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Quality improvement of energy management: an analysis of industries in a developing country

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ABSTRACT

Energy management is a critical question for the progress in developing countries. In fact, it is one of the most important foundations of sustainable development. Optimizing the use of energy resources is an issue with notable multiplier effects on the social evolution of the people of these regions. Similarly, the civil construction industry is also relevant, since it represents a strong economic and social contribution for these countries. It is important to remark that the demands of the construction material industry in combustible consumption for their productions, frequently with low rate efficiency, require a systematic management activity able to detect improvement alternatives, based on process approaches to contribute to the energy efficiency and the quality of the final production. This paper proposes a set of procedures to implement technological and organizational improvements of the combustible consumption practice in brick production plants in the construction material industry in a developing country (Cuba). Quality improvement opportunities are detected, together with the energetic characterization of the process. Some well-defined parameters and indicators have evidenced the improvement potentialities and its execution. The placement of domes in the furnace defines a new zone of quality control with losses from 0.5 - 1.5%, that at the beginning of the research were 2.4 - 4.5%. This enabled to plan a loss level rate at least 1.6% lower and a variability two times lower. Besides it is achieved a consumption rate average of 0.2739 to 0.2387 liters per brick in the covered furnace, saving 11,000 liters of fuel in the semester. The generalization of the procedure in the entity producing roof tiles and clay pipes in Sancti-Spíritus municipality (Cuba) showed a significant contribution since the reductions in the fuel consumption rate were greater than the achieved in the brick productions. As these industrial processes are similar to those in many other countries, this case study shows some analyses, practical applications and results that can be used abroad.

KEYWORDS: Energy management improvement; construction industry; developing countries; product quality.

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Mejora en la calidad de la administración de energía: un análisis de las industrias en un país en desarrollo

RESUMEN

La administración de energía es una cuestión fundamental para el progreso de los países en desarrollo. De hecho, es uno de los pilares más importantes del desarrollo sostenible. La optimización del uso de los recursos energéticos es un tema con notables efectos multiplicadores en la evolución social de los habitantes de cada región. Asimismo, la industria de la construcción civil también es relevante, ya que representa un fuerte aporte económico y social para cada país. Es importante resaltar que las demandas de la industria de materiales de construcción en el consumo de combustibles para sus producciones, frecuentemente con bajo índice de eficiencia, requieren una actividad de gestión sistemática capaz de detectar alternativas de mejora, basadas en enfoques de proceso para contribuir a la eficiencia energética y la calidad de la producción final. Este trabajo propone un conjunto de procedimientos para implementar mejoras tecnológicas y organizacionales de la práctica de consumo de combustibles en plantas de producción de ladrillos en la industria de materiales de construcción en un país en desarrollo (Cuba). Se detectan oportunidades de mejora de la calidad, junto con la caracterización energética del proceso. Algunos parámetros e indicadores bien definidos han evidenciado las potencialidades de mejora y su ejecución. La colocación de domos en el horno define una nueva zona de control de calidad con pérdidas de 0.5 - 1.5%, que al inicio de la investigación eran 2.4 - 4.5%. Esto permitió planificar una tasa de nivel de pérdidas al menos un 1,6% menor y una variabilidad dos veces menor. Además, se logra una tasa de consumo promedio de 0.2739 a 0.2387 litros por ladrillo en el horno cubierto, ahorrando 11.000 litros de combustible en el semestre. La generalización del procedimiento en la entidad productora de tejas y cañerías de arcilla del municipio Sancti-Spíritus (Cuba) mostró un aporte significativo ya que las reducciones en la tasa de consumo de combustible fueron mayores a las logradas en las producciones de ladrillos. Como estos procesos industriales son similares a los de muchos otros países, este estudio de caso muestra algunos análisis, aplicaciones prácticas y resultados que se pueden utilizar en el extranjero.

PALABRAS CLAVE: Mejora de la gestión energética; industria de construcción; países en desarrollo; calidad del producto.

Introduction

Nowadays, an organized production process has vital importance, even more with the world economic crisis and the unavoidable exhaustion of the conventional energy sources. The rational use of the energetic resources depends on the consciousness that people might

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have of the unplanned use in the consumption societies and the environmental pollution that generates an over exploitation of the fossil combustibles (Fernandez et al, 2014; Aguilera, 2020). Referring to this, Nueno (1996) states that management is looking for models that contemplate the integration among people, technology and economic reality. In this context, the quality concept that it is necessary to generate an acceptable product or to work with rejection rates of less than a certain percentage in a production line, is not enough anymore. It is required to consider the client perspective (Abu-Jarour, 2016), and the losses that each product brings to the society. In fact, productive organizations have long been concerned with energy management (Selmer, 1993; Fielden and Jacques, 1997).

In Cuba, the improvement of the productive organizations management is of great importance (Del Castillo Sánchez, 2016) for the continuity of the present growing process. It is a way to place enterprises in indispensable conditions of effective use of resources, guarantee their economic situation, put into practice salary and stimulation systems, implement new tributaries and financial mechanisms, as well as introduce the most updated approaches of the international practice.

Mahto and Kumar (2008) refer that the identification of the relative root causes to the quality problems and the productivity are crictical in the manufacture process execution. In the case of the construction material industry in Cuba, and specifically in Sancti-Spiritus, the root cases are related to its aged technology.

The construction material enterprise in the case study for this research produces more than 60% of the total clay wall elements of the province: mud bricks (hollowed and solid), Creole and French tiles, floor tiles and lattices. It also produces concrete materials as floor tiles and blocks, which represents an annual cipher of 6,200,000 units, equivalent to one thousand houses annually. However, to reach a primary objective of the red ceramic construction enterprises (to achieve the technological leap), they need to work with processes with high energy efficiency (Reyes, 2012). It should be noted that the priority in the search for energy efficiency is in residential buildings or commercial buildings (Guarin, Morano and Sica, 2019; Ylmén, Penaloza and Mjornell, 2019). It must be considered that these enterprises work in a business context characterized by market fluctuations and difficulties in supplying its main inputs and raw materials. These problems are analyzed by Nordelo (2006) and Fernández et al. (2014). These authors consider the importance of these situations in the competitiveness of the Cuban companies, from the perspective of energy efficiency.

Based on the above arguments, the activity of management and assurance of the managerial function gives the enterprise the ability to satisfy, in an efficient way, the energy needs of the productive process, as an alternative to face the problems of high production costs. These costs are associated to the following: high energy consumption of the equipments (fuel oil and fuel wood); poor quality of ceramic productions; customer complaints for poor quality of production; and the emanation of toxic gases into the atmosphere generated by the furnaces.

This paper proposes to implement technological and organizational improvements in fuel consumption practices in brick production industries to facilitate management activity related to energy efficiency and the quality of the finished product. Focusing on the energy issue, which is a critical business problem, it is also a favorable approach to achieve improvements in other identified problems.

This article addresses two key elements for the progress of developing countries: Initially, transformations in the improvement of the productive processes of companies that operate in the area of civil construction, commonly important industrial sector in any economy. Then, energy management is considered, a crucial component for these countries since it is one of the most important foundations of sustainable development. Several examples in the literature prove this statement (Alcorta et al., 2014; Cantore, 2017). This study intends to optimize the use of energy resources, a problem with distinguished multiplier effects on the social, economic and cultural progress of the people that live in these countries.

1. Theoretical background

In this section some concepts that support this article are presented.

1.1. Quality and process improvement

The decision to face the process of improvement requires an analysis of the circumstances in which it will be developed. Typology of the process, general charactheristics of the studied organization and the objective that is pursued are critical elements in this analysis (Gómez, 2007; Abu-Jarour, 2016; Montgomery et al., 2016).

