.3	2602.2

Figure 3 - SPSG to Process Data

Figure 4 shows data collected from EtaPro while Steam Turbine extraction was used for process steam.

SUMMARY OF AVERAGE DATA - ST Extraction to Process				
DATE	AMB TEMP (F)	MW	HEAT RATE (Btu/KW hr)	FUEL USE (mmBTU)
7/13/2010	87.0	216.6	8066.2	1747.3
7/12/2010	86.1	219.5	8066.4	1770.7
7/8/2010	87.7	283.1	7971.9	2248.2
6/6/2010	86.7	284.4	8014.8	2276.8
6/7/2010	78.6	286.9	7910.0	2266.5
7/10/2010	82.9	287.3	8049.1	2309.5
7/7/2010 A	99.7	295.0	7895.1	2327.2
6/16/2010	82.2	296.5	7996.9	2365.6
7/14/2010	89.3	297.5	7966.3	2366.9
6/18/2010	83.1	299.7	8018.6	2397.7
6/3/2010	82.3	306.3	7886.9	2411.3
7/11/2010	91.1	306.8	7831.3	2399.9
7/9/2010	88.1	307.7	7868.2	2418.0
6/28/2010	90.2	309.1	7819.1	2413.9

6/29/2010	89.9	312.8	7806.5	2439.4
7/6/2010	96.6	313.4	7818.8	2448.1
6/1/2010	79.4	314.0	7757.6	2432.7
6/2/2010	84.4	315.1	7790.4	2450.2
6/17/2010	88.6	326.7	7744.5	2528.3
6/15/2010	84.3	330.7	7756.7	2563.1
6/10/2010	88.8	333.6	7714.4	2572.9

Figure 4 - Steam Turbine Extraction Data

Design Comparison

To compare where the facility is currently operating versus where it should be operating based on design, the raw data was scrutinized to find data points that match the expected design values. One such occurrence was found on June 27, 2010. At 4:47 pm, the facility was loaded to 318.3 MW and it was 100.5°F outside. Process steam was coming from SPSG's. The facilities heat rate at that moment was 7939.1 (Btu/KW hr). Another similar occurrence was captured on July 6, 2010 at 4:27 pm. The facility was loaded to 316.9 MW and it was 101.6°F outside. Process steam was coming from Steam Turbine extraction. The facilities heat rate at that moment was 7745.6 (Btu/KW hr). These results give early indication that the plant has the potential to operate closer to design while process steam is supplied from the Steam Turbine (Note: This is only an example comparing two data points. Further information to help support this theory is provided in subsequent sections.)

In conclusion, it can be seen that the plant appears to be operating relatively close to design when process steam is supplied from Steam Turbine extraction. . These are positive results given how long the plant has been operating.

SPSG Vs Extraction

Refer back to Figures 3 and 4, it can be seen that in general the plants heat rate is lower during Steam Turbine extraction versus when the SPSG's are providing process steam flow. This can be seen in Figure 5 below.

