ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 07, Issue, 07, pp.14189-14195, July, 2017

ORIGINAL RESEARCH ARTICLE Open Access

STUDY OF REDUCING VAPOR CONSUMPTION IN BOILERS

[1]Wesley Pacheco Costa, [2]Stéfano Frizzo Stefenon, [3]Adriano Garcia, [3]Leonardo Ceccato de Lima, [2]Anne Carolina Rodrigues Klaar and [4]Cristina Keiko Yamaguchi

[1]Undergraduate Student at University of Planalto Catarinense, Brazil
[2]Doctoral Student at Federal University of Santa Catarina
[3]Postgraduate Student at University of Planalto Catarinense
[4]Professor of University of Extremo Sul Catarinense

ARTICLE INFO

Article History:
Received 05th April, 2017
Received in revised form
23th May, 2017
Accepted 26th June, 2017
Published online 31st July, 2017

Keywords:

Steam,
Boiler,
Blowing.

***Corresponding author**

ABSTRACT

Steam is essential for the pulp and paper industry, it's possible to dry paper whit it, generate power through turbo generators and blow out boiler tubes. With the ever-constant demand for mass production concerning quality, we are looking for more optimizations criteria aimed at reliability and availability, with cost reduction for a quick return on the investment. This work related the steam production through a chemical recovery boiler, looking for an improvement in the soot blowing system of the boiler. Later, an implantation study was proposed for some measuring instruments to control the blowing system, eliminating unnecessary costs of steam at points that did not require such frequent cleaning. It was possible to cover the quantitative method, since these are instruments that will inform in real time the amount in tons per hour of steam used to carry out the blowing.

Citation: Wesley Pacheco Costa, Stéfano Frizzo Stefenon, Adriano Garcia, Leonardo Ceccato de Lima, Anne Carolina Rodrigues Klaar and Cristina Keiko Yamaguchi. 2017. "Study of reducing vapor consumption in boilers", *International Journal of Development Research*, 7, (07), 14189-14195.

INTRODUCTION

Presentation

Since the industrial revolution in the eighteenth century, steam is responsible for the transformation of thermal energy into mechanical energy, a single steam engine could perform the service of hundreds of horses. Currently, steam is used in most industrial processes, equipment, steam-heated processes in industrial plants, factories and steam-powered turbines for the generation of electric energy. The use of steam goes beyond heating processes, having applications in propulsion, atomization, cleaning, humidification, among others. This study will address the use of steam in the paper industry, where we have steam generation through power boilers and recovery, the research will be conducted specifically on the internal cleaning part in the boiler. The use of soot blowers currently do not have efficiency control, and with this study, there's the possibility to verify the system's improvement, how much steam is spent and even evaluate a possible reduction in consumption.

Problem Description

The blowing system uses a large amount of steam to perform internal cleaning of the boiler. Cleaning through a blower activation sequence pattern, frequently performs cleaning at points that do not require as much blowing, as well as points requiring more frequent blowing. Analyzing the context, would it be possible to implement an automatic control system that performs cleaning with greater efficiency? Is it possible to reduce the amount of steam spent for a more efficient blowing? Which measurement instruments would be required to perform this control?

Justification

The steam generation has a hig cost in industries, making it increasingly necessary to find ways of reducing unnecessary expenses. With today technological advance of industrial automation, the equipment is directly connected in the process, performing the continuous analysis of the production line, registering and controlling several variables.

Trough comparing values between the blowing system by sequence and the blowing system by pressure and temperature control, it will be possible to prove an expenditure of tons of steam with unnecessary blowing. With this change in the system, there will be a reduction in the consumption of steam for the blowers, thus saving on production, as industry increasingly needs to improve its efficiency in the production process, whether in corporate management (Eissmann *et al*., 2017; Oliveira *et al*., 2017) or industry improvement (Stefenon *et al*., 2017).

General Objective

Elaborate an automatic control system of blowing by pressure and temperature for the boiler, with little investment and precision in the activation, in order to have a better use in the consumption of steam currently used for blowing.

Specific Objectives

- Carry out the case study for economic viability of improvement in the current project.
- Perform the installation of temperature transmitters and pressure differential transmitters.
- Raise data on the effectiveness of differential pressure and temperature measurements in the process.
- Observe unnecessary activation errors in the blowers.
- Calculate the cost reduction with the new system.

