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Implementation of lockout/tagout (LOTO) methodologies on production lines

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Mestrado em Engenharia Mecânica - Construções Mecânicas

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ABSTRACT

With machines getting increasingly more complex, as technology advances and automation becomes an increasingly important aspect of all types of manufacturing processes, so does the complexity of engaging with machinery increase, which can lead to increased risk, and injury-rates. This is particularly relevant in the packaging industry, where competition and the market's changing demands require that package manufacturers remain flexible and efficient, which makes maintenance, changes, and improvements to machinery a common occurrence. It is then important to promote safety in the workplace, by implementing safety standards and methodologies. One such methodology is known as LOTO, or Lockout Tagout, which aims to control hazardous energies by developing blocking methods for the energies present in industrial equipment and to develop safety procedures to instruct workers on how to perform their tasks safely.

In this context, this dissertation aims to use LOTO methodologies to develop a safety procedure for three different machines, located in a factory specializing in the manufacturing of metal cans used for the packaging of various products. To achieve this goal, some preliminary work was done to develop the resources needed for the implementation of LOTO methodologies, such as the improvement of the tagging system that identifies the equipment and the energy blocking points, and the acquisition of the equipment needed to correctly block and dissipate the energy present in the machines. Following these tasks, each of the three machines was individually analyzed, documenting the tasks performed by workers on the machine and the energies involved in those tasks, as well as the implementation of the needed changes and improvements. Once the needed information was gathered, a safety procedure was developed and implemented for each machine, showcasing the documented tasks, along with the energies that need to be blocked, and a guide on how to perform each task safely.

The implemented changes and safety procedure seemed not to slow down the duration of tasks and were able to reduce the injury rates seen on the machine. However, due to the time constraints placed on this dissertation, and the large timescale needed to correctly evaluate rates of injury, it is suggested to collect more data after implementation of the safety procedures for a more robust conclusion.

KEYWORDS

Mechanical Engineering, Lockout Tagout, Safety Procedure, Workplace Safety, Packaging Industry.

RESUMO

Com o avanço da tecnologia, e com a automação a tornar-se num aspeto cade vez mais importante em todos os tipos de indústrias, todos os dias as máquinas tornam-se também cada vez mais complexas, o que leva a um aumento na dificuldade e complexidade inerente em interagir com estes sistemas mecânicos, o que pode levar a um aumento nos riscos e no número de lesões. Este facto é particularmente relevante na indústria de embalagens, onde a competição e as mudanças nos requisitos do mercado exigem que os fabricantes permaneçam flexíveis e eficientes, o que torna a manutenção, alterações e melhorias em máquinas uma ocorrência comum. É então importante promover a segurança no local de trabalho, através da implementação de normas e metodologias de segurança. Uma destas metodologias de segurança é conhecida pelo nome de LOTO, ou *Lockout Tagout*. Esta metodologia visa controlar as energias perigosas, implementar métodos de bloqueio das energias presentes nos equipamentos industriais, e desenvolver procedimentos de segurança para instruir os trabalhadores sobre como realizar as suas tarefas com segurança.

Esta dissertação tem como objetivo utilizar as metodologias LOTO para desenvolver um procedimento de segurança para três máquinas diferentes, localizadas numa fábrica que se especializa no fabrico de latas metálicas utilizadas em diversos produtos. Para tal, foram realizados alguns trabalhos preliminares de forma a desenvolver os recursos necessários para a implementação de metodologias LOTO, tais como a melhoria do sistema de etiquetagem que identifica os equipamentos e os pontos de bloqueio de energia, e a aquisição dos equipamentos necessários para corretamente bloquear e dissipar as energias presentes nas máquinas. Em seguida, cada uma das três máquinas foi analisada individualmente, documentando quais tarefas são executadas pelos trabalhadores na máquina, e quais as energias envolvidas em cada tarefa, bem como implementadas as mudanças e melhorias necessárias. Uma vez reunidas as informações necessárias, foi desenvolvido e implementado um procedimento de segurança para cada máquina, apresentando as tarefas documentadas, juntamente com as energias que precisam de ser bloqueadas, e um guia sobre como realizar cada tarefa com segurança.

As mudanças implementadas e o procedimento de segurança pareceram não aumentar a duração da realização das tarefas, e conseguiram reduzir as taxas de lesões observadas nas máquinas. No entanto, devido às limitações do tempo impostas nesta dissertação, e à grande escala de tempo necessária para avaliar corretamente as taxas de lesões, sugere-se recolher mais dados após a implementação dos procedimentos de segurança para obtenção de conclusões mais robustas.

PALAVRAS-CHAVE

Engenharia Mecânica, *Lockout Tagout*, Procedimento de Segurança, Segurança do Trabalho, Indústria de Embalagens.

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LIST OF ABBREVIATIONS AND SYMBOLS

List of abbreviations

ISEP	Instituto Superior de Engenharia do Porto
P.Porto	Instituto Politécnico do Porto
LOTO	Lockout Tagout
OSHA	Occupational Safety and Health Administration
EU-OSHA	European Agency for Safety and Health at Work

List of units

L	Litters
bar	Bar
°C	Celsius
g	Grams
V	Volt
I	Ampere
mm	Millimeters
min	Minutes

List of symbols

Q	Flow	l/min
$	Money	Euro

1. INTRODUTION

1.1. Framework

Packaging is one of the main sectors responsible for product protection. From production to actual consumption, packaging serves to protect and conserve the product, avoiding interference from handling and environmental degradation, and guaranteeing the product's integrity. There are as many package types as there are products to distribute, and the study and creation of packaging solutions is a complex and constantly evolving subject due to the industry's need to keep up with consumer's demands, and also the constant development of new products that require new packaging solutions. However, protection and maintenance are not the only functions a package can perform, as attractive packaging can directly interfere with a customer's decision to purchase a particular product. Packages are then also used as a distinguishing factor between brands, used as a vehicle for product marketing, and to increase customer appeal. Thus, package manufacturers must not only ensure the quality of their products, but also make sure they are able to adapt to the consumer's needs, in this ever-changing market.

However, remaining competitive and flexible also involves constant updates and changes to the packages' lines of production, as well as constant improvements and increased use of automation, to meet client demand and increase production capacity. But unfortunately, maintenance and constant changes to complex equipment give rise to many work injuries, as a consequence of engaging with increasing complex systems and machinery.

To mitigate these potential dangers, many safety standards and methodologies have been developed and implemented in all kinds of industries all over the world. LOTO, or Lockout/Tagout, is one of these methodologies, aiding in identifying and controlling hazardous energies, by ensuring equipment is properly identified and deenergized, before workers engage with the machinery. To achieve this goal, a step-by-step plan on how to perform certain tasks is usually developed, providing workers with a useful guide on how to perform their tasks safely, improving workplace security, and protecting workers against unexpected energy release.

1.2. Objectives

The main goal of this dissertation is to implement a LOTO methodology and develop a safety procedure for three machines belonging to the company Colep Packaging, a stamping machine belonging to production line 99, a clinching machine belonging to production 11, and a stamping machine belonging to production line 26. The creation of the safety procedures has the ultimate goal of improving the safety conditions in these production lines. However, actions must first be taken to create the necessary conditions to make possible the implementation of LOTO methodologies in the company. To achieve this purpose, the following objectives must be completed:

- Analyze and understand how packages are manufactured, in order to gain a better grasp of the manufacturing processes used in the packaging industry;

- Develop a standardized tagging system that indicates the type of energy being controlled, and the locations where the energy can be blocked or dissipated;
- Develop solutions to ensure that all the necessary types of energy are able to be adequately blocked;
- Assess the task, hazardous energies and potential risks associated with engaging with the three machines that are receiving a safety procedure, as part of this project;
- Develop and implement a safety procedure using the LOTO methodology for all the assessed machines;
- Verify the impact of the implementation of the safety procedures on the factory.

1.3. Methodology

This dissertation will follow the subsequent methodology as described below:

- Contextualization and analysis of the packaging industry, the relevant manufacturing processes, and the LOTO methodologies;
- Identify and catalogue the problems and improvements necessary to make the implementation of LOTO methodologies possible;
- Development of solutions and improvements for the identified problems;
- Study and analysis of the three machines relevant to this dissertation, with the objective of documenting the tasks workers perform on the machine, and the risks and dangers associated with each task;
- Development of solutions and improvements for the analyzed equipment, to both make the implementation of LOTO methodologies possible, and to improve safety;
- Development and implementation of the safety procedure for each equipment, detailing all tasks, which types of energy need to be blocked to safety perform the tasks, and their respective blocking methods;
- Measurement of the effects of the implementation of the safety procedures, as well as a cost analysis of the changes made to the equipment.

1.4. Structure

This dissertation is divided into four parts, with the first chapter serving as an introduction to the themes and subjects involved in the making of this dissertation, framing the packaging industry in modern terms, and giving context to the many safety concepts that will be used and explained throughout this dissertation.

The second chapter pertains to the literature review, where ideas and concepts that support this dissertation will be further explored, providing a detailed overview of the packaging industry, the concepts that pertain to safety in the workplace and safety procedures, as well as the types of processes performed by the equipment that exists in the company in which this dissertation is focused.

In the third chapter, the development of the solutions and the safety procedures for each equipment will be showcased. The chapter begins with a brainstorming of improvements, and the systems and changes made in the factory to make the implementation of LOTO methodologies possible. Then each machine will be individually analyzed, explaining the processes and tasks relevant to each equipment, and showcasing the developed safety procedure. The chapter concludes by calculating the costs associated with the implementation of the LOTO methodologies, and a measurement of the impact of the implementation of the methodologies in the company.

In the fourth chapter the conclusions and proposals of future works are presented, providing an overview of what was accomplished in this dissertation, and a critical evaluation of the results obtained when compared to the initially proposed objectives, as well as showcasing possible future works relating to LOTO methodologies, and their implementation.

2. LITERATURE REVIEW

2.1. The packaging industry

The packaging industry serves every other industry in the world, facilitating the movement and exchange of goods all over the world [1]. Every product, from food to building materials, is transported or sold in some way in a packaged form. Additionally, many products require the use a series of packages during their transportation, from raw materials to the final product. Figure 1 demonstrates the kinds of packaging a product might need, sequencing them in order of contact the packaging has with the product.

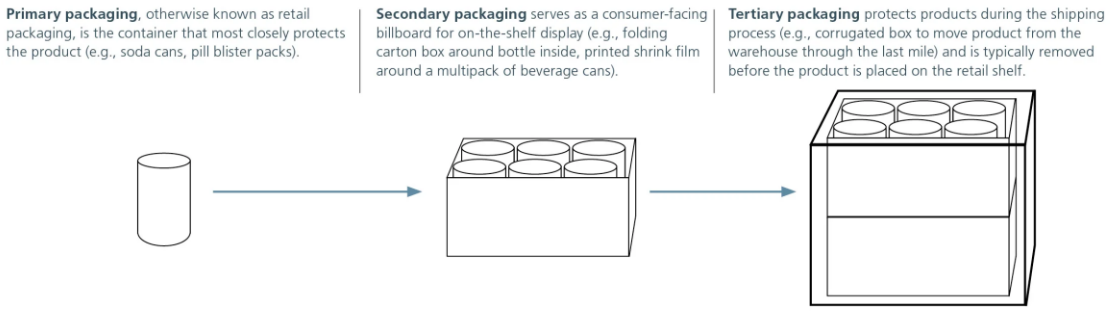


Figure 1 - Types of packaging [2]

When developing a package, it is necessary to consider all the aspects of its usage. Every industry sector has different demands for their packages. Although some clear overlap exists, the specific needs each package must fulfill is dependent on the industrial sector in which the package will operate. In this sense, it's important to take into account the range of materials that can be used, the production processes, the design, and characteristics that the packages present [3].

Packaging is a highly connected and international activity, innovation and keeping up with technological advancements are essential to remain efficient and competitive in such a wide and competitive industry. The relevance of packaging in all other industries encourages innovative solutions that improve lives, change the way consumers engage with products, and the way brands present themselves to the public. The manufacturing of products influences and is influenced by the packaging industry. Because of this, the packaging industry is continually important, and always looking for innovations that make their packaging more efficient, functional, and attractive [4].

2.1.1. History

Even since the beginning, humanity possessed a need to store and transport resources from place to place. While there is no definitive record of when the first package was used, its widely believed by historians that during primitive times, humanity made use of materials such as wood, animal skins and leaves to craft containers and other storing solutions [5]. But as technology evolved, these were soon replaced with clay, metal, glass and even paper, as is demonstrated by the timeline presented in Figure 2. But people did not just use packages for their practical advantages, civilizations also began plastering containers with art, and purposely use rare materials to display status, or signal a ritualistic meaning. Even in these early days of history containers were not only used as a transport solution, packaging was also seen as used as a signifier of culture [6].

Figure 2 - A brief history of packaging [3]

During the Medieval Ages trade became increasingly more important, and the transport of products along trade routes and distant location became increasingly more common. At first wood was famously used as a reliable packaging solution, but eventually metal also began to be used to craft more resilient containers, later seeing extensive use once food preserving technologies advanced, and began to require a strong and sealed package with which to transport food with [3].

Package manufacturing as we perceive it to be today, is based on changes that occurred during the industrial revolution. New advancements in technology and automation led to an explosion in new types of products being manufactured, and increased consumption by the general public [7]. To meet this demand for better quality, the packaging industry had to adapt and evolve, with their products having to meet the following criteria [8]:

- Better and more elaborate packaging capable of fulfilling the many different needs arising from the new variety of manufactured products;
- Food packaging methods, as companies and governments began to focus on increasing the shelf life of consumable products, and the militaries strived for methods to preserve food storage times for troops in the field;
- Smaller and individual packaging options, since citizens’ migration into towns and cities diminished the need to buy in bulk;
- Better looking packaging, since companies began to the use the package itself as a product differentiator, using it in marketing to increase customer appeal.

In the modern age, packages come in all shapes and sizes, being made from a variety of different materials, serving all kinds of purposes, and serving all industries in this increasingly connected world [9].

2.1.2. Packaging market

The packaging industry market comprises several global and regional players, all vying for attention in a contest for market dominance. As of 2022, the global packaging industry was valued at 1,015 billion dollars, and has experienced consistent growth over the last decade, with an expected CAGR (compound annual growth rate) of 3,94% during the periods of 2022-2027 [9]. Figure 3 showcases the expected growth for the packaging industry in the year of 2021. Although globally the packaging industry is long-lasting, many of its sectors are still vulnerable to trends and the general market landscape, like most common products.

Figure 3 - Global packaging market 2021-2025 [4]

The packaging market is heavily fragmented, due to the great variety of clients that request diverse types of packages, and the many producers that specialize in producing packaging solutions for specific usage and clients. This is beneficial for new companies, who are more easily able to set a foothold on the market, when compared to less fragmented industries, but this also increases the amount of competition between the various package producers [4].

Each type of package is highly dependent on the product for which the package was designed to carry. When there is a sudden surge in demand for a given product, it stands to reason that the product's package will also see a surge in demand. This variation is especially important when dealing with seasonal markets who only produce, and thus only require packaging, under specific times of the year [10]. This seasonality further adds complications to producers, who must always plan-ahead and strategize operations in preparation for future packaging orders. However, products can also lower in demand, indirectly influencing the package manufacturers. Analyzing the markets in which the packages operate also becomes important, as to anticipate rises or falls in demand for a given package a company may produce. Figure 4 demonstrate that certain markets consume more packages than others, with food and beverages clearly standing out as the biggest consumers of packages.

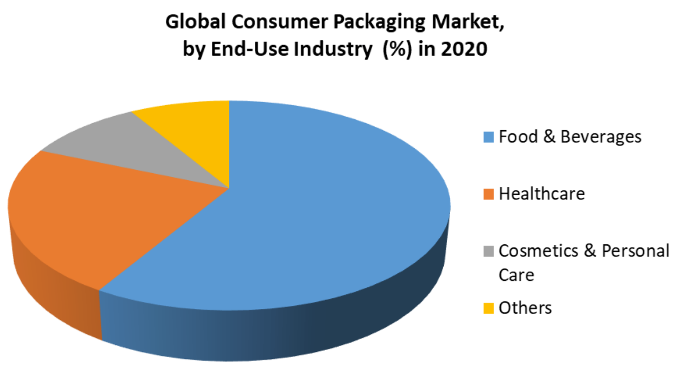


Figure 4 - Global consumption of packages in 2020 [11]

2.1.3. Package production in Portugal

Due to the packages’ nature as product designed to accommodate and contain specific materials, many times packages are forced to be transported in a state that leaves a lot of unused space, making the transportation of packages more expensive when compared to other industries. However, this higher costs of transportation benefits local industries, since producers closer to the client take on less manufacturing costs and are able more cheaply get their products into the hands of its clients, relevant to producers further away from the client [12]. Hence, national producers are less threatened by competition coming from distant countries, but in turn find it increasingly difficult to resolve business with clients further and further away.

Due to these, and many other previously explained market properties, Portugal also contains a similarly fragmented and wide market, as seen in the rest of the world, with many package manufacturers that operate on both national and international bases. Among them, Figure 5 focuses on the three biggest package producers in Portugal [13].

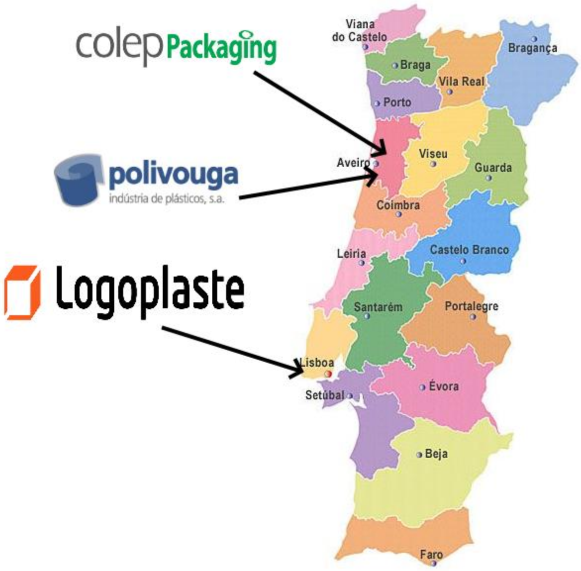


Figure 5 - Biggest packaging companies in Portugal [13].

2.1.4. Package production

As stated before, the packaging industry serves many sectors, and produces a great variety of solutions and products. From bulk long-distance transport to small food containers, the size, shape and material of the packages is highly dependent on the market and context in which the package is used in. Although packaging is a very diverse industry, with many different products and manufacturing, in general companies usually specialize in the production of specific type packages [14], purchasing the initial materials in very raw states, like sheets of aluminum or blocks of plastic, and then through a series of manufacturing processes, in which heating and cooling can be involved, they are reshaped and rearranged into the form of the desired package [15].

2.1.5. Pillars of the packaging industry

In order to understand the various pressures the packaging industry operates in, three topics stand out as the most important pillars of a successful packaging company.

2.1.5.1. Competition

With packaging being a global industry found all around the world, there are many consumers and producers alike, with the packaging industry remains highly competitive and fragmented since no company has been able to become globally dominant [16]. While consumers seek a satisfactory compromise between price and quality, producers also take on board the responsibility of developing new techniques and strategies to fulfill the various requirements set out by costumers, lower costs, and increase efficiency. Having a complete understanding of the development of the industry, material application, as well as innovative strategies, play an important role in remaining competitive in such a fragmented and wide industry [15]. Figure 6 demonstrates some of the several pressures packaging companies are under.

Due to the great variety of consumers, requirements and package types, producers possess a broad scope of package they can manufacture, each with their own specific utility, production, and requirements. However, companies that focus their production on specific sets of industries, or specific package types, narrow the scope of their production, which will also narrow the scope of possible clients, but in turn they are able to allocate resources more efficiently, albeit from production or knowledge of the market [14, 17]. Specialization and choice of your key markets then becomes an important part of remaining competitive and efficient, in such a diversified and fragmented market.

Figure 6 - Challenges in the packaging industry [18]

2.1.5.2. Quality

There are several aspects that must be considered when evaluating the quality of an industry, such as matching customer expectation, following industry standards, and guaranteeing the safety of the product and any worker responsible in its making. To this degree, there are many standards and regulations that must be followed when manufacturing a package, with different packages possessing different associated regulations. Customers will also many times request that the package fulfills specific parameters as part of their specifications, adding more complexities and regulations to the manufacturing process. Nevertheless, the package industry is subject to many types of audits, and improvements [19].

Customer satisfaction is not only key in maintaining customers, but also attracting new ones. The packaging industry is also prone to sending large quantities of packages to the same clients, and singular irregularities are bound to popup in a large amount of product [19, 20]. Its then very important to maintain constant oversight over the packages being produced, and regular maintenance of the equipment.

2.1.5.3. Adaptability

As one may expect, producing such a variety of products to keep up with your client's adapting needs, while remaining efficient and automatized, can be quite challenging. Each machine on the production line must be capable of at least some level of adaptability, or risk being obsolete once a new product is needed, or demand changes.

To mitigate this limitation, companies usually focus on specific sectors of industry and offer standard packaging models, which they later imprint with their customer's brand and logo. Although this inherently narrows their customer base, it allows companies to specialize on the manufacture of a specific kind of package, making their production lines more efficient, since these can always assume certain metrics like shape or material type, while remaining flexible to client's needs, since the imprinted image can always be added or changed [15].

2.1.6. Materials used in packaging

As previously discussed, packages are made to serve multiple purposes and tasks, from guaranteeing the physical integrity and conditions of products for transport, to appeal to customers with design and branding. For this reason, defining which materials will be used for the packaging is a vital step when developing a package solution for a given client, since there are many different kinds of materials available, each offering their own nuances, advantages and disadvantages [17]. Choosing the material of a packaging solution then becomes a balancing act between the needs of the client, regulation, and the production capabilities. Knowing the possible materials to use and their properties is an essential tool when it comes to producing a package solution, especially when it comes to innovating in a fragmented and constantly changing market.

The number of materials that are capable of being transformed into a package is vast, with each material providing certain properties and nuances to the package. Table 1 delineate the most used type of materials for use in packaging, and offers a brief description of its usage and applicability [1, 3].

Table 1 - Materials used in packaging and their properties [1, 3]

Material	Description
Paper and paper products	Although paper products are relatively inexpensive, lightweight, flexible and easy to produce, when compared to other packaging materials, they are not as sturdy, and work as a poor barrier when used in packaging for food, which diminishes the scope of their applicability [3]. But nonetheless, paper packaging remains an extremely popular material for a variety of products or as secondary packaging, and their benefits as an easily recyclable material option should not be overlooked, especially in this increasingly environmentally conscious world.
Glass	Glass has been known and manufactured for millennia. Glass packages showed to possess great ability to protect its contents against odors and external contaminants, being particularly effective as food and beverage packages. In addition, glass containers can easily be shaped in a variety of formats, creating very aesthetically pleasing containers, and are a great sustainable option, since glass can be recycled countless times. The main disadvantages of this packaging solution are its relatively high density, which results in a heavier package and higher transport costs, its high production costs derived from the great deal of heat necessary to manufacture a glass package, and the risk posed by sharp glass fragments in the event of a broken package.
Metal	In modern packaging the most used metals are aluminum, stainless steel and tinplate. These metals can be easily reshaped into a variety shapes and sizes, and offer rigid and effective protection to the package's content [21]. Metals' great adaptability benefits its use in the packaging industry, being able to fulfill many different requirements, and serve a variety of different industries.
Plastic	Plastics are a large family of extremely versatile and malleable compounds. Commonly used for food packaging, plastic is extremely cheap, lightweight, and possess practical production and transport, being a very versatile material, relative to other packaging materials. However, the risk of releasing toxic components, if exposed to very high temperatures, can lead to many dangers and health hazards, requiring care and oversight when handling plastic packages.

Materials possessing different properties also means their usage and popularity can change over time, in Figure 7 is illustrated the demand worldwide for the most common type of material used in packaging in 2019, revealing a striking difference between the usage of each material. Being up to date on their usage and anticipating changes in the market is also an important aspect to take into account, in order to remain competitive in the packaging industry.

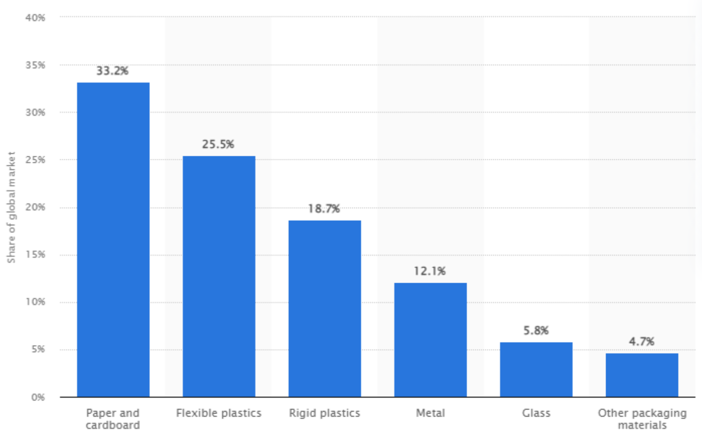


Figure 7 - Distribution of packaging demand worldwide in 2019, by material type [22]

2.1.7. Rules and regulations

There are many rules that regulate packaging manufacturing in the European region. Either to ensure safety or quality, depending on the purpose of the package many different standards must be applied and met. Broadly speaking, the packages must have enough resistance to safely contain the desired product through mundane events and accidents that can occur during transport, or during the product's usage. The package must also efficiently isolate the product inside the packages from outside contaminations, like in the case of food packaging, were the product can be ruined due to spoilage, or contamination [23].

Some packages are more regulated than others and must follow additional legislation in their production. Aerosol cans, for example, must safely contain the high-pressure gas placed inside them, while various food containers must be manufactured with special attention to hygiene, be able to safely seal the food, and be resistant to corrosion, which can negatively impact the food inside the package [19].

2.1.8. Future trends

Packaging will always be an integral part of all industries, even if certain package types and materials may vary in use and popularity. In the last few decades there has been a growing demand for eco-friendly alternatives to packaging, largely caused by an increased awareness of the effects caused by waste and pollution. Packaging that is only meant to be used once, like many plastic containers, which are neither degradable or able to be reused, are starting to be seen as wasteful and a threat to the environment, greatly reducing the business of the manufactures of such products [24]. The packaging industry is working to meet this demand and produce more environmentally friendly solutions, attempting to make packaging that can be repurposed, recycled, or with by-products that are biodegradable.

2.2. Process types in packaging

2.2.1. Manufacturing overview

There are many processes that can be performed as part of package manufacturing, being largely dependent on the type of packages in need of being manufactured. But before showcasing the complexities and challenges that come with each type of process, it's important to start off with an overview of the entire package manufacturing process. As it pertains to metal cans, the most common manufacturing process is showcased in the Figure 8 diagram.

The manufacturing process starts off with a flat plate, more commonly made of aluminum, although a variety of other materials also see its use. The aluminum plate will first go through a lithography step, in which a design and image will be printed onto one of the surfaces, so that the can, when finished, may possess images and logos associated with the product's brand, and any other information the client has requested. Following the print, a stamping process is performed on the plate. This process is done in order to separate the plate into many smaller individual plates, which will constitute the final product, or to reshape an individual plate, like making lids or changing the aspects of its surface. To complete the can, the ends of the plate are connected and joined via welding, giving it a distinct cylindrical shape, and the package is finalized after adding a base and top to enclose the cylinder, both also being joined into the can via welding.

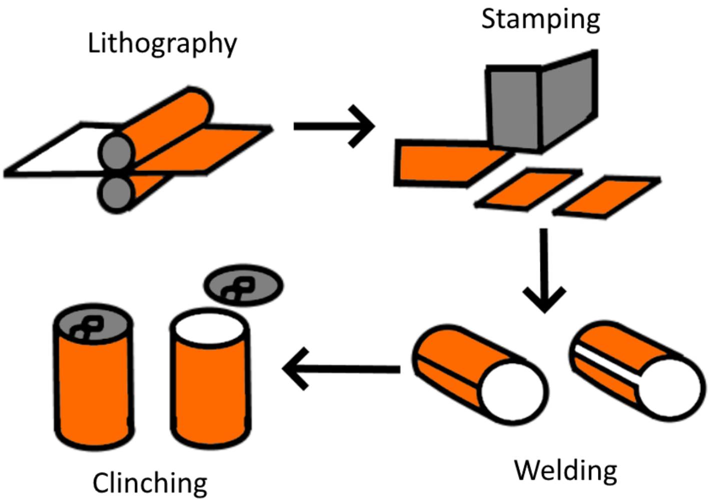


Figure 8 - Packaging sequence diagram

2.2.2. Lithography

Lithography is the act of printing text or images onto suitable materials, which is an important tool when it comes to package manufacturing, since packages usually require some kind of printing added onto them. Since this printing is responsible for the visual impact of the package, the various clients create their own designs and request that the producer be the one to imprint them on the package. These designs can serve many purposes, with the most obvious being the aesthetic appeal of the product since, as stated before, many packages will be used as primary packaging, hence the end-consumer will directly interact with the aspect and appearance of the package. Thus, the packaging is also used as a tool for marketing and brand differentiation. But other than an aesthetical function, the design is also many times used to convey important or mandatory information, such as labels, or the product's contents. The ability and quality of the print, then become important factors to study and considerer when manufacturing a package [25].

There are many ways of printing text and images onto packaging materials, one of the most common techniques is referred to as "offset lithography". In this process, the package first begins as flat plate, which passes through a series of printing rollers that press the ink against the plate, transferring the image onto the materials. Two different cylinders are commonly used to press the plate on both sides, as demonstrated in Figure 9 [26].

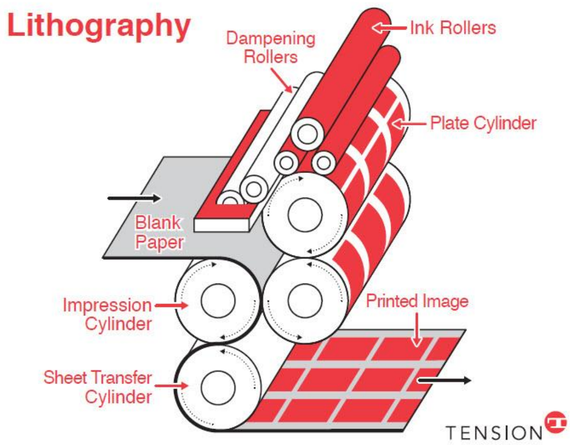


Figure 9 - Typical offset lithography scheme [27]

In this process, the colors are printed separately, following the CMYK system demonstrated in Figure 10, forming images through the combination of the pigmentation of the different colors. Hence, different stages of coloring are needed to print a multicolored image on the plate. These stages are usually executed in a sequence of connected machines that print its specific color, as demonstrated in Figure 11. This process creates a great quality print, since the image can more easily conform to irregular printing surfaces and is able to create various tones of color, by carefully sequencing the combination of pigmentation.

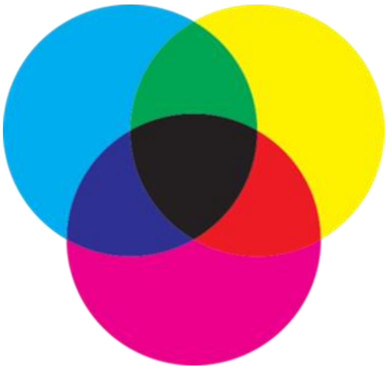


Figure 10 - CMYK color system

Figure 11 - Typical lithography machine with multiple color sequences

The rolling of the cylinders and the application of the ink are very important operations to keep track when printing on a plate, since any small deviation or error can be quickly and clearly noticed in the final print. It is then important for lithography machines to receive regular maintenance and tunning, to ensure that the same printing is clearly applied on all printing plates. The machine also requires frequent changes in setup, since for a new image to be printed or changed, new rubber cylinders have to be changed in the equipment.

Its then important for the equipment to be turned off during maintenance or setup changes, since the unexpected activation of moving equipment can injure workers servicing the machine or damage the equipment. Additionally, unexpected activation or malfunction can also cause dangerous substances to be propelled into workers, damaging their eyes or skin. Which is particular important when dealing with lithography equipment, who often times make use of ink and other chemicals to perform their print.

2.2.3. Stamping

Stamping is the process of manufacturing parts through cutting or deformation of plates in a pressing operation. In this process, a plate or sheet is position in the die of a mechanical press, whose movement/closure promotes cutting or deformation, as demonstrated in Figure 12. Stamping is more commonly used to manufacture parts with low thickness, usually using sheets or strips of various metals and alloys. This operation is an essential part in the manufacturing of many products, and is usually carried out cold, but heating can be applied to facilitate the stamping process, especially when dealing with thicker plates of more resistant metals [28]. Stamping machines can often both cut and deform plates, however when the machine's main and only purpose is to cut the plate, its commonly referred to as a punching machine instead [29].

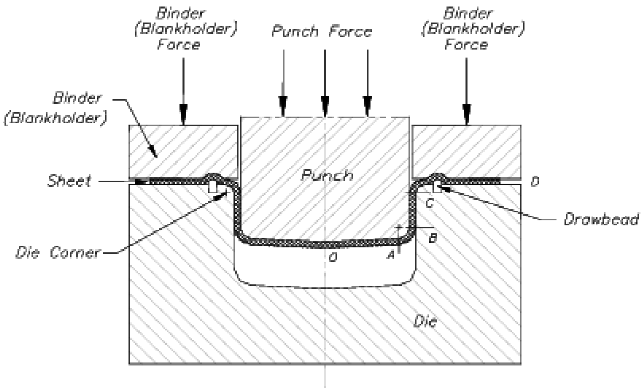


Figure 12 – Typical sheet metal stamping operation [30].

This method of production possesses a relatively high costs for acquiring and setting up the required equipment, but possesses high precision, low operation costs, and a relatively fast production time. Due to these characteristics, this manufacturing process is preferably suitable, and highly used, for large series of parts, providing easy automation and integration in a production series [28]. Figure 13 provides an example of how a common stamping machine used in product manufacturing operates, while Table 2 provides a description of mechanicals parts that can be found therein.

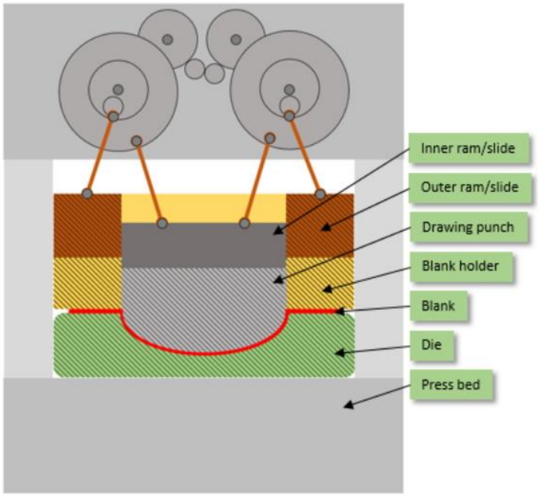


Figure 13 - Double-action deep drawing press [31].

Table 2 - Table stamping

Component	Involved energies	Description
Shaft /hydraulic cylinder	Mechanical/ hydraulic	The main component responsible for moving and exerting the force needed for the stamping process. In the case of mechanical presses, a motor induces torque upon a shaft, while in hydraulic presses liquid pressure is used to move a piston up and down.
Ram/slide	Mechanical/ hydraulic	The ram is the main component directly connected to the shaft/hydraulic cylinder and is responsible for being moved up and down. This component is usually intrinsic to the machine and is only replaced in cases of breakdown or damage.
Punch	Mechanical	The punch is directly moved by the ram, and often serves as an extension of the ram. It is used to better control the force exerted by the press, and to facilitate the creation of a specific stamping operation. The punch is often changed or removed when the part being stamped changes shape or dimensions.
Die	Stationary	The die constitutes yet another mechanical part responsible for changing the shape or cut in the stamping process, serving a similar purpose to the punch, expect it is a stationary component, serving to facilitate and promote the stamping process. Similarly, this component can also be changed or removed, in the cases the part being manufactured changes shape or dimensions.