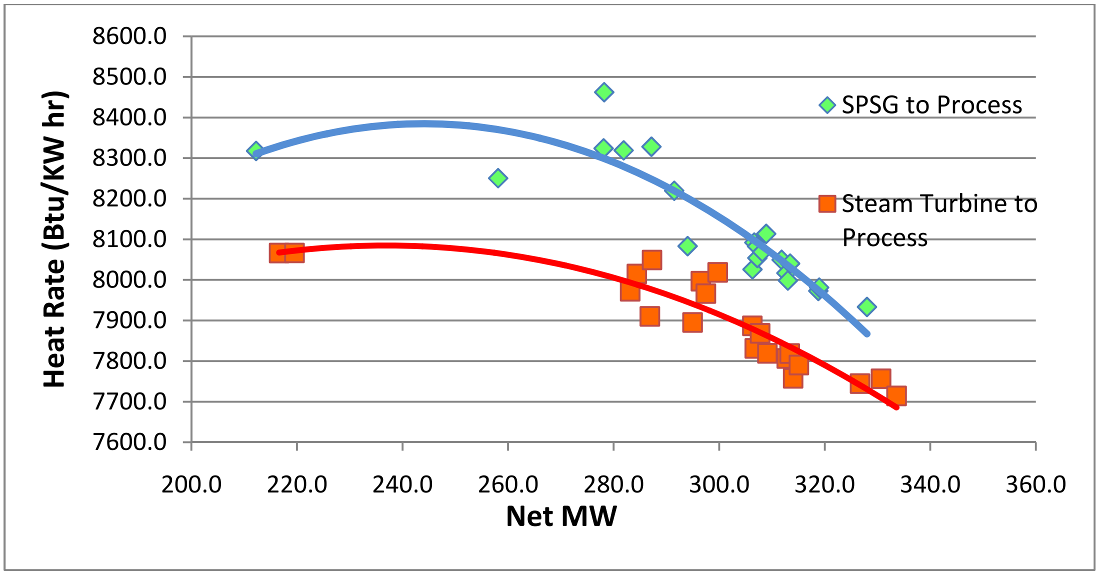

Figure 5 - Captured Data From Actual Dispatches

Figure 5 clearly indicates that on average, the plant has a better heat rate while taking process steam from the Steam Turbine. Figure 6 below illustrates the same information in a different manner. This graph plots heat rate on the y-axis, and data points (i.e. each of the points in Figures 3 and 4) on the x-axis. The data points are arranged increasing from low to high mega-watts. For example, point 1 on the graph represents the first row of data from Figures 3 and 4.

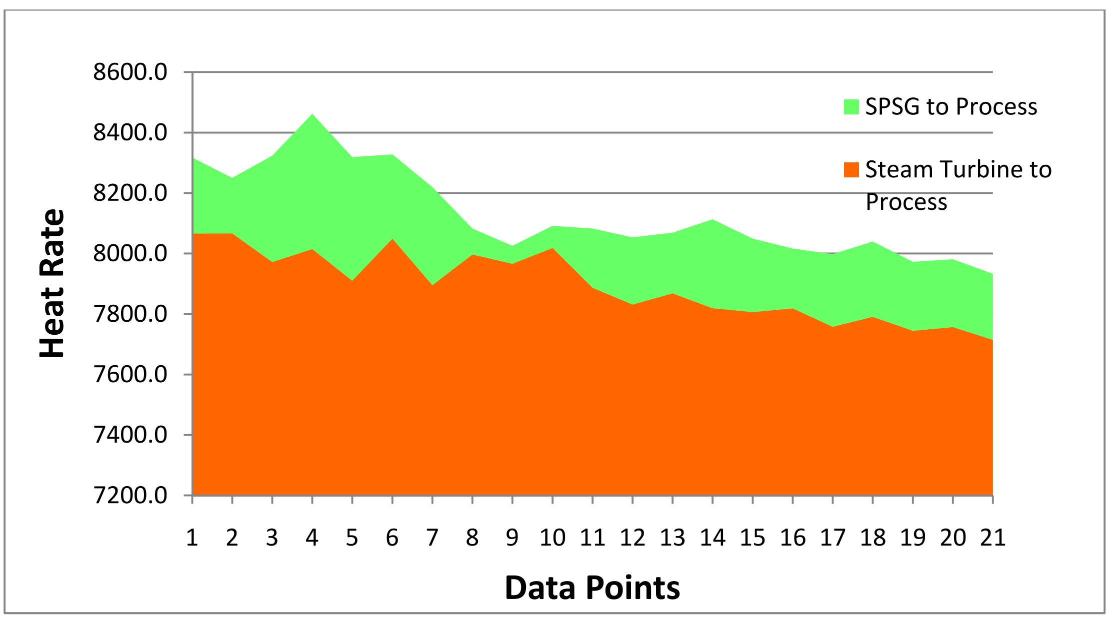

Figure 6 – Heat Rate Comparison, SPSG Vs ST Extraction

For the steady load test, the plant was held at a constant 283 MW while heat rate data was taken on both sources of extraction. Over the course of one hour on Steam Turbine extraction, the facility consumed 2,243 MMBtu's of fuel. This results in a heat rate of 7,925 BTU/KW hr. After swapping extraction points to the SPSG's is was shown that the plant consumed 2,328 MMBtu's of fuel over the course of the hour test. This results in a heat rate of 8,226 BTU/KW hr. So how much more efficiently does the plant run while on Steam Turbine extraction versus running the SPSG's? This question can be answered by reviewing the overall results of the project. These results are illustrated in Figure 7.