METHODOLOGY

The process of cleaning the tubes in boilers was verified in this research, proving the existence of possible improvements in the industrial plants, through the installation of pressure differentials and temperature transmitters in the superheater, evaporator, and economizer of the recovery boiler. Automation and instrumentation were used to maximize the efficiency and control of cleaning in recovery boilers water pipes, and also a reduction in consumption. This allowed collection of data and performance graphs from the case study equipment, presenting results.

Kraft Paper Manufacturing Concepts

In the manufacture study of paper and cellulose, a macroview of it's production is necessary. The main raw material for paper manufacture is cellulose. To begin the process, it's necessary to define the tree from which the pulp will be extracted, this being based on the follow-up in which this industry branch will be composed in the market. Cellulose is characterized by two fiber types.

Figure 1. Ilustration of the steps involved in the wood transformation process (Klabin S.A – 2006)

The first type is the short fiber extracted from eucalyptus, used in the manufacture of sulphite paper, toilet paper, notebooks, books and other products. And the second type is the long fiber drawn from pinus, used for the manufacture of Kraft paper, specified for products that demand more mechanical resistance like cardboard boxes. Figure 1 below shows, by slices, the five main stages of wood transformation into paper (Mocelin, 2005).

Mass Preparation

The pinus from the forest is transported to the factory by trucks in the form of logs and stored in open deposits, where they will stay until there is a need to send them to the paper transformation process. The wood continuously feeds the debarker, a cylindrical rotating drum with grooves that allow the barks to escape. The cylinders are inclined and rotate slowly, which produces an impact between the logs and the walls of the drum, causing the removal of the barks. After the debarking, the wood passes through water jets to remove soil, sand, and stones, and is then cut into small pieces by equipment called chopper. The chopping process is used with the purpose of reducing the logs into fragments, whose size facilitates the cooking liquor penetration. Figure 2 shows an image of the open-pit stock of minced wood from a pulp and paper industry readily available to be transported to the digesters and to start cellulose manufacturing.

Figure 2. Minced wood stock

Cellulose Paste Production

The cellulose paste is produced in the digester. For this paste production, the minced wood and the white liquor ($NaOH$) are introduced into the digester, in addition to steam heated at approximately 170 °C, with a pressure ranging from 8 to 10 kg/cm². Another portion of black liquor is needed to complete the baking volume.

Figure 3. Minced wood ready for baking

Figure 3 illustrates the minced wood before the cooking process. The amount of white liquor and minced wood introduced into the digester are variable and depends exclusively on the humidity of the minced wood. The cooking time is approximately 60 minutes (Klock *et al*., 2005). The purpose of baking is to dissolve the non-cellulosic materials that make up the wood and act as a "cementing agent" between the fibers (lignin). In figure 4 an image of the already cooked and washed cellulose is shown, ready for processing.

Figure 4. Cellulose paste ready for processing.

After the cooking the mass is stored in large capacity tanks and is available for the process according to the demand in question.

Minced Wood Quantity for Cooking

To elaborate a good cooking recipe, the industries monitor the amount of dry minced wood that enters the digester so that this data serves as calculation basis in obtaining the quantity of reagents to be dosed. Obtaining the absolute weight value can vary constantly, so is necessary to have an integrating scale that will continuously monitor the weight in (t/h) on the transporting belts. The roller set is below the belt and through several load cells positioned on the stands, it's then possible to measure the integrated weight in (t/h) as the minced wood goes to the digester. In the cooking control, there are specific chemical parameters for this purpose. One of the main parameters is the cooking degree that is controlled by means of manual samples collected from the material (cooked cellulose) and laboratory analysis, to estimate the amount of lignin present in the cellulose pulp. There are several procedures to perform this type of determination, however, the number of permanganate (Number H), is the most used by industries (Castro, 2009). After the cooking, the cooked mass passes to the Blow-Tank by pressure difference, where it's stored and then refined.

