Power Plant environmental cleaning schedule optimization

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Abstract *— Since switching to natural gas as their primary fuel, the boilers at a power plant of the Puerto Rico Electric Power Authority are kept cleaner and with minimum environmental pollution. According to a consent decreed with the Environmental Protection Agency, the boilers have to be cleaned every 18 months, a standard that was established previously, when the plant was using oil. The purpose of this project is to demonstrate to the Puerto Rico Electric Power Authority that, because it is now using natural gas as primary fuel, their boilers are cleaner and its components are subject to less corrosion, therefore the time between cleanings can be increased from 18 to 36 months. By means of cost analysis, it is demonstrated that there is a considerable amount of money to be saved by extending the time between environmental cleanings. It is also demonstrated that the internal components of the boilers can sustain an extended period of time without service of more than 18 months, but no less than 3 years.*

INTRODUCTION

This study has been dedicated for the last three months to determine a way that the Puerto Rico Electric Power Authority (PREPA) would spend less in their maintenance so that the money they save could translate into savings to its customers. This can be accomplished by convincing management that there is a considerable amount of money to be saved just by optimizing the boilers environmental cleaning schedule, specifically of the boilers fired up using Natural Gas. Only the boilers using Natural Gas are considered because this fuel is cleaner and more efficient and it maintains the boilers clear from asphaltenes , sulfurs, and all the other contaminants found in the derivatives of petroleum. This derivatives cause boilers to get very dirty and perform inefficiently, contaminating surroundings with all these residuals from the combustion process. Because of the existence of all this contaminants found in oil and its derivatives, the Environmental Protection Agency (EPA) demands the cleaning of the boilers at least once every 18 months. This requirement was set prior to PREPA having boilers that are fired up only with Natural Gas.

It is not the purpose of this study to prove that natural gas is a cleaner fuel. That is a fact and it has been proved all over the world. This study is trying to prove that internal components are better preserved when natural gas is used so, the timeframe between environmental cleanings can be doubled.

OBJECTIVES

- Demonstrate that there is a substantial amount of money to be saved by extending the time of environmental cleaning from 18 to 36 months.
- Demonstrate that PREPA boiler's internal components can sustain a period of time of 36 months of continuous use now that it is using Natural Gas instead of Bunker C.

THEORY REVIEW

A *boiler (for purposes of this article)* is a component in a power plant generation cycle which is basically a pressure vessel, an enclosed furnace formed mainly of tube walls, which main purpose is to convert demineralized water into high pressurized superheated steam. This steam is then used to move a steam turbine which will then move a generator producing electricity. A boiler is usually fired up using fuel such as petroleum, gas,

carbon, etc. This combustion process will produce a fireball and then combustion gases that will heat up tubes containing the water, converting it to superheated steam which is used as it was stated earlier in this paragraph. Figure 1 illustrates a boiler and the whole cycle of producing energy on a broad scale.

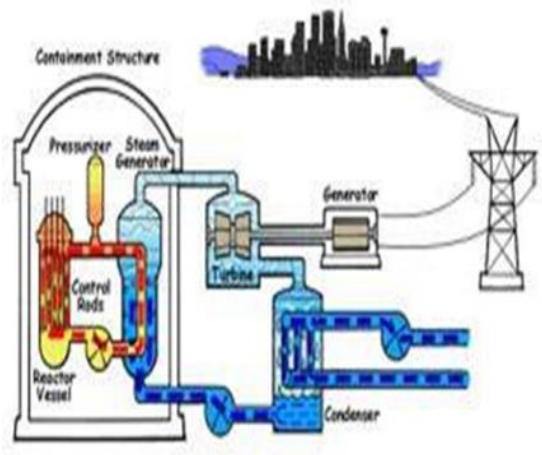

Figure 1
Power Plant Generation Cycle

A *Boiler's Environmental Cleaning* is the process or the activity where the boiler is turned off and all its internal components are cleaned with vapor and pressurized water. The main purpose of this activity is to remove all the contaminants and the entire residue from fuel combustion. The cleaning requires scaffolding of the whole furnace, pressure washing of all the tube components, and repairing all burners and ducts. The scaffolding dimensions inside the furnace are 50ft x 50ft x 128 ft. This scaffold material has to be rented from a company. Figure 2 shows a side view of what a boiler looks like exactly and the identification of its parts. Figure 3 illustrates which components have to be pressured washed and steam washed in the environmental cleaning.

Natural Gas is a hidro-carbon gas mixture containing methane, Carbon dioxide, nitrogen, and very low amounts of hydrogen sulfide. It is found in deep underground rock formations and near petroleum wells. It needs to be processed to remove impurities, and has a series of by-products which are: propane, butane, methane, penthane, helium, nitrogen and water vapor. It is extracted all over the world.