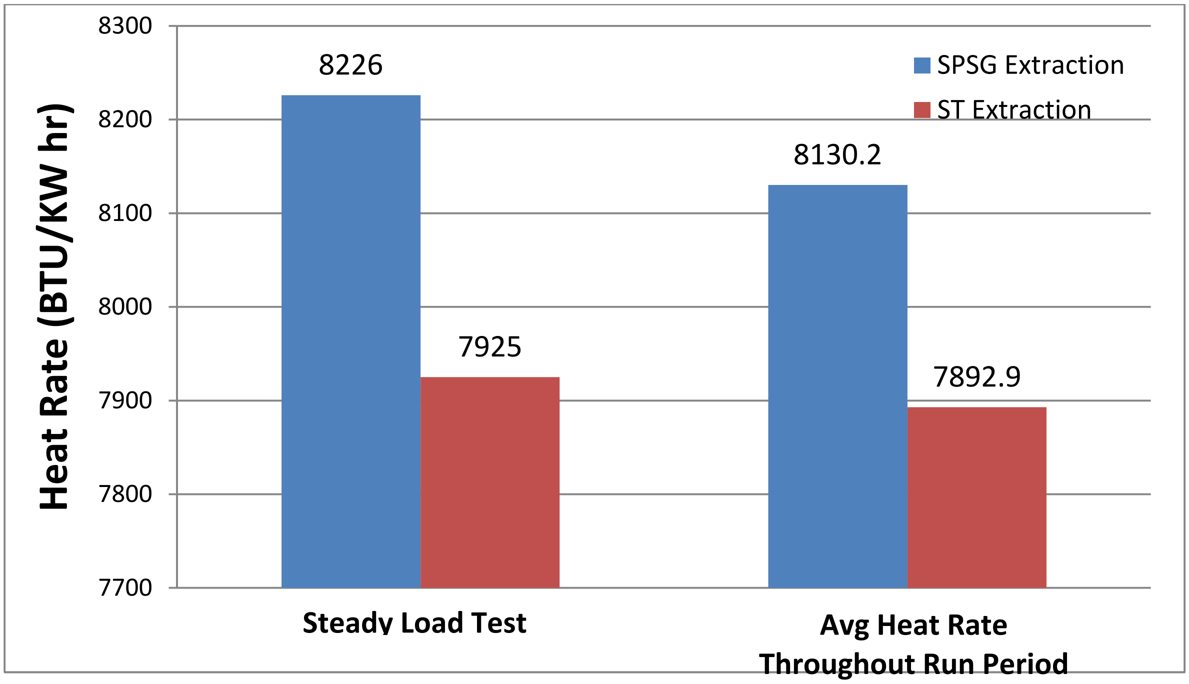

Figure 7 - Overall Results of Analysis

The steady load test showed a difference of 301 BTU/KW hr. By averaging all heat rate data collected throughout the run period, it can be shown that during normal operations a difference of about 240 BTU/KW hr can be achieved. These results clearly show that running on Steam Turbine extraction versus the SPSG's can increase the plants efficiency by roughly 3.0%.

Cost Analysis

There are two situations that were discovered in which the facility can decrease the run time of the SPSG's and switch to Steam Turbine Extraction. One such scenario is during plant start up. The other situation is when the plant is dispatched for a short run period (a six hour dispatch). Both of these situations are discussed below.

Note: For the purpose of this cost analysis, a plant capacity of 336 MW will be used. This is the summer rating at 90°F. Also a heat rate difference of 240 BTU/KW hr will be used as the difference between the two extraction processes. These values were chosen to ensure a conservative cost analysis result.

During start up, the steam turbine can begin to extract process steam when the HP wheel chamber pressure reaches 297 psig. This point normally occurs during the following plant state: The first unit is online and base loaded (≈ 85 MW), the steam turbine is on the grid (≈ 40 MW), and the second unit just went on the header (64 MW). So the plant is typically around 190 MW when the steam turbine is ready to be used for extraction. From this point until the last unit is at base load is about one hour (at this point the plant should be at base load in a steady condition). A typical hot start-up can be seen below in Figure 8.