Cellulose Washing

The cooked mass is washed by four rotating filters, in series, with countercurrent water. The filters are made of rotating drums that rotate slowly inside a compartment as shown in figure 5. As the drums rotate, the water is withdrawn due to a water column constructed below these washers for vacuum formation and thus is sucked. A mass layer is formed just above the washer filters on a special stainless steel surface where the black liquor is sucked into the drum. The mass is washed by a shower of clean water in a set of several washers connected in series, as shown in Figure 6.

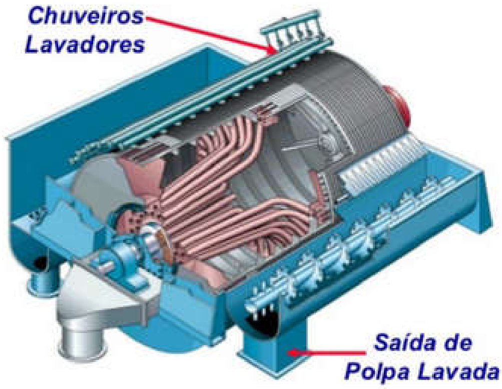

Figure 5. Cellulose washer illustration

Figure 6. External detail of washer set

Each washer has it's wash proportion for the black liquor extraction that will be stored in tanks to become fuel for the recovery boiler later. After burning, the chemical process takes initial proportions to make sodium hydroxide (NaOH).

Paper Machines

After all the transformation of the minced wood into cellulose, we finally came to the paper production. Before the raw material enters the machine, the cellulose fibers undergo a preparation of the mass that has several stages of processing: the refining (maceration) of the fibers, done in disc refiners as shown in Figure 7.

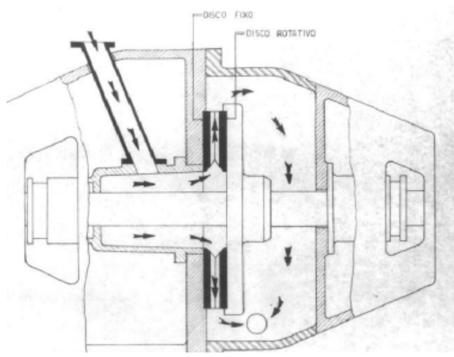

Figure 7. Double disc refiner scheme (Publio, 2012, p.19)

The purification of the mass, to remove foreign materials from the process is done soon after the refining step. The parameters of (pH, consistency and temperature) of the cellulose must be constantly monitored, since they are directly related to paper thickness and humidity.

The preparation of the mass is finished with the decrease of it's consistency, around 1% in the entrance of the machine, since the fibers are scattered on an endless surface, that moves throughout its width. The spreading of the mass is effected by the entrance box, which consists of a level box, equipped with a system of internal rollers, that aid in the mass homogeinization and a lower opening in the form of an adjustable lip that flows the mass in jet form almost horizontally on the moving surface as shown in Figure 8.

Figure 8. Picture of the paper-making table

Most of the water is drained through the surface, with the aid of suction strips installed in the lower part of the surface, the remainder is then removed by pressing rollers, followed by drying rollers, which are hollow and internally heated with steam. After drying, the paper is pressed onto calendering rollers, which give a superficial improvement, making the paper printing easier. The last step is paper winding, followed by rewinding. During the latter, the sheet is cut lengthwise, providing more narrow coils, according to the customers needs.

Kraft Process

In 1853, Hugh Burgess and Charles Watt discovered the wood pulping method that was originally patented in 1853. The first industrial unit based on this process started in 1866. In 1879 the German chemist Carl Dahl developed the Kraft process consisting of Chemical pulping of minced wood where it's possible to obtain cellulose pulp. The chemical wood transformation occurs from an alkaline agent based on sodium sulphide (Na_2S) and sodium hydroxide (NaOH) (Ferreira, 2013). This process minimizes the damages generated in the cellulose fiber. In this process, about 95% of the lignin is removed in the cooking. The first pulp production unit using the Kraft process came in 1885 at Munksjo, Sweden (Vakkilainen *et al*., 2000). A factory that uses the Kraft method of production consists of two fundamental parts. The first stage consists of the pulp production area and, in the second, the recovery and utilities where the objectives are:

- To treat and maximize the regeneration of chemical compounds originaded by the use of sodium sulfide (Na_2S) and sodium hydroxide (NaOH);
- Water supply, steam, compressed air for the equipment and all manufacturing plant, electric energy and effluent treatment.
- Together, these topics form a closed-loop process, where each stage of the process basically depends on each other and thus ensures continuous production.