Although there are many different types of stamping equipment, the following three key areas in which injuries are more likely to occur, being mostly caused by the presence of movable [32]:

- The first area of danger is at the point of operation, where severe injuries can easily occur if someone becomes exposed to, and is crushed by, the closure and movement of the punch/die. These mechanical parts, by design, operate with a high force, since stamping usually requires a lot of force to cut or reshape tough materials. This danger can also be worsened if the press also operates at high production speeds, giving little reacting time to correct any mistake once the press beings to lower its position;

- The second area of danger pertains to any mechanism that transmits energy to the mechanical parts of the machine, especially the press. Mechanical parts like belts, gears and joints can operate at high force and speeds, posing similar risks to the ones described in the press;
- The last area of danger can be much less intuitive than the two described before, pertaining to the projection of materials, instead of direct expose to the equipment's forces. For example, cutting sheets of metal can often times project small metal pieces into sensitive parts of the human body, like the eyes or the mouth, causing many unexpected injuries. Some equipment may even come with a system for the removal of excess material, which is intentionally launched into a disposing unit.

2.2.4. Welding

Welding is a process that aims to forge a permanent localized union between two or more materials, which can be either similar or extremely different. Welding bases itself upon using high heat to create partial melting of a section between the materials we wish to join, creating what is called a "weld pool", which when followed by a cooling period causes fusion of heated material, melting the two materials together, thus creating a localized union [33]. Typically, in addition to melting the base, a filler material is also added to the weld pool. This filler material can be more or less resistant than the base materials, and although its main usage is to serve as a linking material between the unionized parts, increasing the resistance of the union, it can also serve as a coating material, reducing wear and tear, which aids the parts longevity and maintenance [33]. Figure 14 presents the schematic used in a simple welding test, in here we can clearly see how the two base materials are heated and melt together, with the addition of the filler material facilitating the formation of the weld [34].

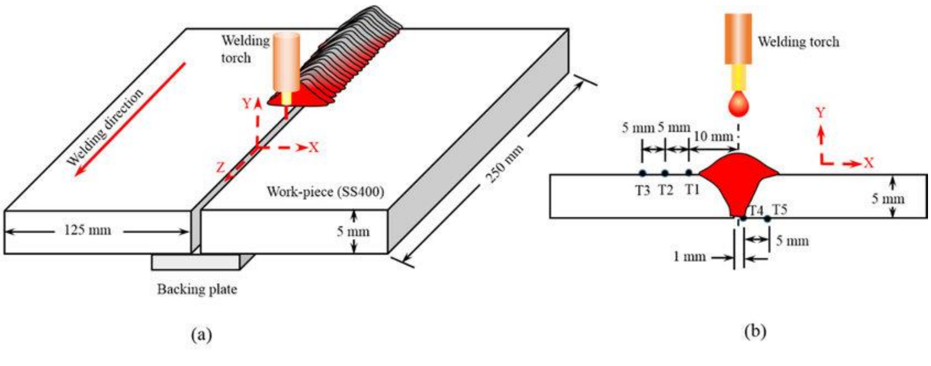


Figure 14 - Schematics used in a welding process [34]

There are many different types of welding, each one with their own methods of heating, filler material delivery types and energy sources, possession their own objectives and particular results. Welding processes are common in various branches of industry, to produce a variety of different parts. However, canning manufacture more commonly relies on a welding method referred to as "spot welding", depicted in Figure 15. In this welding process, points of contact on the metal surface are joined by the application of an electric current which, when met with the electrical resistance of the base materials, create heat, causing the fusion of the materials that, as explained above, is the bases of welding processes. The attractive feature of spot welding is its reliability, simplicity, and the ability to concentrate a large amount of energy in a very short time without overheating the rest of the plate, making it a very popular welding option for automated systems, and lines of production [35].

The amount of heat exerted into the welding point is determined by the resistance between the electrodes and the magnitude and duration of the current. By applying too little energy, the metal will not melt or result in a poor-quality weld, while applying too much energy will create an excessive amount of molten material, creating a hole instead of a weld [36].

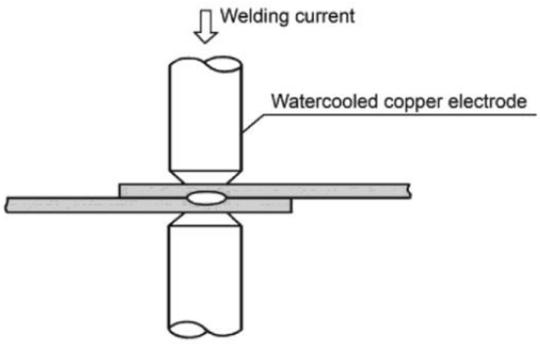


Figure 15 - The principle of resistance spot welding [36]

In order for the welding to be carried out efficiently, the welder must understand the nuances and functions of the welding method, of the equipment in use, and the effects each welding position has on the final result. As depicted in Figure 16, different welding positions may cause the molted material to move differently, affecting the properties of the weld. It is also important to point out that, due to the characteristics of the work, several precautions must be taken when welding, such as eye and hand protection to avoid burns and damage from ultraviolet light. Sometimes, welding also produces toxic fumes, a feature that requires breathing protection. The quality and durability of the weld depends on several factors, including the concentration used in the heat input, the type of filler material added, and the method chosen to carry out the welding [36].

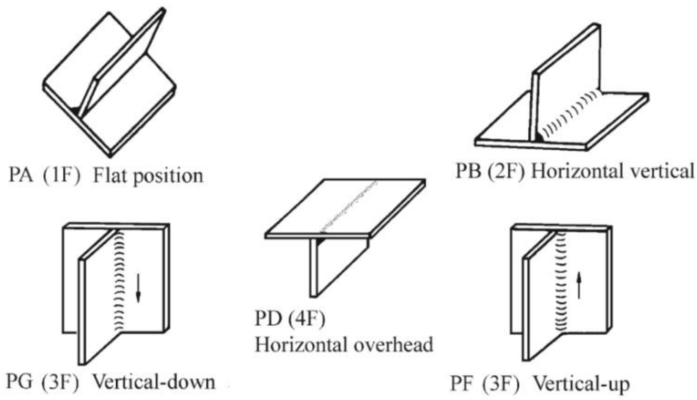


Figure 16 - Definitions of welding positions for fillet welds with designations as given in EN ISO 6947 [36]

2.2.5. Clinching

Clinching, also known as press-joining, is a process in which thin sheets of metal are joined together through the formation of an interlock between the metal sheets. This interlock is created though cold forming, punching the sheets using specialized tools, and not requiring the use of any additional components [31]. When compared to other processes that serve similar purposes, like welding or adhesive bonding, clinching possesses several advantages. Among them is the capability of joining dissimilar materials, on a wide array of different thicknesses levels, allowing for an easy union of lightweight materials or thin parts. The process is also fast, consistent, only involves simple operations, releases no fumes or heat, and operates at lower energy and production costs, which makes it not only an economically viable production option, but an environmentally friendly option as well [31, 37].

Broadly speaking, the clinching process is performed as showcased in Figure 17. Firstly, two or more sheets that overlap in a given section are pressed by a punch, which compress the sheets into the die, giving shape and controlling the deformation of the sheets, manufacturing a resistant interlock between the parts through cold forming [31, 38]. One of the biggest dictators for good mechanical performance of the clinching interlock is the geometry of the joint, which is affected by various parameters that must be controlled and closely observed. While the interlock itself is the main influence that dictates the joint strength under normal loads, neck thickness is imperative when dealing with shear load resistance [37, 38].

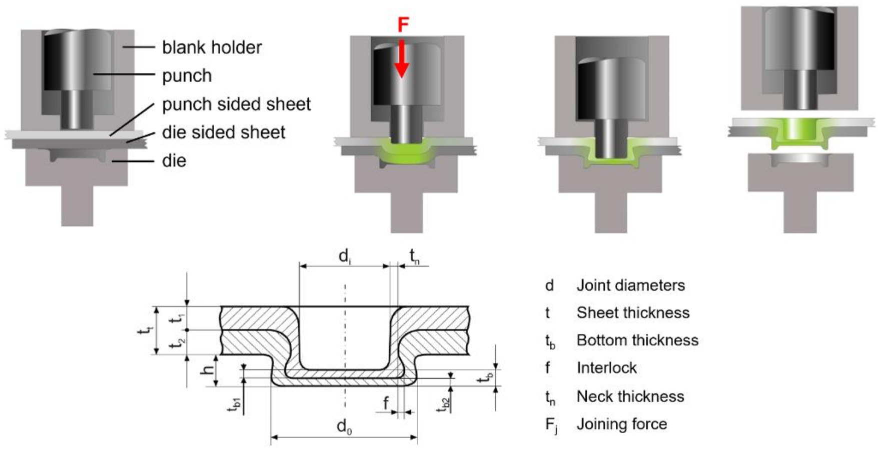


Figure 17 - Steps of the clinching process and important geometric parameters of the clinch joint, according to Böhnke et al. (2021)

A variation of this manufacturing process is commonly referred to as double-seam, this technique is highly used in the canning industry, it was implemented to replace the previous way manufacture would connect the lid and seal from the body of the can, which was mostly done through soldering or welding. However, these processes often introduced harmful contaminants into the inside of the can, which since a lot of the time the cans were used to package food and beverages, this manufacturing process led to many health risks. Double seam then emerged as an innovative technique to seal or place the lid on cans.

The main difference between clinching and double-seam is how the interlock is formed. In double-seam, the can is manufactured by mechanically folding the body and the lid over one another, creating a hermetic seal, which unifies both parts without the use of heat or the addition of any other external material [39, 40].

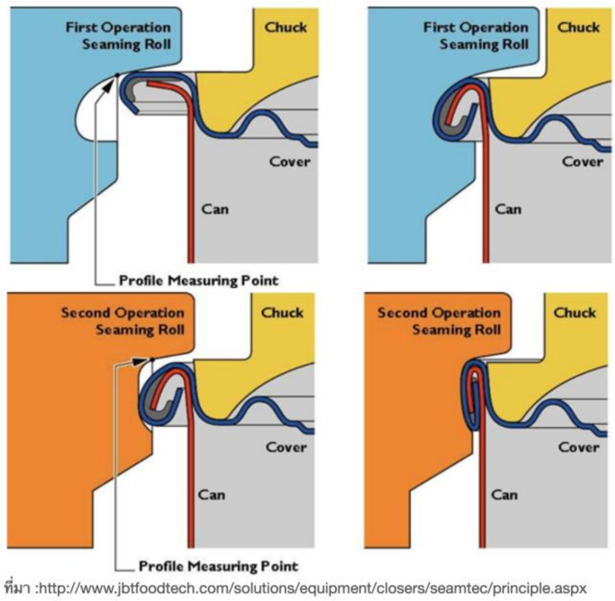


Figure 18 - Double seam operation [41]

There are many ways to produce a double-seam in a can, but the most widely used is exemplified in Figure 18. In this method, the first operation consists in cold forming the cover, by placing the cover above the can, as well as pinching it bellow the tip of the can, so that in the second operation the double-seam may be compressed, permanently locking the can and its cover. The product from such a process can be showcased in Figure 18 [40, 41].

These types of equipment present similar risks as stamping, possessing mechanical punches that operate with a high force and at high speeds. It is then very important to restrict access to the area in which the seaming roll occurs, in order to prevent the entrapment and crushing of areas of the body, resulting from engaging with the equipment. However, double-seam does possess the advantage of being able to operate horizontally, facilitating changes and maintenance of the mechanical punches of the equipment, since the injuries caused by these heavy parts unexpectedly falling due to the effects of gravity are less severe, if the moving parts are positioned horizontally. However, these mechanical parts are still quite heavy and must be operated with caution.

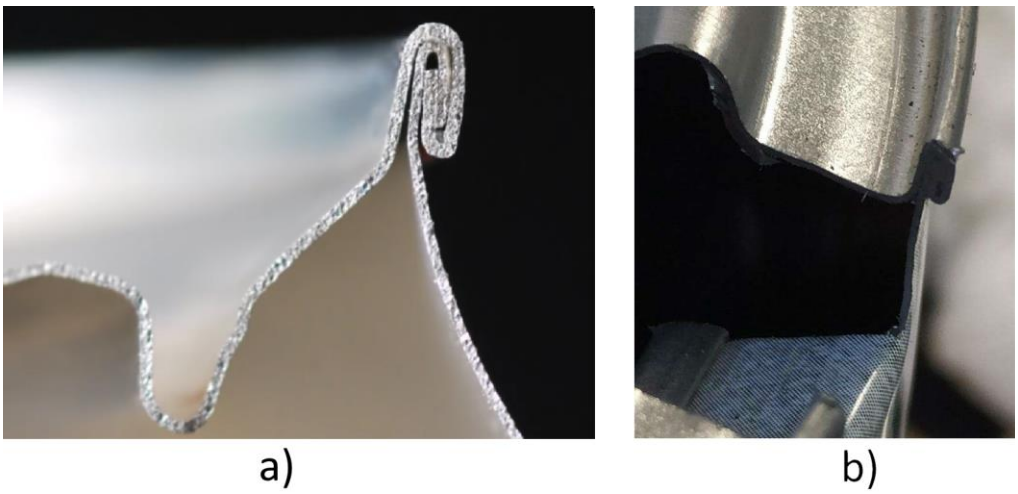


Figure 19 – Two examples of a double-seam operation applied to metal can manufacturing

2.2.6. Automation

All companies and industries constantly seek to improve their manufacturing efficiency, producing more with less whenever possible. One of the ways this efficiency is achieved is by shifting workload from individuals to automated systems. Automation is then the application of technology and system, in order to make mechanisms operate with minimized human input, resolving tasks, taking measurements, and introducing corrections [42]. Automation can also be conceptualized as a set of autonomous machines and equipment that can be applied to a process, aiming to maximize production, and lower the need for human intervention [43, 44]. Figure 20 showcases some of the many benefits the implementation of automation can have on a line of production.

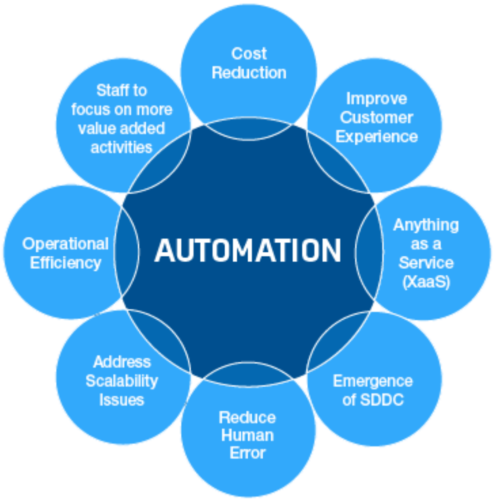


Figure 20 - Benefits of automation [44]

One of the biggest advantages offered by automation is the higher production speed at lower costs, but it also replaces heavy or monotonous physical work. Likewise, tasks that tend to be performed in high-risk environments can instead be performed by machines capable of operating under extreme conditions, like high temperatures, or in a toxic environment. However, not all kinds of tasks are able to be automated at the present moment, albeit from technological limitation, or due to the increased complexity of the tasks [43].

However, automation also brings with it some disadvantages, such as the high Initial investment needed to install the required machinery, and the need for proper and periodical maintenance, since low human intervention also means lower oversight over the production process, leading to many unverified defects if the equipment is not developed to counteract or otherwise detect productions errors. However, even in automated systems, knowledgeable human input is essential in the creation of an automated system since its development requires expertise in both areas of programming and mechanics [42]. The added automation also leads to increases in equipment complexity, with the same machine being designed to perform several tasks and interact autonomously with other automated equipment, which will in turn also add complexity to maintenance and equipment changes, increasing the risk of errors and injuries [45]. It has been demonstrated by several studies that, although automation is very effective in reducing the workload of tasks, the increased speed and complexity of production can cause an increased risk in work-related injuries. It is then important for the automated system to be designed with safety in mind and its impact on the overall line of production be understood [46, 47]. The rise of automation can, sometime, make workers anxious about losing their jobs, as new technology can make the worker's skills and experience unnecessary, making retraining necessary [48].

There are a variety of components and technologies that make automation a reality today. From sensors to machine learning, automation encompasses a variety of technologies and functions. It is then important to understand the equipment that allow the various machines to interact, and product to be moved, from one stage of manufacturing to another.

Table 3 - Equipment used in automation.

Equipment	Description
Sensors	A device capable of producing a signal, as a response to a specific physical or energetic stimulus. These components are essential for automatically tracking and responding to specific situations. These types of system can be found is a variety of machines and systems throughout industry, being useful in many different situations. They can operate in a variety of ways, but the most common way is using electrical energy and electrical signals.
Computer control	To operate an automated system using sensors and various inputs, it is necessary to possess some kind of information processing mechanism, capable of reacting to the various provided inputs. This can be done using specialized systems, like a PLC, or more mundane means, like a computer.
Conveyer belts	Used to move objects from one place to another, conveyor belt consists of two or more pulleys that move a surface along a determined path. These systems are essential to ensure that the product is able to move between the various machines, allowing for multistage manufacturing with minimal human intervention.
Hydraulic systems	Besides transport, objects often times need to be placed in specific positions or locations, such as separating a metal sheet from a pile and placing it inside a mechanical press for stamping. These types of tasks are often carried out using hydraulic systems, making use of liquid pressure to automatically move mechanical components in various ways, being an important part of an efficient line of production.

2.2.7. State-of-the-art

Package production, like all other industries, is in a constant state of improvement and discovery. Whether from the use of new package materials, or the implementation of different manufacturing techniques, the processes and equipment to carry out said processes are constantly changing and being subjected to updates. It is then important to keep up with the recent literature and advancements in package production, not only to remain competitive and efficient, but also to possibly plan and anticipate changes and improvements, leading to a clearer and effective production process.

Table 4 - State-of-the-art for process types in packaging

Author	Work description
Huang, et al [49]	This work strategized an effective use of lithography with the use of light beams and DMD (digital micromirror devices) to project an image directly onto a specialized substrate, printing a digital image onto a physical object. The main problem this work aimed to lessen was the high levels of pixelation seen in previous uses of lithography with DMD, by securing that the substrate remained static, and sequencing various stages of light exposure to overlap the position of the image's pixel, creating a clearer image. This lithography technique has been shown to be reliable and obtain high levels of precision and image fidelity, while operating at fast speeds. Which, if reliably applied to the packaging industry, may lead to an increased manufacturing speed of cans who go through a lithography step.
Fernandes, et al [29]	Tin cans composed of thin steel sheets are frequently used throughout the packaging industry. However, tin coating's softness causes it to easily adhere to the die, which causes early wear and raises issues concerning the preservation the can's lid. Although these issues could be easily resolved by lubrication, such a method is not recommended when dealing with packaging food. To improve the punch and die wear behavior, this study tested the use of two coatings (B4C and Mo), which reduced the transfer of tin material from the metallic sheet to the punch and die, and the friction coefficient of this sheet against some chosen coatings. Demonstrating that it is possible to reduce the amount of tin that transfers from the coated steel sheet to the die and punch. Which prolongs the efficiency of the parts and lowers tool maintenance procedures of the stamping operation.
Bassani, et al [50]	It is always important to evaluate, and attempt to lessen, the impact a given package has on the environment. This article aimed to evaluate and suggest opportunities to reduce environmental impact of packaging used in the pharmaceutical industry, by using a Life Cycle Assessment (LCA)-based ecodesign strategy. Ecodesign guidelines emphasizes both the importance of smaller-sized packaging, avoiding unnecessary components and empty spaces which lowers both material and production costs, and the selection of appropriate transport methods with less environmental impact, taking into account the manufacturing location, and the needs of the package. This ecodesign strategy allowed for robust quantification of environmental impact, gathering data on the environmental impact resulting from a variety of characteristics, such as design, material selection, and packaging production through distribution to the end user. The article ended by emphasizing the important of customized packaging and showcasing the effectiveness of ecodesign in packaging.
Reisinger, et al [51]	Production lines are subject to frequent expansion, and changes, as a result of product changes, improvements, and quick technical advancements. Well-thought-out planning of the production layout and building systems

	are important to support a constantly changing production environment. This article presents a pilot project, introducing a new design approach for automated production layout generation and optimization (PLGO), which generates layout scenarios that can serve as guidelines for designing a more effective structural buildings, when it comes to manufacturing layout. Results imply that the framework can generate workable production layout situations that take flexibility and building specifications into consideration.

2.3. Lockout Tagout

2.3.1. Workplace safety

Work plays a pivotal role in people's lives and occupies a large portion of their time, with the average person spending one third of their life at work [52]. But unfortunately, during the day-to-day life many accidents can occur. Whether through negligence or a mishap, accidents can cause a wide array of physical and phycological damage to workers, which will in turn lead to further problems, such as increased stress and reduction in productivity. Workers may have to take time off work to heal from their injuries, or their effectiveness may be impaired due to lasting injuries or the effects of stress, anxiety, and other phycological conditions. Companies may also be held legally responsible, in the cases where regulations make companies responsible for implementing a certain degree of safety. As it was shown in a recent study [53], workplace accidents negatively impact the company's stock value and profit, as well as incurring additional expenditures, in the form of worker's compensation for injuries, and fines due to noncompliance to the law. It is then essential that organizations understand the importance of workplace safety, not only for the well-being of their employees, but for the continuous well-being of the company itself [54, 55].

However, many employers still pay little attention to safety, and protecting the health and safety of their own workers, with some employers not even being aware they have a responsibility and obligation to maintain the well-being of workers and their workplace environment. As a result, many workers are placed in dangerous situations, often times without even knowing, or having been made aware, that they are being exposed to situations of risk and danger.

OSHA has recommendations on how workplace safety should be handled, in their "Recommended Practices for Safety and Health Programs" section, OSHA has recommended a methodical and proactive approach to dealing with workplace safety, instead of a traditional reactive one. Rather than merely evaluating past accidents and preventing their recurrence, safety should be subjected to continuous analysis and development [56].

2.3.2. Work safety procedures

In the modern era, there are many institutions and standards that effect and regulate the workplace, facilitating and standardizing safety. However, this has not always been the case, with the development of modern industry there also came an increased awareness of the dangers and risks posed to workers, as they managed and engaged with increasingly complex mechanisms [57]. Some of the first safety legislations were largely brough about by incidents that had already occurred, only creating regulations after the fact, but it soon became clear that institutions were required to gather expertise and standardize the various practices needed to ensure safety on a multitude of different industries, who each operate with their own complexities and systems [58]. To fulfill this need for standardization, in 1970 OSHA was created, being followed by the EU-OSH in 1994. These institutions would oversee safety regulations in America and Europe, respectively. Figure 21 showcases the most frequently cited safety violations, reported to OSHA in 2021 [59].

Figure 21 - Most frequently cited safety violations [59]

Many of the injuries that occur in the workplace can be avoided by the implementation and following of safety procedures. For example, in a period between 1992 and 2001, 40% of the victims involved in a work-related accident in Portugal stated that occupational accidents could have been prevented if more attention and safety were taken into account [60]. Additionally, in South Korea's manufacturing industry, a study between 2014 and 2018 found that 84.2% of accidental deaths in that time period occurred due to the equipment not being turned off, while the remaining 15.8% were caused by a participant not noticing the presence of another worker, while repairing or inspection were taking place [61]. Then, in order to standardize and implement the needed precautions in a given work environment, safety procedures become an efficient tool at increasing workplace safety and reducing injury rates, by directly protecting workers, identifying hazards, and offering directions on how the work is to be carried out, and what actions must be taken to eliminate or minimize risk.

However, creating a safety procedure that can be broadly applied to many different industries is a difficult challenge, stemming from the fact that there is a great variety of industries that come with their own complexities and work environments. It is then necessary that safety procedures be studied and developed based on the on-site characteristics of each industry, while following the broad metrics set by legislations and national standards. In this regard, tight cooperation between the several areas of expertise is necessary and highly important to create a robust and effective safety procedure, capable of accurately evaluating and preventing worker's risk and injuries [62].

2.3.3. Lockout-Tagout

To mitigate potential sources of harm derived from operating or maintaining increasingly complex equipment, the LOTO standard was developed by OSHA. This safety standard aims to prevent unexpected energization or startup of machinery, which can occur during equipment servicing or maintenance, and causes a variety of injuries [63]. To improve safety, energy control procedures are then implemented, requiring workers to disconnect equipment from its sources of energy, and dissipating any hazardous energies, before engaging with the system. Additionally, locking and tagging any possible way of reactivating or reenergizing the system without the worker's consent, assures that the task can be carried out without the risk of unexpected releases of energy. Additional steps must also be taken to verify that the energy has been effectively isolated or removed from the work environment, such as checking for pressure inside the tubes, or measuring correct inside cables. Employees and managers are tasked with training their personnel and performing routine inspections to ensure safety, prior to service and maintenance [64]. The LOTO methodology then makes it possible to identify and control the energy sources of equipment, and identifying worker's exposure to risk, defining the mode and type of blocking necessary to perform a task safely.

2.3.4. History of lockout tagout

According to OSHA [65], the failure to properly control for energies accounts for nearly ten percent of serious injuries. The high frequency and severity of these incidents gathered public awareness and prompted OSHA to create a safety standard to more effectively protect workers and prevent these types of accidents from taking place. Until 1971 there was no standard for locking, tagging or disabling machinery, until OSHA published its first industry standard to block hazardous energies. Over the decades OSHA would adapt, add and reinforce certain practices, and in September of 1989 OSHA issued the final rules for the Lockout Tagout procedure. The standard demanded that energy be locked using locking devices whenever possible, unless tagout could be shown to provide *"full employee protection equal to locking"* [63]. With this directions, new and old machines had to be designed and modified to accept lockable energy isolation devices [63].

While the standard was first developed in the United States of America, it quickly spread to other countries and regions. In Europe, the "EU Guidelines 89/655" released in 1989 established minimum requirements for safety when engaging with machinery in the European region, clearly delineating that *"every piece of equipment must be fitted with clearly visible devices with which it can be separated from every energy source"* [66]. These European rules where further expanded in 2008, in the EN 1037 norm, which defines measures regarding the isolation and dissipation of hazardous energies [67].

2.3.5. Hazardous energies

Any energy that can be harmful to workers servicing or maintaining the equipment can be considered a hazardous energy, with especial attention to energies that can be released unexpectedly, whether due to malfunction or mistake. There are many different injuries that can occur from these types of accidents, with their own type and severity being largely dependent on the environment and situation. It is then vital to study and evaluate the hazardous energies present at every worksite to create a procedure capable of properly preventing any type of wrongfully energy release [68]. Figure 22 provides common examples energies that frequently need to be checked and controlled in various different industries.

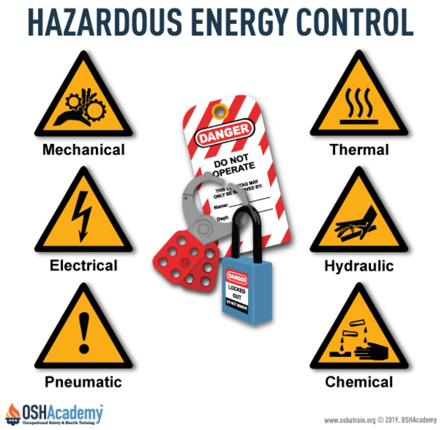


Figure 22 - Hazardous energy control [59]

The control of hazardous energies does not stop at simply disabling its sources and blocking the startup of the equipment. It is also important for workers to be trained and taught about the potential harm that can be caused during the tasks they perform. For example, operating inside a working machine poses obvious risks that can be seen and understood by anyone. However, many times the danger isn't immediately discernable, such as when engaging with electrical systems, where electric current cannot easily be detected by workers, which can cause the electrocution of individuals even all operations seemed normal at first glance, or when engaging with hydraulic systems, where pressure can be stored inside pipes and tubes, even when the machine is not operating and the source of pressure has been blocked, endangering any workers engaged with the equipment [69].

2.3.6. Lockout-Tagout procedure

Each machine and equipment induces its own processes and nuances, and a safety standard can never fully account for all these complexities. Therefore, the development of each procedure must be done based on the analysis and evaluations of the site-specific circumstances, and the dangers present therein. OSHA has outlined the minimal requirements for a typical lockout procedure. Procedures must encompass the *"scope, purpose, authorization, rules and techniques that the employer must use to control harmful energy"* [63]. Thus, the procedures must include the following information [63]:

- A guide on how to use the procedure;
- Outline the procedures to block or disconnect any harmful energy, securing the safety of any worker servicing the machine;
- Delineate the procedures to place, remove or otherwise transfer any Lockout Tagout equipment, along with any important information, such as location, or people in charge;
- Test and verification of the effectiveness of the proposed procedures, or any other energy control labeling;
- Delineate who is authorized to perform each given task.

It is recommended that practical and theoretical training be given to workers in addition with the implementation of the safety procedure, to ensure its correct use, and to facilitate the locking of devices and interpretation of the safety signs placed in the work environment. The information present in the safety procedures must also be periodically checked and updated, to both promote improvement, and account for changes in the machinery, which can occur over time.

2.3.7. Hazard identification and assessment of tasks

An essential part of the LOTO methodology is the identification of hazardous energies present in the workplace, and an assessment of the workers' exposure to risk and sources of harm when performing their various assigned tasks. It is then essential that the work environment be studied and analyzed, so as to effectively prevent injuries and protect workers. In order to obtain reliable information on the various hazards and tasks relevant to the equipment, it is necessary to engage with people directly, gathering the expertise necessary to correctly analyze and evaluate the diverse tasks performed on the worksite [63]. Talking with workers and supervisors who are directly present at the worksite is a recommended initial step, as they are the most well equipped personal to provide information on common practices, daily tasks, and frequently encountered hazards, due to being the ones responsible for directly carrying out tasks and engaging with the company's systems on a more consistent and daily bases. Following that step, investigating and reviewing previous injuries, or near accidents, is also important to help identify recurring hazards, and prevent the repeat of previous incidents. Additionally, it is also important to gather information on non-routine or emergency situations, since these are less common, the risk in these situations can often times be overlooked or undocumented.

However, this gathering of information must be done periodically, and continue well after the procedure has been developed, to better identify recurring hazards and update the procedure to account for possible changes that naturally occur in the workplace. After the tasks and risk have been sufficiently identified and documented, it is important to determine the likelihood and severity of accidents that occur due to the identified hazards, as to prioritize corrective action, and better prepare for the prevention and control of the identified hazards. Figure 23 showcases an example diagram of a management process, in regard to safety and management of risks.

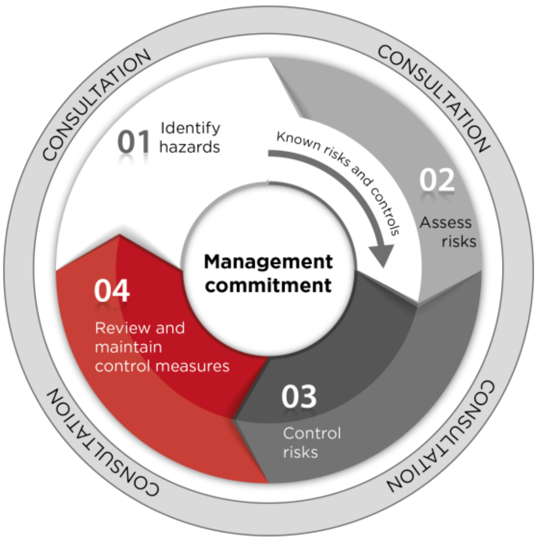


Figure 23 - Risk management process [70]

2.3.8. Hazard prevention and control

Once a hazard has been properly assessed and identified, the LOTO methodology calls for actions to be taken, in order to completely remove the hazard from the workplace. When it is not possible to eliminate the hazard, steps should be taken to lessen its severity or occurrence, by controlling the involved energies, signaling danger, or protecting workers directly with added equipment. The "hierarchy of controls", seen in Figure 24, then becomes a useful concept to evaluate and identify methods of dealing with hazards. Once the options from a more effective control method have been exhausted, options from a less effective degree of control can be considered instead, in the search for a viable control option. The identified solution should then be reviewed for effectiveness, to make sure it does not directly, or indirectly, create a new hazardous situation. Replacing a hazard with another one that is less likely to occur, or less severe, may be the only viable option to increase safety, but nonetheless, it is necessary to avoid introducing new hazard whenever possible.

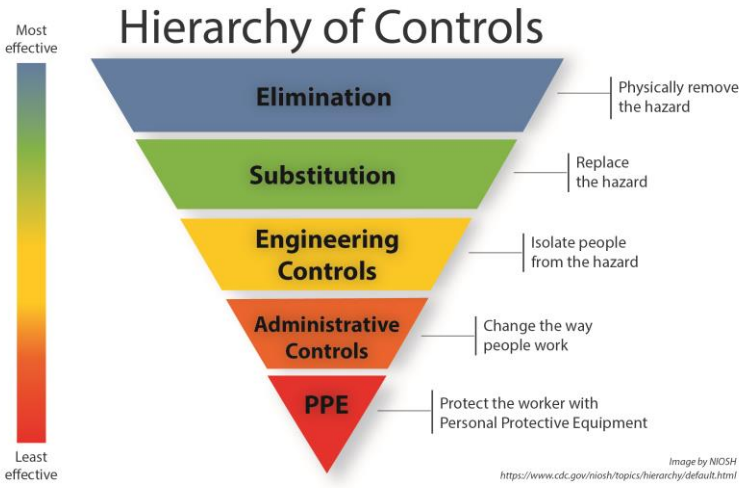


Figure 24 - Hierarchy of control [71]

After a control option has been selected, it is important to review and discuss it with workers and knowledgeable personnel to make sure the option is effective and feasible. During this period, while a long-term control option has not yet been selected or implemented, it is important to use intermedium controls to mediate and lower risks. A review and analysis following the implementation of the control is also advised to verify the effectiveness of the control, and to make sure all participants are operating in accordance with the newly established procedure.

2.3.9. Control equipment and LOTO devices

Many types of different equipment have been developed to aid in the control of hazardous energies, with the explicit goal of facilitating energy blocking and safety awareness. However, there also exists a great variety of mechanical equipment and activation systems, some of which may have not been developed with safety or LOTO methodologies in mind. As a response, a great variety of equipment is required to accommodate the needs and nuances from all these diverse systems. When developing a safety procedure, it is then important to identify the control options available to any given procedure, as well as identifying the effectiveness of the options available, and seeking better or more effective alternatives.