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The conception of quality improvement is a decisive component in all business activities and as the operations of industrial processes are presented, increasingly subjected to the emerging factors of the environment, new approaches are required for the quality concepts. Quality needs constant adjustments to "best production practices", with other forms of comparison and regulation that may differ from those used up to now (Juran and Gryna, 2001, Domínguez and Barroso-Castro, 2017; Leffakis, 2016).

Juran and Gryna (2001) argue on how quality problems are underestimated and what they represent in long-term financial returns. So, the purpose should be oriented to set the tools to achieve the timely detection of the causes that provoke such alterations and to obtain the expected benefits.

As shown by Nofal et al. (2016), the management of quality improvement is adjusted to several elements like technology level and background of organizations, markets, human resources and their cultures. In this sense, the perspective of these authors is how to use the critical factors of the Total Quality Management (TQM) to promote the transformational orientation, in order to create a culture of sustainable efficiency and obtain commercial and competitive benefits in a continuous way. In the Cuban context, experiences in industrial processes have been decisive in the proposed quality practices, to reconcile technological and organizational perspectives with a favorable effect on stability, from the reduction of variability in the process (Gómez et al., 2008).

1.2. Total Quality Management

Total Quality Management (TQM) is a series of relevant practices (Vasantharayalu and Surajit, 2016) which structures a management approach to long-term success through customer satisfaction. The main idea of TQM is to include all members of an organization in participative efforts to improve processes, products, services, and the culture in which the organization works (Aquilani et al, 2017).

Vasantharayalu and Surajit (2016) state that the American Society for Quality recognizes as fundamental elements of TQM: politics, planning and administration; product design; material supply; Production Quality Control; customer relationship; preventive and corrective actions and selection, training and motivation of employees. The identification, contribution and new ways of researching the critical success factors of TQM is a subject under study, which requires the adoption of a broader view regarding the role of the quality

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process as a support to the commitment of the enterprise in the activities with the client (Aquilani et al., 2017; Tenner and DeToro, 2007).

Many authors, like Paladini (2011) as well as Juran and Gryna (2001), associate the use of TQM practices with the best operational performance, with an impact on technological growth.

1.3. Quantitative methods for improvement

Mizuno (2005) proposes the use of qualitative and quantitative methods for identifying improvement opportunities (mainly the last ones) to transform diffuse and unstructured knowledge into structured knowledge. While Banks (2004) points out that the introduction to the quality function in modern manufacturing and service organizations generates statistical information, which is analyzed and discussed in a specific way, and with the resources to manage quality control (Goetsch and Davis, 2016; Marshall, 2006).

The quality problems in industrials processes are often the result of uncontrolled or excessive variability. In studying and solving these problems a crucial role is played by statistical tools and other analytical and quantitative methods.

The application of quantitative methods for improvement must be carried out in a management-based structure to guarantee the success (Montgomery et al., 2016; Carvalho et al., 2017).

1.4. Innovation and energy efficiency in developing countries

The empirical study of Honarpour et al. (2017) establishes that the innovation process is more impacted by TQM than the product itself. It is not surprising considering the fact that new elements introduced into the organization (e.g. material input, task specifications, work and information flow, and equipment) generate innovative products or provide better services. TQM practices, on the other hand, are related to better supply management (raw materials), people management (task specifications), and information and data analysis (working mechanisms and information flow). Similarly, by acquiring, disseminating and applying new knowledge of competitors, suppliers and customers, the generation of ideas from research teams can be increased, leading to new technical specifications and better product functionality (Paladini, 2016).

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Regarding the case study of this research in the manufacture of ceramics for construction, Salas and Oteiza (2008) report on the approach of Latin America Economic Commission that it is important to perform regulatory and technological adjustments aimed at improving the development and application of materials, using local and regional techniques. All these situations should be expressed in formalized processes that show potential for further development, based on process analysis and statistical data. The information generated becomes a decision-making tool for the operation of key variables that ensures improvements in indicators of productive and organizational performance.

The technological progress of the red ceramic enterprises in Cuba, as Reyes (2012) states, needs for few but qualified personnel. It also needs lineal processes, intensive in capital and mostly automated.

On this issue, Reyes (2012) also argues that substantial improvement in energy efficiency comes from processes with some characteristics. It means processes with substantial improvement in energy efficiency through: the use of hot gases from the furnaces for the dryer; cogeneration installations with recovery of energy from exhaust gases; hot air from refrigeration as a source of heat for dryers, clay preparation; computer control of drying and cooking; the replacement of electrical surpluses to the national electric system and the use of natural gas.

From the energetic point of view, the improvements and innovations increase the performance of the different operations in terms of: (1) Reduction of the heat of reaction and of drying; (2) Decrease in temperature levels used; (3) Decrease in the time of operations; (4) Reduction of heat and material losses (breaks); (5) Improvement of the quality of final products; and (6) Use of residual heat.

All the above items are of vital importance for the Cuban economy and constitute a technological advancement that poses challenges to the universities and investigation centers (Reyes, 2012). The country has small and medium-sized plants according to installed resources, which also differ in terms of product quality with high levels of inefficiency due to heat losses through the walls and chimneys. These industries consume large amounts of fuel to heat the structure in each material load as well as the amount of heat that is totally lost during cooling (Reyes, 2012). However, it is a productive sector with material responsibility in the annual housing plan of the territories and its observance is relevant in the global environment, due to the world population growth that demands the production of more than 600 million cubic meters of construction materials (Salas and Oteiza, 2008).

It is also relevant for this research to take into account the complexity of administrative change that implies the implementation of continuous improvement, from the perspective provided by McLean et al. (2017). It includes failure factors of the TQM which are described in eight issues: motives and expectations, culture and environment, management leadership, implementation approach, training, project management, employee performance levels, and feedback and results.

It should be noted that the search for methods that increase energetic efficiency is permanent in developing countries (for instance, see Berg, 2015; Goldemberg et al., 1994).

This effort can be found in studies that analyze the question in countries as Saudi Arabia (Matar et al., 2017; Matar, 2016); Canada (Cai et al., 2008), Nepal (Islar et al., 2017), Brazil (Mesquita and Kós, 2017), Thailand (Foran et al., 2010), Malaysia (Hosseini and Wahid, 2014), Taiwan (Ning et al., 2013), Argentina (Filippín et al., 2017), Peru (Lillo at al., 2015), Mozambique (Jones et al., 2016), Portugal (Capelo et al., 2018) or Mexico (Martínez-Montejo and Sheinbaum-Pardo, 2016). . Different situations have been considered in the studies about energetic politics, like prices (Matar and Anwer, 2017) or sustainable development strategies, a very important dimension of this kind of analysis (Owedraogo, 2017). In addition, success factors for energy management are always considered in different situations (Sivill et. al., 2013). The role of government has been also discussed (Zhang and Huang, 2017).

Even developed countries or in more advanced stages of development prioritize processes to increase the efficiency of the use of different energy sources, prioritizing policies for this purpose (Zierler et al., 2017; Bhati et al., 2017).

Civil construction has also been highlighted in different studies, especially when one considers environmental management resources (Rodriguez et al., 2011; Do and Cetin, 2019), energy performance (Poddar et al., 2017) or even economic performance of accessories (Cetiner and Metin, 2017) or reuse of wastes (Yellishetty, 2008). Characteristics of buildings are also considered for purposes of increasing energy efficiency (Mikola, Simson and Kurnistski, 2019; Marcello, Pilloni and Giusto, 2019).

This same concern appears in various situations that involve energy management, in the most different areas (Balali et al., 2017). The use of natural aspects also is considered (Almeida et al., 2017).

In this way, the present study focuses on a critical issue, especially for developing countries, and in this context, the energetic efficiency of an important productive sector in these countries is analyzed.

2. Materials and methods

This paper presents an applied scientific research, because its results are used later in the solution of problems present in the day-to-day of organizations (Turrioni and Melo, 2012). In fact, this research is inserted in the context of scientific knowledge and without commercial purposes as a main objective (Appolinário, 2006).

