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Identification of energy saving potential in steam boiler through an ISO 50001 standard

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Abstract. The energy performance of steam boilers, such as the efficiency and the evaporation ratio can decrease along time because of the poor combustion, heat transfer fouling, poor operation, and low maintenance rate. The energy indicators assessment allows to observe the abnormal operational deviations to implement corrective action, so it is necessary to find out the level of efficiency in real time to evaluate the thermal performance, which is an obligatory requirement to implement the energy management program in the industry. As a contribution in the area of energy efficiency in steam boilers, the results of an applied research are presented, where the behavior of steam production and gas consumption as input variables were considered to apply the methodology and obtain the energy saving results on a boiler from 125.000lb/h steam capacity. The consumption and energy production control charts, the base and goal line, and base 100 indicators were calculated to facilitate the energy monitoring of the steam boiler for a period six month. Letting the application of the methodology to recognize saving opportunities starting from the analysis of variables that impact the energy consumption affected by different ways energy consumption of the company. The study showed a linear base with the form $E_B = 0.0595x + 0.988$, with a linear correlation equal to $R^2 = 0.973$ and a goal line $E_G = 0.0586x + 1.3814$, with a linear correlation of $R^2 = 0.97$, which means statistical validity in the data collection. Additionally, the base 100 index was calculated to identify satisfactory the peaks of energy efficiency, showing efficiency and inefficiency in the process. The study shows that data reflected below the efficiency rate (100) are considered peaks of energy inefficiency, which means energy saving opportunities for operational control, maintenance management, production planning, besides the typical ones due to technological changes.

1. Introduction

Fossil fuels such as gas, coal, and oil are the most widely used in the world's industrial power generation [1], excessive use of these resources is directly related to carbon dioxide emissions (CO_2). At present, the political states have focused their efforts on environmental problems, where one of the leading aspects is the reduction of CO_2 [2] making a positive contribution to reducing the impact of the greenhouse effect [3]. There are different methods of reducing CO_2 emissions in the industrial sector, including improving the recovery rate of fluorinated gases emitted by industrial processes, and improving the efficiency of systems used by industry for energy generation purposes [4]. Energy consumption in the industrial and commercial sectors account for almost 40% of global greenhouse gas emissions in particular CO_2 [5] and the thermal efficiency of energy generating plants is approximately 30.12% worldwide, and in term of the second law of thermodynamic the boiler is the predominant component, achieving a 80% on the component irreversibility ratio in the power plant [6] The evaluation of the efficiency of these systems, amount of heat that is being absorbed by the steam generated at the net amount of heat supplied to the boiler [7], is fundamental in the consumption and measurement of energy in electricity generation.

Thus, countries such as United States, Korea, and China [8] Colombia [9] among others evaluate the technical and economic potential of boiler technologies, to achieve high efficiencies in the industrial sector. One of the methodologies of more excellent use for process control is energy audits, which are a systematic tool that allows knowing the consumption of mechanical energy and locate processes of Irrational Use of Energy [18], achieving through a thorough analysis to decide on the distribution of budgeted energy in different sections of an organization, plan energy consumption, reduce irrational energy use and impact energy costs [11]. Another methodology used is the quantitative analysis related to the capacity of the boiler/hours integrated into the energy [12], where it is possible to contribute to the energy management system using strategic energy planning in a company, to identify energy saving potentials. In this way, quantification of the energy saving potential based on energy efficiency symbolizes cost-benefit [13] on the basis of the various evaluations that this entails, for example, exergetic assessment of the components of the system [14] and baseline consumption assessments[15], in addition, it should also be noted that the measurement of the efficiency of the production processes, in general, is adjusted to the components that integrate the environmental, economic and energy management systems of the company [16], knowing that the energy management system is primarily based on the improvement cycle, ISO 50001 closes the gap between the systemic approach of audits and the general technical-operational approach, both aspects are channelled into the development of a baseline, with the identification of significant energy users and the development of energy efficiency indicators [17]. Additionally, ISO 50001 is the latest energy management standard that is a successor to ANSI/MSE 2000 and EN 16001 [18].

The standard guides an organization to develop and implement a policy to identify critical areas of energy consumption and commit to energy reduction. The standard does not require any performance criteria specific to another management system standard published by ISO, but if applicable requirements for energy use and consumption, including measurement, documentation and reporting practices, design and provisioning of equipment, systems, processes and personnel that contribute to energy efficiency [19], this makes it easier for agencies to integrate energy management into their overall efforts to improve quality and environmental management.

2. Methodology

In this section, a description of the procedure that allowed the application of mathematical tools for energy characterization and the analysis of energy performance indicators for its measurement, verification, and control of the efficient operation in significant energy uses in a steam boiler is presented. Also, the steps and procedures based on the IEMS are performed as shown in Figure 1, contributing to the continuous improvement of the energy efficiency of the equipment.