Broadly speaking, control devices, as it pertains to LOTO, can be divided into two different types of equipment. Firstly, Lockout devices are equipment capable of holding equipment or energy sources in a safe or "off" position, with different systems requiring different types of equipment to reliably prevent reenergization. In Lockout devices, the worker is offered reliable protection, since these restrains widely function as physical locks, hence they can only be removed by the use of the lock's key, which is held by the worker currently engaged with the machine's systems, or through extraordinary means, like actively breaking the lockout device. Tagout devices, on the other hand, are tools that serve as a warning label to others, indicating that the equipment should not be reenergized, since the machine is currently being serviced by an operator. These devices are easy to remove, providing workers with less protection than lockout devices, but when used in conjunction with Lockout, these devices create a much clearer and organized work environment [63, 72]. Table 5 showcases some examples of common LOTO control devices:

Table 5 - LOTO control devices

Control device	Description
 *Figure 25 - Padlock and key*	**Padlock and key** Considered the basis of the LOTO methodology, padlocks serve as a physical block to a myriad of equipment who are designed with the use of padlocks in mind. The padlocks offer a very useful universality to safety operations, and offer reliable protection, since the only way to remove the padlock through non-destructive means is to open the padlock with the key, which is in the possession of the worker servicing the machine. Thus, as long as the operator has the key, he can be confident that the machine will not reenergize.
 *Figure 26 – Tag*	**Tag** As previously explained, tags are used to convey danger and relay important information, like identifying the worker currently blocking the energy, detailing how long the energy is expected to be blocked, and many other data that may be required to assure safety.

 *Figure 27 - Lockout Hasp [73]*	**Lockout hasp** The occasion may arise when multiple people are in need of blocking the same source of energy, at the same time, such as during maintenance operations, where multiple individuals are engaged with the same machine, and therefore, all workers are required to maintain the equipment depowered and turned off. However, the blocking method may only require, or indeed only accommodate, one padlock blocking it at any given time. Hasps attempt to solve this issue by operating as a singular padlock, capable of blocking like any other regular padlock, with the different that lockout hasps are not locked by use of a key. Instead they allow for the placement of multiple padlocks, who in turn assure that the hasp remains locked, allowing for multiple workers to block the same energy source.
 *Figure 28 - Group lockout box [73]*	**Group lockout box** These special boxes follow the same concept as the hasps, but instead of serving as a replacement to a lock, they serve as a safe to make sure whatever particular item is placed inside the box is not interacted with, until all participants have removed their individual locks. This equipment can be used to prevent a key from a padlock from being used, serving the same purpose as the lockout hasp. However, it can also guard any other relevant object, such as relevant machine parts.
 *Figure 29 - Lockout tagout station [73]*	**Lockout tagout station** These stations are essential for an effective and cohesive LOTO procedure implementation, offering quick and easy access to the equipment necessary to carry out the LOTO procedures.

Figure 30 - Valve lock wire and protector [73]

Valve Lockout

There are various ways of blocking valves, since valves themselves can also be found in many different sizes and modules. But fundamentally, lockout in valves aims to block the valve's movement. It can achieve this in many ways, such as the use of a strong wire to tie a segment of the valve to another rigid nearby segment, thereby blocking the valve from moving, locking the lever with a rigid segment, or even specialized levers that allow for a lock to be placed directly on them.

Figure 31 - Circuit breaker lockout [73]

Circuit breaker lockout

There are many different circuit breakers and electrical appliances, leading to many different types of circuit breaker lockouts. In general, these devices serve to keep the switch from moving, either by blocking the switch's movement, or covering the switch to block any interaction.

Figure 32 - Blocking device for doors or windows

Blocking device for doors or windows

Instead of locking a door or window, a device can be implemented in order to detect if the door/window is open. If it detects an opening, the device will then send a signal to the machine, forcing the machine to suddenly stop, or block certain energies, or areas. Thus, it is assured that no one has access to a dangerous area while the machine is actively working or energized.

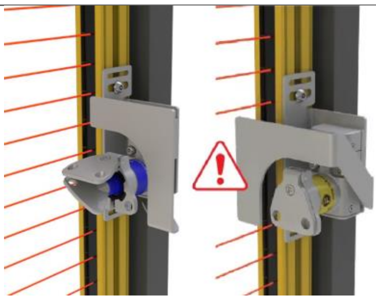


Figure 33 - Blocking device for safety curtains [74]

Blocking device for safety curtains

This device is similar to the aforementioned blocking device for doors or windows, with the difference that there is no physical barrier present on the location. Instead, a laser sensor is used to detect movement, or intrusion in the light's beams, stopping or locking an aspect of the equipment if something is detected between the light beams.

2.3.10. Education and training

As part of the development of a safety procedure, it is also important to develop tools to inform and educate workers and managers on workplace safety, hazards, and the implementation changes. This procedure is not only necessary to make sure the people engaging with the systems are informed on how they should proceed and act, but also to provide a greater understanding of safety and health, which will contribute to a safer workplace, and allow for the workers to be able to contribute and participate in the development of the safety procedure, which promotes improvement and development of the safety procedures. It is also essential that workers obey the established safety and health rules, since members not following the rules or a badly designed procedure can induce a false sense of safety, which can then lead to further hazards and injuries.

There are many methods of educating and increasing awareness. Professional training courses are very useful in helping prepare workers for the daily procedures and challenges of the work environment, especially at a time when new safety procedures are being put into effect. There are training courses that are mandatory and those that help with educating and raising awareness. In both cases, it is essential that all learning is put into practice, and that coordinators and supervisors help guide workers, and contribute to the strengthening of a culture of safety, prevention, and good practices [75].

2.3.11. Program evaluation and improvement

As previously explained, safety procedures are most effective when they are approached in a preventive, methodical and continuous way. For this reason, even after a safety procedure has been developed and implemented, continuous work is still required to maintain the efficiency of the procedure and to improve safety. Initially, the procedure must be evaluated to verify it is being followed, and that the implementation has produced the envisioned results. Following its long-term implementation, it is important to periodically review the effectiveness of the procedure, what is not working and what could function better, if the goals that were set out to complete were in fact achieved, and what needs changing to accomplish those goals. Feedback and participation from workers and coordinators in this phase is essential, since their knowledge and involvement in the procedure drives further improvements, and promotes a more cohesive and participatory safety environment in the workplace. Figure 34 showcases an example diagram, of an evaluation system, with the goal of improving safety.

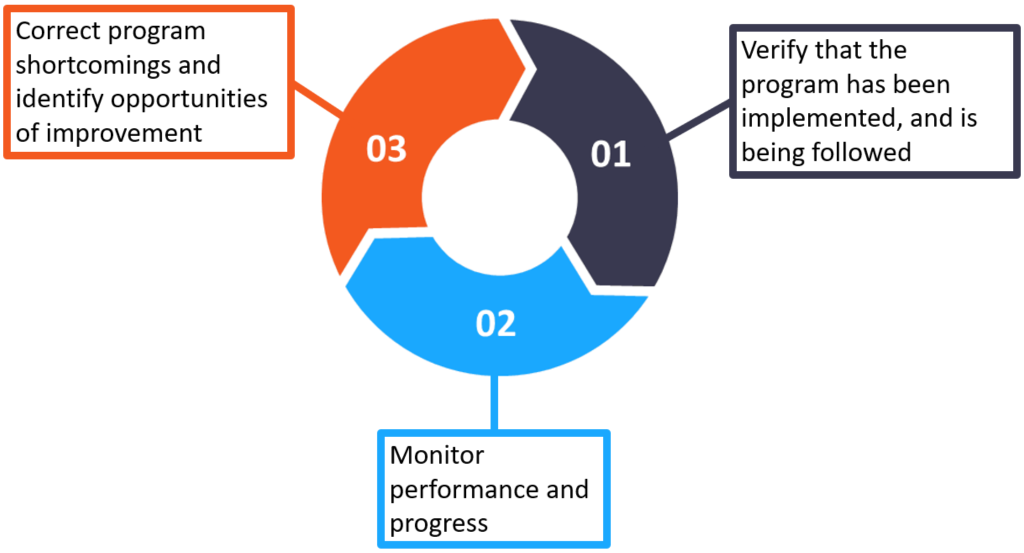


Figure 34 - Program evaluation system

2.3.12. State-of-the-art

The LOTO methodology is a subject that sees constant changes and improvements. Although the methodology has existed for a long time, new technologies and solutions inevitably change the way lockout tagout is implemented. For this reason, in Table 6 a state-of-the-art was made with the goal of assessing the most modern ways of implementing a LOTO methodology, and possible improvements that can be done as part of the development of the safety procedure.

Table 6 - State-of-the-art for LOTO

Authors	Work description
Bulzacchelli, et al [76]	The LOTO standard was created by OSHA with the goal of preventing injuries and protecting workers when engaging with machinery and energized equipment. This study had the objective of assessing the impact of the LOTO standard on machine-related injuries rates. Data obtained from the National Traumatic Occupation Fatalities Surveillance System showed that, in the ten years prior to the LOTO standard taking effect, the number of machine-related injuries per 100,000 workers was declining an average of 0.1% every year, while non-machine-related injuries experienced a decline of 2.8%. However, in the nine years following the implementation of the LOTO standard, the rates of machine-related injuries declined more significantly, experiencing an average decline of 3.5% per year, while non-machine-related injuries experienced only a decline of 1.9%. The comparison then seems to indicate that the implementation of the LOTO standard had an impact in decreasing machine-related injuries.

McCann, et al [77]	With the goal of evaluating the causes of electrical-related injuries that occur during construction operations, which is the fourth leading cause of death among workers in the construction industry, this study compiled data on electrical injuries identified by the *Census of Fatal Occupational Injuries* (CFOI) and the *Bureau of Labor Statistics*. The data indicated that the main cause of electrical deaths and injuries among workers was direct exposure to electrical current, accounting for 53% of all electrical-related deaths in the construction industry, which encompasses contact with active electrical wiring, equipment, arc flashes and light fixtures, while non-electric worker's main cause of electric-related death was contact with overhead power lines. The study finalized by concluding that many of these injuries could be easily avoided if a LOTO methodology had been implemented, protecting workers from engaging with active and energized equipment.
Kim, et al [61]	Non-routine work can sometimes be overlooked during the development of a safety procedure, since its infrequency can lead to less available data and a lack of awareness of the risk. This study evaluated 203 cases of accidental deaths caused by jamming or crushing during non-routine work, that occurred in South Korea's manufacturing industry, with examples including the automotive and shipbuilding industries. The analysis classified non-routine work as maintenance, inspection, repair, replacement, adjustment, cleaning, and removal. In the analyzed cases, 56.5% of jamming accidents occurred during non-routine work, in a variety of different manufacturing equipment, with 84.2% of the analyzed accidental deaths occurring due to failure to fully comply with basic safety rules, or not turning off and blocking powered equipment, as is indicated in a LOTO methodology. The remaining 15.8% was caused by the equipment being turned back on, while another worker was engaged repairing or inspecting the equipment. The study ends by proposing various preventive measures that can be taken to prevent accidental deaths during non-routine work.
Delpla, et al [78]	This case study used machine learning to generate LOTO sheets, based on already existing data. Currently, these sheets that guide workers through the process safely are manually generated and can be very labor intensive when applied to a vast amount of different equipment. Machine learning could then help in speeding up the process of developing these sheets, aiding in gathering and processing a useful database, but also potentially being able to output a more detailed and specific procedure, by only relaying relevant information to the equipment in question, increasing the clarity of the process, and reducing errors and accidents. The authors successfully developed a system that can read the database comprised of the LOTO sheets, outputting the devices that need to be locked, and instructing how to secure them correctly, based on the name of the machine. However, the authors did not manage to develop a program capable of automatically generating the information needed to implement a LOTO procedure, based only on information given by the tested equipment.

Karimi, et al [79]	In this study, a questionnaire composed of 15 questions was performed on 14 Canadian companies. The question pertained to hazardous energy control methods, as is mandated by safety standard and regulations found in the north American region. However, since the standards and regulations only provide general guidelines, the companies were also questioned on the usage of specialized LOTO equipment, such as padlocks, interlocks, warnings, safety procedures, and other safety tools. This procedure aimed at assessing which methods proved to be more effective at controlling hazardous energies, as well as studying the conditions surrounding the implementation of LOTO procedures in Canada. The study found that, while all the companies had understanding of LOTO methods, only 28.5% of them saw any practical implementation and usage of specialized LOTO equipment, calling for an increase in knowledge about lockout methods and regulations, and for an increase in the risk assessments carried out before the implementation of safety solutions.
Karimi, et al [80]	Although some companies have managed to implement safety procedures, these organizations still experience a relatively high number of accidents caused by the release of hazardous energies, which may indicate companies are experiencing difficulties with the practical implementation of a lockout procedures, and the usage of blocking equipment. In an attempt to understand how organizations are implementing lockout methodologies, and if they follow the relevant standards and regulations, 13 Canadian companies were studied by conduction group interviews, and reviewing the documentation and the workplace conditions in each studied company. The study found many shortcomings in the analyzed companies, with the main ones being incomplete LOTO programs; missing steps in the LOTO procedure; and failure to read placards or warning signs. The study also provided some recommendations for addressing or solving the shortcomings found in the organizations.
Kumar, et al [81]	With the goal of reducing the cases of electrocution and machinery-related injuries, which are often caused by improper use of hazardous energy control procedures, a LOTO methodology was planned and carried out in an Indian company, manufacturer of construction equipment. They began by first selecting a group of equipment to implement the methodology, developed several control devices for the equipment selected, and finalized by implementing the changes, and evaluating its impact. The study found the implementation of the LOTO methodologies effective, with the company going from experiencing an average of 7 safety incidents per year, from May 2011 to April 2018, to experiencing no safety incidents from May 2018 to April 2019.

3. DEVELOPMENT

3.1. Characterization of the company

Colep Packaging is a manufacturer of packaging solutions for various products, situated in Vale de Cambra (Portugal), and founded in 1965, seen in Figure 35. The company specializes in the production of aerosol cans, industrial cans for the transport of materials, food cans, and plastic packages. Although this factory is considered to be the headquarters of Colep Packaging, they currently own another two packaging manufacturing factories, with one of them being situated in Navarra (Spain), and another one in Kleszczów (Poland). In 2000, Colep was bought by the RAR group, now belonging to their expanding portfolio of companies.

Originally, the company Colep both produced the packaging, and filled certain types of cans, like aerosol and cookie cans. But as of 2021, the company was split into two distinct entities, with Colep Consumer Products focusing on filling and delivering packages, while Colep Packaging specialized in packaging manufacturing.

Figure 35 - Colep Packaging [82]

Colep Packing produces generic cans that can then be tweaked according to the client's specification, as showcased in the 2.2.1 section of this dissertation. The cans are then sent to the client, or an associated company, to be filled with whatever product the can was designed to carry. The company produces a wide array of can sizes and shapes, as seen in Figure 36, for a variety of clients and industries, such as producing cookie cans for Dancake, aerosol cans for WD-40, and paint cans for CIN.

Figure 36 – Sample of cans produced at Colep Packaging

3.2. LOTO implementation

The first stage of this dissertation consists of an analysis and improvement of the general safety measures and tools used by the company, following the diagram showcased in Figure 37, with the goal of improving the safety systems, in order to implement an effective safety procedure. Firstly, a general analysis of the safety measures and procedures used by the company was conducted, as well as a study of the safety standard the company wishes to comply with. This procedure was done in order to understand what kind of safety measures and tools are available, and are actively being used at the company, which is essential for the development of the safety procedure. Following the analysis, problems with safety measures will be identified, and then solutions developed to resolve or minimize those problems, as well as resolving problems already identified by the company that are yet to be resolved.

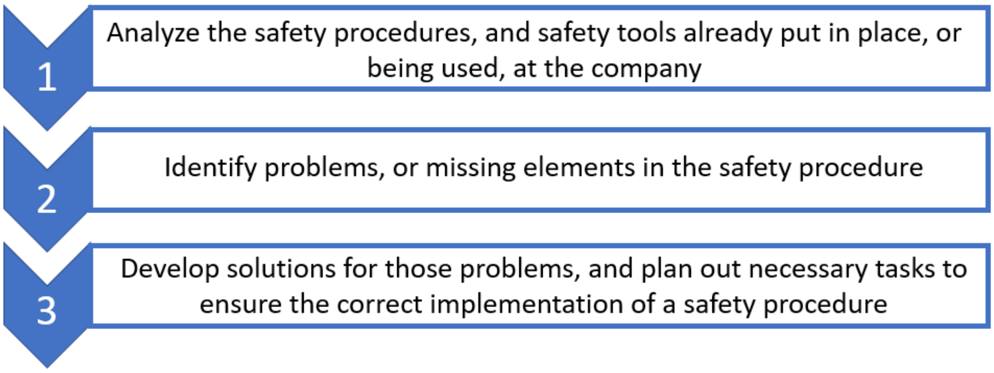


Figure 37 – Diagram of the analysis run on the safety measures

Following that, the development of the safety procedure for each equipment will follow the diagram seen in Figure 38. It begins with a general analysis of the equipment, identifying the tasks that the machine resolves, and the types of energy and systems used. After the equipment has been adequately analyzed, an assessment of the actions and tasks performed by all types of workers who engage with the machine is carried out, in order to better grasp the types and severity of dangers that can occur as part of engaging with the equipment. Additionally, this assessment also aims at minimizing or suppressing any negative impact the development of safety solutions can have on the speed and quality of work, by developing solutions that better integrate the regular workflow. Then, based on the identified problems or improvement opportunity, there will be a development and implementation of solutions, with the goal of increasing safety, and making possible the implementation of a LOTO procedure. Once the equipment has been fully analyzed, and requirements for implementing a LOTO methodology have been met, a safety procedure of the equipment will be developed, tagging the relevant locations, and detailing the procedure for resolving a variety of relevant tasks. To conclude, a measurement of improvement and cost analysis will be made, as an aid to identifying possible future improvements for this process.

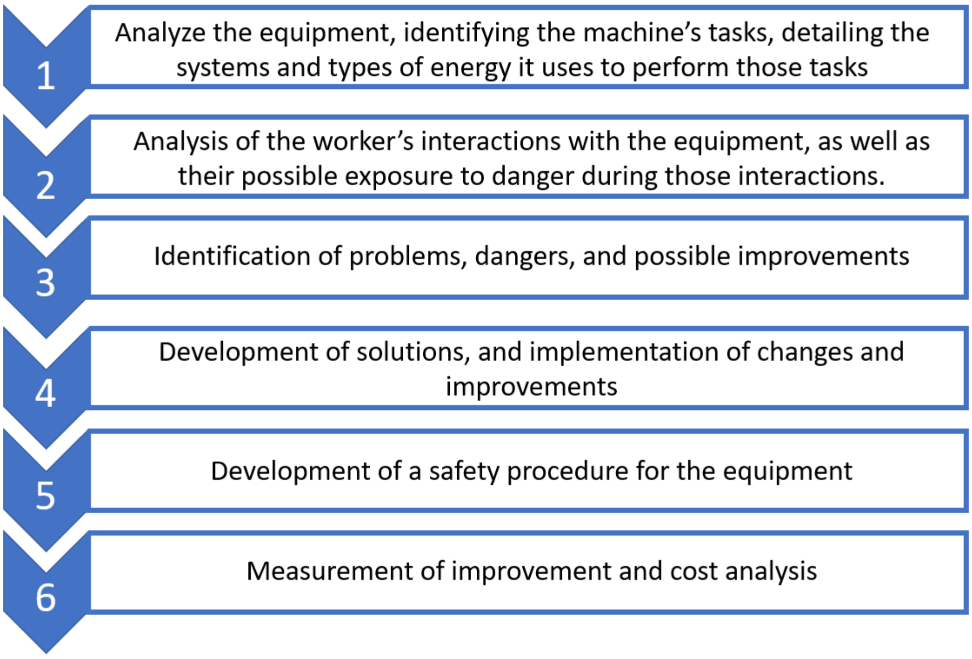


Figure 38 - Development of the safety procedures for each machine

The analysis of tasks and energy sources was done by cataloging every situation in which a worker engages directly with the equipment, assessing the danger associated with the action, and the types of energies involved. To that degree, each action, or task, was analyzed under the following parameters described in Table 7.

Table 7 - Parameters used in the analysis of the tasks and sources of energy

Category	Description
Level	Categorizes the task into one of the five "LOTO Levels", based on the severity of the intervention, and on the type of locking and safety method needed.
Activity	Categorizes the action as falling under a type of activity, such as machine setup, maintenance, cleaning, and many other activities essential for the normal operations of a factory, and equipment.
Main dangerous	Describes the causes of injury or harm, that can be brought about as part of performing the action, or task.
Main risks	Describes the main types of injuries or harm that can occur while performing this action, or task.

Identified energies	Identifies the energies involved in the task.
Energy/control	Categorizes the energy involved in the action, as either independent or shared. Independent energies must be controlled and checked on their own, while shared energies, like electric or pneumatic energy, and be part of a wider system.
LOTO devices	The blocking equipment needed to block the energies, in order to safely perform the action, or task.
Safety position	Describes the recommended safety position of the equipment, if it has any.
Energy blocking points	Describes the energy sources that need to be blocked, in order to perform the task, referencing the tag numbers of the energy sources.
Verification/ improvements/ commentary	Additional spaces to add any relevant information, or comments for future improvements, or note keeping.

In order to increase the comprehension and readability of the safety procedure for each equipment, the procedures are divided into four sections. The first section showcases all the blocking points, as well as their associated tags. The second section contains a table, in which each task comes with a procedure on how to perform the task, which points need to be blocked and their associated tag, the method of blocking, the LOTO level of danger, and additional relevant information, possessing all the information a worker might need to safely perform any given task.

The third and fourth sections were designed as part of this dissertation and were not previously implemented in the company, at the beginning of this dissertation. The third section was added to improve clarity and showcase the various blocking solutions, summarizing the various blocking points used, and their respective methods of blocking, this time being accompanied by pictures, serving as an additional reference and guide, to further explain the different blocking methods workers might need to use. The fourth and final section consists of a simple fillable empty page, in which workers can write notes or warnings, such as informing of changes to the machine's systems, or pointing out tasks accidently left out of the safety procedure. This final section then serves as an easy way workers can document needed changes or updates to the safety procedure, hopefully aiding in the communication and sharing of information between the various individuals that engage with the equipment, and the people in charge of developing the safety procedures, helping to correct mistakes and updating the procedure when needed.

The LOTO levels of danger categorizes task into five distinct "LOTO Levels", based on the level of danger associated with the intervention, and on the type of locking and safety method needed. In regard to assessing the severity and the worker's exposure to risks, this dissertation will follow the standard data system provided by Colep Packaging, in which each task performed by workers will be categorized in one of five distinct "LOTO Levels" on the bases of the severity of the intervention, and on the type of locking and safety method needed.

To choose the level of intervention for each task, it is necessary to carry out a risk assessment of the energies present (including stored and/or potential energy) and consider the worker's exposure during the task. Table 8 identifies the safety levels of operation for the execution of tasks, both in production and maintenance, while Figure 39 showcases a diagram that can be followed when deciding the LOTO level of a task.

Table 8 - LOTO levels of intervention

LOTO level	Intervention level description	Process steps
0	This level is considered the normal operation mode of an equipment, in which there is no direct intervention by a worker.	The worker has no access to the machinery and must act in accordance with its standard worker protocol.
1	In this level, the worker has partial access to the equipment but is kept safe by automated safety systems, present in the machine.	It is assumed that protection is carried out using security interlocks which activate automatically. Therefore the worker is protected against any possible harm.
2	A similar case to the level 1, although the security interlocks are no longer capable of fully covering for all of the worker's possible actions. To ensure safety, additional blocking equipment must be placed to block the equipment's startup.	In this level, the workers must place a lockout device to stop the equipment's startup, before performing any action.
3	On this level, a proper LOTO procedure must be implemented, since the worker actively engages with the machinery, requiring the blocking and dissipation of the equipment's energies, as described in the machine's safety procedure.	To safely operate on this LOTO level, the operator must follow the safety procedure, which broadly follows these steps: - Identify and eliminate the sources of energy; - Place the padlock and tags (1 padlock and 1 key per exposed person); - Dissipate stored energies; - Verify the absence of energies.
4	Some tasks are considered high-risk and must be performed with certain energies active. These types of tasks must only be done by trained and approved professionals, and the use of caution must be emphasized.	To safely operate on this LOTO level, the operator must place warning barriers and signs, operate the machine on a step-by-step mode, and have an accessible emergency button.

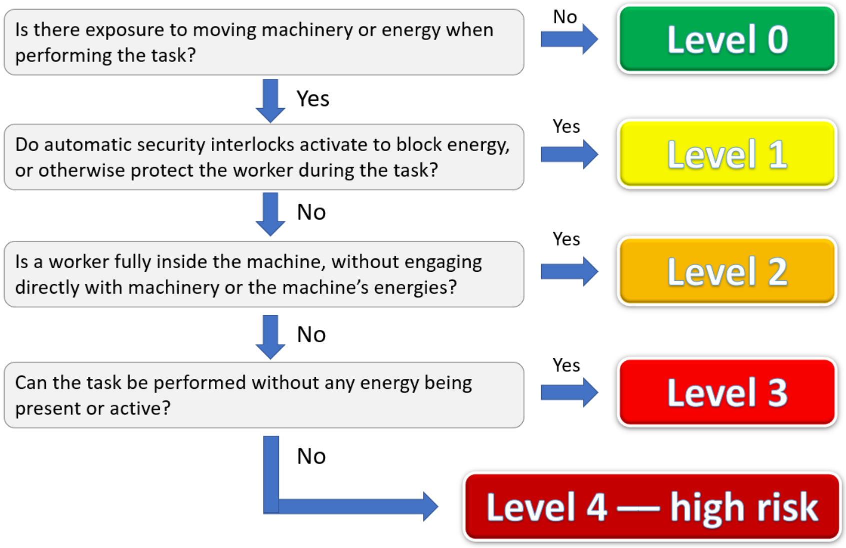


Figure 39 - LOTO levels of intervention choice diagram

3.3. Process characterization

The company produces a wide variety of different metal cans, as shown in Figure 36, with the cans varying on many metrics, such as diameter, height, shape and materials. Figure 40 shows a generic flowchart for the fabrication process of cans, which is applicable to the section of the factory relevant for this dissertation. The manufacturing process begins with a sheet of metal supplied to the company. The sheet then goes through a lithography step in order to imprint it with a pattern or image. Each metal sheet is usually wide enough to fit multiple cans on it, and is thus sent to a stamping machine, where the printed sheet is cut, separating each can pattern into individual sheets, who will later be used as the main body of the can. Once the sheets have been separated, a machine will then bend the sheets, and weld it's edges together, forming a hollow cylindric can. Finally, a bottom, lid or ring is clinched to the cylindric sheet, manufacturing a metal can. Alternatively, a handle can also be welded to the can, to aid in transporting the can.

Additionally, the lids, bottoms and rings that are clinched to the can are also manufactured at the company. In this phase of manufacturing, the metal sheets instead of going through a lithography step are directly sent to a punching machine, where the sheets are cut to acquire the necessary shape to advance to the next manufacturing phases. From there the sheets go through several stamping and punching phases, where the sheets are cut and deformed into metallic components with relatively complex shapes. These metallic components will then be used as the rings, bottoms and lids of the manufactured cans.

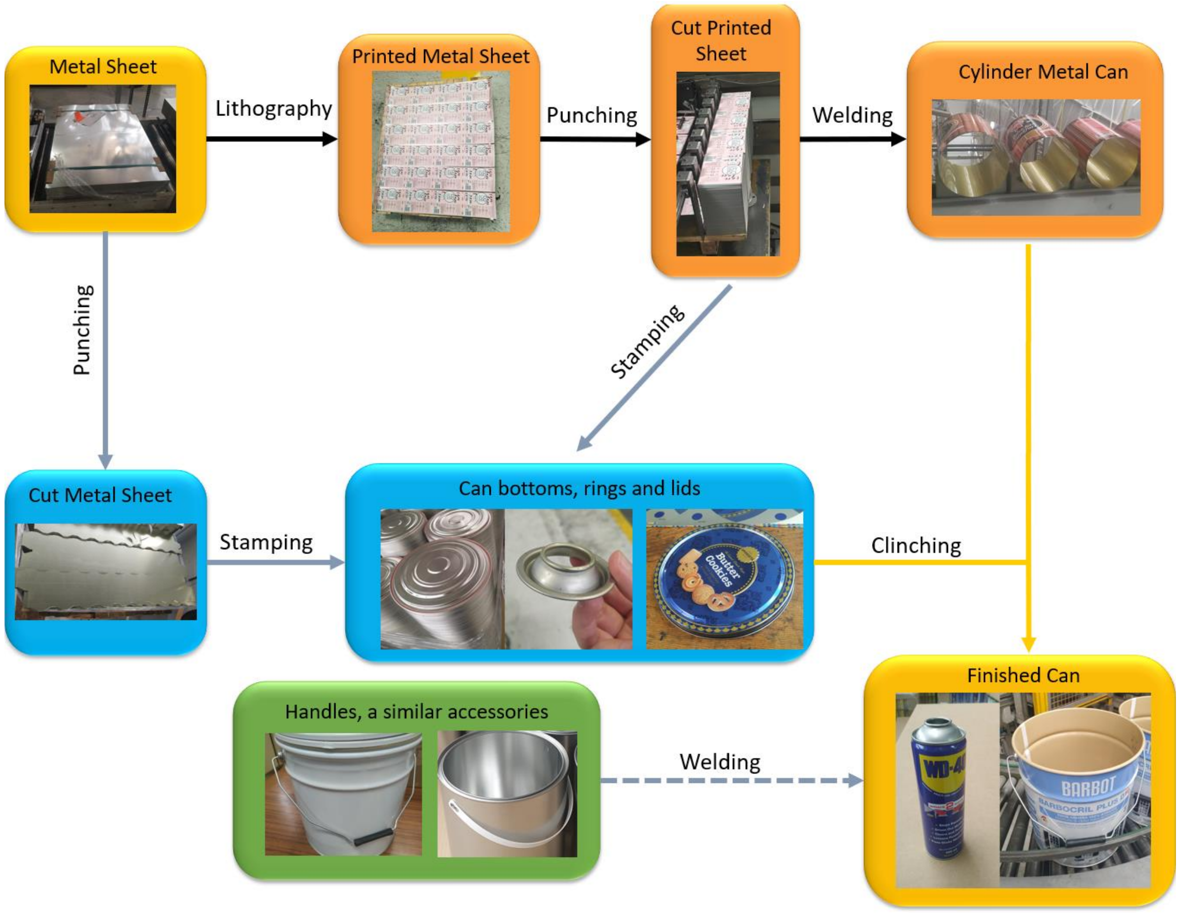


Figure 40 – Process characterization flowchart

3.4. Problem quantification

The topic of this dissertation was brough about by the company's desire to increase safety in the workplace. Currently many of the injuries that occur in the factory can be traced back to an unexpected release in energy, which causes sudden energization of mechanical systems, which can then lead to a variety of accidents and injuries. Whether during maintenance or when servicing mechanical equipment, controlling the energies involved in these systems becomes essential to protect workers.

In order to control the energies found all around the factory, the company decided to implement control equipment and safety procedures, according to a LOTO methodology, as to aid and provide the necessary tools for workers to safely control and block energies. But one of the main hurdles in developing safety procedures is the relative complexity of creating a safety procedure a variety of distinct manufacturing equipment, and in the relative recency of the LOTO project in the company. Although the organization has put in place many safety regulations, and trained workers on how to engage with the equipment, the act of formally creating documentation and safety procedures based on LOTO methodologies is a very recent occurrence in the company, still requiring some preliminary work as to allow for the implementation of such methodologies. Additionally, the factory has manufactured cans since 1965, experiencing changes and growth throughout its existence, creating a very complex and interconnected environment, as well as the possible need to change old or outdated mechanical system that negatively impact workplace safety. Therefore, additional problems emerge:

1. Lack of necessary equipment and systems to successfully develop and implement a LOTO methodology;
2. The variety and complexity of all the equipment will require a thorough analysis of each individual equipment and systems;
3. Required data may be missing, or in need of being gathered, especially for older systems that have not seen recent changes or updates, with examples including the location of relevant blocking points, list of tasks performed on the machine or datasheets on relevant equipment;

These methodologies and procedures are assumed to eventually see wide implementation, therefore it is important for the procedures to be as effective as possible, and to attempt to standardize the procedures as much as possible, reducing complexity and confusion, all the while making sure the solutions provide safety with minimal negative impact on the flow of production.

3.5. Specifications and limitations

The objective of this dissertation is to create an effective safety procedure for three industrial machines, increasing safety and making resolving tasks safer and clearer. However, there are some notable limitations:

- Negatively impacting the general workflow and production output of the equipment, as a result of LOTO implementation, must be avoided. Although some possible minor negative impact can be expected, especially in situations of extreme danger, these should be carefully studied and avoided, as to preserve the performance and output of the production lines;
- Although a general analysis of the safety procedure and methods found in the factory was conducted, only the three machines that will receive a safety procedure as part of this dissertation received a focused analysis, with the remaining machines present at the factory being out of the scope of this dissertation;
- This dissertation was relegated to a duration of 9 months, which limits the total time spent on any one facet of this project;
- The safety procedure was also limited by the suppliers available to the company. Although the creation of customized equipment/parts can be expected as part of this project, more complex and specialized tools might require a supplier able to provide the solutions needed to meet the needs of the LOTO methodology, especially if a vast number of these tools are required, or might be required in the future.

3.6. Brainstorming of improvements

In order to increase safety in the workplace and reduce the number of accidents caused by an unexpected release of energy, it is necessary to implement ways of controlling them. Although there are many ways to block or control these energies, they must be studied for their practicality and impact on the manufacturing process, with factories possessing very complex and expensive systems, and a production flow that must be preserved and maximized.

Pertaining to the blocking procedure, it would be convenient to simply block the energy at its source whenever the blocking is required. This approach not only guarantees that the entire system is deenergized, since the source has been blocked, but a single point of blocking leads to a very clear and straightforward blocking operation. However, many machines often share the same source of energy, like pneumatic energy that uses a central pipe to distribute the pressurized air and may be operating or receiving maintenance at different times, requiring one machine to be active and producing, while the other must turned off and deenergized. If only a single point of blocking is used for a variety of machines, such disparities in active and inactive machine times will negatively impact the workflow, since inevitably one machine will stop its production only because it shares a source of energy with a machine that must be turned off. It is then best to approach blocking on an individual bases, assuring that there are as many blocking points as needed to maintain safety and flow of production. But the existence of many points of blocking also calls the need for specialized systems to block the various points of energy, since they must both be able to be blocked, or otherwise deenergized, while also making sure only the workers in need of blocking the energy are able to remove the block and start the system once again.

The LOTO methodology then offers an effective solution for standardizing the blocking of various different equipment, with individual locks and keys offering a physical barrier that can only be removed by the owner of the lock, being the worker who wishes to block the energy. Then, each equipment needs only to accommodate blocking via a lock, which can often be achieved with minimal changes to the original equipment, thus allowing any worker who possesses a simple lock and key to block and engage with the system.

Additionally, workers can simply receive training on how to use the blocking equipment, and how to block specific machines, providing the knowledge needed for workers to control energies. However, machines often possess complex systems that require study and analysis, and even workers who had formal training on how to engage with the machine, may forget or make certain mistakes. Safety procedures then offer an aid in engaging with a specific equipment, and its blocking systems, by documenting the analysis and showcasing the systems workers are provided with a handy guide on how to conduct their task safely, which they can go back and refer to at any time.

3.7. Tagging system development

As detailed before, equipment and machinery has grown more complex and interconnected, leading to complex work environments to navigate, and higher chances of errors occurring. Tags then become a very useful tool at guiding and educating workers engaged with the machinery, by signaling and relaying relevant information of various kinds, such as labeling the equipment, indicating sources of power, or notifying danger. This is mostly achieved by making use of warning devices, signs and pictograms, that are capable of relaying information in a quick and attention-grabbing manner [83]. These tagging systems can even be seen even outside work related environments, such as the symbols seen in chemical products, electrical signs that indicate risk of electrocution, or safety signs indicating that the floor is slippery, and thus, people passing by must tread with caution.