Based on the objective, a descriptive research is considered for the development of data acquisition techniques in the studied organizations (Turrioni and Melo, 2012; Gil, 2016) refers that descriptive research is the most requested by organizations such as educational institutions, commercial companies, political parties, etc.

The methodology adopted here is the case study since this paper evaluates a specific situation in a business environment (Cauchick, 2007) and addresses a deep diagnosis of an object, so as to allow its wide and detailed knowledge (Berto and Nakano, 2000).

For the development of the work, the analysis methodology takes into account that the increase in fuel costs is one of the factors leading to innovative technologies in the ceramic industry. Most of the development focuses on improving the energy efficiency of furnaces by decreasing the energy consumption of the production processes (Agrafiotis and Tsoutsos, 2001).

The actions to overcome problems of the process constitute the basis for planning new areas of control, conception of the Quality Trilogy (Quality Planning; Quality Control and Quality Improvement – as defined by Juran and Gryna, 2001), considered in the development of the procedure in Figure 1. It has been evaluated the energy consumption and also the performance of the production process, considering the behavior of the technological variables and the quality assessment of the finished product.

The development of this study involves four phases: (1) energy characterization; (2) process evaluation, with the definition of improvements; (3) execution of improvements and (4) definition of expected results.

The procedure begins with the energy characterization, by the necessity test of the Technology of the Total Efficient Management of Energy (TGTEE, Spanish acronym) by Nordelo (2006). The second phase (evaluation) uses the Beltrán's approach (Beltrán et al, 2001). There are four steps here: (1) Identification and sequencing; (2) description; (3) monitoring and control, and (4) improvement. Phase 3 is oriented to the improvements in energy efficiency of greater incidence in the technical requirements of quality in the finished product.

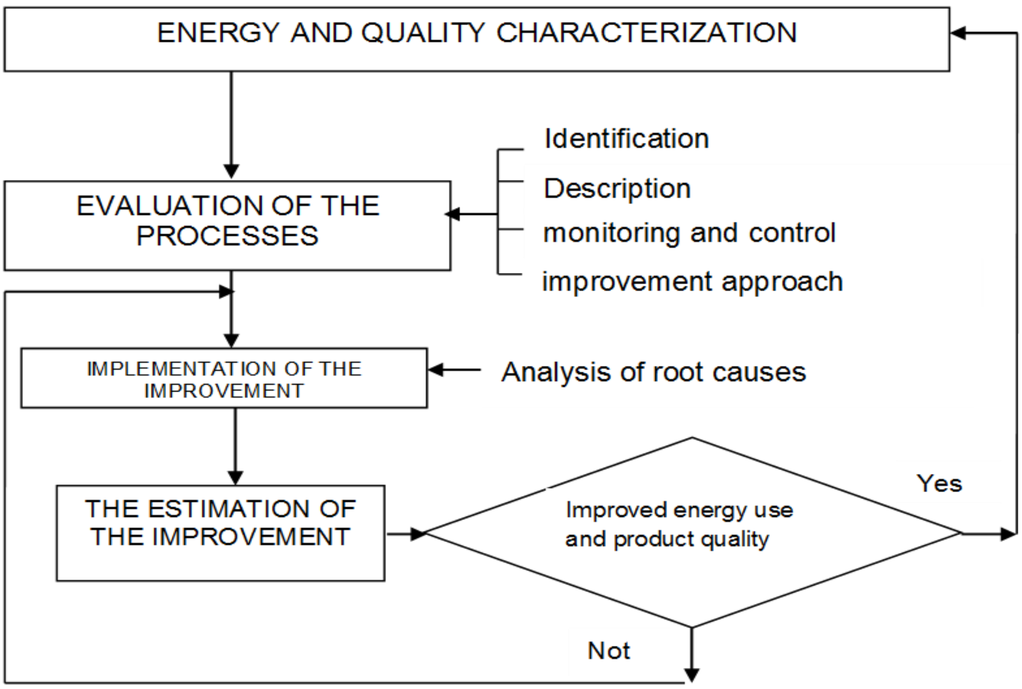

Fig. 1 Procedures to implement technological and organizational improvements in the fuel oil consumption practices in brick production industries

Phase 4 is established in two moments of the process:

(i) If the objectives are not fulfilled, the management defines the corrective actions to ensure conformity of the outputs. The actions prioritize control variables related to energy management and the efficient use of the energy that affect the fulfillment of technical quality requirements of the finished product.

(ii) If the planned results are achieved, opportunities for improvement are identified by their impact on global improvement, to increase the capacity that efficiently meets the energy needs and satisfies technical quality requirements of the finished product.

In phase 3 the implementation of the improvement is considered. The improvements are classified as structural and operational. Structural improvements refer to fundamental conception of the process (redefinition of recipient, expectations, results of the process, sequence of activities). Creative tools and techniques for quality management; customer surveys and reengineering approach are useful here. Operational improvements are basically related to changes in capacity and efficiency.

The estimation of the improvement (phase 4) is analyzed using indicators of energy efficiency and process effectiveness. These indicators evaluate the impact of both on the technical quality requirements of the finished product. The non-conformity in the evaluation requires a return to the execution, and so, the characterization is restarted, in order to plan improvements in a new control zone. The implementation of the procedure involves directing efforts to:

- **Management leadership:** It is necessary for the enterprise staff to perceive that the management knows and evaluates issues related to process supervision. Personnel training and the allocation of human and material resources to develop energy management activities are considered here.
- **Employee participation:** The actions here try to create process management teams and effective recognition for the tasks developed by employees.
- **Training:** It includes equipment operation and also tools and techniques for improvement.

3. Practical support: analysis of the study case

To structure the practical support of this study, three stages have been considered: (1) Analysis of the structure of processes, (2) Characteristics of the realization of the product and (3) Study of causes of the recognized problems.

Stage 1:

For the identification of the structure of processes of the business management in the construction material enterprise in Sancti Spíritus (Figure 2), the relationship with energy

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management was established as a basic criterion in the categorization of processes. Based on this criterion, in order to guarantee the availability of resources and the necessary information in the implementation of regulatory actions, to fulfill the planned objectives and the continuous improvement, three dimensions have been considered: strategic, tactical and operational.

<table>
<tr><td rowspan="3">CLIENT</td><td>Strategic Management
I. Management responsibilities
II. Analysis and improvement.</td><td rowspan="3">CLIENT</td></tr>
<tr><td>Operational Management
III. Realization of the products
IV. Analysis of efficiency indicators.</td></tr>
<tr><td>Tactical Management
V. Purchasing Management
VI. Human resources management.
VII. Commercial Management</td></tr>
</table>

Fig. 2 Classification of the processes for an approach centered on energy management

These dimensions include:

(A) Strategic Actions: Those linked to the scope of responsibilities of the management, related to general planning and others plans linked to key or strategic factors of business management.

(B) Operational Actions: Those related to product realization operations. These actions intervene directly in the efficient use of energy and determine the technical quality requirements of the finished product.

(C) Tactic Actions: Refer to support of operational processes, related to resources linked to the quality of the finished product.

The concepts of Strategic Management, Tactical Management and Operative Management follow the positions of authors in the Quality Management area (Carvalho et al., 2017; Goetsch and Davis, 2016; Marshall, 2006). In order to provide the managerial capacity to efficiently satisfying the energy needs of the production process, the manufacturing process is described.

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Stage 2:

During the product realization process, more than 70% of the high energy consumption equipment is dispended.

The sub-process of burning requires much time (approximately 26 days), due to the high dependence of the relative humidity conditions, and the season of the year, what influence the duration of drying. It consumes the total of energy suppliers and the technical specifications should be closely observed since it causes the greatest amount of losses due to poor quality. A bad operation can imply the loss of all the products.