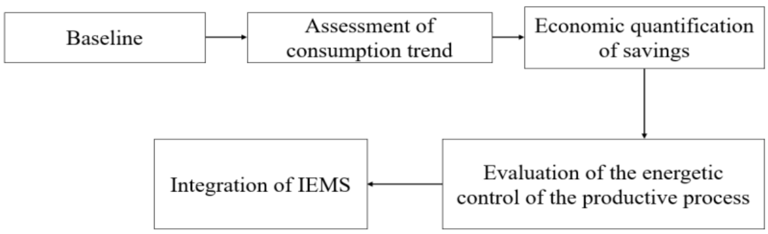

Figure 1. Energy management systems procedure for evaluating the potential of a boiler.

Initially, the real and theoretical data of consumption and energy production of the boiler are studied, using calibrated sensor on a petrochemical plant in order to know the steam boiler behavior, daily data measurements between $04-12-2016$ and $04-12-2016$ about the gas consumption and steam production was held. In addition, the base index 100 is calculated which allows determining operating conditions of saving or eviction of the process.

2.1. Steam generator equipment
For the case study, the steam generator equipment is a water tube with a heat input of 130.51MMBTU/h, according to the operation conditions the generating capacity is 125.000lb/h of superheated steam, under an operating pressure and temperature of 607psig and 750°F respectively, and a feedwater temperature of 248°F . The main fuel type is natural gas with a total fuel consumed per year of 4.860.000SKPC/year, but the equipment usually operates at a fixed load rate of 40% of the boiler design capacity. The main component of the steam generator equipment are the smokestack, gas burner, and the water supply as shown in Figure 2.

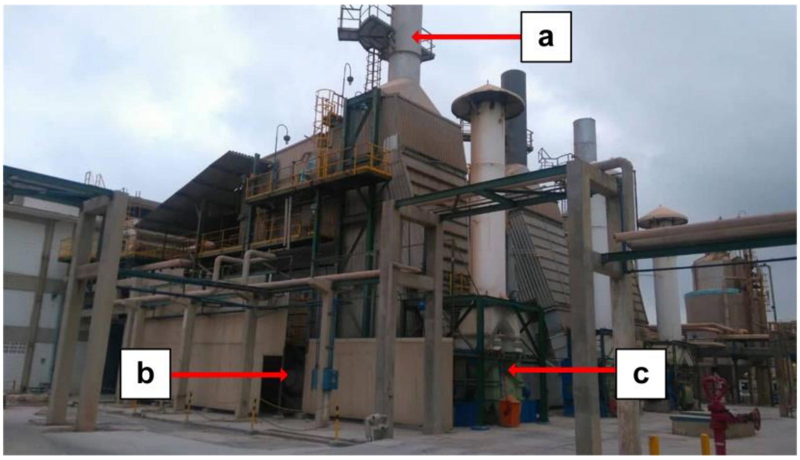

Figure 2. Steam generator main components (a) smokestack, (b) gas burner, and the (c) water supply.

2.2. Energy indicator equations
Initially, for the calculation of the energy indicators, statistical data on energy consumption and production are taken into account, called mathematically as an index of real use (ICactual), Equation (1),

$$IC_{Actual} = {E_{Actual}}/{P} \quad (1)$$

Where E_{Actua} is the real steam production and P is the fuel consumption, while the theoretical consumption index (ICtheoretical) is calculated as (Equation 2),

$$IC_{Theoretical} = {E_{Theoretical}}/{P} \quad (2)$$

Where $E_{theoretical}$ is the theoretical steam production. Another energetic indicator factor corresponds to the energy baseline, which is obtained from the linear regression of historical data on energy consumption and production; receiving the energy baseline, which has a direct form given by Equation 3.

$$E_{Actual} = mP + b \quad (3)$$

Finally, the Base 100 efficiency index, which is an energy management tool that helps to assess the performance of the measured energy consumption over a period of production time, is calculated as follows (Equation 4),

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$$Base\ 100 = \frac{E_{theoretical}}{E_{Actual}} \times\ 100\ \%. \quad (4)$$

Through these calculations, it was possible to identify variations in the energy efficiency of the process, facilitating the analysis of action plans to improve energy efficiency.

3. Results and discussions

The following are the results of applying the tools of an IEMS to a steam boiler. The control charts, based and target line are presented, allowing to determine the base 100 indicator.

3.1. Control charts

Analysis of steam production performance is shown in Figure 3(a), where the upper and lower limits were determined in order to identify the presence of atypical points or abnormal operating conditions in the process. This showed that a slight downward trend in steam production could be observed due to the demand of the process; additionally, the same control study parameters were performed to observe gas consumption in the period, since all the data are between the upper and lower limits, the energy study must be performed on the entire sample shown in Figure 3(b).