Tagging, by its very nature, is only meant to relay information, and does not provide any physical barriers or restraints. Thus, tagging can evoke a false sense of security, making workers believe they are protected when the equipment is still able to be re-energized, whether due to error, or negligence. However, when used as a complement to a lockout procedure, it becomes an indispensable tool for alerting and guiding workers through their servicing process in a safe manner.

3.7.1. Description of the tagging system found in the company

At the start of this dissertation, the company in question had already adopted a tagging system. This tagging system delineated three main types of energies in need of being controlled:

1. Electric, exemplified in Figure 41 1) with the color red and the letter “E”, represents the electric energy that powers many of the machinery found throughout the factory, and many other electric appliances. This electric energy is distributed through an electric grid that encompasses the entire factory, beginning with a central energy input, which is then disseminated to all the needed equipment using cables and switchboards;
2. Pneumatic, exemplified in Figure 41 2) with the blue color and the letter “P”, refers to the pressurized air that many machines use in their manufacturing sequence, as part of their pneumatic mechanisms. Similar to the electric energy, the pressurized air also operates under a grid that covers the entire factory, beginning with a system that compresses air and then sends it through a central pipe that runs through the entire factory. Each machine or line of production then possesses a connection to the central pipe, allowing the pressurized air to reach the needed regions and equipment;
3. Mechanical, exemplified in Figure 41 3) under the yellow color and the letter “M”, refers to the innerworkings of each individual machine, possessing mechanical parts that operate in motion.

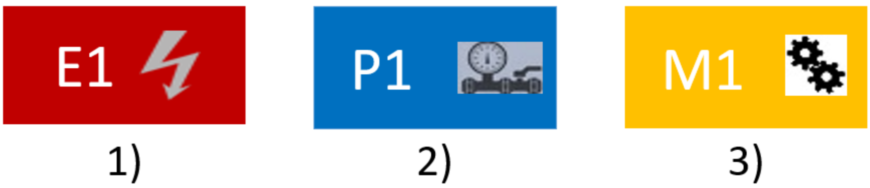


Figure 41 – Tagging examples

The tags are then used to signal the location of the equipment, or section, that is used to block its respective energy. But since energies can be interconnected from place to place, such as the electric and pneumatic energies that operate under a factory-wide grid, it is important for the tags to also indicate the sequence of the transportation of energy, helping workers identify which energy blocking mechanism they need to use for their particular task. To this degree, the tags also come with a number, starting from 1 to indicate the original energy source, that then goes up by 1 on any derivative energy points, as exemplified in Figure 42. Thus, if a worker wishes to safely operate on an equipment or system getting its source of energy from E2, for example, the worker can block E2 or E1 to ensure no energy reaches the equipment being operated on. Alternatively, if the worker is operating directly on the E2 equipment instead, such as to repair a damaged cable, the worker must block E1, ensuring no energy reaches E2.

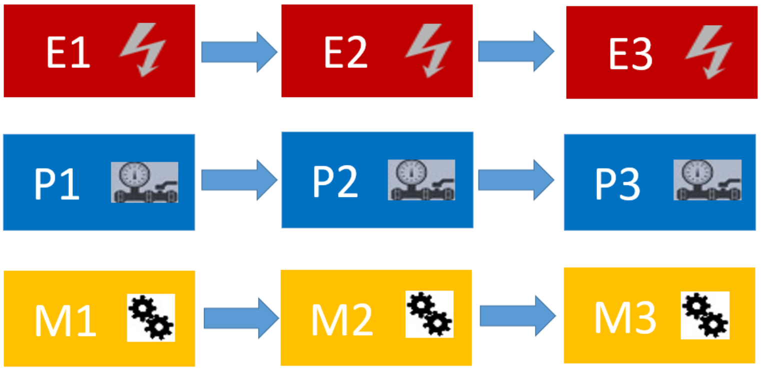


Figure 42 - Tagging system sequence

3.7.2. Problem quantification

The tagging system that was already implemented at the company is simple and easily understood. However, due to its simplicity it is only applicable to linear, and localized sequences of energy. The mechanical tags, for example, are able to operate under this system, because each machine typically, operates independently of each other, possessing their own moving parts and functionality, with mechanical energy being contained within each individual equipment.

The pneumatic tags are also able to operate under this system, although it operates on a grid that covers the entire factory, each pneumatic section is mostly self-contained, supplying only a handful of machines in a given area, and operating under a very visible and direct sequence of valves and pipes, being easily identified, even to an untrained eye. All of these pneumatic sections are then supplied by the same central pipe, which allows the pressurized air to reach any place in the factory.

However, electric energy is much harder to perceive, being carried on cables and switches who are often obscured, or deliberately hidden, making it hard even for trained personal to accurately ascertain were the electric energy is going, and from where it is coming from. Moreover, electric grids are very complex, possessing a variety of divergences, which span entire factories. The goal is then to improve the electrical tagging system, in order to accommodate changes in the electrical grid, and future expansions.

3.7.3. Tagging system main requirements

In order to improve the electrical tagging system, its important to begin by accessing the main goals of the tagging system, and what roles it must fulfill. For the purposes of this dissertation, the tagging system is going to be used as complement to the lockout procedure, being mainly used in locks to identify the worker(s) currently blocking the source of energy and servicing the machine, as well as labeling the equipment/energy blocking point, and signaling its position. Therefore, for the tagging system to be effective, he must perform well according to the following criteria:

- Be clear and attention grabbing;

- Signal the location of a blocking equipment, as well as the type of energy being blocked;
- Be able to relay the required information, while still being quickly understood;
- Allow for expansion or changes to the equipment/line of production.

According to these metrics, the previous system fails in relaying the required information, since by only using one number to represent a direct connection between equipment and its various points, inevitably different blocking points will possess the exact same tag, which will create unnecessary confusion, and an ineffective tagging system. These problems don't manifest in the pneumatic and mechanical energies, since each segment of each system is mostly localized and isolated, while the electric system operates on an expansive grid, possessing numerous derivatives, and blocking locations very far apart from one another, being hard to ascertain the exact location of the equipment's blocking point.

To create an effective electric tagging system, an analysis of the electric grid present at the factory must be done to understand the grid's layout and operating, more specifically, the section of the grid that pertains to the scope of this dissertation. Figure 43 showcases a diagram on how the electric energy is divided throughout the company, beginning with a set of transformers that receive the electric energy, and divide it among the various main electric switchboards found in the company. The zone of the factory that falls under the scope of this dissertation possesses four main electrical switchboards, with three out of the four switchboards belonging to the "Assembly" section, while the fourth belongs to the "Stamping" section (being called "Montagem" and "Estampagem" in Portuguese respectively). From the main electrical switchboards, the electric current then either goes directly to a machine's switchboard, supplying that machine with electrical power, or to a localized switchboard, transferring the current to a variety of other machines.

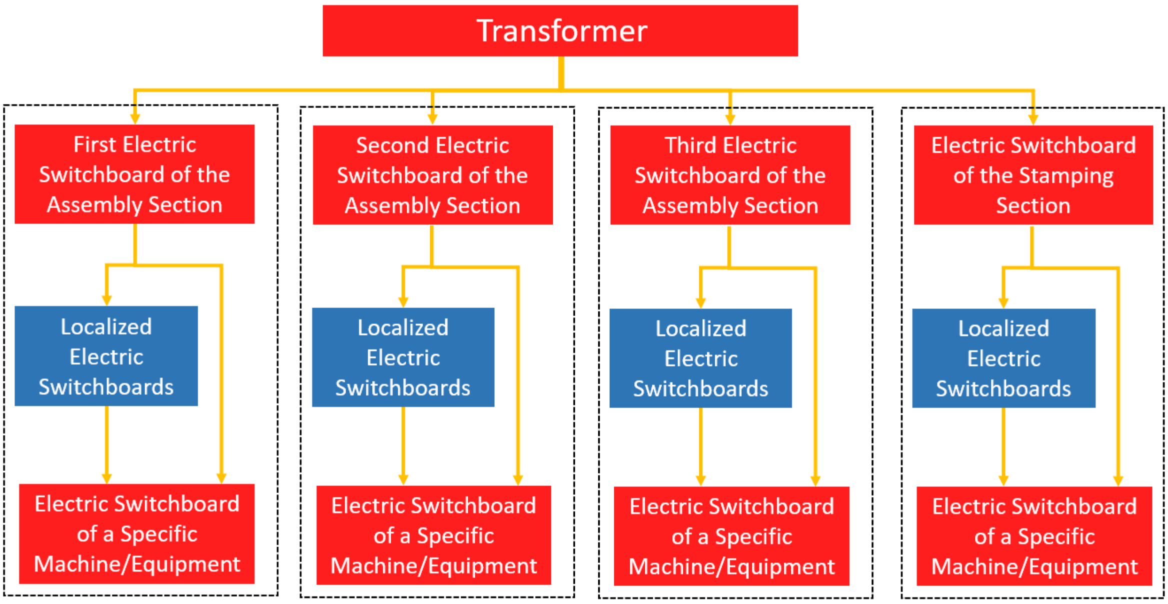


Figure 43 - Energy sequence diagram, as found in the company

The tagging system must also avoid repetition of the same electrical tag, and clearly identify that specific machine/equipment, and only that specific machine/equipment. To this degree, a sequence of numbers could be used to identify each equipment, creating a logical code that both allows for the certainty that the same code is not repeated between machines, while also possibly giving information on the sequence and path of the electrical current. As such, the first iteration of this system is showcased in Figure 44.

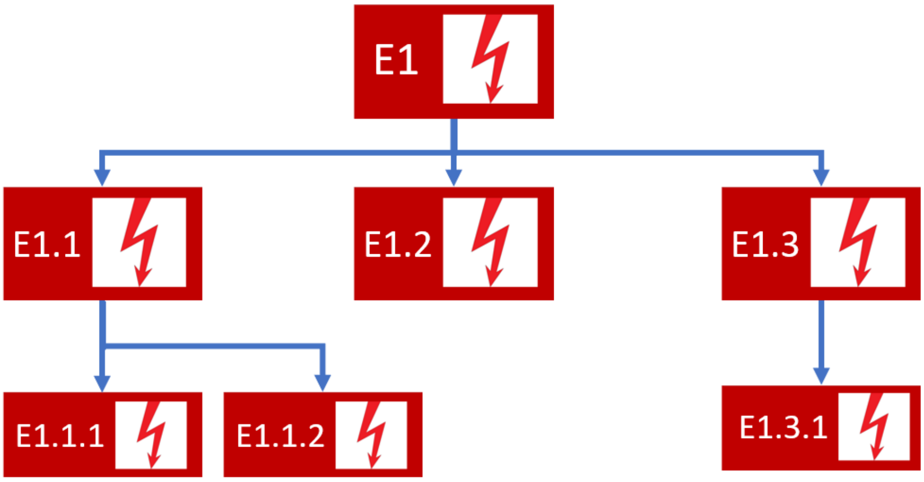


Figure 44 - First iteration of the tagging system

In this system the "E" and the color red were kept to represent the type of energy being controlled, which in this case represents electrical energy. Nonetheless, a series of numbers following the letter "E" were added to tag that specific equipment. If, however, the equipment then transfers electrical current to another derivative equipment, the derivative equipment will keep the same tag as its source of current, with an added number on the right side. In the case the same equipment transfers current parallelly to more than one equipment, the added number will be different for each derivative equipment, we generally being at the number one, and then increase it by one for each other parallel derivate equipment. All the numbers on the tag are separated between each other by using a dot. This procedure allows for clear and unique identification of each equipment, while also allowing for immediate knowledge of the sequence of the current, since, for example, if a worker wishes to operate the equipment tagged with E1.1.1 in Figure 44, the worker can immediately understand that the device to block the electrical current suppling the equipment can be found in the equipment tagged E1.1, with the same principle applying to all the other tags. Additionally, changes to the grid are easily accounted for, if a new equipment gets added or removed, simply a new tag with a different number is added or removed respectively. Any tags pertaining to derivative equipment may also need to be updated, in the cases where the sequence of the electric current is changed.

Other identification methods for the sequence were proposed. Table 9 showcases some of the ideas proposed to the company, and the rejection reason, as a pivotal part of the tagging system.

Table 9 - Brainstormed improvements

Thought of improvement	Reasons against their implementation
Using "/", ";", or ">" to separate the numbers instead of "."	The full stop emerged as the most effective separation method, being less visually intrusive, which led to a clearer visual separation, allowing the numbers on the tag to be more pronounced and highlighted, which are the carriers of the relevant information.

Using a conjunction of separating symbols, to delineate specific areas of the factory, or other properties of the equipment. Considering E1.2/1 for example, which uses both "." And "/" to separate the numbers in its tag.	Using a combination of more than one symbol to separate the numbers on the tag was considered unnecessary complex, since the possible benefits did not outweigh the added complexity that having two number separating systems would bring to the tag.
Using letters like A, B and C instead of numbers.	Numbers were deemed better at demonstrating a clear sequence and being immediately discernable.

One of the immediate flaws of this system was the relative abstractness of the numbering system in the tags. Although the numbering sequence clearly identified the equipment, the large string of numbers was not only daunting at first look, risking easy confusion, but also did not provide any immediate information on the type or location of previous equipment, leaving it up to acquired knowledge of the tags nomenclature, or the use of the specific safety procedure. To that degree, letters were added to the system, to grant additional information to the tag.

As it can be seen in Figure 45, once the electric current reaches a line of production or individual equipment, it is transferred in a mostly linear manner, with the problem mainly lying before that, where the great variety of switchboards distributed all around the factory create various different connections, increasing the grid's complexity, and making the exact and full path of the electrical current extremely hard to ascertain, without the careful use of a proper guide. And so, five "levels" of electrical transference can be identified, as seen in Figure 45.

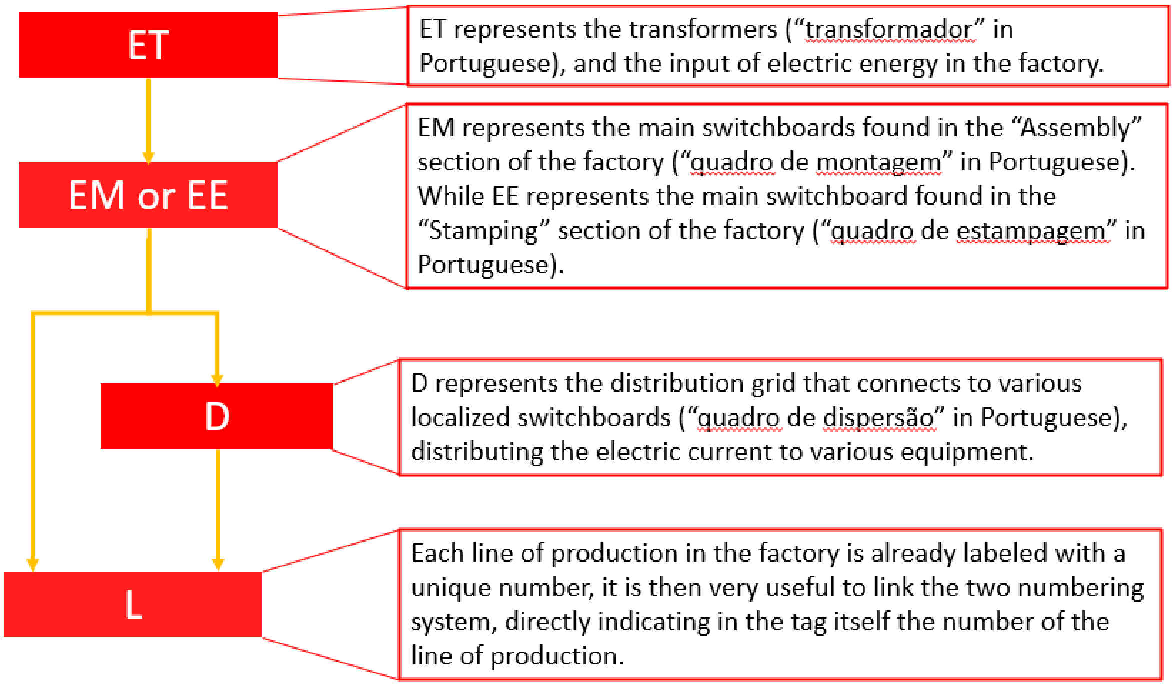


Figure 45 - Tagging letter

There is more than one main switchboard in the assembly section of the factory. As such, a number following the EM will further identify each specific switchboard. While there is only one main switchboard in the stamping section, it is important to anticipate changes, and provide a number to the switchboard in the stamping section. The transformers were also removed from the tags, due to the fact that the connection between the transformer and the main switchboards are much fewer in number, since the connection between the transformer and the respective main switchboard is direct and highly visible, being rarely worked on, and always operated by extremely specialized and technical personnel. It was then deemed worth it to remove that information, which is mostly unneeded, in order to create a clearer tag. The product of the addition of the lettered tags can be seen in Figure 46.

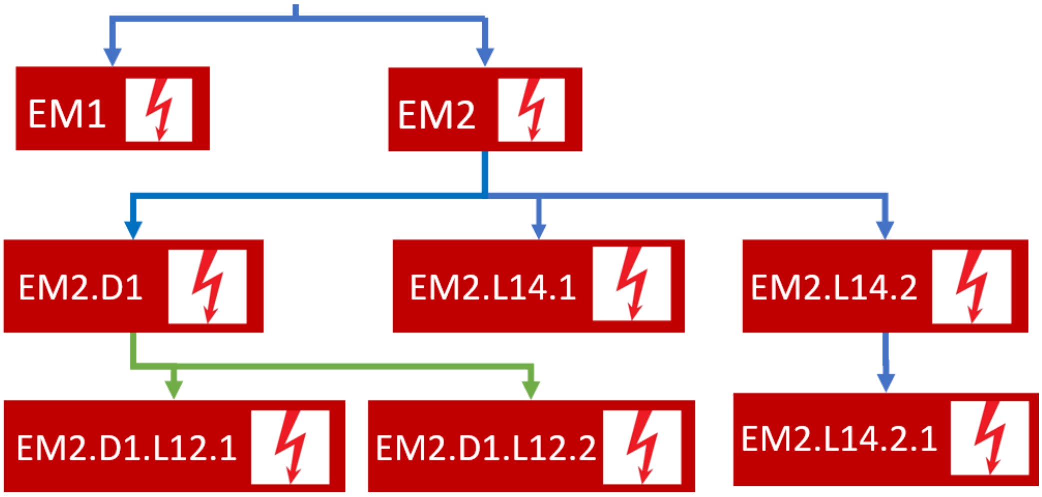


Figure 46 - Second Iteration tagging system development

As can now be seen, the letters help identify the type of equipment, while the numbers specify a singular equipment. So, using examples from Figure 46, if a worker wishes to block the electrical current coming to the equipment tagged EM2.L14.2.1, without even needing a guide, the worker can immediately discern that to safely block the equipment he must block the equipment tagged with EM2.L14.2, which can clearly be found in assembly switchboard tagged EM2. Likewise, if the worker wishes to work on the EM2.D1.L12.1 equipment instead, he must block the energy coming into the EM2.D1 , a localized switchboard, which the worker can do by going to the EM2 switchboard.

3.8. Acquisition of equipment

Over the course of this project, various types of equipment and locking solutions were needed to efficiently develop the safety procedure for each type of equipment. However, there was some general equipment and systems needed on all the equipment worked on, as part of this project. As such, before the development of the safety procedure on each line of production, the gathering of the required equipment will be showcased.

3.8.1. Circuit breaker and switch lockout

Circuit breakers are an important part of any electrical system, or grid. These devices are used in an electrical system to protect it from harm brough about due to power outages, which are typically caused by overcurrent circumstances, such as overloading or short circuit. The circuit breakers' ability to reset after interrupting the circuit is one of their key features, although operating as a switch is not its main purpose. Actually, in a factory environment they often serve both as a protection device, and an electrical switch. Circuit breakers come in a variety of shapes and sizes, from small devices that protect a home's electrical system, to massive devices that safeguard the high-voltage current that supplies an entire city or factory.

Due to these characteristics, circuit breakers are widely used in all electrical systems found in the factory and constitute the main way the current of the electrical grid is blocked and controlled. Circuit breakers can be found in all the switchboards, and in many of the equipment. However, two main problems were identified with the electrical system, for the purposes of developing a safety procedure:

1. At the beginning of development, there was no equipment capable of supporting LOTO methodologies, and reliably blocking any of the circuit breakers;
2. The great quantity and variety of circuit breakers found in the factory complicated the acquisition of a LOTO equipment, since it was highly unlikely that any singular blocking solution would be appropriate for all the circuit breakers.

Before acquiring or developing blocking solutions for the circuit breakers, it is important to first catalogue and evaluate the types and quantities of the various circuit breakers found in the zone of the factory under the scope of this project. The resulting catalog can be seen in Appendix A, but a more comprehensive summary can be seen in Table 10.

Table 10 - Electrical devices catalog

	Circuit breaker			Electrical switches			
	Type 1	Type 2	Type 3	Type 1	Type 2	Type 3	Type 4
							
Number of Components	4	37	66	28	5	6	10

As can be seen, there are many shapes and sizes of both circuit breakers and switches, requiring a careful analysis of any proposed blocking equipment, since it preferable to use as few different blocking equipment as possible, as to standardize the process among the various switches and circuit breakers. It is also important that the switches and circuit breakers possess reliable blocking equipment, capable of assuring that the electrical device cannot energize the system. For the scope of this project, it was chosen to only focus on the circuit breakers, since these are the ones more directly tied to the manufacturing equipment, and no satisfactory blocking solution was found.

To acquire the blocking equipment two companies were contacted, Brady and Comprose, with both companies providing samples and suggesting their own solutions, based on the company's demands. Brady is an American corporation specialized in technical equipment, and was the first to provide samples, which can be seen in Table 11. None of their products ended up being chosen for use in this project, but the description and reasons for their rejection is provided in Table 11.

Table 11 – Rejected equipment

Photo	Equipment's description, and reasons for rejection
 *Figure 47 – Rejected circuit breaker – type 1 blocker [73]*	Used to block type 1 - circuit breaker. This equipment locks the switch in its place by locking its movement to a stationary indentation near the switch. Once closed, a lock can be placed in the available space, preventing the switch from moving. However, the equipment was rejected due to its necessity of a nearby indentation, with which to lock the switch. Since the type-1 circuit breakers did not possess such an indentation, the sample provided by the supplier proved to be unable to block any circuit breaker.
 *Figure 48– Rejected circuit breaker – type 1 and 2 blocker [73]*	Circuit breaker used to block circuit breaker – Type 1 and 2. In this equipment, additional support pieces are added to sides of a switch, supporting the placement of a lock and stick, thus blocking the movement of the switch. This solution was rejected, due to the impracticality of adding these support pieces to all the switches, since there are a vast number of these switches, and many of them did not possess the required space for the installation of the extra pieces.
 *Figure 49 - Rejected Circuit Breaker – Type 3 Blocker [73]*	Used to block circuit breaker – Type 3. This equipment is able to snap itself directly into the circuit breaker, blocking the switches movement, with a slot available for the placement of a lock. However, the sample provided did not fit any of the circuit breakers tested and, thus, it was rejected from being used in this project.

The second company that provided samples and solutions was Comprose, a Portuguese national company, and it too specializes in the manufacturing and sale of technical equipment. This time, the equipment provided was deemed acceptable for use in this project, warranting a more in-depth analysis.

The equipment that blocks both type 1 and 2 circuit breakers operate by blocking the path ahead of the switch, preventing the circuit breaker from switching states, and energizing the equipment. It accomplishes this task by first, possessing a threaded screw that is capable of being moved up and down. If the screw is correctly tightened, the switch will be compressed, sticking the equipment and the switch together, not allowing the removal of the equipment, until the equipment is unscrewed, as seen in Figure 50 a). As to block access to the screw, assuring the blocking equipment cannot be removed, a cover piece can be positioned on top of the screw, leaving space available for the placement of a lock, thus blocking the circuit breaker from reenergizing the system, until the operator removes its personal lock, and remove the blocking equipment, allowing the switch to once again be moved. This process can be seen in Figure 50 b) and c).

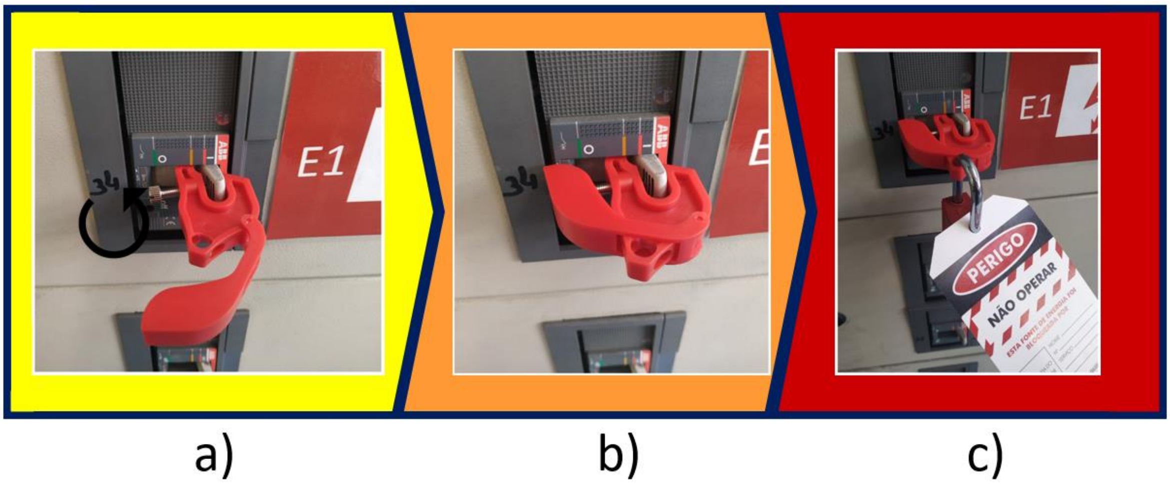


Figure 50 - Installation sequence of a type 1 and 2, circuit breaker blocking equipment

The equipment to block the circuit breaker - type 3 makes use of a special feature of these types of circuit breakers, presenting a small open section in the middle of the switch's path. The instillation of the equipment is shown in Figure 51. To correctly block the circuit breaker, the worker must firstly move the middle section of the equipment down, as shown in Figure 51 a), in order to allow the tip of the equipment to be manually compressed, as seen in Figure 51 b). Once compressed, the equipment is now able to fit between the spaces of the circuit breaker and be inserted in a special section of the circuit breaker, as shown in Figure 51 c). Once the worker seizes to manually compress the tip of the equipment, the section will extend, thus disabling the equipment from being removed from the circuit breaker and blocking the switch's path. However, the equipment can still be manually removed by another worker. Thus, to prevent unwanted removal, the middle section of the equipment must be moved up, as shown in Figure 51 d), revealing a section where a lock can be placed, disabling the removal of the blocking equipment, until the lock is opened.

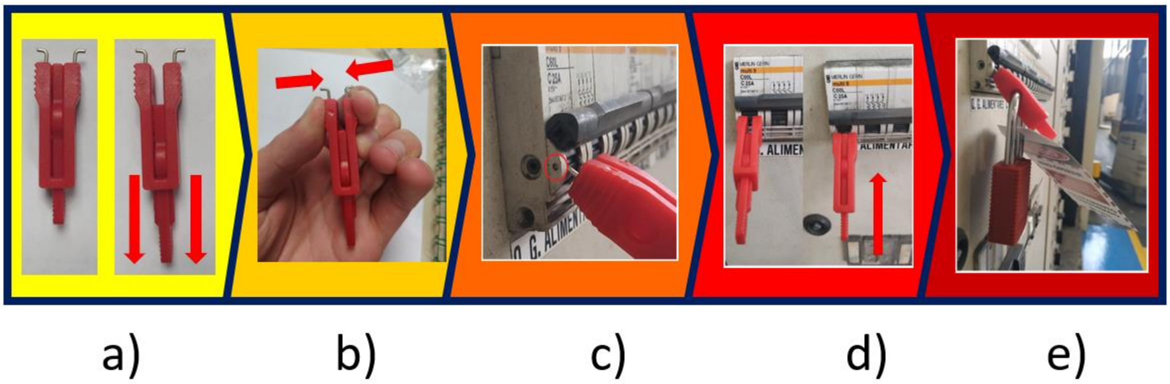


Figure 51 – Installation sequence of a type 3 circuit breaker blocking equipment

One of the main advantages present in both equipment, is that they do not require the installation of any additional element, or the presence of a specific feature that is not already present in a standard model of these circuit breakers, only requiring the use of a standard lock used throughout the LOTO procedures and equipment. This feature provides the following benefits:

1. Greater simplicity, since all the operator is required to do, in order to block the circuit breakers, is retrieve the specific blocking equipment, and apply it to the specific circuit the operator wishes to act on;
2. The equipment can be applied to all variants of a given type of circuit breaker, with no additional installation being required;
3. Circuit breakers that share the same type as the blocking equipment added in the future will also be able to be blocked using the same acquired equipment;
4. Since the same equipment works on multiple circuit breakers, it becomes unnecessary to have one equipment for each individual circuit breaker, which reduces the impact of storage, and the overall cost of implementing this safety feature.

As it pertains to the stock of the acquired equipment, as previously explained, there is no need of possessing an equipment for each individual circuit breaker, but a necessary amount must always be available, to assure that there is never a lack of the required equipment. To this degree, the professionals in charge of most of these kinds of operations were informally inquired about the daily usage of such an equipment, providing a rough estimate of the use of 4 per day. With this information, and already accounting for the future loss or damage of the equipment, it was decided to buy 10 of each circuit breaker blocking equipment, being considered more than sufficient stock for normal days of operation, and possible extraordinary outliners. The costs of acquiring the equipment is detailed in the Costs section of this chapter.

3.8.2. Lockout pneumatic valve

Similar to electric energy, pneumatic energy can also be found all around the factory, and it operates in a grid that covers the entire factory. Likewise, it is also important to possess an overview of the entire grid, as it operates in the factory. Figure 52 showcases a basic diagram of how the pressurized air is distributed to all the equipment found in the factory. As it can be seen, this grid is much more linear and simpler in execution, being mainly constituted by initial compressors that take in air and introduce pressure onto it, sending the pressurized air through a main pipe that covers the entire factory. Then, depending on the localized needs, a deviation from the main pipe is added, sending a portion of the pressurized air into a localized pipe, that then disperses the air into various machines/equipment from a specific line of production. A series of valves are used to control the flow of pressurized air, allowing to block specific sections of the pneumatic grid, preventing pressurized air from reaching section of the grid, without having to completely shut down the entirety of the pneumatic grid.

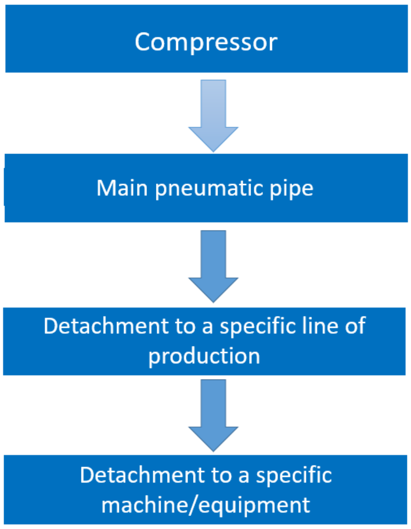


Figure 52 - Pneumatic sequence diagram, as found in the company

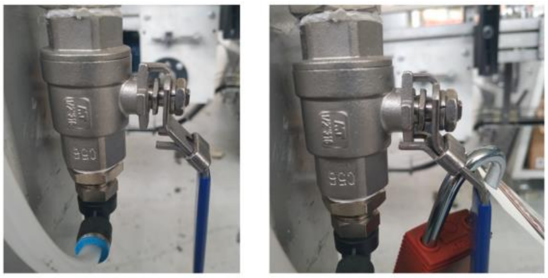
One of the main differences between pneumatic and electric energy, as it pertains to blocking and deenergizing systems, is the existence of stored energy in the form of pressure inside the tubes and pipes. In electrical systems, once the source of electricity is shutdown or disconnected, the remainder of the systems stops receiving continuous power, and any cables are thus immediately rendered deenergized. But the same does not occur in pneumatic and other pressure-based systems, since even if a section is cutoff from its source, the pressurized energy remains stored inside the tubes and pipes, requiring a way of safely releasing the stored pressure to completely deenergize the system.

There are many hazards that can be caused by stored pressure inside pipes and tubes, as the stored energy can be unexpectedly released, briefly energize the system, causing unexpected movement and equipment activation, which can in turn be the cause of several injuries, such as jamming or crushing. Stored energy can be easy to overlook when performing tasks, requiring proper study and procedure development to avoid these situations. It is then up to employers and managers to assess equipment for possible stored energies and educate employees. To correctly, and safely, block and deenergize a pneumatic system, these steps must be followed:

1. Block the source of pressurized air coming to the section involved in the task, more commonly by the use of a valve;
2. Lock the equipment used in the blocking of the pressurized air, as to make sure it cannot be activated until the operator stops servicing the equipment;
3. Discharge any stored energy, using a release valve or other release methods;

4. Confirm that the energy has been properly released with the aid of manometers, to correctly ascertain the pressure inside the system.

As explained in the 2.3.9 Control equipment and LOTO devices section of this dissertation, a “lockout valve lever” is specialized lever, which allows for the blocking of a valve, using a standard LOTO lock and key as shown in Figure 53. The lever achieves this task by possessing a vacant space, and a special piece covering the vacant space, which can be moved up and down. If the piece is moved up, it reveals the vacant space, at which point a lock can be introduced, locking the system. While in this state, the special piece also interlocks with the valve, stopping its movement or change in state, until the lock is properly removed.



a) b)

Figure 53 –Installation sequence of a valve blocking equipment

This system has already been implemented in the factory, being a reliable way of blocking valves, while remaining easy to use, since all a worker needs to block the valve is a standard LOTO lock and key, even if it requires the installation of a specialized valve and lever to allow for locking. However, this system lacks both a way of safely releasing the stored pressurized air that is left inside the pipes, and a way of confirming that the pressure has been sufficiently released, requiring both a manometer to ascertain the pressure inside the tube, and a way of discharging the pressurized air.

A solution developed by the company is presented in Figure 54, in which an initial valve is able to cutoff the remaining section away from the main grid of pressurized air, while a deviation ending in an output provides an opening, from which the stored pressure can be easily released. The opening also possesses a valve, to stop the pressurized air from being released when it is not desirable, and a manometer provides information on the current pressure inside the system, in order to verify that the system is indeed deenergized.

Figure 54 – Pressure release solution, developed by the company

However, some notable flaws were found with this type of solution:

1. It is possible for both valves to be simultaneously open, thus releasing pressurized air directly from the main grid, which creates unnecessary waste;
2. The pressurized air released possesses no barrier or filter, being directly released into the environment. This can cause hazardous situations, as possible trapped pieces of metal, or chemical elements mistakenly present in the plumbing, are released with great force and speed, in conjunction with the pressurized air. This danger can be further acerbated, when the release valve is positioned directly towards the side, at eye level, where another worker could be possible walking by, like is seen in Figure 54;
3. Two valves need to be locked for this solution to work, requiring the use of two locks to fully safeguard the equipment.

The initial pondered solution can be seen in Figure 55, where a 3-way ball valve with an L-bore could be used to prevent the release of pressurized air directly from the grid, and require only the use of one valve. This specialized valve achieves this task by only connecting two of its openings at any given time. If properly installed, it is possible to only connect the main grid input to the line of production, and the line of production to the pressure release, making it impossible for pressurized air to be accidentally released from the main source of pressurized air. Finally, the addition of a manometer would, likewise, allow to verify the pressure inside the system, and a filter could be added at the end of the release pipe, preventing the release of pressurized air directly to the environment.