The typology for the brick production and the requisites are defined in branch norms (NC 360: 2005) that are achieved through process norms (figure 3). Brick production has been a permanent reason for concern and attention in different countries, due to the characteristics of the production process (Luby et al, 2015; Gomes and Hossain, 2003).

In the burning process of the ceramic products the cooking is done, with high temperature level (higher than 850ºC). Homogeneity is needed in all the furnace equipment to avoid heat, fume leaking to the atmosphere and guarantee the main quality parameters of the finished production.

In the evaluation of the preheating and cooking stages, the efficiency and effectiveness indicators were considered: percentage of absorption, with incidence in the resistance to the rupture of the finished product (it defines the use); percentage of defective units, that affects the cost of production; and indices of consumption of fuel oil and fuel wood that determine the energy efficiency.

These indicators of energy efficiency and finished product quality are essential in making strategic decisions that have improvements in the customer value chain, as well as the incorporation of new knowledge and skills in the management team (Domínguez and Barroso-Castro, 2017). According to Paladini (2011), the goal of analyzing and evaluating processes effectively is a fundamental element of quality management.

Stage 3:

For the study of causes, three years of activity of the enterprise were analyzed, in which 68.5% of the combustible used was fuel oil and 19.9%, fuel wood.

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<table>
<tr><td colspan="3">ENTERPRISE:
Construction Material production</td><td colspan="2">Brick Production Process</td></tr>
<tr><td colspan="3">Process: Brick production Process</td><td colspan="2">Owner: Central Administrator</td></tr>
<tr><td colspan="4">Mission: To perform brick production achieving the quality parameters established for the satisfaction of customers.</td><td>Documentation: FD7.</td></tr>
<tr><td>SCOPE</td><td colspan="4">Starts: When there is raw material, technology and qualified personnel.
Includes: Preparation of the raw material forming the product, drying, baking and selection.</td></tr>
<tr><td colspan="5">Inputs: Orders from customers. Raw materials and energy carriers.
Suppliers: Logistics.</td></tr>
<tr><td colspan="5">Departures: Signed contracts, finished production and realizes sales.
Clients: External customers.</td></tr>
<tr><td colspan="3">Inspections: Weekly inspection of quality and evaluation of consumption.</td><td colspan="2">Records: Control by qualities.</td></tr>
<tr><td colspan="3">CONTROL VARIABLES
• Dosing
• Times of the stages
• Optimum temperatures
• Energy intensity.</td><td colspan="2">INDICATORS:
• % of defective units
• % absorption
• Consumption index</td></tr>
</table>

Fig. 3: File of the brick production process

Based on the result obtained from the relationship between production and fuel oil consumption (Figure 4), the emphasis was on reducing production losses, on meeting the technical quality requirements of production and on observing the conditions for efficient energy operation. The production of Trinidad municipality was selected due to the analysis of its representativeness (approximately 50% of the hollowed bricks), in addition to the characteristics of the energy scheme, which is aggravated by technological obsolescence, and clay characteristics of the deposits (high content of iron oxides and silicates), which imply a higher melting point. The behavior of losses in the brick production plants of the municipality of Trinidad is shown in figure 5.

The production losses in process are above average (5%). Santa Bárbara production plant, in April (2017), doubles the losses compared to the average. This situation implied a loss of income in the enterprise of US$ 3,743.64 in a year, what represents about 118,469 thousands of units (bricks).

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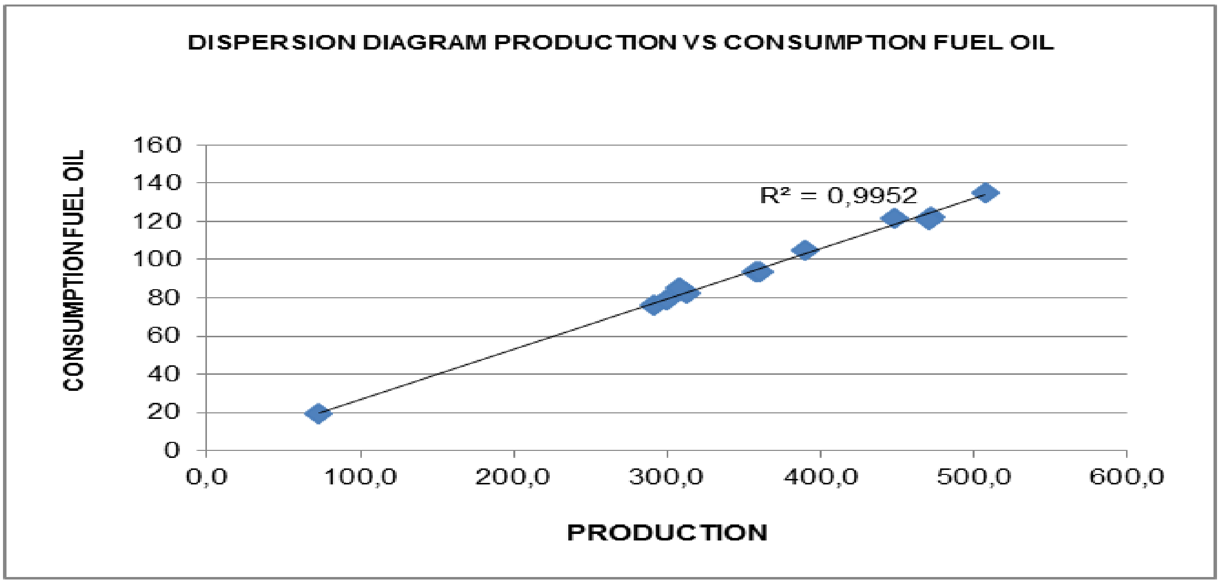

Fig. 4 Relation between production and fuel oil consumption (a year analysis)

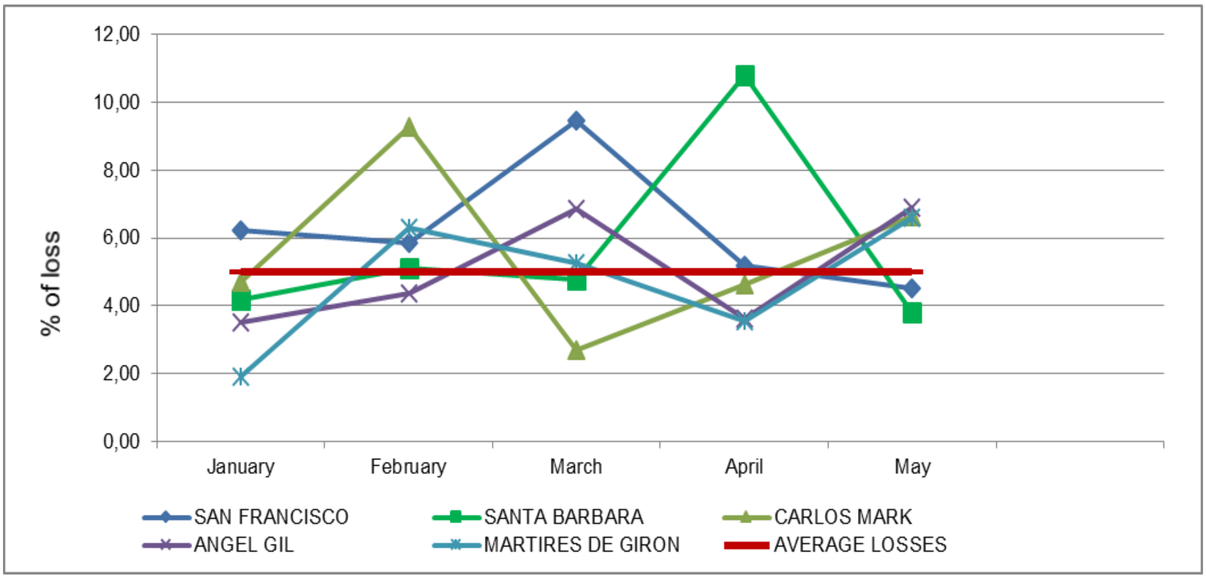

Fig. 5 Loss rate in Trinidad brick production plants

4. Diagnosis and project of improvement for the study case

The Pareto analysis obtained from the technical reports of the nonconformities allowed to identify that in the process losses, low resistance caused 61% of the nonconformities in the finished production (>16% of absorption).