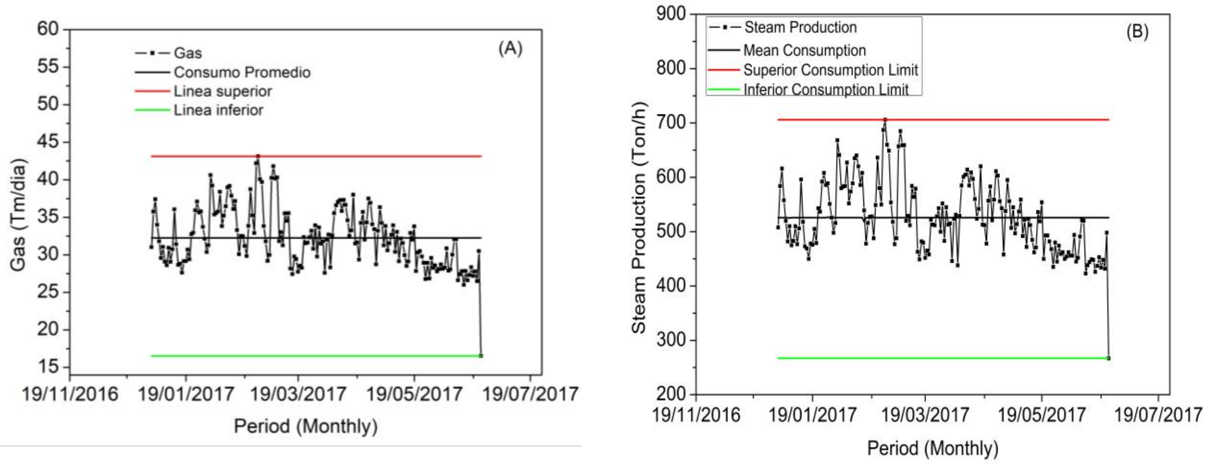

Figure 3. Control charts graph (a) Steam Production, (b) gas consumption.

3.2. Baseline and target line

When a graph of energy and production was obtained from the data provided, a baseline with an acceptable linear correlation was initially obtained, as the data did not show atypical behavior by than three standard deviations away from the mean. However, filtering of data was carried out in order to establish a more stable correlation; with the purpose of not losing functionality between production and energy when it comes to energy indicators analysis, selecting as final criteria 2 standard deviation. Baseline of the form $E_B = 0.0595\text{x} + 0.988$ and with linear correlation equals to $R^2 = 0.973$ and a target line $Y = 0.0586\text{x} + 1.3814$, with linear correlation of $R^2 = 0.9933$; this is shown in Figure 4.

3.3. Base 100 index

The analysis of the base 100 index was carried out on the efficiency of the boiler, in order to establish adequate energy efficiency peaks, as shown in Figure 5, those which are above the 100% average, in the same way, variations that are below the efficiency rate are considered energy inefficiency peaks. It is important to note that the low efficiency peaks of 22 January, 17 February and 20 February are associated with the random nature of the process and are not the result of variation in the energy management system.

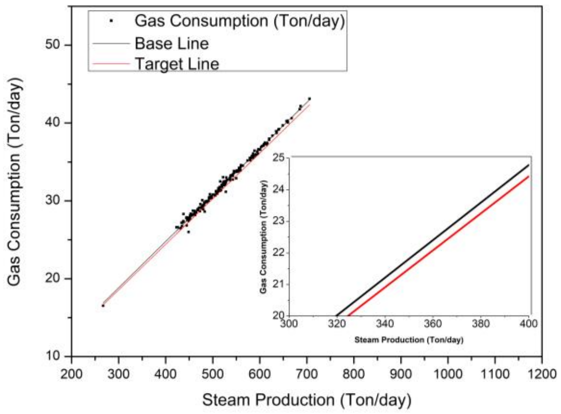

Figure 4. Baseline and Target line graph.

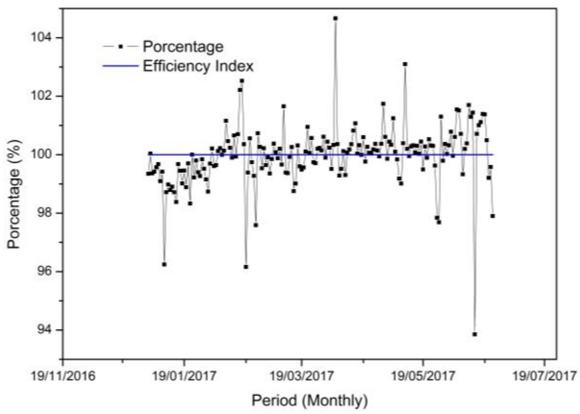

Figure 5. Base 100 efficiency index.

4. Conclusions

The IEMS is based on three levels, strategic, tactical and operational, which includes the management of human, environmental, technological and financial talent, these processes are evaluated in an integral manner with the explicit criteria in the ISO 50001 standard, which bases the audit as an inspection tool for the continuous improvement of the process, aiming at the development and implementation of a policy to identify critical areas of energy consumption and commit to energy reduction, facilitating the inclusion of energy management with the improvement of quality and environmental management. Likewise, supported by the ISO 50001 standard, the methodology presented can be extended to any type of steam boiler. The ISO 50001 Standard includes the implementation, operation, monitoring, measurement and analysis of energy management in companies, which is why energy planning in high impact equipment for consumption is the basis for saving, thanks to the implementation of an energy management system capable of identifying opportunities for improvement, these savings are achieved. Also, it is essential to highlight the application of sound operating practices without forgetting the quantification of real consumption, which facilitates identification through energy indicators.

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