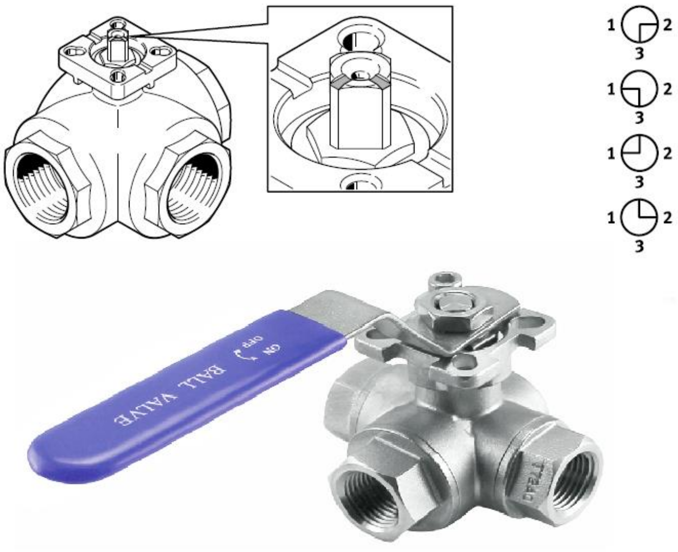


Figure 55 - 3-way ball valve [84]

Another solution was also found using the equipment presented in Figure 56, operating in a similar manner to the 3-way valve. This equipment does not allow for the release to connect directly with the main source of pressurized air, which generates unneeded waste. Its main difference, however, is that the manometer and release have been directly implemented into the valve, with the release possessing a filter, and the manometer being installed on the side of the valve. The manual lever also supports LOTO methodologies, possessing a section for the placement of a standard LOTO lock and key, which blocks the valve. This system possesses an easier installation process, since all the needed components for an effective pneumatic energy blocking solution come preinstalled in the valve, only needing to be directly installed in the pipping system, being preferable when it comes to standardizing the safety procedures of a large number of different equipment. A complete data sheet of the valve can be seen in Appendix B.

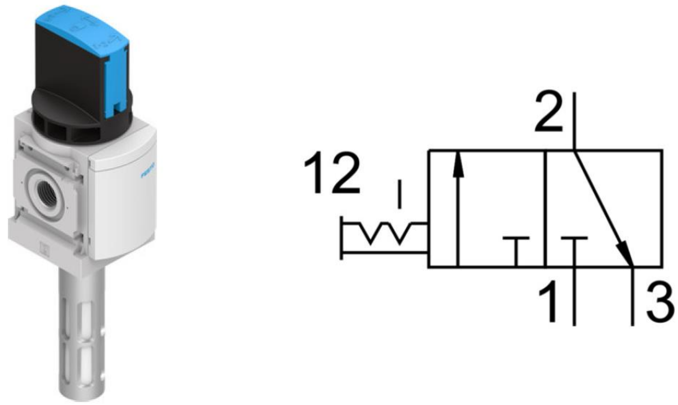


Figure 56 - MS6-EM valve [84]

To aid in the choice of the best system for implementation, a cost analysis of both solutions was made. As it can be seen in Table 12, the MS6-EM valve can be acquired for a lower price, while remaining the easiest to install and the best for standardization, emerging as the best choice for implementation, as part of this dissertation. However, since the MS6-EM valve only has a flow rating of 8700 l/min, it is not recommended for implementation in high flow sections of the pneumatic grid, mainly, zones closely connected with the main pipe. The MS6-EM valve will then be used to block the flow of pressurized air coming to a specific equipment, with the future recommendation to use the 3-way valve for blocking in the main pneumatic grid, due to being more robust and withstanding higher flow rates.

Table 12 - Lockout vale cost analysis

	On/Off valve MS6-EM	**Cost (€)**	**3-way valve**	**Cost (€)**
	MS6-EM valve	61.85	3-way valve, L-Bore	65.43
	Installation support + filter + manometer	10.06	Manual Lever	9.46
			Manometer	7.47
Total Cost (€)	71.85		82.36	

3.8.3. Costs

To finalize, Table 13 summarizes the costs associated with the acquisition of the needed equipment, presenting a total cost of 314.65€.

Table 13 - Acquisition of equipment cost analysis.

Equipment	**Number purchased**	**Total Cost (€)**
Circuit Breaker Blocker P/DM-11 (Type 3)	x11	94.68
Circuit Breaker Blocker P/DMT (Type 1 and 2)	x 10	148.12
On/Off Valve MS6-EM	x 4	247.40
MS6-MV1 Union Model	X4	21.24
Total cost of all the equipment (€)		314.65

3.9. Production line 99 – stamping machine

3.9.1. Analysis of the production line 99

Before the development of the safety procedure, it is essential to first conduct an overview analysis of the equipment, in order to fully understand what kind of tasks the machine performs, upon which basic mechanisms it operates on, what type of interactions do operators need to have with the machine during its normal processing, and the general sequence of actions the machine performs on the product.

The first equipment for which a safety procedure will be developed is part of production line 99, seen in Figure 57 (a), which manufactures the removable lid of wide radius tin cans, commonly used as packaging for cookies and other food products. It takes sheets of aluminum, and through several stamping operations done by different machines, which both cut and reshape, the aluminum sheet is turned into many circular lids as seen in Figure 57 (b), ready to be used in cans, or to advance to another production step, in which additional printing or shape is given to these aluminum lids.

Figure 57 – Production line 99 (a) and example of a final product (b)

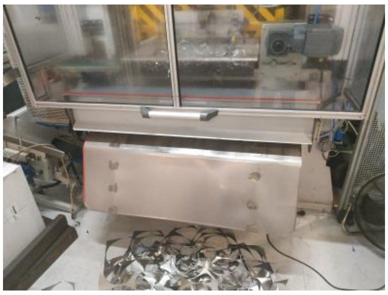
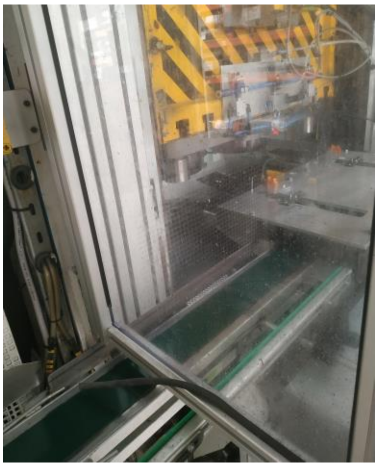
However, for the scope of this dissertation, only the stamping machine of production line 99 will receive a safety procedure, being the focus of this section of the dissertation. Nonetheless, the interaction the equipment has with other machines, and being aware of the equipment's purposes in the wider production process, are important concepts to understand when developing a safety procedure.

3.9.2. Analysis of the stamping machine – production line 99

The primary purpose of the stamping machine in production line 99 is to receive sheets of aluminium and cut them using stamping, in order to produce circularly shaped sheets. The general operation process of the stamping machine is shown in Table 14. The process beings with a stack of aluminium sheets, which are manually placed on the machine, with the aid of a forklift. Then, using a pneumatic system to automate mechanical movement, the aluminum sheet is separated from the stack, grabbed by suction cups, and raised to the machine's table, where it will continue to be moved in order to perform several stamping operations in the same sheet. Any excess, or incorrect sheets, are then ejected by the press into a container, whose purpose is to store the unused material for disposal or repurposing.

Table 14 - General operation sequence of the stamping machine

Step	Description	Picture
1	The supply entrance of the machine can be seen in Figure 58. Firstly, a stack of aluminum sheets sitting atop a pallet is manually delivered to the entrance of the stamping machine by a forklift, with the pallet serving as an aid for the transportation of the sheets. Once a stack of sheets is depleted, and a new stack needs to be placed in the machine, a worker must open the window to gain access to the machine's interior, remove the previous pallet, which is now empty, and push the stack inside the machine, an action that is made easy by using rolling cylinders.	 *Figure 58 - Stamping machine - operation step 1*
2	Each sheet is separated from the stack in the section seen in Figure 59, by a set of suction cups, which grab the topmost sheet, and using an automated pneumatic system, the sheet is raised and placed in the machine's table. The system can also be manually controlled by a control panel at the side of the machine, but typically operates automatically.	 *Figure 59 - Stamping machine - operation step 2*

3	The machine's positioner table, which can be seen in Figure 60, uses both mechanical and pneumatic energies to grab the sheet and move it in various directions, but always towards the mechanical press. The sheet then undergoes a stamping operation, and a circular shape is cut. During this process, the sheet is moved to the front, left and right. This is to maximize the number of circular shapes that can be cut out of the original aluminum sheet.	 *Figure 60 - Stamping machine - operation step 3*
4	Finally, the circular sheets of aluminum are then placed in a conveyor belt, seen in Figure 62, where they are transported to the next machine in the production line. Wasted sheet is directly stored in a bin, for later disposal, as seen in Figure 61.  *Figure 61 - Stamping machine – wasted sheet disposal*	 *Figure 62 - Stamping machine - operation step 4*

3.9.3. Analysis of electric system and blocking points

As previously explained, the electric energy is distributed throughout the entire factory using an electric grid. But, for the purposes of the stamping machine in production line 99, the path of the current is relatively linear, and can be seen in Figure 63, along with the tags given to each relevant electrical equipment, following the system developed in section 3.7 of this dissertation. For the purposes of developing the safety procedure, the electric current that reaches the stamping machine begins in the main electric switchboards, being controlled by a specific circuit breaker, which then transmits the electric signal through a cable, reaching the stamping machine's switchboard directly. From there, the electric energy is used in a variety of systems inside the switchboard, and in electric equipment found inside the stamping machine. Additionally, an extra tag was added to the manual console outside the machine's cabin, in order to identify the console, and add continuity between the stamping machine and its electric switchboard by tagging both equipment in relation to one another.

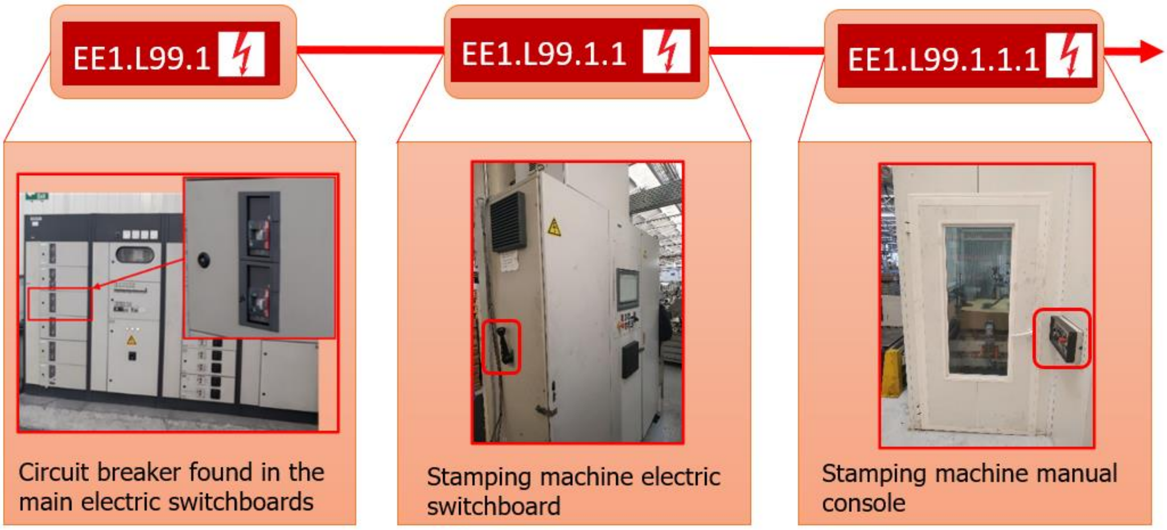


Figure 63 – Sequence of the electrical current that reaches the stamping machine

The blocking methods for each equipment can be seen in Table 15, with EE1.L99 being a circuit breaker, making use of the equipment acquired in the 3.8 section of this dissertation, while EE1.L99.1 has a specialized blocking solution built directly in the machine's electric switchboard.

Table 15 - Blocking methods for the electrical system of the stamping machine

Designation of the blocking point	Blocking method diagram	Blocking method description
EE1.L99.1	 *Figure 64 - Circuit breaker blocking method*	1. Turn off the circuit breaker; 2. Unscrew the locking equipment, and place it on the top of the switch; 3. Screw the locking equipment, clutching the switch; 4. Place and lock the padlock in the locking equipment.
EE1.L99.1.1	 *Figure 65 – Stamping electric switchboard blocking method*	1. Place the lever in the OFF position; 2. Reveal the piece on the lever shown in Figure 65; 3. Place and lock the padlock in the lever.

EE1.L99.1.1.1	 *Figure 66 - Stamping machine manual console emergency button*	1. Pressing the emergency button will shutdown the equipment but not block its restart.

3.9.4. Analysis of the pneumatic system and blocking points

The distribution sequence for the pressurized air found in the stamping machine, seen in Figure 67, is relatively linear. Once the air reaches production line 99, by traveling through the central pipe, it is transferred through a series of pipes, reaching the machine's pressure control system seen in P6, which then uses rubber tubes to transfer the pressurized air through the stamping machine as needed. The sequence would be linear, with the exception of P3, P5, P7, and P8. Point P3 is a bypass for that section of the grid, presenting an alternative route for the pressurized air to pass through in order to reach the machine, in case of the section in which P1 and P2 are located is blocked or damaged, P5 is an output section where a hose is connected, commonly used for cleaning and other maintenance activities that benefit from the use of pressurized air, P7 is an air tank used exclusively to supply pressurized air directly to the mechanical press, and must then be manually decompressed whenever a worker engages with the press, and P8 is the pressure system connected to an oil tank used by the positioner table, which must be depressurized when providing maintenance to the oil system, or to fill the oil tank.

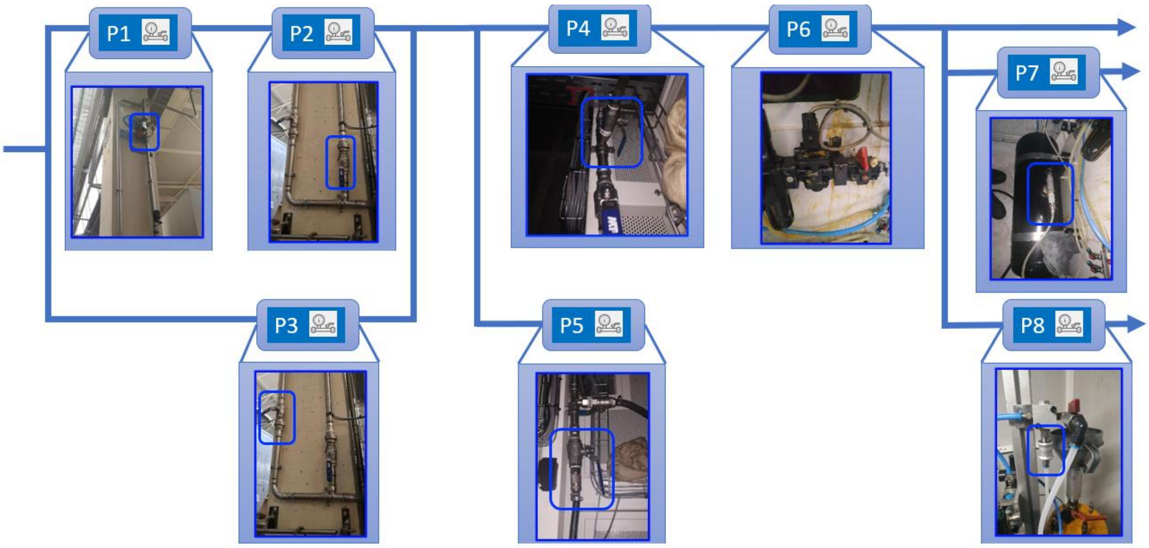


Figure 67 – Pneumatic sequence of the stamping machine

All blocking points of the pressure system are composed of valves, using the blocking methods seen below in Table 16, with P6 using a different valve and ,therefor, a slightly different blocking method.

Table 16 - Blocking methods for the pneumatic system of the stamping machine

Designation of the blocking point	Blocking method diagram	Blocking method description
P1 P2 P3 P4 P5	 *Figure 68 - Pneumatic valve blocking method*	1. Close the valve; 2. Place and lock the padlock in the valve, as shown in Figure 68.
P6	 *Figure 69 - Pneumatic valve blocking method*	1. Close the valve; 2. Place and lock the padlock in the valve, as shown in Figure 69; 1. Verify with the manometer that the system has been depressurized (zero pressure) before intervening.
P7	 *Figure 70 - Compressed air tank decompression method*	1. Open the valve located in the tank to begin decompression; 2. Check the pressure levels in the press' manometer; 3. Begin operation once the pressure has been fully released.
P8	 *Figure 71 - Oil tank decompression method*	1. Move the valve down, beginning the decompression process; 2. Check the oil tank's pressure by observing the tank's manometer; 3. Begin operation once the pressure has been fully released.

3.9.5. Analysis of the mechanical system and blocking points

All the mechanical blocking points and their tags are presented in Figure 72. In comparison with the pneumatic and the electrical, the mechanical system is heavily centralized, and mostly contained within each equipment. The mechanical tags are identified with a number ranging from M1 through M7, used to tag the doors and windows that allow access to the interior of the cabin where the machine is operating. While the machine is energized these must remain closed, as to not allow anyone to access dangerous and energized zones of the equipment, except designated personal, and while the machine is in a step-by-step mode.

On the other hand, the mechanical tag M8 is the blocking mechanism for the mechanical press, which is especially important when providing maintenance to the machine. Due to the press' high weight, and the high forces it usually operates in, any unexpected or sudden movement of the press can lead to many severe injuries. Therefore, it is important for there to be a way to manually block the movement of the press. Similarly, the M9 tag is also a way to block the movement of an equipment, but in this case, it is in reference to an elevation table that must likewise be unable to move while an operator is engaging with related systems.

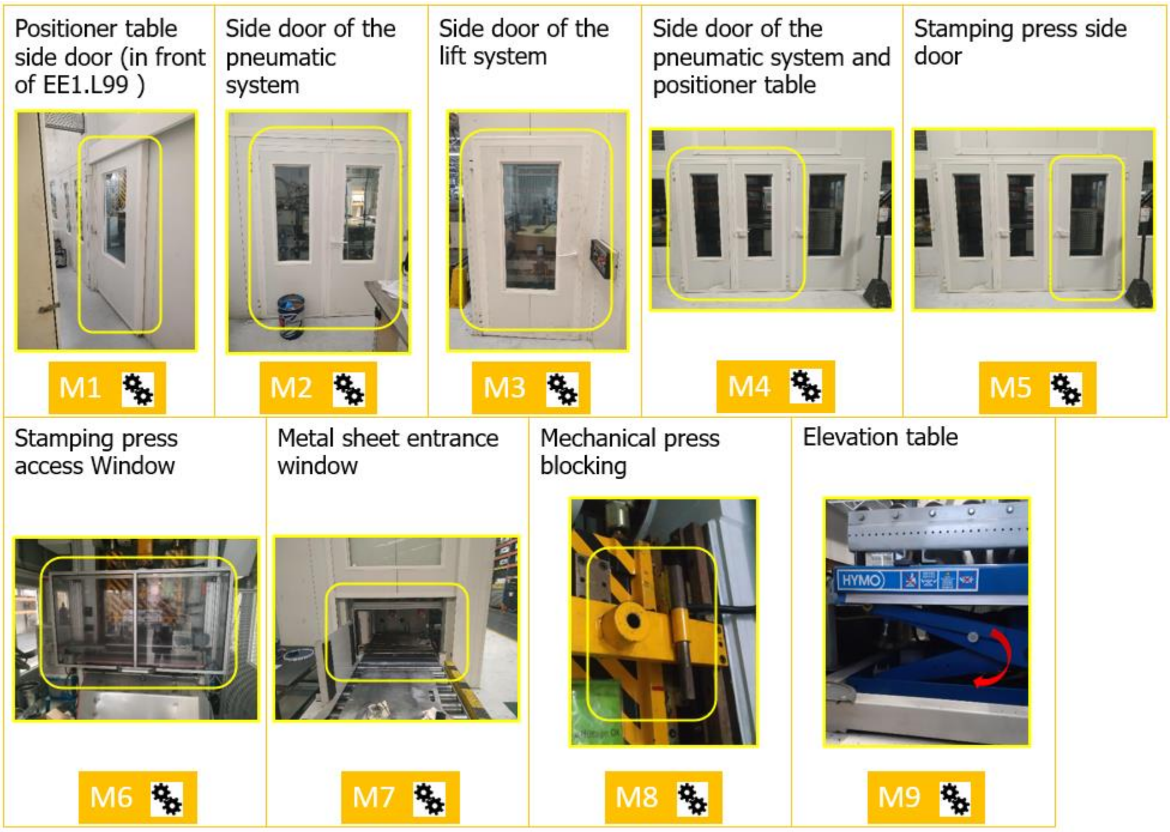


Figure 72 – Mechanical blocking points

The blocking solutions, they are showcased below in Table 17, with the mechanical tags M1 through M7 using the same system, which consists of an electronic sensor that detects when the door or window is open, and immediately sends a signal to the machine, forcing the machine to shut down if the door or window is opened. On the other hand, the mechanical tags M8 and M9 simply consist of a blocking shaft that is placed manually, physically blocking the equipment's movement, with its specific placement also being explained in Table 17. Additionally, M8 also possesses a sensor that detects when the blocking shaft is removed from its support, which also informs the machine that the press is currently being physically blocked, which stops the machine from energizing the press, even while in a step-by-step mode. This procedure is done to make sure operators are protected from the press's movement, and also to prevent damage to the press by accidentally moving while it is blocked.

Table 17 - Blocking methods for the mechanical system of the stamping machine

Blocking Point	Blocking Method Diagram	Blocking Method Description
M1 M2 M3 M4 M5 M6 M7	 *Figure 73 - Door/window blocking method*	1. Opening the door/window will immediately stop the machine; 2. The machine can only be started again when the door/window is closed.
M8	 *Figure 74 - Press blocking method*	1. Remove the metal shaft from its support; 2. Place the shaft on both sides of the press as shown in Figure 74.
M9	 *Figure 75 - Elevation table blocking method*	1. Place the platform in the lowest height; 2. Place the lever on the platform, as shown in Figure 75.

3.9.6. Analysis of tasks and energy sources

The analysis of the tasks requires gathering information from a variety of sources and individuals, which can be mainly divided into two groups. Production and maintenance, the production group is tasked with operating the machine, managing the setup, performing cleaning, and minor adjustments. The maintenance group is generally tasked with performing repairs, maintenance and making changes to the equipment. Within the maintenance group, professionals are additionally specialized in performing either electrical or mechanical maintenance, even if some overlap between the two specializations exists. Then, to gather the needed data for this section of the dissertation, the diagram seen in Figure 76 was followed.

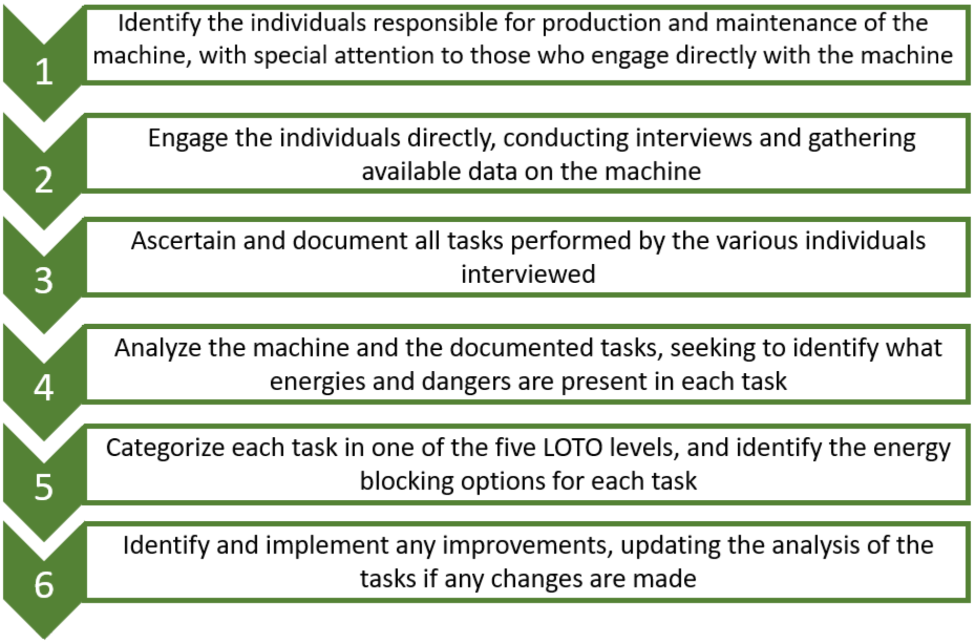


Figure 76 - Diagram of the analysis of tasks and energy sources

A detailed and comprehensive analysis of the tasks and energy involved can be seen in Appendix C, but in this section only the most relevant information will be showcased, with a summary of the analysis seen in Table 18.

Table 18 - Analysis of tasks and energy sources – production line 99 – stamping machine

LOTO Level	Task	Main risks	Main dangers	Identified energies
0	Normal working operating conditions.	None.		n/a
0	Manual suppling metal sheets, which are placed at the entrance of the machine.	Circulation of Forklift/worker; pallet fall; tool handling (strap and film cutting); and metal sheet handling.	Hitting/crashing; crushing; trapping; cut/ abrasions.	Mechanical; Electric.
0	Repositioning and lifting of the sheet stack, on the lifting table, which requires the use of the external console to raise the platform and lift the sheets, as rollers to manually push and pull the sheets and the pallet.	None.		n/a
0	Compressing the unused, and wasted material, in the waste container.	Working with scraps of metal sheet.	Cuts/abrasions	n/a
0	External Cleaning of Equipment.	None.		n/a
0	Check Start, and trigger Shutdown of the equipment	Abrupt shutdown of the machine can still leave residual energy.		n/a
1	Removing the previous pallet before suppling the machine with a new stack of metal sheets.	Platform can go up and down while the window open, someone can place their hand on the active bearings.	Crushing and entrapment.	Mechanical.
1	Unjamming, or cleaning the press through the entrance window.	Difficult access to certain elements; presence of scraps of metal; mechanical press movement.	Trapping or cut/abrasions.	Mechanical; Electric; Pneumatic.
2	Cleaning the inside area of the equipment, and cleaning the chain elements.	Fatigue; moving parts.	Trapping or electrification.	Mechanical; Electric.
2	Clean or replace vacuum filters.	Presence of pressure inside the tubes.	Projection of impurities or objects.	Pneumatic;
2	Change/check the oil levels.	Presence of pressurized oil.	Projection of oil or impurities	Pneumatic.

	Clean or replace the lubrication filter.			
2	Unjam the sheet from the table, or replacing the vacuum suction cups.	Movement of the positioner table.	Crushing, trapping or cut/abrasions.	Mechanical; Electric; Hydraulics; Pneumatic.
2	General cleaning of the electric switchboard.	Presence of electricity.	Electrocution/electrification.	Electric.
3	Making changes to the Pneumatic Installation. Examples include, checking Air Leaks, compressed air tubes, valves leaks, pressure gauges, injectors, regulators, valves and cylinders.	Presence of pressure inside the tubes.	Projection of impurities or objects.	Pneumatic.
3	Perform changes on the solenoid valve.	Presence of electricity and pressure inside the tubes.	Electrocution/electrification, or projection of impurities or objects.	Electric; Pneumatic.
3	Intervention/replacement of electrical components.	Presence of electricity.	Electrocution/electrification.	Electric.
3	Central lubrication of the mechanical press.	Difficult access to certain elements; unscheduled start of engines, roller movement, tool manipulation.	Crushing; trapping and cut/abrasions.	Mechanical.
3	Intervention/replacement of electric motors; belts, supports, guides, rollers, mechanical parts.	Starting the motor connected to the parts; Presence of Electricity; Handling of parts; tool handling.	Trapping and cut/abrasions.	Mechanical. Electric;
3	Repair of sensors and cables.	Positioning and difficult access to some elements; press movement; presence of energies.	Crushing; trapping; cut/abrasions; electrification	Mechanical. Electric; Pneumatic.
3	Changing and adjustment of the press' wheel belts.	Press start and movement; cylinder movement.	Crushing and trapping	Mechanical; Pneumatic.
3	Replace servomotor's x/y shafts.	Tool handling; weight of shafts; working on uneven heights.	Crushing and trapping	Mechanical;

				Potential.
3	Replace press shock absorbing cylinders.	Start of a mechanical press; handling of parts; tool handling, use of a moving platform; different work heights.	Crushing; trapping; falling parts; cuts/abrasions; impact against structures; run overs; fall from height.	Mechanical; Pneumatic.
3	Replace ripper roller and belt. Swap scrap conveyor fabrics.	Mechanical press motor start; handling of parts; tool handling.	Crushing; trapping; falling parts; cuts/abrasions.	Mechanical; Electric; Pneumatic.
3	Interventions/replacements in the pneumatic system of the mechanical press.	Presence of pressurized air; mechanical press movement; elevator and feeder table movement; start of mechanical rollers; tool manipulation.	Crushing; trapping; falling parts; cuts/abrasions.	Pneumatic; Potential.
3	Intervention/repair in the electrical control command.	Presence of electricity; tool manipulation.	Electrocution/electrification; crushing; cut/abrasions.	Electric.
3	Replacement / manipulation of the supply window motor.	Presence of electricity; tool manipulation; window movement.	Electrocution/electrification; crushing; cut/abrasions.	Mechanical; Electric.
3	Replacement/repair of motors or electrical cables of product output conveyors.	Presence of electricity; tool manipulation; conveyor belt movement.	Electrocution/electrification; crushing; cut/abrasions.	Mechanical; Electric.
3	General Review.	Pressured air; press movement; elevator and feeder table movement; mechanical roller movement; stored energy (in the tank); working in altitude (2 meters); tool manipulation.	Crushing; trapping; falling parts; cuts/abrasions; fall from heights; electrocution/electrification.	Mechanical; Electric; Hydraulics; Pneumatic.
3	Check/repair the mechanical punch of the stamping machine.	Motion of the mechanical press; mechanical roller movement; tool manipulation.	Crushing; trapping; cuts/abrasions.	Mechanical; Electric.
3	Intervention/repair on the electrical switchboard or power cables.	Presence of electricity; tool manipulation.	Electrocution/electrification; trapping; cut/abrasions.	Electric.

	Spindle replacement (servomotor).	Presence of electricity.	Electrocution/electrification.	Electric.
4	Check flywheel/belts/shafts clearances.	Mechanical press start, mechanical part movement; tool handling; use the special equipment to dismantle and move steering wheel of the press.	Crushing; trapping; falling parts; cuts/abrasions; fall from heights; electrocution/electrification.	Mechanical; Pneumatic.
4	Thermographic analysis.	Operation of the Equipment with the employee inside the machine.	Electrocution/electrification; trapping; cut/abrasions.	Mechanical; Electric.
4	Identification of breakdown or damage.	Movement of the mechanical press, positioner table movement (cylinder), and roller movement.	Electrocution/electrification; trapping; cut/abrasions.	Mechanical; Electric; Hydraulics; Pneumatic.

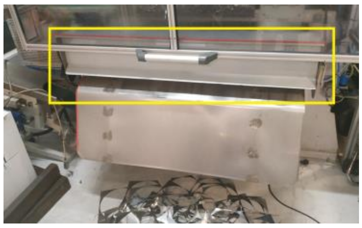
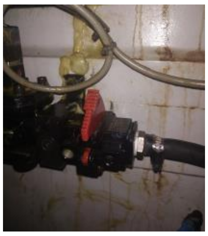
3.9.7. Problem quantification and implementation of changes

After the tasks and their associated dangers where analysis, several changes and improvements were made to both make the implementation of a LOTO procedure possible, and to improve safety conditions in the equipment.

Throughout this dissertation, in this section of each machine, the EN13857 standard was used to gauge the safety and level of exposure of workers to equipment, by specifying safety distances from a variety of situations where a worker might be exposed to energies or activate machinery. The problems and the implemented changes are showcased in Table 19.

Table 19 - Problem quantification and implementation of changes – production line 99 – stamping machine

	Problem description	Implemented changes
Problem 1	None of the blocking points or equipment had any type of LOTO tag.	The tags were made, printed, and applied to their respective equipment.  *Figure 77 – Added tags to the stamping machine*
Problem 2	Existence of commands identified in foreign languages, which does not comply with safety standards.  *Figure 78 - Command in a foreign language*	Change of the identification on all commands, to the language spoken at the company, which in this case is Portuguese, or use standardized symbology to clearly delineate its function.  *Figure 79 – Changed button identification*

Problem 3	Possibility of trapping on the roller associated with the output of waste. It is necessary to implement protection to prevent access to the area. The opening for the waste output must comply with the provisions of the EN13857 standard.  *Figure 80 - Waste output roller*	The rollers were covered by adding an additional barrier, which leaves enough vacant space for the scraps of metal sheets to pass and be ejected, while hands or larger objects are unable to pass, thus complying with the EN13857 standard.  *Figure 81 - Waste output roller with added protection*
Problem 4	Lack of general power cut device for the machine's pneumatic system, with the possibility of locking in the off position.  *Figure 82 - Previous stamping press valve*	The locking valve was added to the machine's pneumatic system.  *Figure 83 - Added locking valve*

3.9.8. Safety procedure – production line 99 – stamping machine

After the analysis of the tasks is performed, and the needed improvements are implemented, the safety procedure can finally be developed. The procedure begins by identifying all the energy blocking points relevant to the machine, as well as the tags associated with each equipment. Lists are also created for all the documented tasks, with each task possession the following information:

- The energy point that require blocking in order to safely perform the task;
- The group of people who can perform that task;
- A guide on how to perform the task and block the energy points;
- Additional relevant information;
- The LOTO level of the task.

The safety procedure of the stamping machine belonging to production line 99 can be found in Appendix D. A summary of the safety procedure, showcasing the most relevant, information can be seen in Table 20.