Other nonconformities are classified as cracks, out of dimensions and as contraction which are achieved in the drying sub-process (inefficiency in the productive process).

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In the burning, where the causes of higher incidence of nonconformities are concentrated (see Table 1), almost all the high energy consumption equipment are used since, as stated above, it is a very extensive process (approximately 26 days). This demonstrates the need for an improvement process approach in burning.

NONCONFORMITY	CAUSES
• Products with low resistance (more than 16% absorption)	• Difficulties and inefficiency in burning
• Products out of dimension	• Difficulties in molding and shrinkage during drying.
• Products with cracks	• Poor preparation of mixtures

Table 1. Nonconformities and their causes. Source: Technical reports.

In preheating, the bricks are baked in different percentages of moisture and fuel wood has irregularities in drying, which involves additional time and energy costs to bring the total mass of the furnace to the optimum temperature. While cooking, burners are open to the atmosphere, which have high temperature variability. Their heat dissipates to the atmosphere in the superior area, which implies the increase of temperature in the inferior area in a value greater than 900°C. The fusion of the material placed often occurs. The entire situation requires attention and monitoring, to detect opportunities for improvement in the efficient use of energy, and in the consumption practices for the technological process. For this purpose, the causes associated with the insufficiencies in the flaring (grouped by categories) were classified (Figure 6).

To achieve the quality parameters of the finished product, the analysis of nonconformities has been structured. The conclusions are reflected on brainstorm process and they are weighted by the Delphi Method (Oliveira et al., 2016). The consensus is evaluated by the Kendall coefficient (W = 0.857).

The following priorities were obtained:

(1) Required temperature levels are not achieved in the upper half of the furnace.

(2) There are lack of air-tightness and leakage of heat into the atmosphere.

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(3) It is necessary to identify personnel who decide on energy efficiency, and to train in a specialized way the management and personnel involved in the production, transformation or use of energy.

(4) The brick closed position in the furnace.

(5) There is not heat circulation.

(6) The frames of burners were stuck (archery of the ovens jammed).

(7) There were leaks in the burning systems.

(8) The drying of wood for preheating was insufficient.

(9) The quality of fuel oil was low.

(10) The temperature control was inaccurate.

The analysis of the indicators of the first semester in this study (year I) in the "Mártires de Girón" production plant from Trinidad bricks production industry (deposit with high content of iron oxide and silicates) evidences the criticality of the process (utilization of Creole burners and centralized ventilation systems). Figure 7 shows the case of water absorption. The non-homogeneity of the burner temperature affects the non-compliance of the resistance parameters of the ceramic (not transformed). In addition, the inefficient combustion implies insufficient heating of the furnace and also generates great amount of smoke to the atmosphere.

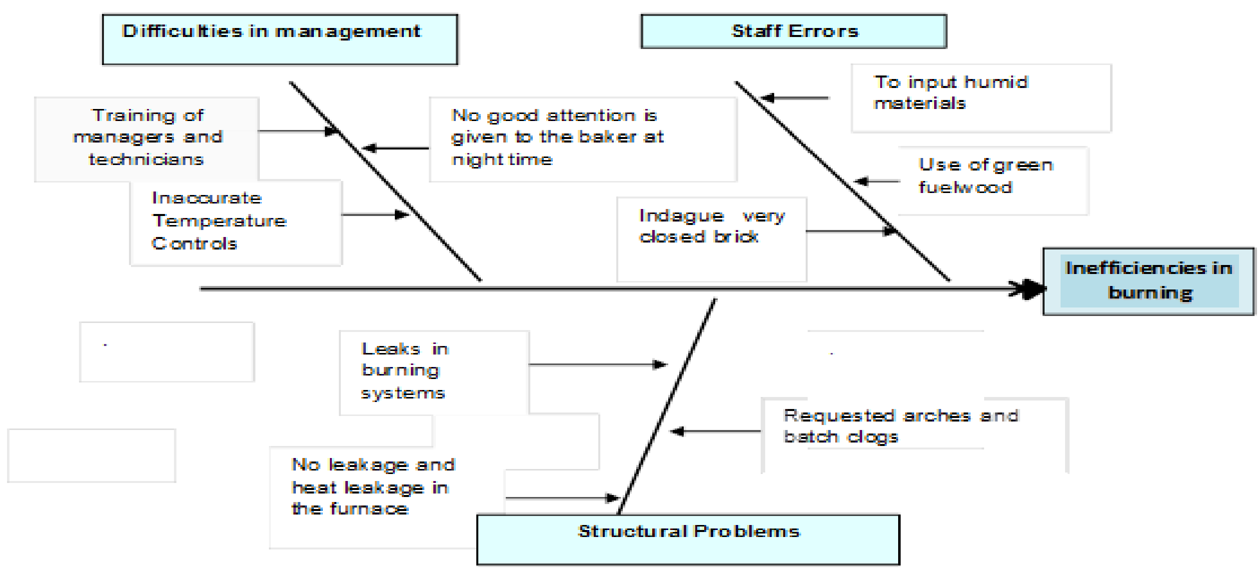

Fig. 6 Possible causes that influence on the burning inefficiency

This behavior is characteristic of the Trinidad Municipality (the same raw material), and constitutes the main cause of the customer complaints, related to the nonconformity in the quality requirements of the finished product.

4.1. Analysis of improvements for the study case

The situation analyzed is recurrent for years in the enterprise. However, due to the lack of a process approach, the magnitude of the problem had not been recognized. Figure 8 represents the scheme to follow in implementing the improvements. From the main cause categories (Figure 6), the structural and functional stages for improvements are established for improvement opportunities, namely, the structural and the functional stages.

- Structural stage: Organizational and personnel phases are established, involving actions related to improvements in supply management, requirements, flow of activities and training of personnel.
- Functional stage: Improvements are made on phases of capacity and control and are linked to actions of changes in the process.

Once the actions are implemented (date / deadlines / participants / responsible), the process indicators are evaluated as a contribution to the organization and planning of the work. Once favorable results are reached, new opportunities are identified. If an unfavorable result is observed, the phases and actions executed are reconsidered.

The constructive technology of the furnaces is similar in all the production plants of the province. Burners are open in their superior parts, with great heat blasting. It is necessary to homogenize the temperature, in particular by the valued characteristics, in the industries of the municipality of Trinidad, which does not reach the planned results. The actions in this respect, according to the specialized literature (Reyes, 2012), are oriented towards technologies for the construction of the furnaces, which includes the artisan ones, closed with a hermetic roof, dome-typed, to make better use of heat, with closed gas circulation, better distribution of the internal temperature and minimum heat loss by emanation into the atmosphere.

With these elements and as shown in Table 2, the improvement for Trinidad´s "Mártires de Girón" production plant was designed.