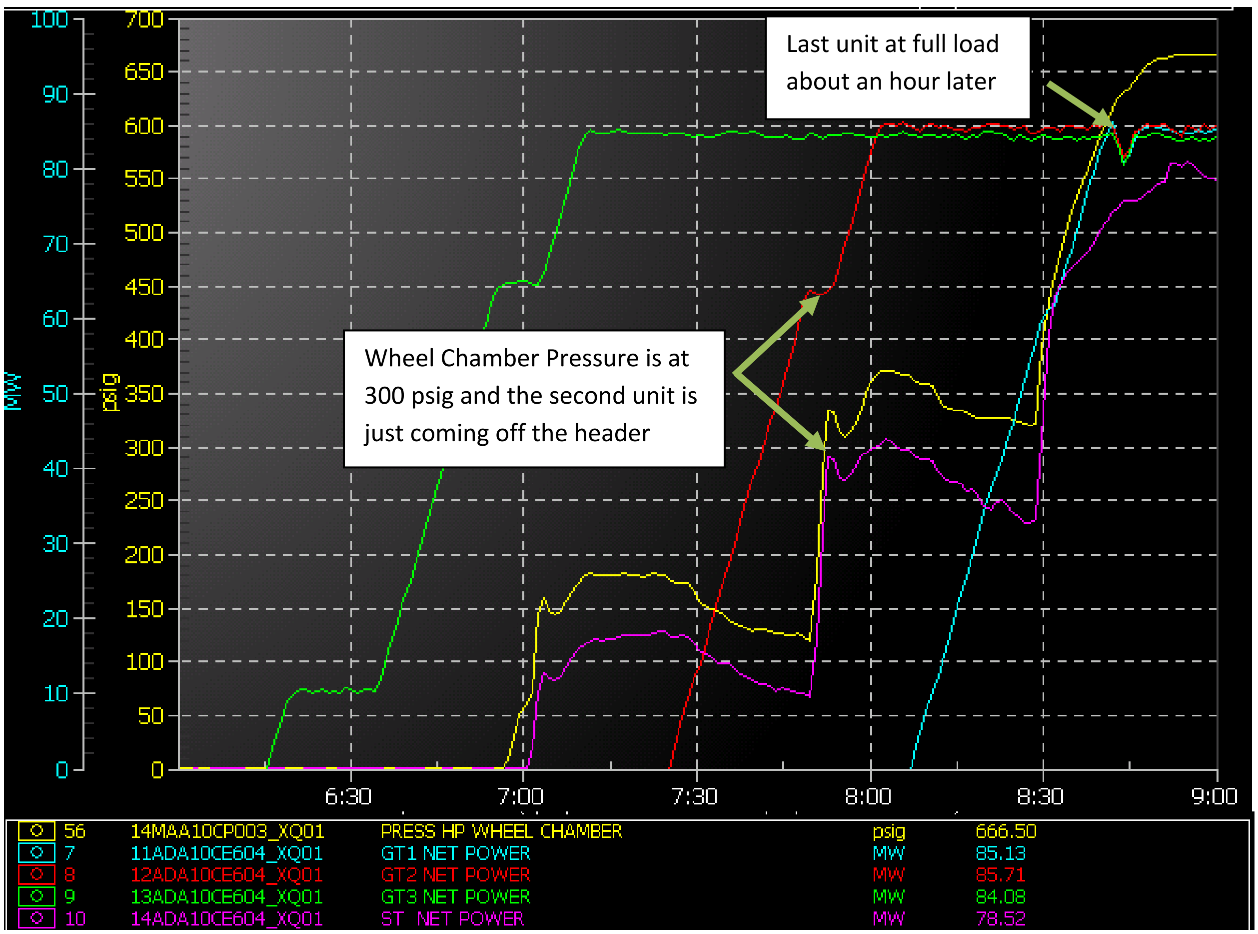

Figure 8 - Typical Start-Up Curve w/ Wheel Chamber Pressure

Operators typically hold steam turbine process from taking over for this hour (sometimes longer) to ensure that the plant is in a steady condition before starting another transient process. However, the startup program is designed to do this in a safe and reliable manner. Thus there is an hour of opportunity that the SPSG's can be offline during each startup that we are not currently taking advantage of. That equates to about 200 hrs (≈ 200 starts) a year. To quantify this hour of opportunity, the heat rate difference between being on the SPSG's versus using Steam Turbine extraction must be converted to a dollar amount. This can be done by using the following equation.

