Energy Saving Potential for

Industrial Steam Boiler

Yulineth Cárdenas Escorcia¹, Guillermo Valencia Ochoa² and Juan Campos Avella³

¹ Industrial Eng., Research Group on Efficient Energy Management
Universidad of Atlántico, km 7 antigua vía Puerto, 081008
Barranquilla, Colombia

² Mechanical Eng., Research Group on Efficient Energy Management
Universidad of Atlántico, km 7 antigua vía Puerto, 081008
Barranquilla, Colombia

³ Research Group on Efficient Energy Management
Universidad of Atlántico, km 7 antigua vía Puerto, 081008
Barranquilla, Colombia

Abstract
This paper presents the methodology and results of applying a performance analysis of a 75,000-pound capacity / hour capacity boiler integrated into the energy management system for energy planning in a company, in order to identify the potentials of energy saving. The fundamental data used to estimate the energy performance indicators, a brief description of the equipment characteristics and the results of the quantitative analysis of the process are presented. In addition, the methodology proposed for this study is based on the use of the tools of an energy management system, using the stages that carry this procedure, these stages allow the improvement the energy consumption of the company. The study showed a linear correlation $R^2 = 0.9615$ and a target line of the form $Et = 73.147P + 49.061$ with a linear correlation $R^2 = 0.9782$ and a saving potential by good manufacturing practices, which are not associated with production of 6.52%, which shows that although there are good operating practices.

Keywords: Steam Boiler, energy management system, energy performance indicators
1. Introduction

Boilers are pressure vessels used to heat water whose purpose is the production of steam, which is used to generate electricity through the conduction of steam turbines [1], and that the use of steam at the manufacturing level corresponds to the maximum energy saving potential for a company's energy system [2]. The quantification of this energy saving potential based on the energy performance indicator are very useful, an example of this is the formulation of methods for the estimation of exergetic loss and the exergetic efficiency of the boilers [3], another case is the evaluation of the performance of a boiler in an ethanol production plant by means of exergy and irreversibility analysis where the individual components of the system are evaluated [4]. Other investigations are oriented to determinate performance evaluation of the actual efficiency in the boiler, being able to present estimates of the real efficiency and the expected efficiency, having with based the set of historical data of the equipment [5]. On the other hand, some investigations estimate the uncertainty in the measurements intended to determine the thermal equilibrium of a coal boiler by different analytical method allowing to simulate the system [6].

In this way, the concept of efficiency in boilers relate the net amount of heat that is being absorbed by the steam generated and the net amount of heat supplied to the boiler [7], as a result of this the improvement in efficiency allows to identify savings in energy consumption, less use of fossil fuels and reduction of CO2 emissions [8]. It should be noted that measuring the efficiency of these equipment is linked to the efficiency of the overall production process, through the energy management of the industry, articulating environmental management systems and economic, environmental and energy indicators of the company [9], [10], associating it with the different forms of efficiency evaluation, among the most outstanding being the calculation of performance indicators related to energy consumption and productivity [11], [12].

This paper presents the results of an energy diagnosis by assessing energy indicators based on historical information on the energy consumption of an industrial boiler, identifying opportunities for organizational, energy and technological company, in order to integrate the energy management in the different processes that underlie integral management. In additions, the paper aims the application of the operational data monitoring in order to obtain energy performance indicators for a industrial steam boiler located in Colombia, with the purpose to reduce the energy consumption based on a implementation strategic decisions strategy and energetic characterization.

2 Methodology

In this section of the paper, a brief description of the 75,000 lbs / hr steam boiler used as an equipment to produce steam in an industrial company, also the energy performance indicator is presented as a tool in the energy management to identify energy-saving potentials. Finally, the steps and procedures are presented based on
the quality management, supporting the continuous improvement of the energy performance of the equipment.

2.1. Description of the steam generation system

The steam boiler studied is from the NEBRASKA CALDERAS COMPANY which is shown in Figure 1a, manufactured in 11-05-1993 which a capacity of 75,000 lbs / hour and design pressure of 300 PSI. Also the initial operation pressure corresponds to 250 PSI, with current operating pressure of 205 PSI and with target operating pressure of 180 PSI, taking into account the recommended air excess of 10% regulated with the control systems implemented as shown on Figure 1b.

![Steam Boiler Image](image1.png)

Figure 1. Steam Bolier, a) generation system; b) control system.

2.2. Assessment the energetic performance

The methodology proposed for this study is based on the use of the tools of an energy management system, using the stages that carry this procedure, these stages allow the improvement (reduction) of the energy consumption of the companies, in these stages highlights the strategic decision that seeks the participation of company executives, with the purpose of providing resources for the implementation of the Energy Management System, later stage two lies in the calculation of energy performance indicators through the identification that are considered significant within the main areas of the company, finally, the so-called operational stage is denoted, where constant monitoring of the socialization of the energy performance indicators is carried out, thus achieving the evaluation of business energy practices, maintenance, the production and coordination achieved through the execution of projects, this process according to the ISO 50.001 international standard is shown below in Figure 3.
The main objective in the continuous improvement of the use, energy consumption and energy efficiency is the operational control of the significant use of the energy, where the base line and the indicator plays a principal role, due to without this information there is not a referent to improve.