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ENTERPRISE : CONSTRUCTION MATERIAL PRODUCTION	BRICK PRODUCTION PROCESS Mártires de Girón de Trinidad
INDICATOR SHEET INDICATOR: % Absorption.	REFERENCE:FD7
PLANNED OUTPUT	≤16%
CALCULATION FORM: [(Wet weight - dry weight) / dry weight]* 100	
INDICATOR: Consumption index	
PLANNED OUTPUT	4.1 Brick * Liter of *Fuel oil*
CALCULATION FORM: Number of units / Energy carrier units SOURCES OF INFORMATION: Record laboratory samples	
FOLLOW-UP AND PRESENTATION: Samples of production 1st semester year I	

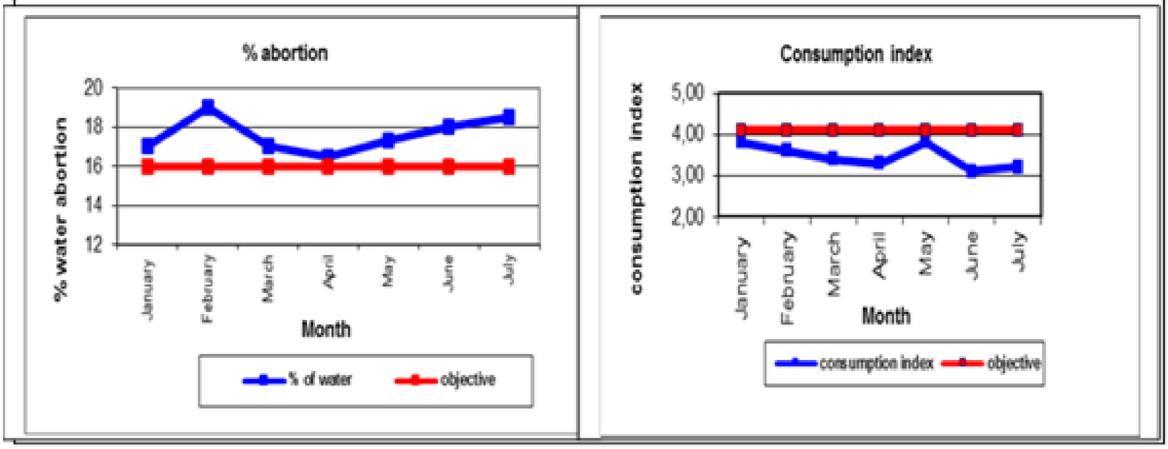

Fig. 7 Indicators file: percentage of water abortion- consumption index

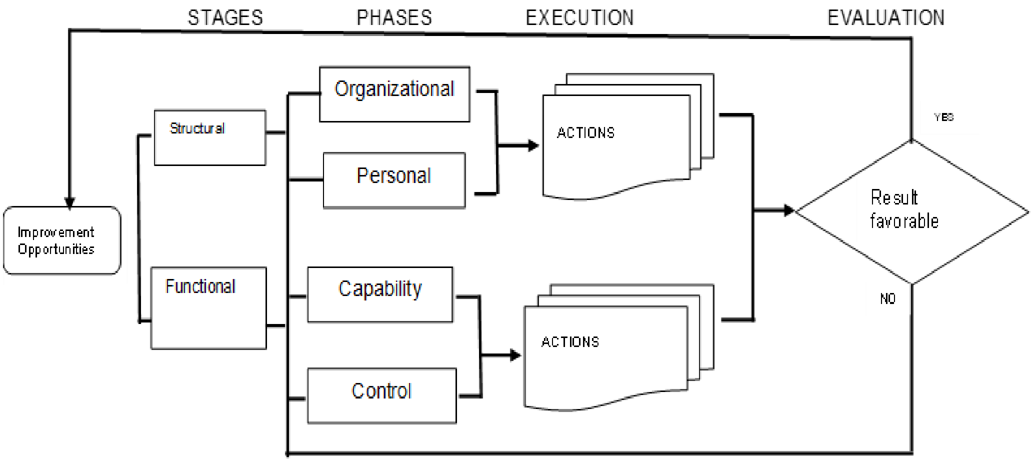

Fig. 8 Flow Diagram to implement the improvements

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The placement of domes and the other actions brought about a decrease in production defects, improvements in the quality requirements of the finished product, and a reduction of the consumption index. In six months fuel oil consumption decreased in 11,000 liters (US$ 330.00). Figure 9 shows the improvement of the "Mártires de Girón" production plant, based on the Juran Quality Trilogy, in a new "quality control zone" with values of losses between 0.5 - 1.5%, which represented loss rates at least 1.6 times lower.

Type of improvement	Action	Date / fulfillment Year of study	Participation	Responsible
Structural	Include in the contract with the refinery and forestry clauses regulating the quality of fuel oil and fuel wood.	July	Commercial and legal technician	Director and Head of Supply Responsible
	Instruct staff working on quality issues related to: Moisture of the baking bricks. Correct endague in the furnaces so that there is adequate circulation. Correction of leaks and correct manipulation of the burner.	November	Technical staff and experts	Technical Head and trainer
Functional	Calculation, design and installation of ovens with vault dome on the "Mártires of Girón" that reduce the escape of smoke and heat to the atmosphere and keep the heat in the top of the oven.	December	Civil construction technician and construction brigade	Director U/B Trinidad and Production Manager
	Manage the purchase of pyrometers to achieve temperature control.	October	Purchasing specialist	Director and Head of Supply

Table 2. Action Plan for the improvement

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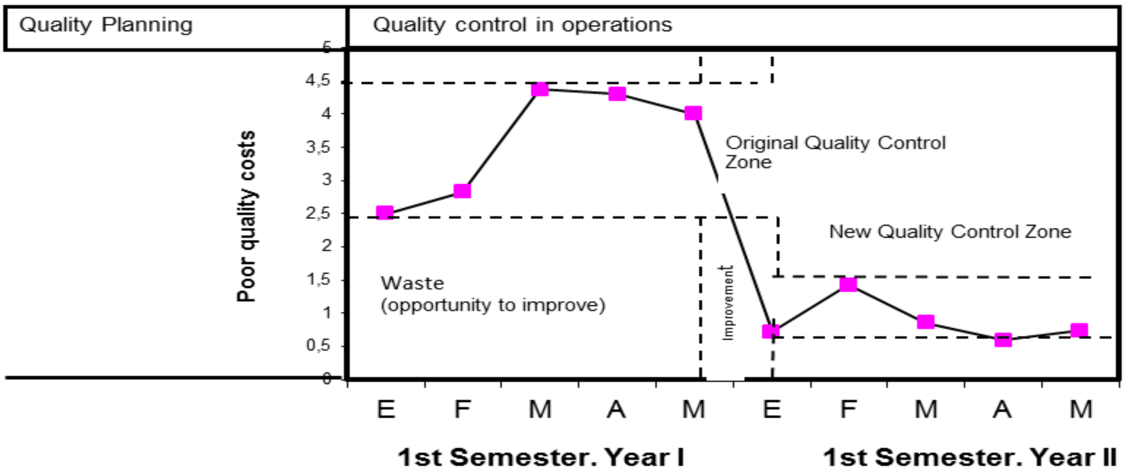

Fig. 9 Analysis of losses before and after the improvement actions in "Mártires de Girón" production plant

The evaluation of the significance of the improvement shown in Figure 10 compares loss reduction from year to year, in range, and median (4 to less than 1).