Table 20 - Safety procedure – production line 99 – stamping machine

Tasks	Energy blocking points	Blocking methods	Additional information	LOTO level
1. Supply of metal sheets: - Lower the previous empty pallet and remove it from M3; - Open the M7 access window; - Push the pallet containing the sheets to the inside of the machine; - Center the pallet and raise the table; - Close the M7 window.	M3 + M7	1. Warn the workers involved; 2. Open the access window, forcing the machine to shutdown; 3. Once the task is performed close the window and resume operation.	1. The mechanical blocking point is always though the door from where the supplied sheets enter; 2. The elevation table must be at the same level as the entrance.	2
2. Unjamming sheets or other components stuck in the press (through the M6 window); 3. Clean the press' table (through the M6 window).	M6	1. Warn the workers involved; 2. Open the access window, forcing the machine to shutdown; 3. Once the task is performed close the window and resume operation.		2
4. Adjustment or tuning of the positioner table; 5. Unjam sheet from the positioning table; 6. Replacement of suction cups; 7. Cleaning of the chain drivers; 8. Centering and adjusting; 9. Disassemble / assemble of the press guides; 10. Replace screws in the punch of the press; 11. Setup to replace the punch of the press; 12. General lubrication of the equipment; 13. Cleaning of the line inside the machine's cabin.	M1 or M2 or M3 or M4	1. Warn the workers involved; 2. For the tasks 8, 9, 10, 11 place the console in manual mode.	1. Check if the machine is in manual mode and with suspended energies (only small movements are allowed and controlled inside the machine); 2. For tasks 10 and 11 block the mechanical press (M8); 3. For task 9 block the press (M8) whenever it is not necessary to move head manually; 4. For task 11 turn off harting plug before performing any operation.  *Figure 84 – Harting plug*	2

14. Refill the oil tank inside the cabin; 15. Clean or replace sheet lubrication filter.	M1 + P8 or M2 + P8	1. Warn the employees involved; 2. Open the M1 or M2 door and put padlock; 3. Close compressed air valve and put padlock + hazard signal label.	1. Close the compressed air valve P8; 2. Check pressure gauge (zero pressure) compressed air in the tank before the intervention.	3
16. Eliminate flywheel clearances; 17. Engine replacement/repair of the pallet entrance window; 18. Exchange/repair of electric motors or electric cables of the conveyors; 19. Change of screens in the conveyor (inside and outside the cabin); 20. Intervention/repair in the manual frame of the feeder; 21. Intervention/replacement of sensor, electrical cables and other electrical components inside the cabin; 22. Intervention / repair in belts, supports, guides, rollers, and other mechanical elements;	EE1.L99.1.1	1. Warn the employees involved; 2. Turn off the electrical panels and place the padlock + danger signal tag; 3. Press START/STOP button (for verification purposes).	1. For tasks 17, 18 and 19, disconnect Harting plugs from the conveyor.  *Figure 85 – Harting plug*	3
23. Intervention/repair of the steering wheel belts; 24. Replace servomotor’s x/y shafts; 25. Replace shock absorber cylinders; 26. Replace roll bags scraps and belt; 27. Change conveyor screens; 28. Replace mechanical fuses and adjust press pressure; 29. Repair of sensors, cables and pneumatic solenoid valves; 30. Interventions/substitutions vacuum filters;	EE1.L99.1.1 + P6	1. Warn the employees involved; 2. Turn off electrical panels and put padlock + danger signal tag; 3. Close compressed air valve and put padlock + hazard signal label; 4. Press START/STOP button (for verification purposes).	1. Close the compressed air valve P6; 2. Check the section is decompressed using the manometer (zero pressure) before the intervention; 3. For task 27, turn off Harting plug before performing any operation.	3

			 *Figure 86 – Harting plug*	
31. Interventions/replacements in the pneumatic system of the press; 32. Intervention in the central lubrication system of the press; 33. Intervention/replacement of the P7 tank; 34. Check press guides.	EE1.L99.1.1 + P6 + P7	1. Warn the employees involved; 2. Turn off electrical panels and put padlock + danger signal tag; 3. Close compressed air valve and put padlock + hazard signal label; 4. Press START/STOP button (for verification purposes).	1. Check the absence of energy with a multimeter; 2. Close the compressed air valve P6; 3. Check the section is decompressed using the manometer (zero pressure) before the intervention; 4. Dissipate present energies - depressurize lung P7.	3
35. General review;	EE1.L99.1 + P6	1. Warn the employees involved; 2. Turn off electrical panels and put padlock + danger signal tag; 3. Close compressed air valve and put padlock + hazard signal label; 4. Press START/STOP button (for verification purposes).	1. Check the absence of energy with a multimeter; 2. Close the compressed air valve P6; 3. Check the section is decompressed using the manometer (zero pressure) before the intervention; 4. Dissipate present energies - depressurize lung P7.	3
36. Replacement/repair of lift table side motors.	M3 + M9 + EE1.L99.1.1	1. Warn the employees involved; 2. Turn off electrical panels and put padlock + danger signal tag; 3. Lock M9 and place the padlock 4. Press START/STOP button (for verification purposes).	1. For task 34, turn off Harting plug before performing any operation.  *Figure 87 – Harting plug*	3

37. Intervention/repair on the electrical panel or power cables; 38. Change or tighten screws exposed to high voltage; 39. General cleaning of the electrical switchboard;	EE1.L99.1	1. Warn the employees involved; 2. Turn off the electrical panels and place the padlock + danger signal tag; 3. Press START/STOP button (for verification purposes).	1. Check the absence of energy with a multimeter.	3
40. Identification of malfunctions. 41. Thermographic analysis		1. Warn the workers involved; 2. Place safety barriers and danger signs; 3. Placing the machine in manual mode; 4. Coordination between 2 technicians; 5. Accessible emergency button.	1. Ensure that only qualified and trained people in LoTo can perform this operation; 2. Ensure proximity to an emergency button; 3. Requires work permit.	4

3.9.9. Measurement of improvement

Reaching a definitive conclusion on the impact that the implementation of the safety procedure had on safety was impossible under the scope of this dissertation, since the occurrence of injuries is a relatively abnormal phenomenon. Proving an increase in safety, and therefore, a decrease in the rate of injuries, would require a long-term analysis, which was not possible due to the time constraints placed on this dissertation. Nonetheless, an analysis on the available timeframe is still possible, with the number of injuries that occurred before and after the implementation of the safety procedure on the stamping machine belonging to production line 99 being seen in Table 21. By calculating an average monthly rate of injury, before and after the implementation, it is possible to observe a decrease in the monthly rate of injury, from roughly 0.83 injuries per month, to 0 injuries. Thus, an increase in safety was achieved, within the available timeframe of this dissertation.

Table 21 - Number of injuries that occurred in the stamping machine

Number of recorded injuries from 6/1/2021, to 6/1/2023	2	Average injuries per month before the implementation of the safety procedures	0.083(3)
Number of recorded injuries from 10/1/2023, to 13/7/2023	0	Average injuries per month after the implementation of the safety procedures	0

Additionally, it is also possible to analyze the impact the LOTO procedures had on the duration of maintenance activities. Since these activities are frequently done, there was enough available data to reach a satisfactory conclusion. The recorded durations of preventive maintenance activities done before and after the implementation of the safety procedure were compared. If on average the activities done after the implementation took longer, then the safety procedure added details or steps that significantly slow down maintenance activities, while if on average the duration remained relatively the same, it is possible to assume the safety procedures did not negatively impact the maintenance activities. Additionally, preventive maintenance tasks are more likely to be performed under the same circumstances, and thus be more accurately comparable, since they are routine activities, while corrective maintenance is in response to a breakdown or malfunction, and thus each repair cannot be adequately compared with each other, since they occur under very different conditions. Three activities performed as part of preventive maintenance were chosen based on their frequency of occurrence, since the more times a task was performed, the more reliable the data gathered should be, with each task being accompanied by its duration and date of execution, seen in Table 22. The duration of each task was documented by the professionals who performed the tasks, usually rounding up the duration of the tasks to their nearest minute.

Table 22 - Duration of preventive maintenance, before and after the implementation of the safety procedures in the stamping machine

Tasks	Maintenance done after the implementation of the safety procedure		Maintenance done before the implementation of the safety procedure	
Verify/repair supports, guides and mechanical parts.	Date	Duration (min)	Date	Duration (min)
	17/3/2023	15 min	12/9/2022	10 min
			11/6/2022	5 min
			12/8/2022	15 min
Analysis of the press' flywheel.	Date	Duration (min)	Date	Duration (min)
	17/3/2023	15 min	12/9/2022	10 min
	8/4/2023	5 min	12/4/2022	5 min
	14/2/2023	5 min	10/5/2022	5 min
	11/1/2023	5 min	11/6/2022	5 min
			12/8/2022	5 min
Check press' guides.	Date	Duration (min)	Date	Duration (min)
	17/3/2023	5 min	12/9/2022	10 min
	8/4/2023	5 min	12/4/2022	5 min
	14/2/2023	5 min	10/5/2022	5 min
	11/1/2023	5 min	11/6/2022	15 min
			12/8/2022	5 min

With the duration of each instance of the task now gathered, by calculating the average duration of each task, the value reached should be an accurate representation of the time it takes to perform the maintenance task on an ordinary instance, with the averages being seen in Table 23.

Table 23 – Average duration of the tasks, before and after the implementation of the safety procedures in the stamping machine

Tasks	Average duration of the task after the implementation	Average duration of the task before the implementation	Difference
Verify/repair supports, guides and mechanical parts	15 min	10 min	5 min
Analysis of the press' flywheel	7 min	6 min	1 min
Check press guides	5 min	8 min	-3 min
Average difference of duration between the activities			1 min

As can be seen, each activity's duration increased on average 1 minute, suggesting that the procedures did slow down the duration of the maintenance operations, even if only slightly. However, it is important to note that more occurrences of the task are necessary to definitively assert the effects the implementation of the safety procedure had on the duration of maintenance operations. In one of the tasks, namely the "check press guides" task, a decrease in the maintenance duration of 3 minutes was observed. Although the sample size of the data was not wide enough to definitively access if the safety procedures helped in reducing the maintenance time for this particular task, it is possible that the safety procedure helped guiding workers when executing the tasks, and whether by providing the worker with an extra sense of security, or by quickly indicating the equipment workers ought to use, the task was done more efficiently, in these instances.

Additionally, in the "verify/repair supports, guides and mechanical parts" task, an increase of 5 minutes was observed. This can be due to worker's taking extra time to analyze the newly implemented safety procedure, or the fact that the task was only performed once after the implementation of the procedure, which may indicate the duration of the task recorded may not be indicative of the actual duration of the task, after the implementation of the procedure.

3.10. Production line 11 – clinching machine

3.10.1. Analysis of the production line 11

Production line 11 is tasked with manufacturing the body of the can and adding a handle, as seen in Figure 88 . The first operation takes a sheet of aluminum (1), supplied to the production line, and welds the edges of the sheet together, forming an aluminum cylinder (2) that constitutes the body of the can. Following the welding, a circular sheet is clinched to the end of the can, covering its bottom, while a ring is added to the top, also by clinching, allowing for the introduction of a lid (3), which will be done later in the manufacturing cycle. The clinching performed on the cans is a specific type of clinching, known as a double-seam, as explained in 2.2.5. Following the clinching operation, a plastic handle can be optionally added to the can (4) by welding a metallic point, allowing the can to be more easily moved and transported. If no handle is required, the can is instead sent to the customer or transported to the next line of production, as seen in the state seen in (3).

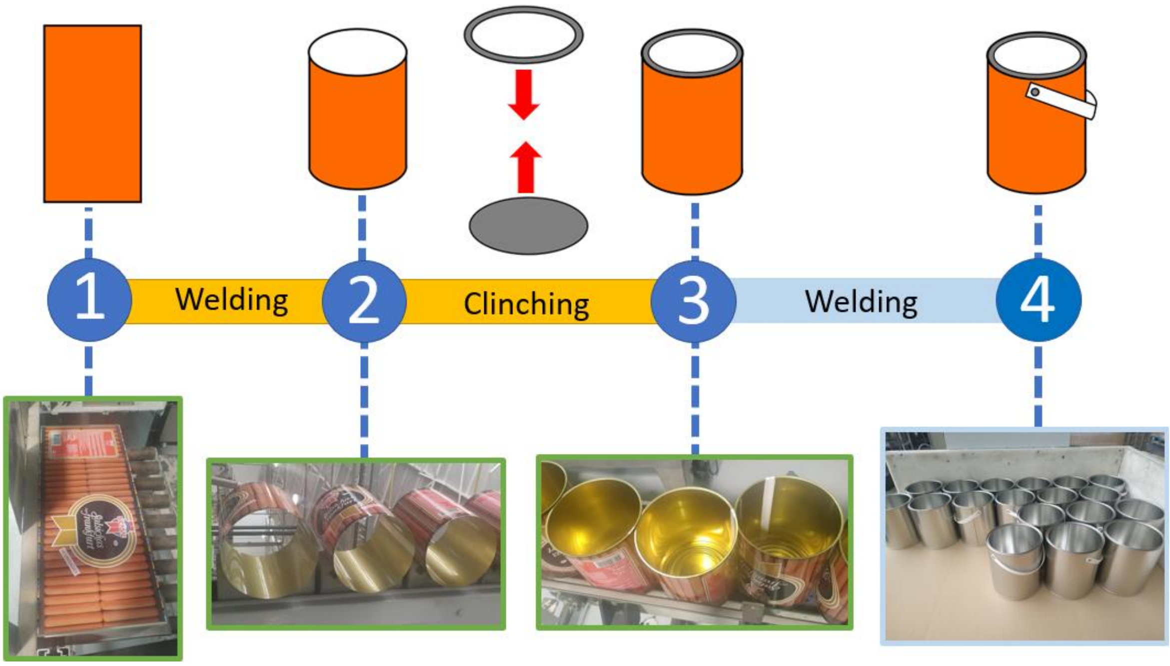


Figure 88 – Sequence of can manufacturing performed by production line 11

However, this section of the dissertation will only focus on the clinching machine, which places the bottom and the ring on the can by performing a double-seam clinching.

3.10.2. Analysis of the clinching machine – production line 11

The clinching machine found in production line 11 is tasked with receiving cylinder-shaped aluminum sheets and clinching a circular sheet to the bottom of the cylinder, forming the bottom of the can, and clinching a ring to the top of the cylinder, allowing for the placement of a lid or cover, later in the production process. The general operation process of the clinching machine is described in Table 24. The aluminum cylinders are inserted into the machine by an automated system and are moved using a pneumatic and mechanical system of transport. Operators must manually supply the machine with a series of bottoms and rings, placing them on the appropriate sections of the machine. The cylinder is then subjected to a series of clinching operations, exiting the machine with a bottom and ring, being then transported by a conveyor belt to the next machine in the line of production.

Table 24 - General operation sequence of the clinching machine

Step	Description	Picture
1	Firstly, a series of metal rings and bases must be manually placed in the correct sections, by a worker operating the machine, in order to provide the material necessary for the double-seam to add a base and the ring to the can. Once the rings or bases are depleted, a worker must manually supply the machines with new batches of materials, which can be done even while the machine is running due to the worker's inability of accessing zones of danger when suppling the machine.	 *Figure 89- Clinching machine - operation step 1*
2	Cylinders made from a metal sheet are then introduced into the machine, via an automatic system of transport, using conveyor belts. The cylinders are then placed in the machine's internal conveyor belt, seen in Figure 90, which makes use of gears, shafts and sensors to move the cylinder inside the machine.  *Figure 90 - Clinching machine conveyor belt*	 *Figure 91 - Clinching machine - operation step 2*

3	The machine then performs two double-seams on the metal cylinder. The first double-seam clinches a base to the cylinder, protecting and covering one of the sides of the cylinder. The second double-seam, clinches a metal ring around the border of one of the sides, covering that area, and allowing for the addition of a lid later on in the manufacturing process.	 *Figure step 3*
4	Once the two double-seams are performed, the can is ejected into another conveyor belt, where it will be transported to another machine, and into the next step of the can's manufacturing process.	 *Figure 93 - Clinching machine - operation step 4*

3.10.3. Analysis of the electric system and blocking points

The electric current in this production line also beings in the main electric switchboard marked as EE1, similar to the stamping machine in production line 99. However, the current is then sent to a distribution grid, where distribution boards redirect some of the current in the grid to a specific machine. Figure 94 is an example of one of these grids used in the factory. The electric current, represented in yellow, arrives at the grid from one of the main switchboards, and is then sent to all the distribution boards connected to the grid, each distribution board is then connected to the switchboard of a machine, supplying electric current to all equipment in the line of production.

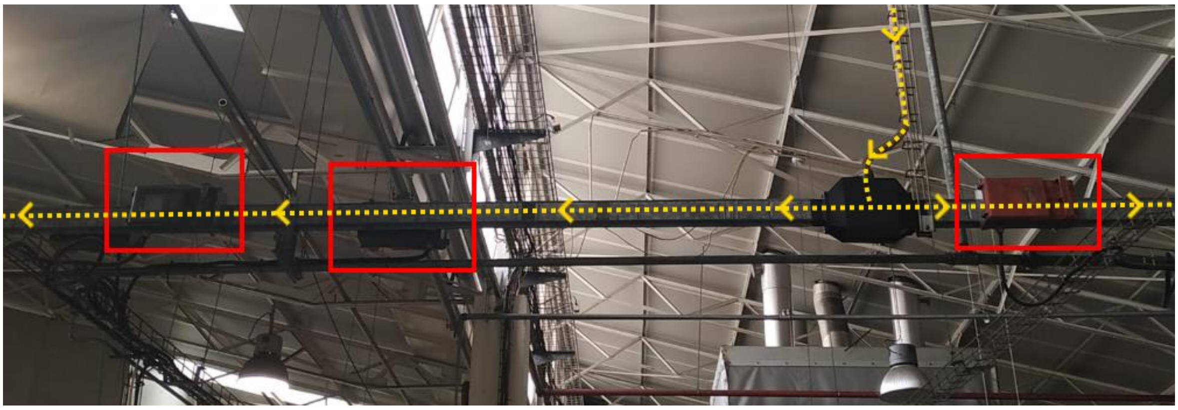


Figure 94 - Example of a distribution grid

The clinching machine uses two distribution boards, one that directs electricity towards the electric switchboard of the stamping machine, and the other that directs power towards the switchboard responsible for managing and powering the transporting system of conveyor belts in the line of production, interacting with a variety of machines in the line of production. Since the can transportation system is an intrinsic part of all the equipment in production line 11, which includes the clinching machine, the way to safely interact with the transportation system of production line 11 will also be included in the safety procedure of the clinching machine. The path of the current can be seen in Figure 95, along with the tags given to each electrical equipment.

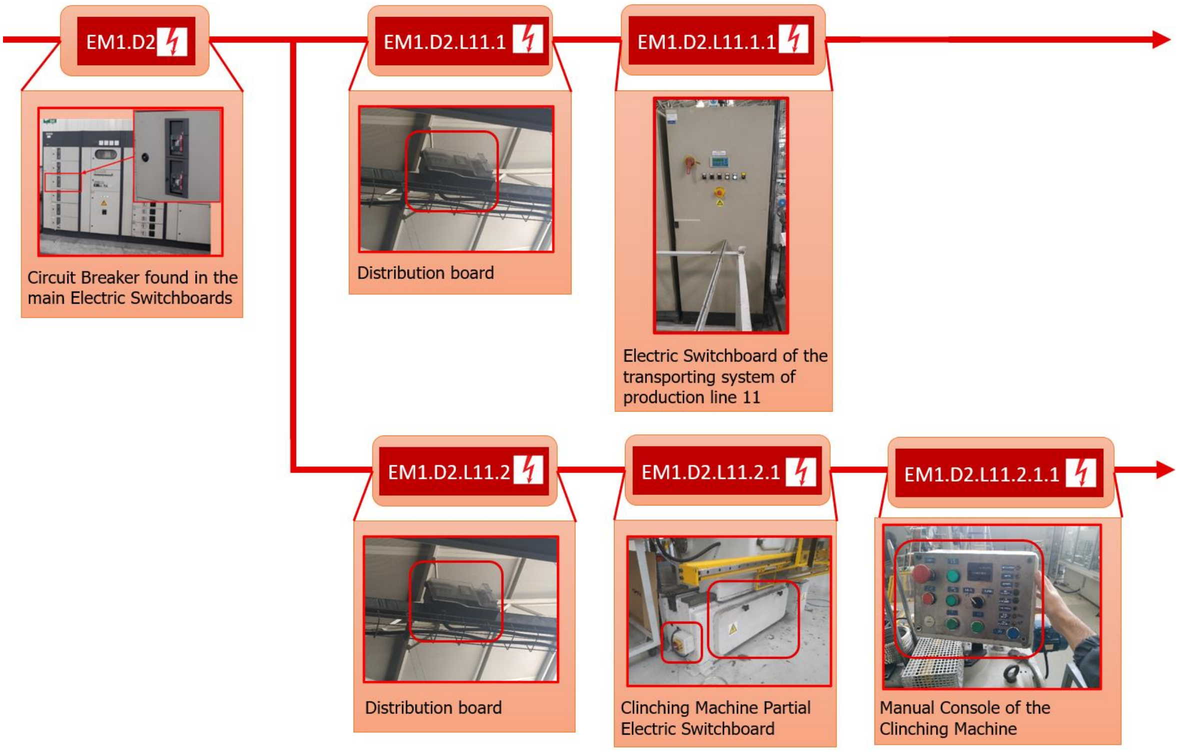


Figure 95 - Sequence of the electrical current that reaches the clinching machine

The blocking methods for each equipment can be seen in Table 25, with EE1.D2 being a circuit breaker, while EE1.D2.L11.1 and EE1.D2.L11.2 are distribution boards controlled by electric switches. Therefore, all three make use of the equipment acquired in the 3.8 section of this dissertation. EE1.D2.L11.1.1 and EE1.D2.L11.2.1 are electric switchboards, and possess their own specific blocking method, while the console possesses only an emergency button.

Table 25 - Blocking methods for the electrical system of the clinching machine

Designation of the blocking point	Blocking method diagram	Blocking method description
EM1.D2	 *Figure 96 - Circuit breaker blocking method*	1. Turn off the circuit breaker; 2. Unscrew the locking equipment, and place it on the top of the switch; 3. Screw the locking equipment, clutching the switch; 4. Place and lock the padlock in the locking equipment.

EM1.D2.L11.1 EM1.D2.L11.2	 *Figure 97 - Electric switch blocking method*	1. Turn off the electric switch; 2. Fit the locking equipment on the switch as shown in Figure 97; 3. Place and lock the padlock in the locking equipment.
EM1.D2.L11.1.1 EM1.D2.L11.2.1	 *Figure 98 – Clinching machine switchboard blocking method*	1. Turn off the switchboard; 2. Place the padlock in the exposed section seen in Figure 98; 3. Lock and tag the padlock.
EM1.D2.L11.2.1.1	 *Figure 99 - Clinching machine manual command*	1. Pressing the emergency button will shutdown the equipment but not block its restart.

3.10.4. Analysis of the pneumatic system and blocking points

A diagram representing the sequence of pneumatic energy can be seen in Figure 100, along with the tags added to which relevant equipment. The path of the pressurized air in the double-seam machine is relatively simple, only possessing three blocking points. The first valve, tagged P1, is connected to the main pipe that delivers pressurized air to the whole factory, while P2 is an intermediate valve between P1 and P3, with P3 being the main pneumatic control module of the clinching machine.

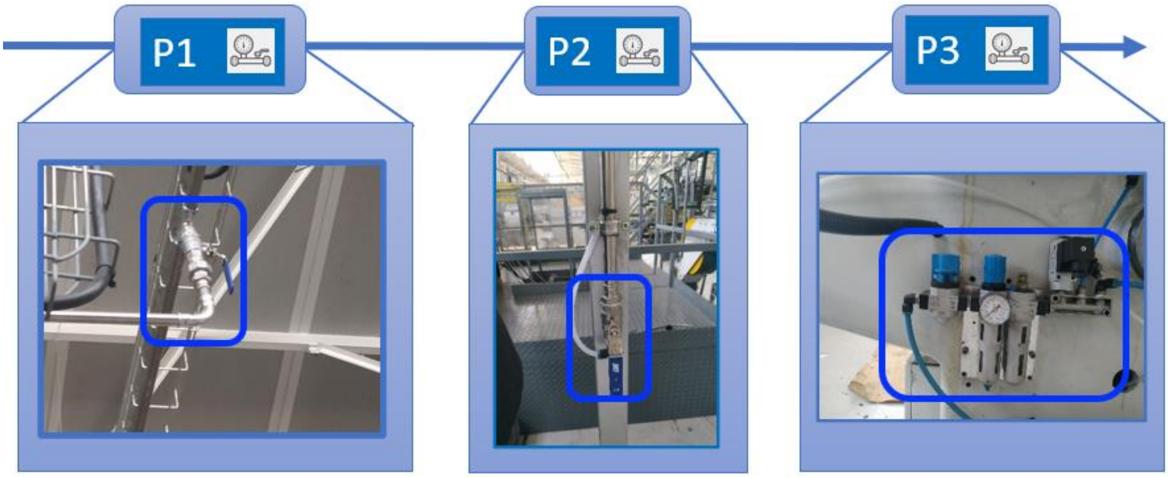


Figure 100 - Pneumatic sequence of the clinching machine

The blocking methods for each of present valves can be seen in Table 26.

Table 26 - Blocking methods for the pneumatic system of the clinching machine

Designation of the blocking point	Blocking method diagram	Blocking method description
P1 P2	 Figure 101 - Pneumatic valve blocking method	1. Close the valve; 2. Place and lock the padlock in the valve, as shown in Figure 101.
P3	 Figure 102 - Pneumatic valve blocking method	3. Close the valve; 4. Place and lock the padlock in the valve, as shown in Figure 102; 5. Verify with the manometer that the system has been depressurized (zero pressure) before intervening.

3.10.5. Analysis of the mechanical system and blocking points

The mechanical blocking system of the double-seam machine is exclusively constituted by a series of windows and a barrier, which barge any individuals from accessing the interior of the machine, and its moving parts, while the machine is energized and operating. However, the windows do not completely cover all sections of the machine, since these should leave some vacant space for the cylinders and cans to pass through. But nonetheless, it is impossible to engage with the inside of the machine, since the vacant spaces are too narrow for anyone to engage with machine while it is receiving the cans, and any dangerous zones are out of reach, even if an individual uses the vacant spaces to gain access to the inside of the machine, while it is operating. All the windows are identified, along with their respective tags, in Figure 103.

Figure 103 - Mechanical blocking points of the clinching machine

In terms of blocking, they all follow the same solution, seen in Table 27.

Table 27 - Blocking methods for the mechanical system of the clinching machine

Designation of the blocking point	Blocking method diagram	Blocking method description
M1 M2 M3 M4	 Figure 104 - Door/window blocking method	1. Opening the door/window will immediately stop the machine; 2. The machine can only be started again when the door/window is closed.

3.10.6. Analysis of tasks and energy sources

A detailed and comprehensive analysis of the tasks and energy involved can be seen in Appendix C. In this section, only the most relevant information will be showcased, with a summary of the analysis being represented in Table 28.

Table 28 - Analysis of tasks and energy sources – production line 11 – clinching machine

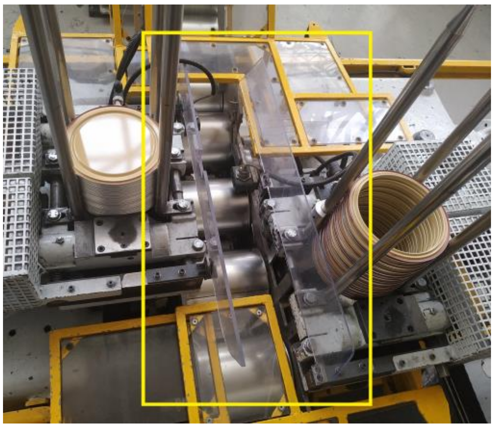
LOTO Level	Task	Main Risks	Main Dangers	Identified Energies
0	Normal working operating conditions.	None		n/a
0	Manual suppling of metal rings and circles, which can be done as the machine is working due to protective safety.	Fatigue; moving parts.	Trapping or electrification.	Mechanical; Electric.
0	External cleaning of equipment.	None		n/a
0	Check start, and trigger shutdown of the equipment	Abrupt shutdown of the machine can still leave residual energy.		n/a
1	Unjamming, or cleaning the clinching machine.	Difficult access to certain elements; moving parts and presence of electricity.	Electrocution/electrification and trapping	Mechanical; Electric.
2	Adjust sensor.	Fatigue; moving parts.	Trapping or electrification.	Mechanical; Electric.
2	Clean or replace vacuum filters.	Presence of pressure inside the tubes.	Projection of impurities or objects.	Pneumatic.
2	General cleaning of the electric switchboard.	Presence of electricity.	Electrocution/electrification.	Electric.
3	Making changes to the pneumatic installation. Examples include, checking Air Leaks, compressed air tubes, valves leaks, pressure gauges, regulators, valves and cylinders.	Presence of pressure inside the tubes	Projection of impurities or objects.	Pneumatic.
3	Perform changes on the solenoid valve.	Presence of electricity and pressure inside the tubes.	Electrocution/electrification, or projection of impurities or objects.	Electric; Pneumatic.
3	Intervention/replacement of electrical components.	Presence of electricity.	Electrocution/electrification.	Electric.
3	Central oil and lubrification systems.	Difficult access to certain elements; part movement, tool manipulation.	Crushing; trapping and cut/abrasions.	Mechanical.

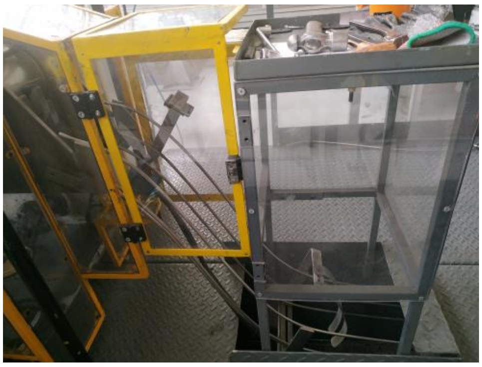
3	Intervention/replacement of electric motors; belts, supports, guides, rollers, mechanical parts.	Starting the engine connected to the parts; presence of electricity; handling of parts; tool handling.	Trapping and cut/abrasions.	Mechanical; Electric.
3	Repair of sensors and cables.	Positioning and difficult access to some elements; press movement; presence of Energies.	Crushing; trapping; cut/abrasions; electrification	Mechanical; Electric; Pneumatic.
3	Intervention/repair in the electrical control command.	Presence of electricity; tool manipulation.	Electrocution/electrification; crushing; cut/abrasions.	Electric.
3	Replacement/repair of motors or electrical cables of product output conveyors.	Presence of electricity; tool manipulation; conveyor belt movement.	Electrocution/electrification; crushing; cut/abrasions.	Mechanical; Electric.
3	General Review.	Pressured air; press movement; elevator and feeder table movement; mechanical roller movement; stored energy (in the lung); working in altitude (2 meters); tool manipulation.	Crushing; trapping; falling parts; cuts/abrasions; fall from heights; electrocution/electrification;	Mechanical; Electric; Hydraulics; Pneumatic.
3	Intervention/repair on the electrical switchboard or power cables	Presence of electricity; tool manipulation.	Electrocution/electrification; trapping; cut/abrasions.	Electric.
4	Check belts and shafts clearances.	Mechanical press start, mechanical part movement; tool handling;.	Crushing; trapping; falling parts; cuts/abrasions; fall from heights; electrocution/electrification;	Mechanical; Pneumatic.
4	Thermographic analysis.	Operation of the equipment with the employee inside the machine.	Electrocution/electrification; trapping; cut/abrasions.	Mechanical; Electric.
4	Identification of breakdown or damage.	Movement of mechanical parts.	Electrocution/electrification; trapping; cut/abrasions.	Mechanical; Electric, Hydraulics; Pneumatic.

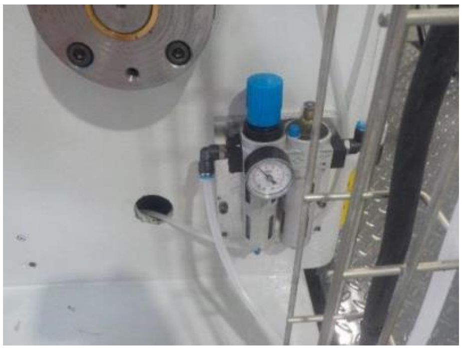
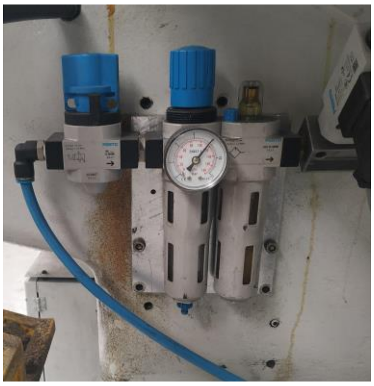
3.10.7. Problem quantification and implementation of changes

After the tasks and their associated dangers where analysis, several changes and improvements were made to both make the implementation of a LOTO procedure possible, and to improve safety conditions in the equipment. The problems and the implemented changes are showcased in Table 29.

Table 29 - Problem quantification and implementation of changes – production line 11 – clinching machine

	Problem description	Implemented changes
Problem 1	None of the blocking points or equipment had any type of LOTO tag.	The tags were made, printed, and applied to their respective equipment.  *Figure 105 – Added tags to the clinching machine*
Problem 2	There was an open section on the top of the machine, enabling uninterrupted access to danger areas of the machine, while it was operating. Although some protective barriers were already implemented, these were not enough to fully block access.  *Figure 106 - Open section of the clinching machine*	A two-sided window was added to the top of the equipment, blocking access to the inside of the machine from the top section, and shutting down the machine if the two-sided window is opened.  *Figure 107 - Added protection to the top of the clinching machine*

Problem 3	The section from which the cans exited the machine was also open, providing no protection, and allowing full access to dangerous zones inside the machine, while the machine was energized and operating. Additionally, the exposed hole on the floor for the cans to travel is likewise exposed, which may lead to tripping or failing.  *Figure 108 - Open can exit section*	The exist section was covered up, preventing access to the inside of the equipment and covering the hole on the floor, with an added window on the side, allowing access for maintenance or unjamming, but stopping the machine from operating while the window is open. Thus, the equipment now complies with the safety distances, as described in the EN13857 standard.  *Figure 109 - Protections added to the can exit section*
Problem 4	The machine's main switchboard had no tag or sign to clearly identify this section as a switchboard, possessing dangerous high voltage, and electric equipment.  *Figure 110 - Unidentified electrical switchboard*	A LOTO tag and a danger sigh were added, clearly identifying the switchboard as an electric equipment, and signaling danger.  *Figure 111 – Added tag and signaling*

Problem 5	Lack of general power cut device for the machine's pneumatic system, with the possibility of locking in the off position.  *Figure 112 - Air pressure module with no blocking option*	A locking valve was added to the machine's pneumatic system.  *Figure 113 – Added blocking valve to the air pressure module*

3.10.8. Safety procedure – production Line 11 – double-seam machine

The safety procedure of the stamping machine, belonging to production line 11, can be found in Appendix D. In Table 30, a summary of the safety procedure is presented, showcasing the most relevant information.