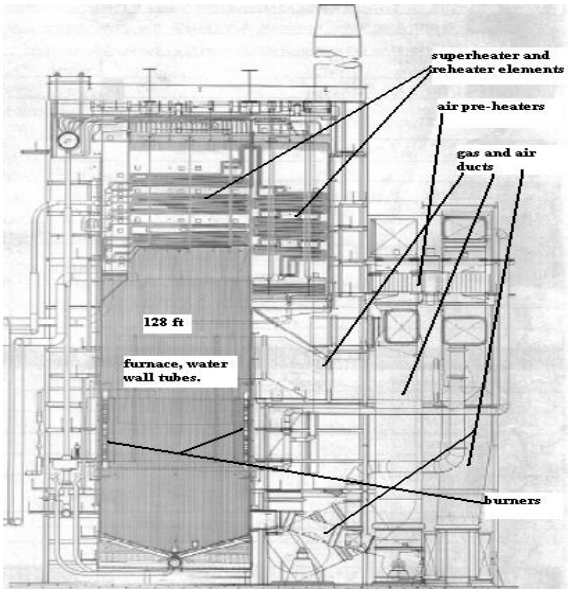

Figure 2
Boiler Component Identification

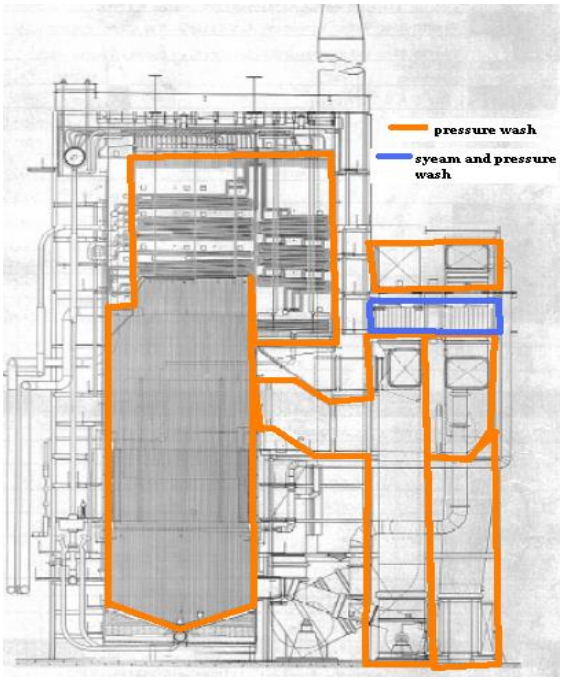

Figure 3
Components pressure washed and steam washed

On the other hand, *Bunker C* is a petroleum derivative which is made of long hydrocarbon chains, particularly alkanes, cycloalkanes and aromatics. It is normally composed of asphaltenes, vanadium, and sulfur too.

Figure 4 shows the contaminants found on a sample of Bunker C as it is used today at PREPA facilities. Here it can be seen that all of the substances are below the permitted limit; still these compounds are very dangerous contaminants to the environment and to human health. While asphaltenes and sulfur contaminate the environment; vanadium is greatly related to cause cancer. On the other hand, in Figure 5 shows a sample taken from the Natural Gas as it is received today. It can be noticed that the composition of Natural Gas is very different from that of Bunker C.. It has no compound that causes cancer or can pollute the environment. Even the traces of sulfur are so small that are negligible.

From Figures 4 and 5, it can be appreciated that in the gas sample there isn't anything that can cause these boiler to get dirty to a point where it loses its efficiency. And here is the big difference with Bunker C. The asphaltenes contained in Bunker C adhere to the tubes preventing the heat transfer needed to convert the water into steam, and the sulfur corrodes the metal in the tubes reducing its life. This causes a big loss of efficiency.