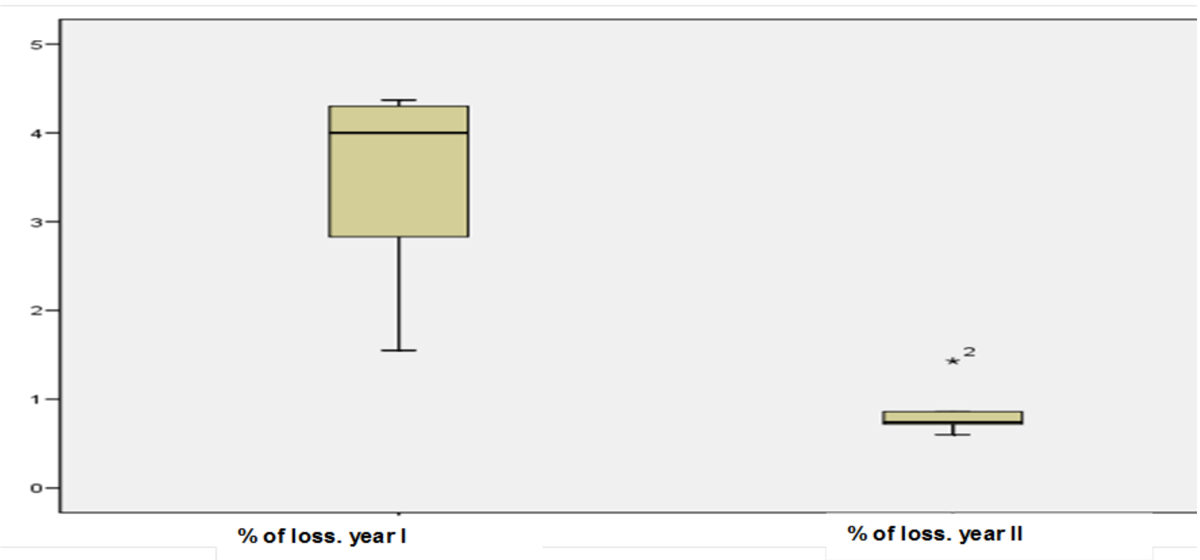

Fig. 10 Improvement signification in range and median

These reductions in losses, in relation to the fulfillment of the quality requirements, are shown in Figure 11, with the decrease of the amount of raw brick with more than 16% of humidity in year II.

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The monitoring and measurement of the process improvements by changing the furnace cover, are expressed by indicators (Table 3). They include decrease in "% of defective units"; reduction of production costs and compliance with the quality requirements of finished production. It is important to point that the "% of absorption" indicator has meant a greater effectiveness in the burning and also a reduction in the consumption of fuel oil and fuel wood.

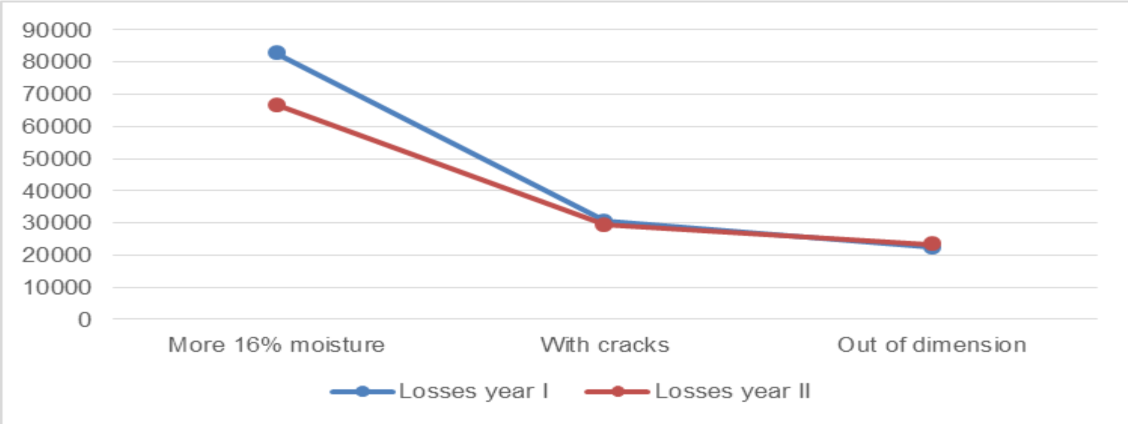

Fig. 11 Improvement in the quality requirements in Trinidad brick industries

Process	Improvement Actions	Improvement type		Indicator	Plan	Current	Result
		ST	FU				
Bricks Producti on	Calculation, design and assembly of valuated dome furnaces on the "Mártires de Girón" roof that reduce the escape of smoke and heat to the atmosphere and keep the heat in the upper part of the furnace.		X	% of defective units	3%	2.38%	-
				% of absorption	<16%	13.48%	-
				Index of consumptio n	4.1	4.12	-
Improvement type: ST: Structural; FU: Functional.							

Table 3. Result of the observation and the indicator measurements

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The same concern regarding the use of ovens exists in relation to other forms of burning, such as the use of stoves, for example (Jones, 2015). Different areas have been considered when the use of ovens is necessary (Despotovic and Babic, 2018).

These processes involve high-consumption equipments with more than 88.4% in the consumption structure of the enterprise. Besides, resistance to rupture increased. With that improvement, the possibility of using the products in more complex constructions and edifications was verified.

To maintain the improvements and extend them to the remaining production plants of Trinidad and to other type of productions, the managing structure of the enterprise elaborated an action plan (Table 4) where elements such as personnel training, university supervision and investment planning have been incorporated.

	Action	Fulfillment	Participation	Responsible	Observations
1	Train the company's personnel in the energy field, fundamentally those related to the areas with highest consumption of energy carriers.	Annual	All workers	Enterprise manager	
2	Create mechanisms to motivate staffs who decide on energy efficiency and dissemination about the need for energy saving in the enterprise	Permanent	Workers at key positions	Energy specialist	Permanent execution. Use of moral and material simulation
3	Include in the planning the replacement of the ceiling of the furnaces by vaults in all the centers of Trinidad	July Year II	Centers of Trinidad Manager	Enterprise manager	It is foreseen in the plan of economy
4	Use energy intensity as an instrument to measure efficiency and for decision making	Permanent		Enterprise manager	
5	Implement the Total Efficient Energy management Technology (TGTEE) in the enterprise by defining IT resources for the energy area	December Year I		Enterprise manager	Participation of university specialists

Table 4. Action plan to maintain the achieved improvements

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From this plan to maintain the improvements and generalize the procedure in the rest of the production plants, two plants of the Municipality of Sancti Spíritus were selected which manufacture (1) clay tiles and (2) clay pipes. The clay used has more plasticity than that of production plants from Trinidad and requires a maximum heating temperature of about 45°C, a parameter that facilitated the optimization of the burning process. With the proposed generalization, it was possible to achieve greater reductions than those achieved in the production of bricks (Table 5).

Other type of productions	Fuel consumption Liter / units	
	Before the improvement	After the improvement
Roof tiles	0.1125	0.0952
Clay pipes	1.2937	1.0990

Table 5. Improvement in the consumption index - procedure generalization for roof tiles and (2) clay pipes

With these indicators and according to the monthly production of clay tiles (60,000 units and 10,000 pipes), they consumed in the semester 6,228 liters less in floor tiles and, in pipes, 11,682 liters less (Figure 12). These elements support the effectiveness of the procedure, which has a positive impact on one relevant indicator for the management in the construction material enterprise.