Table 30 - Safety procedure – production line 11 – clinching machine

Tasks	Energy blocking points	Blocking methods	Additional Information	LOTO level
1. Adjustment or tuning of the machine; 2. Unjam cans, sheets, or scraps that fall inside the machine; 3. General lubrication of the equipment; 4. Cleaning of the line inside the machine's cabin; 5. Visual inspection.	M1 or M2 or M3 or M4	1. Warn the employees involved; 2. Open the window/door.		2
6. Changes in layout; 7. Replacement/repair of the machine's motors; 8. Intervention/replacement of sensor, electrical cables and other electrical components inside the cabin; 9. Intervention/repair in belts, supports, guides, rollers, and other mechanical elements; 10. Intervention/repair in the machine's manual console (EM1.D2.L11.2.1.1).	EM1.D2.L11.2.1	1. Warn the employees involved; 2. Turn off the electrical panels and place the padlock + danger signal tag; 3. Press START/STOP button (for verification purposes).	1. Check the absence of energy with a multimeter.	3
11. Changes in the machine's pneumatic system.	P3	1. Warn the employees involved; 2. Close compressed air valve and put padlock + hazard signal label.	1. Check the absence of energy with a multimeter; 2. Close the P3 compressed air valve; 3. Check if the section is decompressed using the manometer (zero pressure) before the intervention.	3

12. Repair of sensors, cables and pneumatic solenoid valves; 13. Interventions/replacement of the vacuum filters; 14. Check/replenish crankcase oil levels; 15. Check/replace oil levels in the compressed air lubricating cup.	EM1.D2.L11.2.1 + P3	1. Warn the employees involved; 2. Turn off electrical panels and put padlock + danger signal tag; 3. Close compressed air valve and put padlock + hazard signal label; 4. Press START/STOP button (for verification purposes).	1. Check the absence of energy with a multimeter; 2. Close the P3 compressed air valve; 3. Check if the section is decompressed using the manometer (zero pressure) before the intervention;	3
16. Intervention/repairs in the conveyor belts.	EM1.D2.L11.1.1	1. Warn the employees involved; 2. Turn off the electrical panels and place the padlock + danger signal tag; 3. Press START/STOP button (for verification purposes).	1. Check the absence of energy with a multimeter.	3
17. Changes in the pneumatic distribution system.	P2 + P3	1. Warn the employees involved; 2. Close compressed air valve and put padlock + hazard signal label; 3. Press START/STOP button (for verification purposes).	1. Close the P2 and P3 compressed air valves; 2. Check if the sections are decompressed using the manometer (zero pressure) before the intervention.	3

18. General review.	EM1.D2 + P2 + P3	1. Warn the employees involved; 2. Turn off electrical panels and put padlock + danger signal tag; 3. Close compressed air valve and put padlock + hazard signal label; 4. Press START/STOP button (for verification purposes).	1. Check the absence of energy with a multimeter; 2. Close the P3 and P2 compressed air valves; 3. Check if the sections are decompressed using the manometer (zero pressure) before the intervention.	3
19. Intervention/repair on the electrical panel or power cables; 20. General cleaning of the electrical switchboard;	EM1.D2	1. Warn the employees involved; 2. Turn off the electrical panels and place the padlock + danger signal tag; 3. Press START/STOP button (for verification purposes).	1. Check the absence of energy with a multimeter.	3
21. Identification of malfunctions; 22. Thermographic Analysis.		1. Warn the workers involved; 2. Place safety barriers and danger signs; 3. Placing the machine in manual mode; 4. Coordination between 2 technicians; 5. Accessible emergency button.	1. Ensure that only qualified and trained people in LOTO can perform this operation; 2. Ensure proximity to an emergency button; 3. Requires work permit.	4

3.10.9. Measurement of improvement

Following the same methods used in the 3.9.9 section, the number of documented injuries that occurred in the clinching machine can be seen in Table 31. By calculating the average monthly rate of injury before and after the implementation, its possible to obverse a reduction of the monthly rate of injury, from 0.041 injuries per month, to 0 injuries. It is important to highlight once again that a definitive conclusion cannot be reached with these findings. Nonetheless, a reduction of the injury-rates was observed in the available timeframe.

Table 31 - Number of injuries that occurred in the clinching machine

Number of recorded injuries from 6/1/2021, to 20/3/2023	1	Average injuries per month before the implementation of the safety procedures	0.041(6)
Number of recorded injuries from 20/3/2023, to 13/7/2023	0	Average injuries per month after the implementation of the safety procedures	0

As for the tasks and their duration, performed as part of preventive maintenance, they can be seen in Table 32.

Table 32 - Duration of preventive maintenance, before and after the implementation of the safety procedures in the clinching machine

Tasks	Maintenance done after the implementation of the safety procedure		Maintenance done before the implementation of the safety procedure	
Check/replace belts and chains	Date	Duration (min)	Date	Duration (min)
	13/5/2023	5 min	9/8/2022	5 min
			1/7/2022	5 min
			6/5/2022	5 min
			12/2/2022	5 min
	2/4/2023	5 min	21/1/2022	5 min
			13/12/2021	5 min
			9/8/2022	5 min
	29/3/2023	5 min	1/7/2022	5 min
			21/17/2022	5 min
			13/12/2021	5 min
Check/replenish crankcase oil levels	Date	Duration (min)	Date	Duration (min)
	13/5/2023	5 min	9/8/2022	5 min
			1/7/2022	5 min
			6/5/2022	5 min
			12/2/2022	5 min
	2/4/2023	5 min	21/1/2022	5 min
			13/12/2021	5 min
			9/8/2022	5 min
	29/3/2023	5 min	1/7/2022	5 min
			21/17/2022	5 min
			13/12/2021	5 min
General lubrication	Date	Duration (min)	Date	Duration (min)
	13/5/2023	10 min	9/8/2022	10 min
			1/7/2022	5 min
			6/5/2022	10 min
			12/2/2022	10 min

	2/4/2023	10 min	21/1/2022	10 min
			13/12/2021	10 min
			9/8/2022	10 min
	29/3/2023	15 min	1/7/2022	5 min
			21/17/2022	10 min
			13/12/2021	5 min
Check/replenish oil levels in the compressed air lubricating cup	Date	Duration (min)	Date	Duration (min)
	13/5/2023	5 min	9/8/2022	5 min
			1/7/2022	5 min
	2/4/2023	5 min	21/17/2022	5 min
			13/12/2021	5 min

With the duration of each instance of the task now gathered, by calculating the average duration of each task, the obtained values should be an accurate representation of the time it takes to perform the maintenance task on an ordinary instance, with the averages being seen in Table 33.

Table 33 - Average duration of the tasks, before and after the implementation of the safety procedures in the stamping machine

Tasks	Average duration of the task after the implementation	Average duration of the task before the implementation	Difference
Check/replace belts and chains	5 min	5 min	0 min
Check/replenish crankcase oil levels	5 min	5 min	0 min
General lubrication	11 min	8 min	3 min
Check/replenish oil levels in the compressed air lubricating cup	5 min	5 min	0 min
Average difference of duration between the activities			45 seconds

As can be seen, each task's duration increased by an average of 45 seconds, with only 1 of the tasks seeing any increase in duration, while the duration of the other tasks remained the same. This indicates a very slight increase in the duration of the tasks, even if the increase may not be meaningfully relevant. It is also interesting to note that the average increase in the duration of the tasks seen in production line 11 is slightly smaller than the average increase in duration seen in production line 99. Since the safety procedure of the production line 11 was implemented after the safety procedure of the production line 99, this difference may indicate that workers have become more accustomed to the LOTO methodology.

3.11. Production line 26 – stamping machine

3.11.1. Analysis of the production line 26

Production line 26 manufactures the metal rings placed on the edges of the can, allowing the placement of a lid later on the manufacturing process of the can, as can be seen in Figure 114. The process begins with a metal sheet (1), that is then cut by a stamping process, creating multiple metal rings (2) from a singular sheet, and leaving behind wasted sheet (6). Each metal ring then goes through another stamping operation, this time to deform the ring, giving it a different shape (3). Finally, a machine applies a thin layer of rubber to the ring (4), adding a layer that protects the ring against corrosion, which is extremely important if the ring is to be used in food packaging.

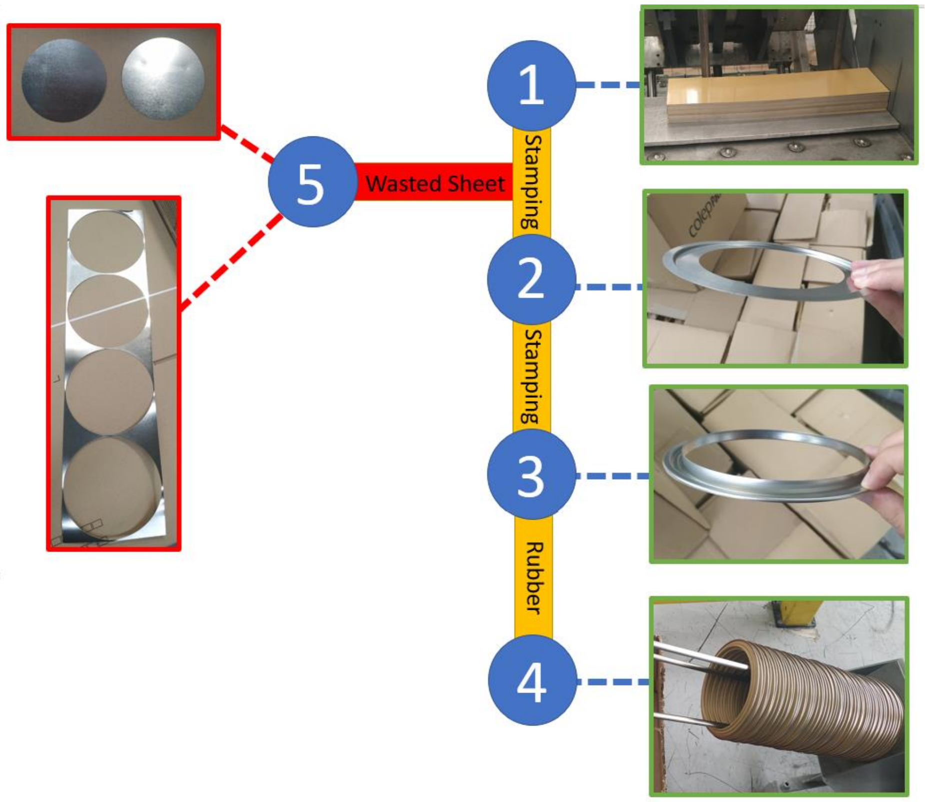
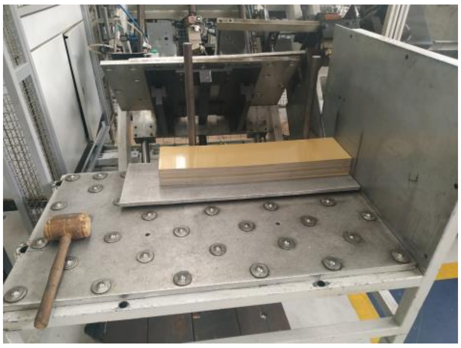


Figure 114 - Sequence of can manufacturing performed by production line 26

3.11.2. Analysis of the stamping machines – production line 26

For the purposes of this dissertation, only the two stamping machines belonging to production line 26 were analyzed. Although they are two separate machines, they are connected and similar enough, to warrant a joined safety procedure that covers both the stamping machines. The stamping machines are tasked with cutting and deforming a metal sheet, in order to manufacture a metal ring, to be later clinched on cans, similar to the manufacturing process seen in the clinching machine of production line 11. The general operation process of the stamping machines is described in Table 34. The production process begins with the metal sheets being manually placed into the machine, with each sheet being automatically separated and moved into the fist stamping machine, where the sheet will be cut, creating a ring of metal. The rings are then transported into the second stamping machine, using an automated system of conveyor belts, where the ring will be deformed, changing its shape.

Table 34 - General operation sequence of the stamping machines

Step	Description	Picture
1	Firstly, rectangular sheets must be manually supplied to the machine by an available worker. The sheets must be placed on the supply table, as seen in Figure 115, and pushed towards the edge of the table next to the machine, aided by rollers on the table that facilitate the movement of the sheets. Once the sheets are placed, the machine's table is moved down, and the sheets are once again manually pushed, this time to the inside the machine. The machine's table is then lifted once again, and the process can start once again.	 *Figure 115 - Stamping machines - operation step 1*
2	Once the sheets are correctly placed on the machine's table, they are then automatically separated, and sent to the mechanical press, where the first stamping operation will take place. The machine's table can be seen in Figure 116.	 *Figure 116 - Stamping machines - operation step 2*
3	The first stamping operation transforms the sheet from stage (1) to stage (2) as seen in Figure 114. This is achieved by a double action press that cuts two circles on the sheet, performed by the press seen in Figure 117, with the two circles possessing different diameters, but centered on the same point. Thus, the sheet is transformed into a group of aluminum rings that are then transported to the next stamping machine. The rest of the sheet is then discarded into two bins as seen in Figure 118, with the first bin storing the wasted rectangular sheet, while the second one stores the circular sheets, as seen in Figure 114 (6).	 *Figure 117 - Stamping machines - operation step 2*  *Figure 118 - Stamping machines wasted sheet*

4	In the second stamping operation, the circular sheets are deformed by the press seen in Figure 119, taking the ring from stage (2) to stage (3), as seen in Figure 114, deforming the metal ring, giving it a different shape.	 *Figure 119 - Stamping machines - operation step 4*

3.11.3. Analysis of electric system and blocking points

Production line 26 also uses a distribution grid, as explained in the section 3.10.3 of this dissertation. The electrical system of the stamping machines can be seen in Figure 120.

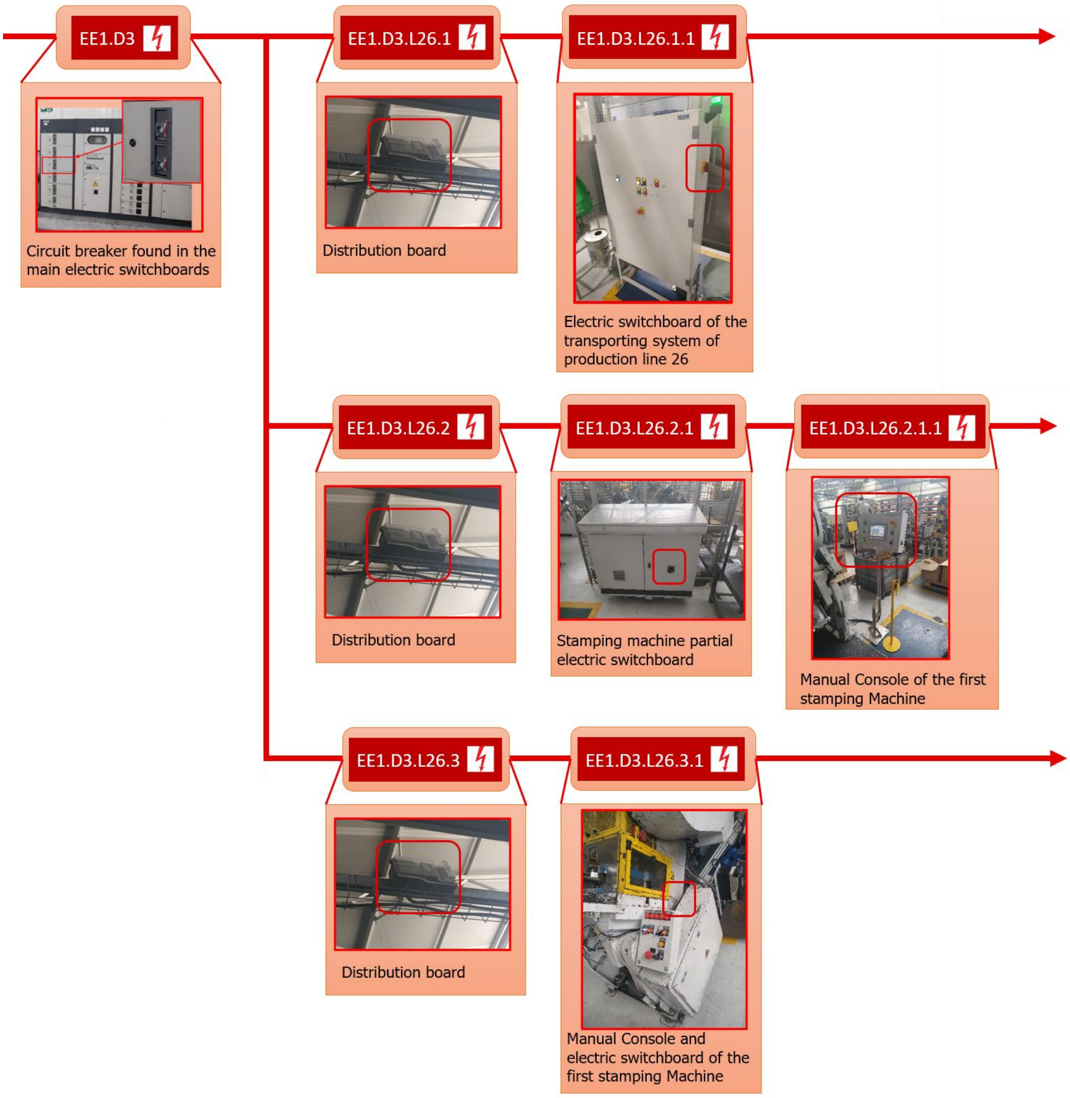


Figure 120 - Electric sequence of the stamping machines

Connected to the grid there are three distribution boards: the first supplies the transportation system of the line of production, such as the conveyor belts and other systems, the second one supplies the first stamping machine, and the third supplies the second stamping machine. Although both stamping machines possess a manual console, the console belonging to the second stamping machine is built in conjunction with its electric switchboard. Thus, both equipment were given the EE1.D3.L26.3.1 tag.

The blocking methods for each equipment can be seen in Table 35, with EE1.D3 being a circuit breaker, while EE1.D3.L26.1 and EE1.D3.L26.2 are distribution boards controlled by electric switches. Therefore, all three make use of the equipment acquired in the 3.8 section of this dissertation. EE1.D3.L26.1.1, EE1.D3.L26.2.1 and EE1.D3.L26.3.1 are electric switchboards, and possess their own blocking method, while the console possesses only an emergency button.

Table 35 - Blocking methods for the electrical system of the stamping machines

Designation of the blocking point	Blocking method diagram	Blocking method description
EE1.D3	 *Figure 121 - Circuit breaker blocking method*	1. Turn off the circuit breaker; 2. Unscrew the locking equipment, and place it on the top of the switch; 3. Screw the locking equipment, clutching the switch; 4. Place and lock the padlock in the locking equipment.
EE1.D3.L26.1 EE1.D3.L26.2 EE1.D3.L26.3	 *Figure 122 - Electric switch blocking method*	1. Turn off the electric switch; 2. Fit the locking equipment on the switch as shown in Figure 122; 3. Place and lock the padlock in the locking equipment.
EE1.D3.L26.1.1 EE1.D3.L26.2.1 EE1.D3.L26.3.1	 *Figure 123 – Switchboard blocking method*	1. Turn off the switchboard; 2. Place the padlock in the exposed section seen in Figure 123; 3. Lock and tag the padlock.
EE1.D3.L26.2.1.1	 *Figure 124 - Clinching machine manual command*	1. Pressing the emergency button will shutdown the equipment but not block its restart.

3.11.4. Analysis of the pneumatic system and blocking points

The path of the pressurized air can be seen in Figure 125, beginning in P1 which is a valve connected to the main pipe that delivers pressurized air to the whole factory. The pressurized air then reaches the first and second stamping machines, passing P2 and P3 to reach the second stamping machine, and passing P5 and P6 to reach the first stamping machine. Both stamping machines also possess an air tank, which must be individually depressurized, in order to secure that the system has been properly deenergized.

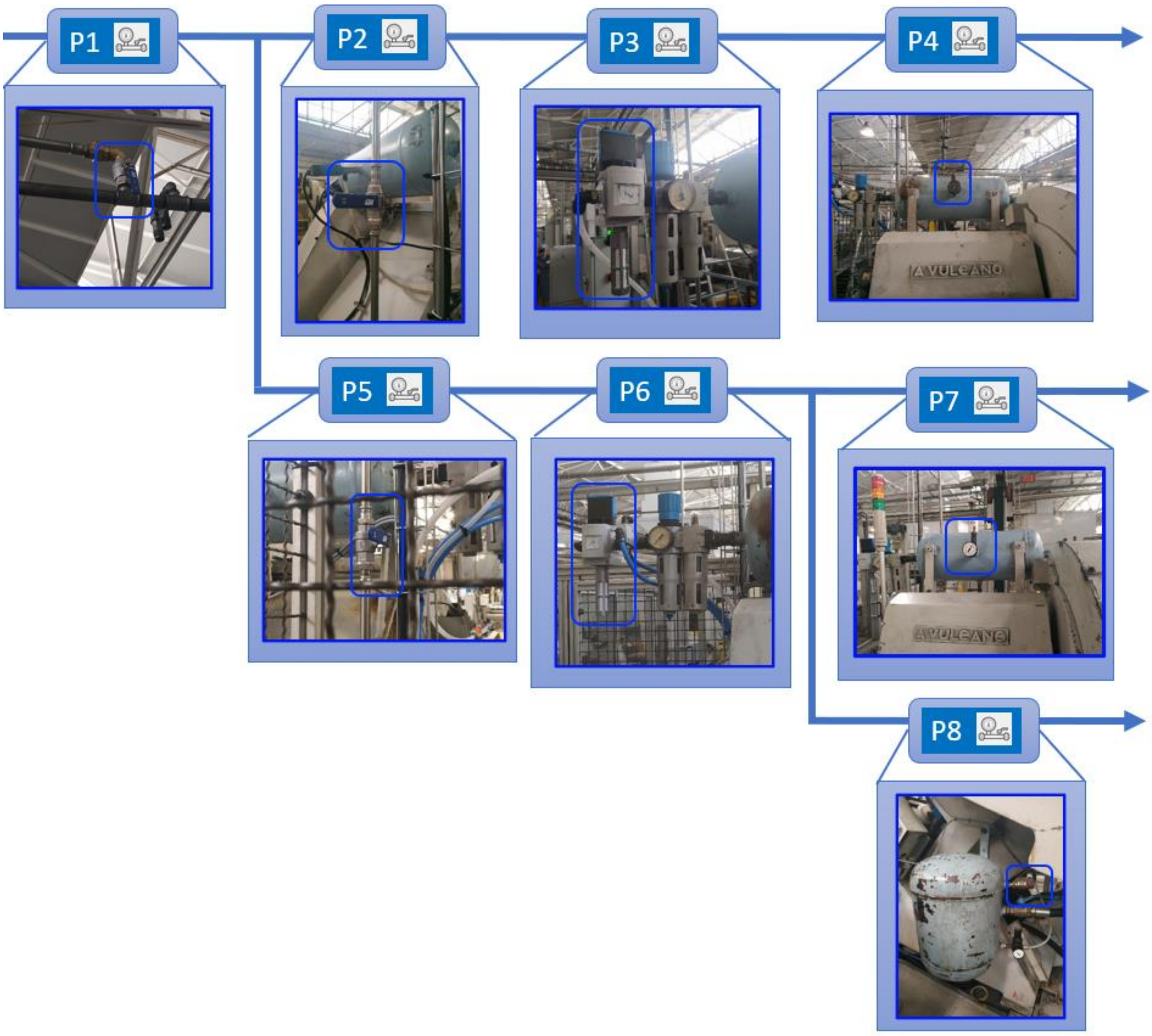
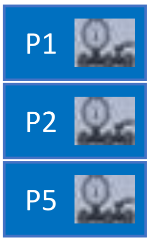
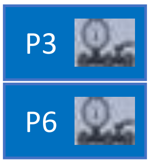
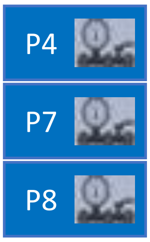


Figure 125 - Pneumatic sequence of the stamping machines

The blocking methods for the pneumatic valves can be seen in Table 36.

Table 36 - Blocking methods for the pneumatic system of the stamping machines

Designation of the blocking point	Blocking method diagram	Blocking method description
	 *Figure 126 - Pneumatic valve blocking method*	3. Close the valve; 1. Place and lock the padlock in the valve, as shown in Figure 126.
	 *Figure 127 - Pneumatic valve blocking method*	6. Close the valve; 7. Place and lock the padlock in the valve, as shown in Figure 127; 1. Verify with the manometer that the system has been depressurized (zero pressure) before intervening.
	 *Figure 128 – Pressurized air tank*	1. Open the valve located in the tank to begin decompression; 2. Check the pressure levels in the press' manometer; 3. Begin operation once the pressure has been fully released.

3.11.5. Analysis of the mechanical system and blocking points

The mechanical blocking systems of the stamping machines are constituted by a series of doors and windows, which barge any individuals from accessing the interior of the machine and its moving parts, while the machine is energized and operating, and a series of mechanical shafts used to block the press' movement, similar to the press blocking seen in the stamping machine of production line 99. All the blocking points are identified, along with their respective tags, in Figure 129.

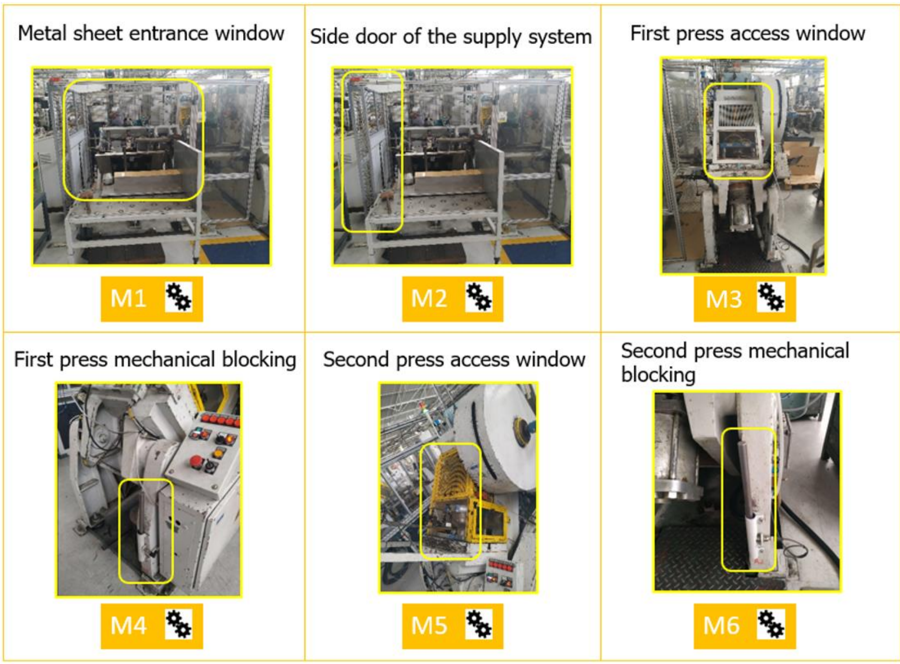
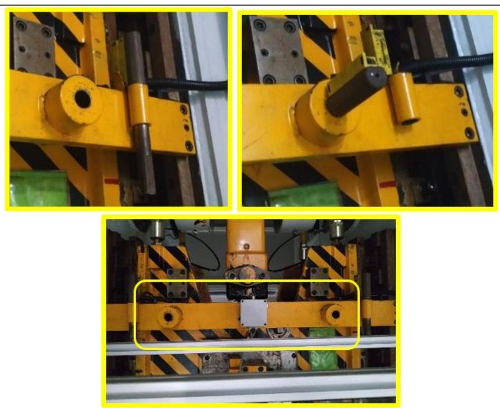


Figure 129 - Mechanical blocking points of the stamping machines

The blocking methods for all the mechanical equipment are described in Table 37.

Table 37 - Blocking methods for the mechanical system of the stamping machines

Designation of the blocking point	Blocking method diagram	Blocking method description
M1 M2 M3 M5	 Figure 130 - Door/window blocking method	1. Opening the door/window will immediately stop the machine; 2. The machine can only be started again when the door/window is closed.
M4 M6	 Figure 131 - Press blocking method	1. Remove the metal shaft from its support; 2. Place the shaft on both sides of the press, as shown in Figure 74.

3.11.6. Analysis of tasks and energy sources

A detailed and comprehensive analysis of the tasks and energy involved can be seen in Appendix C. In this section, only the most relevant information will be showcased, with a summary of the analysis being represented in Table 38.

Table 38 - Analysis of tasks and energy sources – production line 26 – stamping machines

LOTO Level	Task	Main risks	Main dangers	Identified energies
0	Normal working operating conditions.	none		n/a
0	Manual suppling metal sheets, which are placed at the entrance of the machine.	Tool handling (strap and film cutting); and metal sheet handling.	Crushing; trapping; cut/ abrasions.	Mechanical.
0	Compressing the unused, and wasted material, in the waste container.	Working with scraps of metal sheet.	Cuts/abrasions.	n/a
0	External cleaning of equipment.	None		n/a
0	Check start, and trigger shutdown of the equipment.	None	Abrupt shutdown of the machine can still leave residual energy.	n/a
1	Unjamming, or cleaning the presses through the entrance window.	Difficult access to certain elements; presence of scraps of metal; mechanical press movement.	Trapping or cut/abrasions.	Mechanical; Electric; Pneumatic.
2	Cleaning the inside area of the equipment, and cleaning the chain elements.	Fatigue; moving parts.	Trapping or electrification.	Mechanical; Electric.
2	Clean or replace vacuum filters.	Presence of pressure inside the tubes.	Projection of impurities or objects.	Pneumatic.
2	Change/check of the oil level. Clean or replace the lubrication filter.	Presence of pressurized oil.	Projection of oil or impurities.	Pneumatic.
2	Unjamming the sheet from the table or replacing the vacuum sucker cups.	Movement of the positioner table.	Crushing, trapping or cut/abrasions.	Mechanical; Electric; Hydraulics; Pneumatic.

2	General cleaning of the electric switchboard.	Presence of electricity.	Electrocution/electrification.	Electric.
3	Making changes to the pneumatic installation. Examples include, checking air leaks, compressed air tubes, valves leaks, pressure gauges, injectors, regulators, valves and cylinders.	Presence of pressure inside the tubes.	Projection of impurities or objects.	Pneumatic.
3	Perform changes on the solenoid valve.	Presence of electricity and pressure inside the tubes.	Electrocution/electrification, or projection of impurities or objects.	Electric; Pneumatic.
3	Intervention/replacement of electrical components.	Presence of electricity.	Electrocution/electrification.	Electric.
3	Central lubrication of the mechanical press.	Difficult access to certain elements; unscheduled start of engines, roller movement, tool manipulation.	Crushing; trapping and cut/abrasions.	Mechanical.
3	Intervention/replacement of electric motors, belts, supports, guides, rollers and mechanical parts.	Starting the engine connected to the parts; presence of electricity; handling of parts; tool handling.	Trapping and cut/abrasions.	Mechanical; Electric.
3	Repair of sensors and cables.	Positioning and difficult access to some elements; press movement; presence of energies.	Crushing; trapping; cut/abrasions; electrification.	Mechanical; Electric; Pneumatic.
3	Replace the press' shock absorbing cylinders.	Start of a mechanical press; handling of parts; tool handling, use of a moving platform; different work heights.	Crushing; trapping; falling parts; cuts/abrasions; impact against structures; run overs; fall from height.	Mechanical; Pneumatic.
3	Interventions/replacements in the pneumatic system of the mechanical presses.	Presence of pressurized air; mechanical press movement; elevator and feeder table movement; start of mechanical rollers; tool manipulation.	Crushing; trapping; falling parts; cuts/abrasions.	Pneumatic; Potential.
3	Intervention/repair in the electrical control command.	Presence of electricity; tool manipulation.	Electrocution/electrification; crushing; cut/abrasions.	Electric.
3	Replacement/manipulation of the supply window motor.	Presence of electricity; tool manipulation; window movement.	Electrocution/electrification;	Mechanical;

			crushing; cut/abrasions.	Electric.
3	Replacement/repair of motors or electrical cables of product output conveyors.	Presence of electricity; tool manipulation; conveyor belt movement.	Electrocution/electrification; crushing; cut/abrasions.	Mechanical; Electric.
3	Replacement/repair of conveyor belts, and other components of the transporters.	Tool manipulation; conveyor belt movement.	Crushing; trapping.	Mechanical.
3	General review.	Pressured air; press movement; elevator and feeder table movement; mechanical roller movement; stored energy (in the tank); working in altitude (2 meters); tool manipulation.	Crushing; trapping; falling parts; cuts/abrasions; fall from heights; electrocution/electrification;	Mechanical; Electric; Hydraulics; Pneumatic.
3	Check/repair mechanical punch of the stamping machine.	Motion of the mechanical press; mechanical roller movement; tool manipulation.	Crushing; trapping; cuts/abrasions.	Mechanical; Electric.
3	Intervention/repair on the electrical switchboard or power cables.	Presence of electricity; tool manipulation.	Electrocution/electrification; trapping; cut/abrasions.	Electric.
4	Check flywheel/belts/shaft's clearances.	Mechanical press start, mechanical part movement, tool handling; use of special equipment to dismantle and move steering wheel of the press.	Crushing; trapping; falling parts; cuts/abrasions; fall from heights; electrocution/electrification.	Mechanical; Pneumatic.
4	Thermographic analysis.	Operation of the equipment with the employee inside the machine.	Electrocution/electrification; trapping; cut/abrasions.	Mechanical; Electric.
4	Identification of breakdown or damage.	Movement of the mechanical press, positioner table movement (cylinder), and roller movement.	Electrocution/electrification; trapping; cut/abrasions.	Mechanical; Electric; Hydraulics; Pneumatic.

3.11.7. Problem quantification and implementation of changes

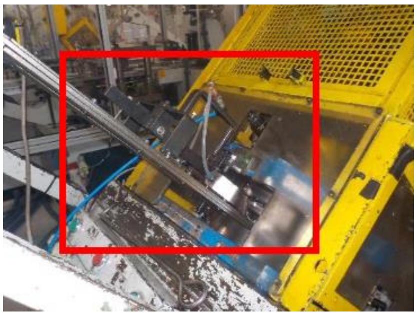
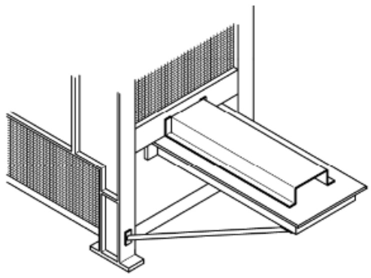
After the tasks and their associated dangers where analysis, several changes and improvements were made to both make the implementation of a LOTO procedure possible, and to improve safety conditions in the equipment. The problems and the implemented changes are showcased in Table 39.

Table 39 - Problem quantification and implementation of changes

	Problem description	Implemented changes
Problem 1	None of the blocking points or equipment had any type of LOTO tag.	The tags were made, printed, and applied to their respective equipment.  *Figure 132 – Add tags to the clinching machine*
Problem 2	The pneumatic system lacked a way of blocking and decompressing the system.	Two locking valves were added to the line's pneumatic system.  *Figure 133 - Valves and decompression methods added to the production line 26*

Additionally, there were a series of identified problems and needed changes that were approved, but not yet implemented, due to the time constraints set for this dissertation. The identified problems and the proposed solutions can be seen in Table 40.

Table 40 - Identified problems, and proposed solutions

	Problem Description	Proposed Solution
Problem 3	Possibility of access to the first press through the supply section. Although the access is limited, the barriers placed do not sufficiently limit access to the inside of the press.  *Figure 134 - Free access to the first press*	The protection window could be extended, covering the open section of the press, and providing sufficiently cover.
Problem 4	Possibility of access to the movement of the second press. No protections are placed to prevent the access to the inside of the press.  *Figure 135 - Free access to the second press*	A protection could be added to prevent access to press, by placing a tunnel-like protector to the top of the section, similar to the protection seen in Figure 136.  *Figure 136 - Potential protection*

3.11.8. Safety procedure – production line 26 – stamping machines

The safety procedure of the stamping machines, belonging to production line 26, can be found in Appendix D. In Table 41, a summary of the safety procedure is presented, showcasing the most relevant information.