Chemical Recoveries

Within the pulping process there's the reagents recovery used in the delignification of minced wood. For this to occur, the composition of three stages is essential (Ferreira, 2013). I. Evaporation of the black liquor obtained in the pulp washing after it's cooking, looking for raising of the solids concentration for later burning in the recovery boiler; II. Process executed in the boiler for reduction of sodium-containing compounds still present in the liquor, then the dissolution of the melted "SMELT" for transformation into green liquor and also; III. The mixture of CaO (calcium oxide) in the green liquor for the transformation of the sodium carbonate (Na_2CO_3) through decanter tanks regenerates the same until sodium hydroxide (NaOH) is obtained, which is the main product in the lignin separation from the wood.

Recovery Boiler

A chemical recovery boiler has several important functions for a pulp and paper industry. The burning of the liquor triggers a calorific content for the production of steam that will be used in the generation of energy and for the production of pulp and paper. But beyond the energy issue, the boiler will provide the important chemicals in the manufacture of the white liquor (NaOH). It's main function for chemical transformations is the production of sodium carbonate (Na_2CO_3) and sodium sulphide (Na_2S), due to the reduction of sodium sulfate (Na_2SO_4) (Ferreira, 2013). After burning the liquor inside the boiler, more specifically at the bottom of the furnace, components such as carbonate and sodium sulfide are melted in the form of "SMELT" and are directed to a dissolution tank. The composition obtained in this tank containing Na_2S and Na_2CO_3 is called green liquor. (Ferreira, 2013). Figure 9 shows a schematic representation of a modern recovery boiler, with it's major internal components, such as the boiler nose and the location of the air intakes and the liquor injectors.

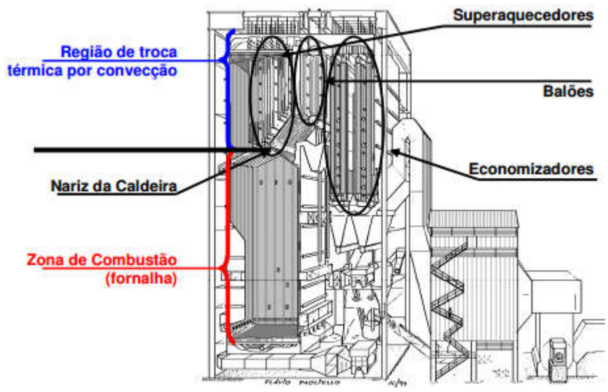

Figure 9. Schematic representation of a recovery boiler (Paolielio *et al*., 2012)

The structure that is called the boiler nose delimits the space between the furnace and the other components region. Figure 10 illustrates a recovery boiler model with it's location and air feed levels. Sodium salts are recovered by creating a reducing environment that occurs through the interaction of the primary air. The combustion of the liquor involves three steps: drying, releasing of volatile compounds (pyrolysis) and the combustion of the carbonate above the outer layer of the carbonized bed (Ferreira, 2013).

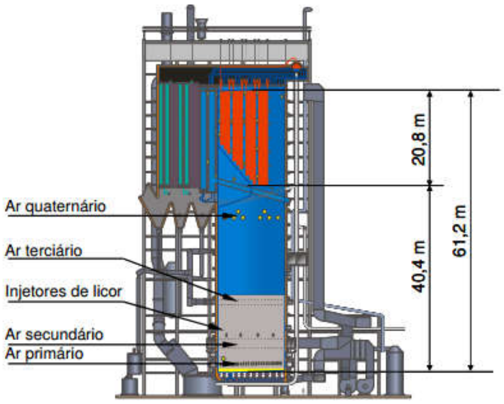

Figure 10. Location of air levels and black liquor feed in a recovery boiler (Ribeiro *et al*., 2007)

The diagrams for the liquor combustion stages in the bottom of the boiler is presented by Figure 11.