### 2.3. Energy indicators Equations

In order to calculate the Energy indicators, a statistical treatment of the energy consumption and production was conducted, allowing to determinate the base and target line, the base 100 efficiency indicator, the graphs of accumulate trend and finally the consumption index according to the equations (1-4).

The real consumption index (IC) was calculated with energy consumption and production (p) as shown as follow

\[
IC_{Actual} = \frac{E_{Actual}}{p}, 
\]  

(1)

while, the theoretical consumption index was calculated as

\[
IC_{Theoretical} = \frac{E_{theoretical}}{p}. 
\]  

(2)

The energy base line is obtained from the linear regression of historical data of energy consumption and production; energy base line has the linear form as follow

\[
y = mx + b. 
\]  

(3)

Finally, the efficiency Base 100 index, which is a tool for energy management that helps to evaluate the behavior of energy consumption measured during a period of production time, was calculates as

\[
Base\ 100 = \frac{E_{theoretical}}{E_{Actual}} \times 100\%. 
\]  

(4)
By means of this calculations were possible to identify the variations in the energy efficiency of the process, facilitating the analysis of action plans with a view to improving energy.

3. Results and Discussion

Below are the results of the application of the energy characterization tools and the analysis of the energy performance indicators for their measure, verification and control of effective operation in significant uses of energy in the steam boiler.

Control Charts

As shown in Figure 4, for the control limit graph for steam production, an upper limit and a lower limit were set apart by three times the average deviation of the supplied data, where it is shown that some data of the days November 2nd, November 3th and November 17th are below the lower production limit, which possibly correspond to maintenance stops. These data are considered atypical or abnormal operation conditions; which will not be taken into account for the analysis of the energy performance indicators.

![Figure 4. Control limit graph for the Steam Production](image)

On the other hand, Figure 5 shows the graph of control limits for Gas Consumption data, where it is observed that, as in Figure 4, some data from November 2, November 3 and November 17 below the lower production limit, which will not be included for energy analysis.
When a graph of energy and production was obtained from the data supplied, a baseline was obtained initially with a very low linear correlation due to atypical data, and after data filtering to achieve an acceptable correlation for the analysis of the energy performance indicators without losing the functionality between production and energy, a baseline of the form $E_{\text{base}} = 74.392P + 52.478$ was obtained with a linear correlation $R^2 = 0.9615$ and a target line of the form $E_{\text{target}} = 73.147P + 49.061$ with a linear correlation $R^2 = 0.9782$ shown in Figure 6, in which the energy saving potential associated with good manufacturing practices is observed. Here the target line was constructed from the production data and power consumption that are below the baseline.
Base 100 Indicator

For the application of the base efficiency index 100 for the Boiler, shown in Figure 7; points above the black line are considered to be good energy performance data located in the energy efficiency zone of the plant. Otherwise, when the efficiency index is less than 100%, the data is located below the black line and indicates that the data belong to a zone of energy inefficiency of the plant. However, it is important to note that low efficiency peaks such as November 2nd and November 18th are associated with the random behavior of processes and are not the result of changes in the energy management system.

Figure 7. Base 100 efficiency index

Accumulated sum Indicator

Taking into account the frequency of the month in Figure 8, three periods of time with a clear tendency of consumption are observed, the first period presents from November 1th to the November 7th, where one does not observe stable behavior with good trend towards saving and a good energy yield. The second period is the only one that is clearly visible from November 7th to November 10th, where it is observed that there is a poor trend towards saving and regular energy efficiency, the third period from November 10th to November 21th shows an unstable behavior with a low energy efficiency but with a good tendency to save. In addition, it must be taken into account that the peaks in some periods do not represent any trend, since they can correspond to maintenance days or plant stops.
Finally, the analysis of the saving potential by good manufacturing practices for energy not associated with production can be reduced by 6.52%, which shows that although there are good operational practices, this can be to improve; and with respect to the given period, there is a tendency to increase the energy efficiency.

4. Conclusions

Energy planning in high impact equipment for consumption is the basis of energy savings in a company, thanks to the implementation of an energy management system can identify opportunities for improvement, thus achieving energy savings, it is important to highlight the importance of to execute good operational practices taking into account and as basis of the analysis the study of energy indicators which a more detailed analysis of the possible opportunities of energy saving. Finally, it is concluded that the structuring and implementation of a methodology based on an overall evaluation of the process allows the correct management of energy systems in a company.

References


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