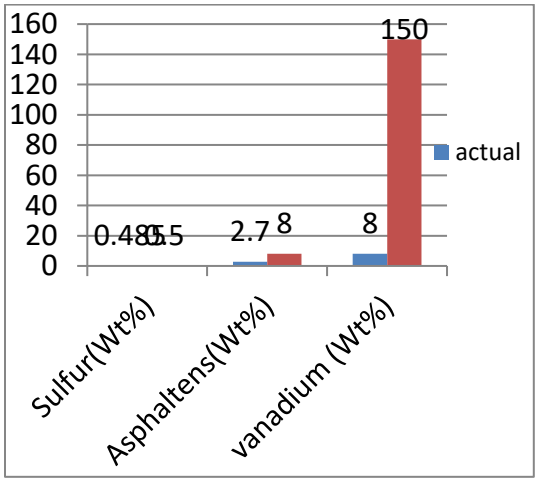

Figure 4
Bunker C Sample Composition

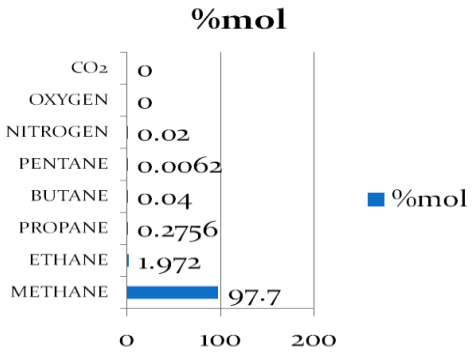

Figure 5
Natural Gas Sample Composition

METHODOLOGY

First of all, the unit that will be used as model for this project's calculations will be unit 5 of PREPA's facility in the South Coast plant. The total cost of all the activities related to the environmental cleaning will be calculated, including, scaffolding rental and mounting, pressure wash, burner, ducts and chimmey repair, all related purchased orders, and all related overhead. This tabulation will be performed for the last 3 environmental outages of this unit and an average value will be calculated. It takes 6 weeks to complete a boiler environmental cleaning.

The second thing that will be calculated is the cost related to energy replacement. What this means is that it is being assumed that an unit on natural gas produces 300 MW per day for 31 days a month. When the unit that burns natural gas is turned off, the energy it is not producing has to be replaced with another less efficient unit, probably fired with a more expensive fuel. It is calculated with Equation (1) as follows:

$$\textbf{Cost to generate} = \textbf{heat rate of unit}\left(\frac{BTU}{KWh}\right) * \textbf{cost of fuel}\left(\frac{\$}{MMBTU}\right) * 300\ MW * 24hrs * 30\ days \quad (1)$$

This cost difference will be calculated for a unit using natural gas and a replacement unit burning bunker c, each unit with its own heat rate.

Heat rate for unit 5 is 10,500$\frac{BTU}{KWh}$, and for the replacement units, 12,000$\frac{BTU}{KWh}$. The cost of NG is 13.3$\frac{\$}{MMBTU}$ and for Bunker C is 18.58$\frac{\$}{MMBTU}$. The result will be for a month and it has to be tabulated weekly so it can be calculated for the six weeks period of the environmental cleaning outage.

The next thing that has to be calculated is the cost of turning back the unit. This cost is calculated as follows: 120 barrels of diesel are needed to turn the unit on, and the cost of the barrel of diesel is $140/barrel. This cost is calculated to be $16,800. All these calculations will be analyzed over a 9 year period since it is being suggested here the cleaning should be performed every 3 years. Results will be shown in the next section.

RESULTS AND ANALYSIS

Table 1 shows all the total costs associated to an environmental cleaning. As it can be seen that the cost of performing the environmental cleaning every 3 years is as expected, half of what the company is spending right now.

Table 1
Results

ACTIVITY	TOTAL COST ($)
BOILER CLEANING (avg. for unit 5 last 3 cleanings)	2,800,000
ENERGY REPLACEMENT NG – BC (EQ. 1)	26,992,440
COST OF DIESEL TO TURN THE UNIT BACK ON	16,800
TOTAL	29,809,240
EVERY 18 MONTHS FOR 9 YEARS (TOTAL x 6 periods)	178,855,440
EVERY 36 MONTHS FOR 9 YEARS (TOTAL x 3 periods)	89,427,720

From Figures 6, 7, and 8 it can be appreciated a new burner component versus the components that came out of the unit in this last outage. Based on experience, of the author of this article determined that those parts used for three years have approximately 6 more months of use, so it means that they can sustain being on service for more than 3 years in a row. This has yet to be proven with more data, since the author's experience is not a proven scientific method for validating a process.

Figure 6
Boiler's Burners New

Figure 7
Boiler's Burner Components (3 years of use)

Figure 8
Boiler's Burner Components (3 years of use)

CONCLUSIONS

It has been demonstrated that over a 9 year period and performing the cleaning every 36 months; the amount of money to be saved in this activity is $89,427,720. This represents an amount of $9,936,413 annually. It is concluded that this is a substantial amount of money and for that reason, PREPA should pursue its defense against EPA on changing the clauses of the consent decreed that deal with the environmental cleaning schedule for our boilers on natural gas. The circumstances have changed; there is a new fuel in use, a cleaner fuel, called natural gas. There is no need to be spending all that money on unnecessary cleanings, when it can be put to better use finding ways of making the company more competitive economically.

On the subject of component resistance; it is understood by the author that more data is needed to make responsible conclusions. Even though there are samples of components that have been in use for more than 3 years, more samples are needed to emit a responsible opinion.

FUTURE WORK

Recollection of data on Air emission tests for Bunker C and Natural Gas, and recollection of more data on Component resistance over time. The next step of this project will be to present the case to PREPA management and convince them to go against EPA and try to change the cleaning schedule of PREPA's boilers.

REFERENCES

[1] Moran-Shapiro,M-Hl, "*Fundamentals of Engineering Thermodynamics", 4th ed.*,Chapters 7-10.

[2] Lindeburg, M, "Mechanical *Engineering Reference Manual", 12th ed., pp. 61-1 to 68-1.*