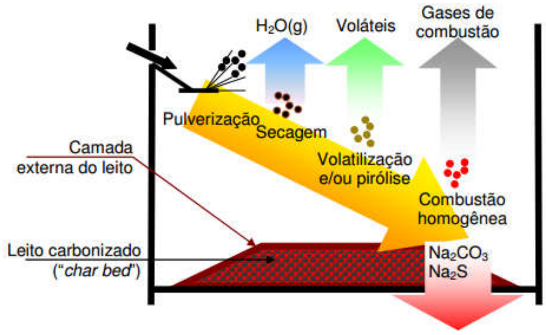

Figure 11. Sequence of steps involved in burning the black liquor inside the furnace of a recovery boiler (Ferreira, 2013).

Causticization

The causticization area of a pulp and paper industry is responsible for producing sodium hydroxide (NaOH) for the wood cooking. This alkali is constituted by the green liquor received by the recovery boiler, where virgin lime from the oxidation furnaces produced in the plant is mixed in this liquor and sent to settling tanks so that the regeneration of the chemical components is established and the formation of the caustic soda completed (Reis, 2014). The Goodwin curve is applied in advanced controls of causticizing plants, where it establishes the best condition to control the causticization efficiency with the total alkalis of the white liquor.

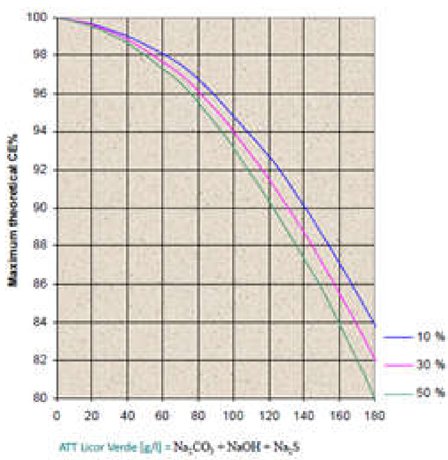

Figure 12. Representation of the Goodwin curve (Source: Metso, 2012)

Components for The Steam Reduction Study

The furnace is the boiler part where combustion takes place. It's shape and dimension must allow the fuel to burn completely; (Usually rectangular), where the walls are heating pipes, which are elements of the circuit for heat generation. The heat recovery sections include (Figure 13): superheater, water/steam pipe, evaporator and economizer.

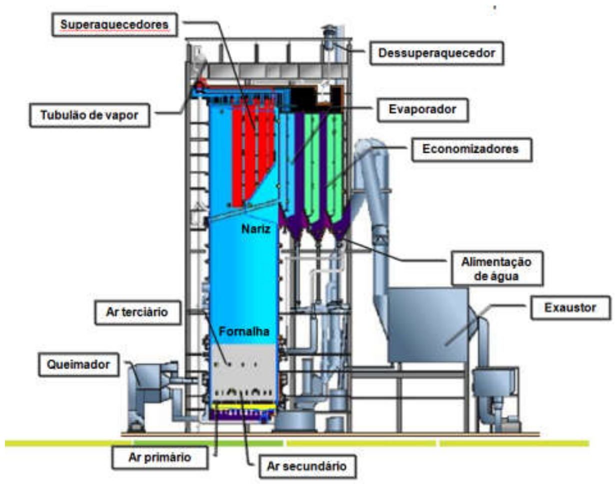

Figure 13. Recovery boiler illustration (Klabin S/A, 2007).

Consequences of The Black Liquor Burn

The burning fuel in the recovery boiler is the black liquor, with the combustion is generated waste, ash, soot and slag. They saturate the pipes, causing loss in the heat exchange, wich aggregates to the metal of the pipe and increases the probability of corrosion, reducing the useful life.

Soot Blowers

Soot blowers have the high pressure water vapor (21 kgf/cm²) as cleaning fluid to remove deposits of ash and slag from the surfaces of the superheater tubes, evaporators and economizers (Altafini, 2016). They consist of a steam pipe, a retractable hollow lance, a motor with reducer for the lance introduction drive. With this system the steam is forced into the boiler while removing the soot, ash and slag, thus keeping the tubes unblocked, allowing a better thermal exchange.