$$Cost\ per\ hour = \left[\frac{Heat\ Rate\ Difference\ (BTU)}{KW * hr}\right] * [Plant\ Load\ (KW)] * \left[\frac{Cost\ (\$)}{1{,}000{,}000\ BTU}\right]$$

The average fuel cost over the course of a typical year varies. For this analysis a cost of $7.00 per MMBtu will be used. This value was chosen after reviewing past years fuel costs. During this hour of start-up, a linear ramp rate will be assumed for the net MW of the facility. In other words, ramping from 190 MW to 336 MW in a linear fashion (based off of the start-up curves this assumption is reasonable). Thus over the course of the hour the facility would average 263 MW. Using the abovementioned values with a heat rate difference of 240 BTU/KW hr results in an additional cost of $442.00 per hour that the plant is incurring while the SPSG's are used for process steam versus using Steam Turbine extraction. This results in a potential cost savings of $88,400.00 a year during start-up.

In addition to start-ups, another opportunity that we can shut down the SPSG's occur during short dispatches. During short run periods (dispatches of six hours), it has been normal operating practice to leave the SPSG's operating. It was thought that the wear and tear the boilers receive when cycled over this short time would be of greater cost (in the long run) than the cost of the efficiency decrease absorbed by the plant when the SPSG's are online. In other words, the *value* of shutting down the boiler and using steam turbine extraction was unknown. In 2009, the plant was dispatched a total of 206 times. Of these 206 dispatches, 49 were dispatches of six hours (that's roughly 24%). That equates to 276 hours a year that the SPSG's are being used for process steam instead of the Steam Turbine. Using the same cost analysis as above with the only difference being the plant load during this time (an assumption of 336 MW instead of 263 MW), results in a total cost of $564.00 per hour. This equates to a potential cost savings of $155,796.00 a year during short run periods.

Conclusion

This heat rate project clearly indicate that the plant operates more efficiently while on Steam Turbine extraction versus using the SPSG's to supply process steam. It also indicates that when using Steam Turbine extraction the facility can operate closer to its design specifications. After these results were concluded, it was found that the facility has two specific cost saving opportunities, one being during start-up and the other being during short dispatches. The cost analysis suggests that a potential cost savings totaling $244,000.00 is possible. However it must be realized that there are many variables that would alter this projection including Automatic Generation Control (AGC), varying ambient temperatures and gas prices, how many start-ups and short runs the plant has each year, etc. This analysis attempted to capture these variables by using averages of previous year's data. Thus the projected savings is probably not 100% obtainable. Nonetheless, these cost savings opportunities are still present on a daily basis.

Emissions savings based on EtaPro Heat Rate Project

This data is a snap shot taken on December 14th and 15th with the gas turbines at full load and running 24 hours

The 15th the auxiliary boilers had to run 20 hours that day.

The ppm's of NOx on the gas turbines averages 28.9 ppm's, the boilers is 40.3 ppm's

The average pounds of NOx per hour for the boilers is 140.0

Using the ratio of ppm's (0.7171) the gas turbines would produce 100.4 pounds of NOx. Or a savings of 39.6 lbs/hr.

A non-leap year has 8760 hours

On a good year the gas turbines run 30% of the time

The reliability of the plant is 98%

The short dispatches reduces the run time by 276 hours

There is an hour lost at the beginning and end of a gas turbine run. With 200 starts/runs per year there is another 400 hours reduced.

Based on 39.6 lbs/hr savings of NOx

8760	Hours per year
2628	Hours the gas turbines run
2575	Hours plant is reliable
2299	Hours less the short dispatches
1899	Hours after beginning and end of the runs are taken out
75,200.4	pounds of NOx saved
37.6	Tons per year savings