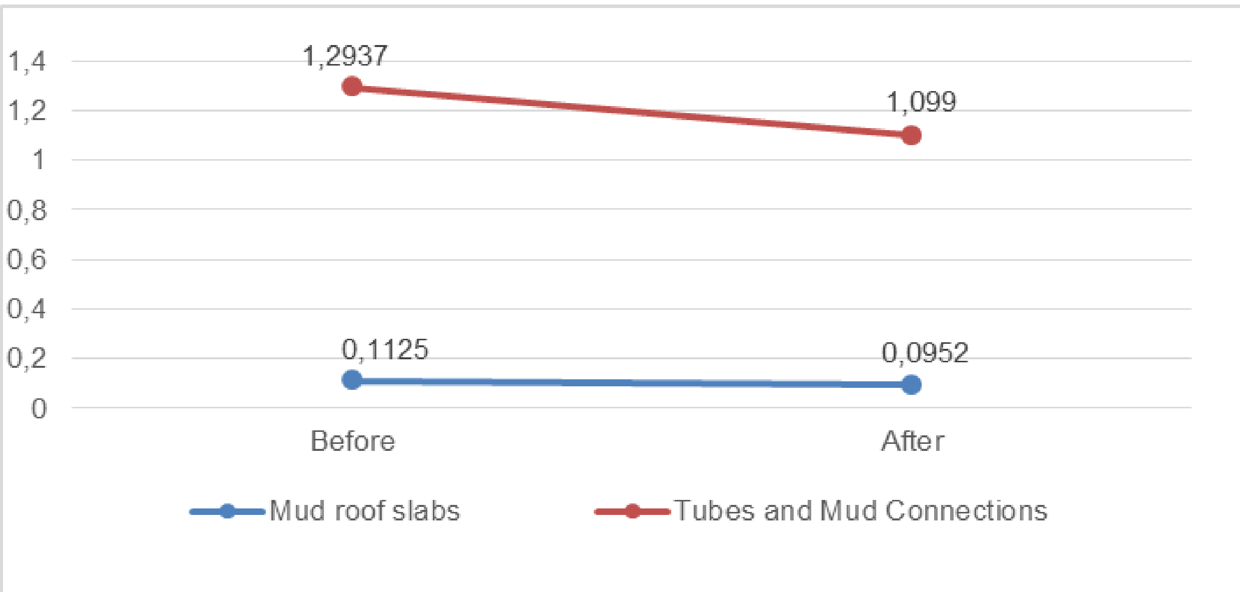

Fig. 12 Reduction of the fuel oil consumption in a semester per production

The procedure conception, the outcomes obtained in the study case and the generalization realized in other types of productions, allowed the authors to obtain a model that support a structure to organize the execution of energetic improvements in the industrial process of the oriented actions. It is presented in four stages: training, motivation, instrumentation and evaluation (Figure 13).

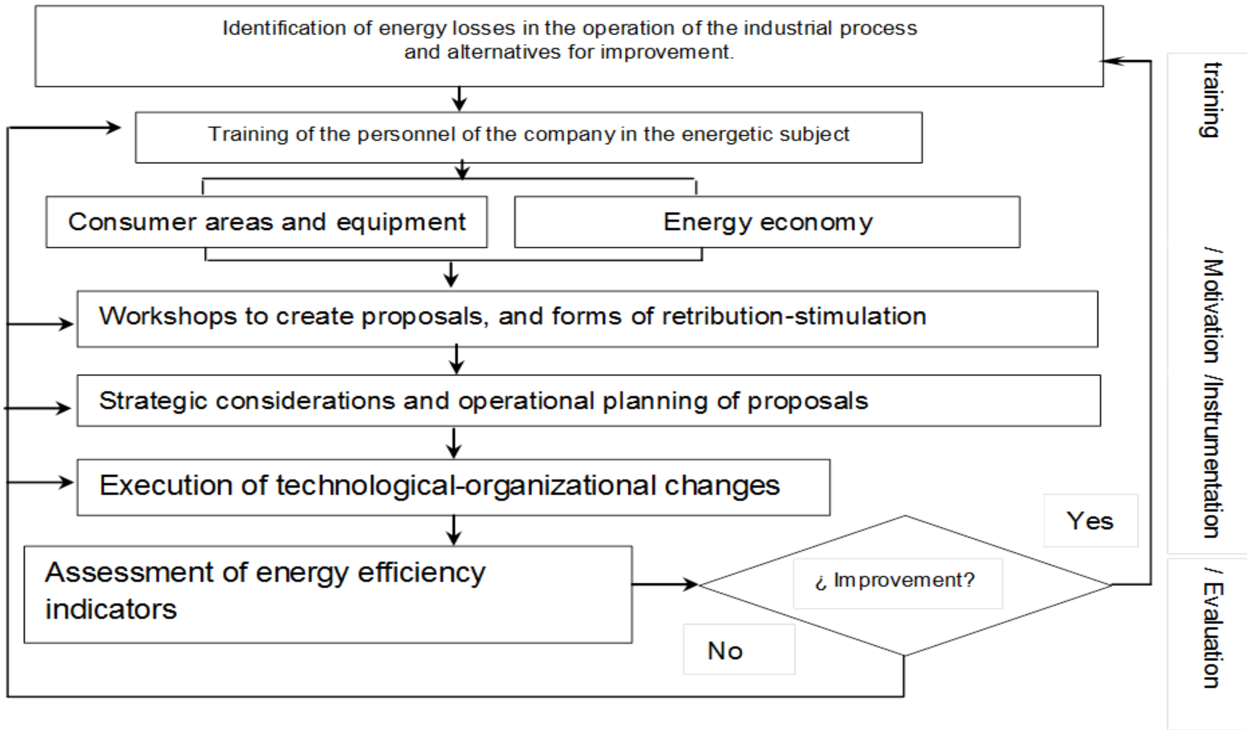

Fig. 13 Procedure to maintain the improvements

It must be noted that the experiences of the construction material production are conceptualized, departing from the quality improvements in energy management. It is an experience that can be extended to other organizations.

Continuous improvement in productive processes has an impact on several areas of the organizations, like enterprise perspicacity and leadership; critical and analytical thinking; employee performance and cultural change. It also affects the process management, improvement tools and quality value. All these changes come from a perspective strategy, related to the organizational sustainability (Cudney and Keim, 2017). Not unreasonably, alternative sources of energy, such as wind, are always considered and a permanent source of study (Jones and Gautam, 2014).

Conclusions

The conclusions obtained in this case study are the following:

1. The quality improvement in industrial processes, particularly in the manufacture of building materials, when analyzed from the perspective of quality approaches, facilitates the projection of quality practices with impact on business strategy. This is essential in the development of managerial activities. These activities systematically detect alternatives for improvement through the selection and development of tools, which with a process approach, integrate organizational and technological aspects. With better exploitation of available technology, it is possible to raise current levels of energy efficiency and production quality.
2. In the brick production process, the highest consumption of energy is observed (>70%). In the production plants of Trinidad municipality, the clay that is processed has a high content of iron oxides and silicates (higher melting point), and although they have low technological development, they assume approximately 50% of the brick production of the territory. This situation results in non-compliance with technical requirements for the low quality of the finished product, with losses higher than average (5%), so that no more than US$ 3,743.64 is allowed in the year. The evidence of the opportunity for improvement is clearly present here.
3. In the analysis of the total losses of the five brick-making production plants of Trinidad in years I and II a decrease of the crude brick (≥16% of humidity) in the factories was evidenced by improvements made only in one production plant. A new quality control zone (according to Juran Quality Trilogy) was defined in year I (2.5-4.5% losses). For year II, losses were fixed on 0.5-1.5%. This involved planning a level of losses at least 1.6 times lower and variability 2 times lower. In addition, a reduction of the consumption index of 0.2739 to 0.2386 L/brick, in the furnace was achieved, for a saving of 11,000 liters of fuel oil in 6 months.
4. The actions established by the management staff were aimed at preserving the improvements achieved and extending them to other production centers. This way, significant improvements were achieved in fuel consumption rates, in units of the municipality of Sancti Spíritus dedicated to the manufacture of roof tiles and clay pipes. For both products the raw material used had parameters that facilitated the optimization

of the burning process, expressed in significant savings in fuel consumption according to the volume of production executed: 6,228 L/ semester in roof tiles and 11,682 L/ semester in pipes.

5. This research identifies best quality management practices and approaches to improve production performance based on the quality product degree and the orientation of the process technology used in the manufacturing system (Leffakis, 2016; Sarosky, 2017).

This study dealt with an industrial sector that plays an important role in the economy of developing countries, which is that of construction materials, a sector that generates many jobs and produces resources for the people involved.

For this sector, this research shows considerable improvements, particularly in terms of energy management, which is also a major priority for developing countries. In this sense, a model is presented to execute actions aimed at energy improvements in an industrial process, where experiences are conceptualized, and according to the development of competences in quality professionals as proposed by Cudney and Keim (2017).

It should be noted that the conclusions presented here, the results displayed and the recommendations made are directed to the studied industry. The generalization of these aspects is limited to the analytical context of the study.

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