Use of Measuring Instruments In Control

Instruments will be used in this work to perform a continuous measurement of the process. The soot accumulation is the cause of incrustation in the boiler pipes, causing heat loss in the pipe, the steam blowing operation has the function of removing this incrustation, but as the system was carried out sequentially there were unnecessary expenses of tons of steam by day, which were eventually wasted (Altafini, 2016). With the use of instruments in the measurement of differential pressure and temperature in each part of the boiler that requires blowing, such as superheaters, evaporators and economizers, it was possible to implement an automatic control of the blowers that are activated according to the amount of encrustation in the tubes, measuring the differential pressure of the hot gases passing through the tubes and the temperature.

Figure 14. Differential Pressure Transmitter Installed

Automatic Control System Costs

The automatic control system costs consists of the purchase of instruments, installation and software, table 1 shows the investment figures.

Table 01. System costs table

	Cost in Reais (R$)	Amount	Total
Differential Pressure Transmitters	2.976,00	6	17.856,00
Temperature Transmitters	1.892,91	24	45.429,84
Software	550.000,00	1	550.000,00
Installation workforce	10.000,00	1	10.000,00
Total Cost in Reais (R$)			623.285,84

Reduction In Steam Consumption

This study was carried out due to the necessity of controlingf the blowers, enabling a reduction in the vapor consumption. As we did not have a control of how each part of the boiler was, consumption was high from 350 tons of steam per day, as shown in Figure 16.

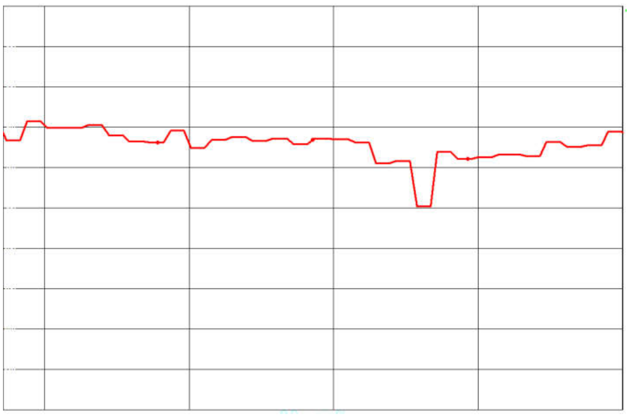

Figure 16. Amount of steam spent per sequence control

Due to the installation of the differential pressure and temperature transmitters in the tubes of the superheaters sections, evaporators and economizers, it was possible to perform an automatic control of the blower activation, so when the output pressure has a differential greater than 10 mmH2O than the inlet pressure the blower is activated to perform the cleaning by removing the soot, or when the temperature drops in the section, the operator identifies it by supervisory and activate the blowers in manual mode. With this installation the reduction was considerable, from 335 tons/day, to 245 tons/day, as shown in Figure 16. At a cost of about R$ 40.00 for the production of one ton of steam. Currently the cost reduction in the industry has been studied extensively, as has the return on investment using new technologies (Agostinho *et al*., 2017; Righez *et al*., 2016; Folster *et al*., 2016).

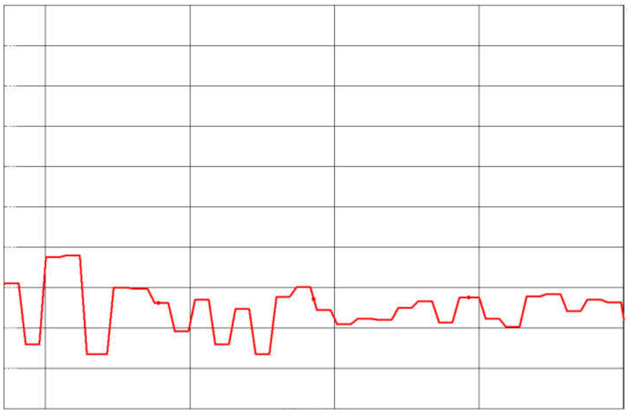

Figure 16. Amount of steam spent with automatic control

Table 2 shows the cost reduction achieved with the installation of the automatic blowing system.

Table 2. Daily steam consumption table

	Ton/day	Cost by ton in Reais (R$)	Total
Daily Consumption (before)	335	40,00	13.400,00
Daily Consumption (after)	245	40,00	9.800,00

We achieved an economy of R$ 3,600 a day, which results in the amount of R$ 1,314,000.00 in one year. We had an investment of R$ 623,285.84, and obtained back the amount invested in approximately 5 months and 20 days.

Final Considerations

In this research the process of cleaning the tubes in boilers was verified, proving the existence of possible improvements in industrial plants, through the installation of differential pressure transmitters and temperature in the superheater, evaporator, and economizer of the recovery boiler. Automation and instrumentation were used to maximize the efficiency and control of water pipes cleaning in recovery boilers, as well as a reduction in consumption, with which data and performance charts of the case study equipment were collected, presenting results. With the study it was possible to make feasible improvements in the project, performing the installation of differential transmitters of pressure and temperature. Data on the effectiveness of the measurement control in the process were obtained, observing the errors of triggering all unnecessary blowers, and thus effecting the improvement. Presenting the calculations of the reduction in steam consumption with the new system, together with a significant and valuable economy. The study had a great impact on the knowledge regarding instrumentation and the chemistry used in this project to solve a generally common problem in boilers, not only in the recovery, reducing the steam consumption and maximizing a good result.

REFERENCES

Agostinho FR, Rocca GAD, Ferreira FCS, Stefenon SF 2017. Estudo sobre a viabilidade financeira na atualização tecnológica de uma planta fabril: Utilização de motores elétricos de alta eficiência e iluminação LED. Revista

Espacios, 38(12): 5-17. Available in: http://www.revistaespacios.com/a17v38n12/17381205.html

Altafini CA 2016. Caldeiras**.** Available in: <http://www.fluidcontrols.com.br/site/upload/pdf/Apostilas_sobre_Caldeiras-Prof_Carlos_Albero_Altafini.pdf

Castro HF 2009. Papel e celulose: processos químicos industriais II. 4. ed. Escola de Engenharia de Lorena, São Paulo, 30 pp.

Eissmann JC, Stefenon SF, Arruda PA 2017. Gestão Estratégica como Ferramenta para a Governança Corporativa: Um Estudo de Caso. Revista Espacios, 38(16):22-36. Available in: http://www.revistaespacios.com/a17v38n16/a17v38n16p23.pdf

Ferreira DJO 2013. Modelagem de caldeira de recuperação química. Available in: <http://www.teses.usp.br/teses/disponiveis/3/3137/tde-26072013-122445/publico/Tese_FerreiraDJO_unprotected.pdf>

Folster LP, Madruga GG, Ferreira FCS, Stefenon SF 2016. Estudo Sobre a Eficiência no Sistema de Iluminação em Salas de Aula (UNIPLAC). Revista Espacios, 37(21):24-35. Available in: http://www.revistaespacios.com/a16v37n21/16372124.html

Klock U, Muñiz GIB, Hernandez JA 2005. Química da madeira. Doctoral Thesis, Universidade Federal do Paraná, Curitiba, Brasil.

Mocelin EZ 2005. Antraquinona e surfactante para otimização do processo kraft com pinus spp. Masters Dissertation, Universidade Federal do Paraná, Curitiba, Brasil.

Oliveira RP, Stefenon SF, Branco NW, Oliveira JR, Rohloff RC 2017. Lean Manufacturing em Associação à Automação Industrial: Estudo de Caso Aplicado à Indústria Moveleira. 38(17):24-40. Available in: http://www.revistaespacios.com/a17v38n17/a17v38n17p24.pdf

Reis HM 2014. Análise exergética e ambiental do processo de obtenção do licor de cozimento kraft para extração de celulose. In: XX Congresso de Engenharia Química, Universidade Federal de Itajubá, Instituto de Engenharia Mecânica, 20:1-8

Righez FO, Rocca GAD, Arruda PA, Stefenon, SF 2016. Análise de Viabilidade Técnica e Financeira de um Site de Internet Banda Larga Fixa. GEINTEC-Gestão, Inovação e Tecnologias, 6(4):3537-3552. doi:10.7198/geintec.v6i4.984

Stefenon SF, Oliveira JR, Coelho AS, Meyer LH 2017. Diagnostic of Insulators of Conventional Grid Through LabVIEW Analysis of FFT Signal Generated from Ultrasound Detector. IEEE Latin America Transactions, 15(5):884-889. doi: 10.1109/TLA.2017.7910202

Vakkilainen EK, Gullichsen J, Paulapuro H 2000. Kraft recovery boiler. Tappi Press.

****