Table 41 - Safety procedure – Production line 26 – stamping machines

Tasks	Energy blocking points	Blocking methods	Additional Information	LOTO level
1. Supply of metal sheets: - Manually place the sheets on the table; - Lower the transport table; - Push the sheets into the transport table.	M1	1. Warn the workers involved; 2. Once the task is performed, close the window and resume operation.	1. The mechanical blocking point is always through the door from where the supplied sheets enter; 2. The transportation table must be at the same angle as the entrance.	2
2. Unjamming sheets or other components stuck in the press (through the M3 or M4 windows); 3. Clean the press' table (through the M6 window); 4. Disassemble/assemble press guides; 5. Replace screws in the punch of the press; 6. Setup to replace the punch of the press; 7. General lubrication of the equipment; 8. Cleaning of the line inside the machine's cabin.	M3 or M4	1. Warn the workers involved; 2. Open the access window, forcing the machine to shutdown; 3. Once the task is performed, close the window and resume operation.	1. To intervene in the first press, open M3, and to intervene in the second press, open M4; 2. For tasks 5 and 6 block the mechanical press (M4 or M6); 3. For task 4 block the press (M4 or M6) whenever it is not necessary to move head manually.	2
9. Adjustment or tuning of the positioner table; 10. Unjam sheet from the positioning table; 11. Replacement of suction cups; 12. Cleaning of the chain drivers; 13. Centering and adjustment;	M1 or M2	1. Warn the workers involved; 2. Open the access window, forcing the machine to shutdown; 3. Once the task is performed, close the window and resume operation.	1. The mechanical blocking point is always through the door from where the supplied sheets enter; 2. The transportation table must be at the same angle as the entrance.	2
14. Exchange/repair of electric motors or electric cables of the conveyors; 15. Change of screens in the conveyor.	EE1.D3.L26.1.1 + EE1.D3.L26.2.1 + EE1.D3.L26.3.1	1. Warn the employees involved; 2. Turn off the electrical panels and place the padlock + danger signal tag; 3. Press START/STOP button (for verification purposes).	1. Check the absence of energy with a multimeter; 2. Verify the that the press that interacts with the transport is also turned off and blocked.	3

16. Motor replacement/repair of the sheet entrance window; 17. Intervention/repair in the manual console of the entrance window; 18. Intervention/replacement of sensor, electrical cables and other electrical components inside the cabin of the first press; 19. Intervention/repair in belts, supports, guides, rollers, and other mechanical elements of the first press; 20. General cleaning of the first press.	EE1.D3.L26.2.1	1. Warn the employees involved; 2. Turn off the electrical panels and place the padlock + danger signal tag; 3. Press START/STOP button (for verification purposes).	1. Check the absence of energy with a multimeter; 2. For task 16, disconnect harting plugs from the conveyor.  *Figure 137 – Harting plug*	3
21. Intervention/replacement of sensor, electrical cables and other electrical components inside the second press; 22. Intervention/repair in belts, supports, guides, rollers, and other mechanical elements in the second press; 23. General cleaning of the second press.	EE1.D3.L26.3.1	1. Warn the employees involved; 2. Turn off the electrical panels and place the padlock + danger signal tag; 3. Press START/STOP button (for verification purposes).	1. Check the absence of energy with a multimeter.	3
24. Interventions/replacements in the pneumatic system of the press; 25. Intervention in the central lubrication system of the press; 26. Replace shock absorber cylinders; 27. Replace mechanical fuses and adjust press pressure; 28. Repair of sensors, cables and pneumatic solenoid valves; 29. Interventions/substitutions vacuum filters.	EE1.D3.L26.3.1 + P3 + P4 or EE1.D3.L26.2.1 + P5 + P6 + P7	1. Warn the employees involved; 2. Turn off electrical panels and put padlock + danger signal tag; 3. Close compressed air valve and put padlock + hazard signal label; 4. Press START/STOP button (for verification purposes).	1. Close the compressed air valve P6; 2. Check if the section is decompressed using the manometer (zero pressure) before the intervention; 3. Close the compressed air valves; 4. Check if the section is decompressed using the manometer (zero pressure) before the intervention; 5. Dissipate present energies in the P7, P6 or P4 tanks.	3

30. General review.	EE1.D3 + P5 + P6 + P7	1. Warn the employees involved; 2. Turn off electrical panels and put padlock + danger signal tag; 3. Close compressed air valve and put padlock + hazard signal label; 4. Press START/STOP button (for verification purposes).	1. Check the absence of energy with a multimeter; 2. Close the P6 compressed air valve; 3. Check if the section is decompressed using the manometer (zero pressure) before the intervention; 4. Dissipate present energies - depressurize lung P7.	3
31. Intervention/repair on the electrical panel or power cables; 32. General cleaning of the electrical switchboard;	EE1.D3	1. Warn the employees involved; 2. Turn off the electrical panels and place the padlock + danger signal tag; 3. Press START/STOP button (for verification purposes).	1. Check the absence of energy with a multimeter.	3
33. Identification of malfunctions; 34. Thermographic analysis.		1. Warn the workers involved; 2. Placement of barriers and signage; 3. Placing the machine in manual mode; 4. Coordination between 2 technicians; 5. Accessible emergency button.	1. Ensure that only qualified and trained people in LoTo can perform this operation; 2. Ensure proximity to an emergency button; 3. Requires work permit.	4

3.11.9. Measurement of improvement

Unfortunately, as the last safety procedure to be implemented, there was not enough data available to reach a definitive conclusion on the effectiveness of the implemented safety procedure, due to the time constraints placed in this dissertation.

3.12. Cost analysis of the implementation of a LOTO methodology

To finalize, Table 42 summarizes the costs associated with implementation of the safety procedures, the purchased equipment, and the changes made. In total, this entire dissertation accrued a cost of 1655.64€.

Table 42 - Cost analysis of the implementation of the safety procedures

Machine/equipment	Change made	Total cost (€)
Production line 99 – stamping machine.	Purchase of a On/Off valve MS6-EM .	252.71
	Change command identification language to Portuguese.	30.00
	Add protection to the rollers of the wasted sheets.	40.00
Production line 11 – clinching machine.	Purchase of a On/Off valve MS6-EM.	252.71
	Add protections to the machine's windows.	320.00
Production line 26 – stamping machines.	Purchase of two On/Off valve MS6-EM.	505.42
Circuit breaker.	Purchase of the circuit breaker blockers.	242.80
Tagging the various equipment.	Print and add the tags to all the equipment.	12.00
Total cost of the implementation of a LOTO methodology (€)		1655.64

4. CONCLUSIONS AND FUTURE WORK PROPOSALS

The packaging industry is a very diverse and expansive market, and is projected to grow even bigger, possessing a diverse array of different packaging options and many different clients, each with their own needs. Innovation and adaptability are one of the cornerstones of this industry, meaning changes and maintenance to industrial equipment are commonplace, and mandatory if the company wishes to remain efficient and competitive. On the other hand, as industries expand, and technology advances, the increase in complexity of industrial equipment and lines of production is inevitable, especially since automation continues to be a preferred method of increasing efficiency and production output in all types of industries. However, the increase in complexity must also be met with an improvement of safety measures, since high complexity increases the number of errors and mistakes, which will in turn can lead to increased danger throughout the workplace.

Whether providing maintenance to the equipment, or performing simple interactions, assessing the possible dangers, and developing countermeasures is an important task to maintain workplace safety, and reduce worker injury. The LOTO methodology then becomes a useful tool to control and lock possible hazardous energies, guiding the design of safety procedures capable of effectively preventing accidents, and increasing the overall awareness of safety and possible risks in any type of workplace.

Over the course of this dissertation, a LOTO methodology was implemented in a can manufacturing factory. The implementation of the methodologies began by developing a tagging system for the electrical equipment found in the company. Since these operate under a wide and complex electrical grid, a specialized tagging system was created, attempting to both relay the relevant information, while being quickly understandable. Following the development of the tags, the necessary equipment to safely block the energies present at the company was acquired, obtaining a solution to block circuit breakers, switches, and pressurized air valves, with the valve possessing both blocking and decompression capabilities, with an additional built-in manometer, allowing workers to quickly ascertain the current pressure inside the section. After these tasks were completed, the implementation of LOTO methodologies became possible at the company.

Once the implementation of LOTO methodologies was accomplished, three machines belonging to three different lines of production were thoroughly analyzed, namely a stamping machine, a clinching machine, and two stamping machines who received a conjoined safety procedure being treated as one equipment. Each machine was subjected to various improvements, adding protective barriers or equipment that has the capability of being blocked, and a safety procedure was developed and implemented in each of the machines, guiding workers through their tasks, indicating the blocking methods, and blocking points.

After the implementation of the safety procedures, a decrease in the injury rates was observed, as well as a very minor increase in the duration of preventive maintenance tasks. However, these analyses were done in a relatively short timeframe, not allowing this dissertation to reach a definitive conclusion on the effects of the implemented safety procedures but serving as a preliminary example of their possible effectiveness.

Future works could better analyze the impact of the implementation of LOTO methodologies in the workplace, by performing a more long-term analysis of the injury-rates and the duration of maintenance tasks, the data acquired should help in reaching more definitive conclusions, which can in turn provide useful data on the effectiveness of the methodologies, as well as showcase aspects in which the methodology is more effective. Other works could also expand and develop new blocking solutions for equipment not touched upon during this dissertation, but that exist in other companies or industries, or develop new tools and methods to better organize and create safety procedures for a variety of different machines and equipment.

REFERENCES

1. Coles, R., D. McDowell, e M.J. Kirwan, *Food packaging technology*. Vol. 5. 2003: CRC press.
2. Henkes, T., *Is It Time for Brand Owners To Think Beyond Omnichannel Packaging?* 2020, Lek.
3. Marsh, K. e B. Bugusu, *Food packaging—roles, materials, and environmental issues.* Journal of food science, 2007. **72**(3): p. R39-R55.
4. Maida, J., *Packaging Market Size to Grow by USD 170.61 Billion | By End-user, Type, and Geography | Growth, Trends, Covid-19 Impact, and Forecasts (2021 - 2025)* 2022.
5. Twede, D., *History of packaging*, in *The Routledge companion to marketing history*. 2016, Routledge. p. 115-129.
6. VE, J.U.D.R.L., *Benefit Package: Evolution and Options for Change.* Lessons from the First Twenty Years of Medicare: Research Implications for Public and Private Sector Policy, 1988: p. 1.
7. LLP, G.P., *A Brief History of Packaging*. 2021.
8. Risch, S.J., *Food packaging history and innovations.* Journal of agricultural and food chemistry, 2009. **57**(18): p. 8089-8092.
9. Intelligence, M. *Global Packaging Market - Growth, Trends, COVID-19 Impact, and Forecasts (2022 - 2027)*. 2021.
10. Pursley, R. e P. Howard. *The ability to respond to peak seasonal demand*. in *IEE Colloquium on Agile Manufacturing (Digest No. 1995/179)*. 1995. IET.
11. MMR, *Consumer Packaging Market: Global Industry Analysis and Forecast (2021-2027)*. 2020.
12. Litman, T., *Transportation cost and benefit analysis.* Victoria Transport Policy Institute, 2009. **31**: p. 1-19.
13. Europages, *Fabricantes de Embalagens em Portugal* Europages, Editor. 2021.
14. Bamber, E.M. e R.J. Ramsay, *An investigation of the effects of specialization in audit workpaper review.* Contemporary Accounting Research, 1997. **14**(3): p. 501-513.
15. Hansen, P.A. e G. Serin, *Materials and strategies for successful innovation and competition in the metal packaging industry.* Technology in Society, 1999. **21**(3): p. 307-322.
16. Intelligence, M., *Paper Packaging Market - Growth, Trends, COVID-19 Impact, and Forecasts (2023 - 2028)* 2020.
17. Bocken, N.M., I. De Pauw, C. Bakker, e B. Van Der Grinten, *Product design and business model strategies for a circular economy.* Journal of industrial and production engineering, 2016. **33**(5): p. 308-320.
18. e-Zest, *BI for Printing & Packaging Industry*. 2019.
19. Heckman, J.H., *Food packaging regulation in the United States and the European Union.* Regulatory Toxicology and Pharmacology, 2005. **42**(1): p. 96-122.
20. Purwanto, A., *Does Quality, Safety, Environment and Food Safety Management SystemInfluence Business Performance? Answersfrom Indonesian Packaging Industries.* International Journal of Control and Automation, 2020. **13**(1): p. 22-35.
21. Piergiovanni, L. e S. Limbo, *Metal packaging materials*, in *Food Packaging Materials*. 2016, Springer. p. 13-22.
22. Fernández, L., *Distribution of packaging demand worldwide in 2019, by material type.* Statista, 2022. **1**.
23. Alemanno, A., *How Much Better is Better Regulation?: Assessing the Impact of the Better Regulation Package on the European Union–A Research Agenda.* European Journal of Risk Regulation, 2015. **6**(3): p. 344-356.
24. Jain, P. e D.M. Hudnurkar, *Sustainable packaging in the FMCG industry.* Cleaner and Responsible Consumption, 2022. **7**: p. 100075.

25. Paine, F.A. e H.Y. Paine, *A handbook of food packaging*. 2012: Springer Science & Business Media.
26. Dunn, R., R. Hester, e A. Readman, *From letterpress to offset lithography.* Print and Electronic Text Convergence, 2001: p. 81-108.
27. Lubin, N., *Print Basics: Lithography, the Direct Mailer's Muse.* 2020.
28. Lim, Y., A.G. Ulsoy, e R. Venugopal, *Process control for sheet-metal stamping*. 2013: Springer.
29. Fernandes, L., F. Silva, M. Andrade, R. Alexandre, A. Baptista, e C. Rodrigues, *Improving the punch and die wear behavior in tin coated steel stamping process.* Surface and Coatings Technology, 2017. **332**: p. 174-189.
30. Emblom, W.J. *Strains in Aluminum Stamp Formed Pans Resulting From Closed-Loop Control of Local Forces*. in *ASME International Mechanical Engineering Congress and Exposition*. 2015. American Society of Mechanical Engineers.
31. Ren, X. e C. Chen, *Research on a single-point butt clinching process with various forming forces.* CIRP Journal of Manufacturing Science and Technology, 2022. **39**: p. 308-316.
32. Evrot, D., J.-F. Petin, e M. Dominique, *Formal specification of safe manufacturing machines using the B method: application to a mechanical press.* IFAC Proceedings Volumes, 2006. **39**(3): p. 281-286.
33. Tahir, A.M., N.A.M. Lair, e F.J. Wei. *Investigation on mechanical properties of welded material under different types of welding filler (shielded metal arc welding)*. in *AIP conference proceedings*. 2018. AIP Publishing LLC.
34. Ikram, A. e H. Chung, *The effect of EN ratio and current on microstructural and mechanical properties of weld joined by AC-GMAW on square groove butt joints.* Applied Sciences, 2017. **7**(3): p. 261.
35. Manladan, S., F. Yusof, S. Ramesh, M. Fadzil, Z. Luo, e S. Ao, *A review on resistance spot welding of aluminum alloys.* The International Journal of Advanced Manufacturing Technology, 2017. **90**(1): p. 605-634.
36. Weman, K., *Welding processes handbook*. 2011: Elsevier.
37. Schramm, B., S. Martin, C. Steinfelder, C.R. Bielak, A. Brosius, G. Meschut, T. Tröster, T. Wallmersperger, e J. Mergheim, *A Review on the Modeling of the Clinching Process Chain-Part I: Design Phase.* Journal of Advanced Joining Processes, 2022: p. 100133.
38. Kupfer, R., D. Köhler, D. Römisch, S. Wituschek, L. Ewenz, J. Kalich, D. Weiß, B. Sadeghian, M. Busch, e J. Krüger, *Clinching of aluminum materials–methods for the continuous characterization of process, microstructure and properties.* Journal of Advanced Joining Processes, 2022. **5**: p. 100108.
39. Romanko, A., D. Berry, e D. Fox. *Simulation of Double-Seaming in a Two-piece Aluminum Can*. in *AIP Conference Proceedings*. 2004. American Institute of Physics.
40. Birkeland, S., H. Bergslien, A. Strand, e M. Sivertsvik, *Technical note–effects of seaming conditions on external and internal double-seam characteristics in round metal cans.* Packaging Technology and Science: An International Journal, 2005. **18**(5): p. 279-283.
41. Chanathip, *Sealants*. 2022, Ubisasia.
42. Shell, R., *Handbook of industrial automation*. 2000: CRC press.
43. Morton, S.E., J.L. Knopp, J.G. Chase, P. Docherty, S.L. Howe, K. Möller, G.M. Shaw, e M. Tawhai, *Optimising mechanical ventilation through model-based methods and automation.* Annual Reviews in Control, 2019. **48**: p. 369-382.
44. Voss, M., *Getting started with automation.* Next-Generation-Infrastructure, 2021.
45. Samy, S. e H. ElMaraghy, *A model for measuring complexity of automated and hybrid assembly systems.* The International Journal of Advanced Manufacturing Technology, 2012. **62**(5): p. 813-833.
46. McDermott, F.T., *Repetition strain injury: a review of current understanding.* Medical journal of Australia, 1986. **144**(4): p. 196-200.

47. Everett, J.G., *Ergonomics, health, and safety in construction: opportunities for automation and robotics.* Automation and Robotics in Construction XI, 1994: p. 19-26.
48. Granulo, A., C. Fuchs, e S. Puntoni, *Psychological reactions to human versus robotic job replacement.* Nature human behaviour, 2019. **3**(10): p. 1062-1069.
49. Huang, L., C. Liu, H. Zhang, S. Zhao, M. Tan, M. Liu, Z. Jia, R. Zhai, e H. Liu, *Technology of static oblique lithography used to improve the fidelity of lithography pattern based on DMD projection lithography.* Optics & Laser Technology, 2023. **157**: p. 108666.
50. Bassani, F., C. Rodrigues, P. Marques, e F. Freire, *Ecodesign approach for pharmaceutical packaging based on Life Cycle Assessment.* Science of The Total Environment, 2022. **816**: p. 151565.
51. Reisinger, J., M.A. Zahlbruckner, I. Kovacic, P. Kán, X. Wang-Sukalia, e H. Kaufmann, *Integrated multi-objective evolutionary optimization of production layout scenarios for parametric structural design of flexible industrial buildings.* Journal of Building Engineering, 2022. **46**: p. 103766.
52. Naber, A., *One third of your life is spent at work.* Gettysburg College, 2007.
53. Mossink, J. e M. de Greef, *Inventory of socioeconomic costs of work accidents*. 2002: Office for Official Publications of the European Communities Luxembourg.
54. Dai, Y., X. Tong, e L. Wang, *Workplace safety accident, employee treatment, and firm value: Evidence from China.* Economic Modelling, 2022. **115**: p. 105960.
55. Génesis, C.-A., G.-C. Stefania, P.-J. Karen, G.-D. Claudia, S. Harold, e G.-C. Yulineth, *Occupational Safety and Health Management Systems As A Component Of Labor Productivity.* Procedia Computer Science, 2022. **203**: p. 667-672.
56. Safety, O. e H. Administration, *Recommended practices for safety and health programs.* Occupational Safety and Health Administration: Washington, DC, USA, 2016.
57. Rogers, D.W., *From common law to factory laws: The transformation of workplace safety law in Wisconsin before progressivism.* Am. J. Legal Hist., 1995. **39**: p. 177.
58. Cameron, D., *History of workplace health and Safety.* EcoOnline Global, 2022. **1**: p. 4.
59. Administration, O.S.a.H., *Top 10 Most Frequenty Cited Standars*. 2021. p. 1.
60. Macedo, A.C. e I.L. Silva, *Analysis of occupational accidents in Portugal between 1992 and 2001.* Safety Science, 2005. **43**(5-6): p. 269-286.
61. Kim, S., J. Lee, e C. Kang, *Analysis of industrial accidents causing through jamming or crushing accidental deaths in the manufacturing industry in South Korea: Focus on non-routine work on machinery.* Safety Science, 2021. **133**: p. 104998.
62. Leplat, J. e J. Rasmussen, *Analysis of human errors in industrial incidents and accidents for improvement of work safety.* New technology and human error, 1987. **15**: p. 157.
63. Mutawe, A.M., R. Tsunehara, e L.A. Glaspey, *OSHA's lockout/tagout standards: A review of key requirements.* Professional safety, 2002. **47**(2): p. 20.
64. Charlot, E., J.P. Kenné, e S. Nadeau, *Optimal production, maintenance and lockout/tagout control policies in manufacturing systems.* International journal of production economics, 2007. **107**(2): p. 435-450.
65. Bulzacchelli, M.T., J.S. Vernick, G.S. Sorock, D.W. Webster, e P.S. Lees, *Circumstances of fatal lockout/tagout-related injuries in manufacturing.* American journal of industrial medicine, 2008. **51**(10): p. 728-734.
66. Communities, T.C.o.t.E., *EU Guidelines 89/655*. 1989.
67. Standardization, E.C.f., *Safety of machinery - Prevention of unexpected start-up*. 2008.
68. Poisson, P. e Y. Chinniah, *Managing risks linked to machinery in sawmills by controlling hazardous energies: Theory and practice in eight sawmills.* Safety science, 2016. **84**: p. 117-130.
69. Bulzacchelli, M.T., J.S. Vernick, D.W. Webster, e P.S. Lees, *Effects of the Occupational Safety and Health Administration's control of hazardous energy (lockout/tagout) standard on rates of machinery-related fatal occupational injury.* Injury prevention, 2007. **13**(5): p. 334-338.

70. Australia, S.W., *Energy & Risk assessment* 2020.
71. Barnett, R.L., *On the safety hierarchy and hierarchy of controls.* American Journal of Mechanical Engineering, 2020. **8**(2): p. 61-68.
72. Trout, J., *Lockout/Tagout (LOTO) Explained*. 2019, Reliable Plant.
73. Europe, B., *Lockout / Tagout Solutions for hazardous energy control*, Brady, Editor. 2022.
74. Fortress, *Light Curtain and Photoelectric Blocking Device – PBL*, in *Product Expertise*, Fortress, Editor. 2023.
75. Administration, O.S.a.H., *Training requirements in OSHA standards*. 2020: Occupational Safety anf Health Administration.
76. Bulzacchelli, M.T. *An assessment of the impact of OSHA's Lockout/Tagout Standard using an interrupted time-series analysis*. in *Annual Meeting*.
77. McCann, M., K.L. Hunting, J. Murawski, R. Chowdhury, e L. Welch, *Causes of electrical deaths and injuries among construction workers.* American journal of industrial medicine, 2003. **43**(4): p. 398-406.
78. Delpla, V., K. Chapron, J.-P. Kenné, e L. Hof, *Towards intelligent manufacturing system safety strategies: generating LockOut/TagOut sheets by Machine Learning–a case study.* IFAC-PapersOnLine, 2022. **55**(10): p. 1001-1006.
79. Karimi, B., D. Burlet-Vienney, Y. Chinniah, e B. Aucourt, *Hazardous Energy Control on machinery: Understanding the use of alternative methods to lockout.* Safety science, 2019. **118**: p. 519-529.
80. Karimi, B., Y. Chinniah, D. Burlet-Vienney, e B. Aucourt, *Qualitative study on the control of hazardous energy on machinery using lockout and alternative methods.* Safety Science, 2018. **107**: p. 22-34.
81. Kumar, S., *Development of a state of the art Internet of Things (IoT) based Lockout Tagout (LOTO) device for accident prevention in hazardous industries.* 2020.
82. DDS, *Colep reporta melhor desempenho em saúde e segurança na fábrica de Vale de Cambra.* Revista Packaging, 2023.
83. Standards, O.S.a.H., *1910.147 - The control of hazardous energy (lockout/tagout)*. 1910.
84. FESTO, *Valves from Festo – extremely universal and efficient*, FESTO, Editor. 2022: Festo.com.

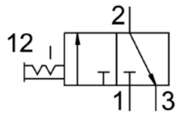
APPENDIX A – CIRCUIT BREAKER AND SWITCH CATALOGUE

		Disjuntor Moldado		Disjuntor Modelar				Interuptor				
		Marca 1	Marca 2	1 Polo	De 2 Polos	De 3 Polos	De 4 Polos	Tipo 1	Tipo 2	Tipo 3	Tipo 4	
												
Quadro da Estampagem (Q13)	Secção 1		12									
	Secção 2			6	1		5			1		1
	Secção 3		2					10				
	Secção 4							4				
	Total	0	14	6	1	0	5	14	0	1	0	1
Quadro da Montagem 3	Secção 1	4	8									
	Secção 2			5	2	7			1	1		1
	Secção 3		5					6				
	Secção 4			3	1	4	7					
	Total	4	13	8	3	11	7	6	1	1	0	1
Quadro da Montagem 2	Secção 1					2	1		1	1	5	1
	Secção 2			1	1	12			1	2	2	
	Total	0	0	1	1	14	1	0	2	3	7	1
Quadro da Montagem 1	Secção 1		8					2				
	Secção 2			5	1	1	1		2	1		1
	Secção 3		2					6				
	Secção 4										3	
	Total	0	10	5	1	1	1	8	2	1	3	1
Numero Total de Componentes para a a area de montagem/estampagem		4	37	20	6	26	14	28	5	6	10	4

APPENDIX B – VALVE DATASHEET

Válvula de fecho
MS6-EM1-1/2-S
Número de referência: 541268

FESTO



Ficha de dados

Característica	Valor
Construção	Calha deslizante
Tipo de atuação	Manual
Função de escape de ar	Não estrangulável
Tipo de controlo	Direto
Símbolo	00991670
Função da válvula	Solenoide duplo, 3/2 vias
Pressão operacional	0 bar ... 18 bar
Valor C	30.8 l/sbar
Valor b	0.57
Taxa de fluxo nominal padrão	8700 l/min
Meio de funcionamento	Ar comprimido de acordo com ISO 8573-1:2010 [7:4:4] Gases inertes
Nota sobre o meio operacional/controlo	A operação lubrificada é possível (no caso em que a operação lubrificada será sempre obrigatória)
Classe de resistência à corrosão (CRC)	2 - tensão moderada da corrosão
Observação sobre os materiais	Em conformidade com a RoHS
Em conformidade com LABS	VDMA24364-B1/B2-L
Temperatura do meio	-10 °C ... 60 °C
Temperatura ambiente	-10 °C ... 60 °C
Alimentação segura	Ver informação complementar do material
Tipo de montagem	Alternativa: Instalação em linha Através dos acessórios
Posição de montagem	Qualquer um
Direção de fluxo	Não reversível
Peso do produto	655 g
Conexão pneumática 1	G1/2
Conexão pneumática 2	G1/2
Conexão pneumática 3	Silenciador pneumático integrado Não canalizado
Material de vedações	TPE-U(PU)
Material da caixa	Alumínio fundido

14/03/23 - Sujeito a alteração - Festo SE & Co. 1/1

APPENDIX C - ANALYSIS OF TASKS AND ENERGY SOURCES

Equipamento: L99 - Alimentador + Prensa										
Nível	Atividades		Tarefas	Perigos principais	Riscos principais	Energias Identificadas	Energia/controlo			Comentários
	Produção	Manutenção					Independente	Partilhada	Detalhe partilha	
0	X		**Trabalho de operação normal**	n/a	n/a	n/a	n/a	n/a	n/a	Por vezes os operarios desmontam os interlocks de segurança, porque demora demasiado tempo a desligar a maquina
0	X		**alimentação de matéria prima** - colocar de balote no transportador (empilhador) - cortar as cintas, retirar filme estiravel, retirar a 1ª folha	Circulação empilhador/ operador Queda do balote Manipulação de ferramentas (corte de cinta e filme) Manipulação de folha de flandres	Atropelamento/ Choque contra Esmagamento Entalamento Corte/ escoriações	Mecânica Eletrica	X	--	--	

0	X		**Reposicionamento e elevação da matéria prima na mesa de elevação** -Usando a consola externa do equipamento -Baixar a plataforma, movimentar as folhas usando as roldanas, e levantar a plataforma	n/a	n/a	n/a	n/a	n/a	n/a	
0	X		**Calcar/Acamar contentor desperdício técnico**	Retalhos das folhas	Corte/ escoriações	n/a	n/a	--	--	
0	X		**Limpeza Externa do Equipamento**	n/a	n/a	n/a	n/a	n/a	n/a	
0		X	**Verifficar Arrance, Disparo e Encerramento dos equipamentos**	Encerramento abrupto da maquina pode ainda deixar energias residuais	n/a	n/a	n/a	--	--	Check-list segundo as verificações
1	X		**Remover a palete anterior antes de adicionar nova materia prima** -É necessario retirar a palete anterior, antes de posicionar a matéria prima	Plataforma pode subir e descer com a janela aberta e sem sensor, alguém pode por a mão nos rolamentos ativos	Esmagamento Entalamento	Mecânica	\	n/a	n/a	Os rolamentos rodam em ambas as direções, aumentando os danos que possam ser potencialmente causados

1	X	X	**Desencravamento/limpeza da prensa, através da janela da entrada**	Posicionamento e acesso difícil a alguns elementos Movimentação da prensa Presença de Energias	Esmagamento Entalamento Corte/ escoriações	Mecânica Pneumática	X	--	--	
2	X		**Limpeza da zona interior do equipamento, e limpeza de elementos de corretes**	Fadiga Entalamento Partes moveis	Entalamento Eletrização	Mecânica Eletrica	n/a	n/a	n/a	Limpeza com ar comprimido pode lançar peças pequenas para pessoas dentro da cabine
2	X		**Limpar ou Substituir Filtros de Vácuo**	Pressão dentro dos tubos	Projeção de impurezas ou objectos	Pneumática	n/a	n/a	n/a	
2		X	**Mudar ou verificar o nivel de Óleo -Limpar ou Substituir Filtro Lubrificação Folha**	Pressão do óleo	Projeção de óleo ou impurezas	n/a	n/a	--	--	O óleo pode ser assedido sem primeiro desligar a pressão
2	X		**- Desencravar a folha na mesa - Substituição de ventosas**	Movimentação da mesa do posionador Mudança de formato (peso e forma do cunho)	Esmagamento Entalamento Corte/ escoriações	Mecânica Elétrica Hidráulica Pneumática	X	--	--	

2	X		**Limpeza Geral do Quadro Eléctrico**	Presença de Eletricidade	Eletrocussão/ Eletrização	Elétrica	n/a	--	--	
3		X	**Fazer alterações na Instalação Pneumática** -Verificar Fugas de Ar, Tubos de Ar comprimido, Escapes das Válvulas, Manómetros, Injectores , Reguladores, Válvulas, cilindros etc…)	Pressão dentro dos tubos	Projeção de impurezas ou objectos	Pneumática	X	--	--	
3		X	**Fazer alterações em Eletrovalvula**	Presença de Eletricidade Pressão dentro dos tubos	Eletrocussão/ Eletrização	Elétrica Pneumática	X	--	--	
3		X	**Intervensão/Substituição de componentes eletricos**	Presença de Eletricidade	Eletrocussão/ Eletrização	Elétrica	X	--	--	
3		X	**Lubrificação Central da Prensa**	Movimento da prensa Movimento da mesa do elevador Movimento dos rolos Manipulação de ferramentas	Esmagamento Entalamento Corte/ escoriações	Mecânica Pneumática	X	--	--	

3		X	**Lubrificação Geral**	Dificil acesso a certos elementos Arrance não programado dos motores Movimento dos rolos Manipulação de ferramentas	Esmagamento Entalamento Corte/ escoriações	Mecânica	X	--	--	
3		X	**Reapertar Parafusos expostos a alta carga / Ajuste de cabos eletricos**	Presença de Eletricidade Manipulação de ferramentas	Eletrocussão/ Eletrização	Elétrica	X	--	--	
3		X	**Intervenção/Substituição de Motores Eletricos; Correias, Suportes, Guias, Rolos, Peças mecanicas**	Arranque do motor ligado as peças Presença de Eletricidade Movimentação de peças Manipulação de ferramenta	Entalamento Corte/ escoriações	Mecânica Elétrica	X	--	--	O motor da tela de transporte do desperdicio pode ser cortada exteriormente sem desligar a maquina, ou bloqueio mecanico
3		X	**Reparação de sensores e cabos**	Posicionamento e acesso difícil a alguns elementos Movimentação da prensa Presença de Energias	Esmagamento Entalamento Corte/ escoriações Eletrização	Mecânica Elétrica Pneumática	X	--	--	

3		X	**Trocar e ajustar correias do volante**	Arranque da prensa Movimentação de cilindro	Entalamento Esmagamento	Mecânica Pneumática	X	--	--	
3		X	**Substituir eixos x/y do Servomotor**	Manipulação de ferramentas Peso dos veios Trabalho em Altura/ desnivelado	Entalamento Esmagamento Queda dos veios	Mecânica Potencial	X	--	--	
3		X	**Substituir cilindros amortecedores**	Arranque da prensa Movimentação de peças Manipulação de ferramentas Utilização de plataforma Trabalho em Altura	Entalamento Esmagamento Queda de peças Corte/ escoriações Choque contra estruturas Atropelamento Queda em altura	Mecânica Pneumática	X	--	--	
3		X	**Substituir rolo saca retalhos e correia** **Trocar telas do transportador dos retalhos**	Arranque do motor da prensa Movimentação de peças Manipulação de ferramenta	Entalamento Esmagamento Queda de peças Corte/ escoriações	Mecânica Elétrica Pneumática	X	--	--	

3		X	**Intervenções/ substituições no sistema pneumático da prensa**	Pressão (ar) Movimento da prensa Movimento da mesa do elevador e alimentador Arranque de rolos Manipulação de ferramenta	Entalamento Esmagamento Corte/ escoriações	Pneumática Potencial	X	--	--	
3		X	**Intervenção/ reparação nos quadros elétricos de comando**	Presença de Eletricidade Manipulação de ferramentas	Eletrocussão/ Eletrização Corte/ escoriações Entalamento	Elétrica	X	--	--	
3		X	**Substituição / reparação de motor da janela de alimentação de balotes**	Presença de Eletricidade Manipulação de ferramentas Movimento da janela	Eletrocussão/ Eletrização Corte/ escoriações Entalamento	Mecânica Elétrica	X	--	--	
3		X	**Substituição/reparação de motores ou cabos elétricos dos transportadores de saída de produto**	Presença de Eletricidade Manipulação de ferramentas Movimento do transportador	Eletrocussão/ Eletrização Corte/ escoriações Entalamento	Mecânica Elétrica	X	--	--	
3		X	**Revisão Geral**	Pressão (ar) Movimento da prensa Movimento da mesa do elevador e alimentador Arranque de rolos Energia armazenada	Entalamento Esmagamento Queda de peças Corte/ escoriações Queda em altura	Mecânica Elétrica Hidráulica Pneumática	X	--	--	

				(pulmão) Trabalho em Altura >2m Manipulação de ferramentas						
3		X	**Verificar/Reparar Cunho**	Movimento da prensa Movimento dos rolos Manipulação de ferramentas	Esmagamento Entalamento Corte/ escoriações	Mecânica Pneumática	X	--	--	
3		X	**Intervenção/ reparação no quadro elétrico ou cabos de potência**	Presença de Eletricidade Manipulação de ferramentas	Eletrocussão/ Eletrização Corte/ escoriações	Elétrica	X	--	--	
3		X	**Troca do Fuso (servomotor)**	Presença de Eletricidade	Eletrocussão/ Eletrização	Elétrica	X	--	--	
3		X	**Substituir cabos e esteira**	Presença de Eletricidade	Eletrocussão/ Eletrização	Elétrica	X	--	--	

4 (trabalhos de manutenção dentro da área de risco da máquina)		X	**Verificar folgas no Volante / correias / veios**	Arranque da prensa Movimentação de peças Manipulação de ferramentas Utilização de garibalde para desmontar e movimentar volante	Entalamento Esmagamento Queda de peças Corte/ escoriações Choque contra estruturas Atropelamento Queda em altura	Mecânica Pneumática	X	--	--	
4 (trabalhos de manutenção dentro da área de risco da máquina)		X	**Análise Termográfica**	Funcionamento do Equipamento com o colaborador dentro da máquina	Entalamento Esmagamento Corte/ escoriações Eletrização	Mecânica Elétrica	X	--	--	É necessario ver a temperatura de um equipamento em funcionamento ao long do tempo
4 (trabalhos de manutenção dentro da área de risco da máquina)		X	**Identificação de avarias**	Movimento da prensa Movimento da mesa do posicionador (cilindro) Movimento dos rolos	Entalamento Esmagamento Queda de peças Corte/ escoriações	Mecânica Elétrica Pneumática Hidraúlica	X	--	--	Tarefa a realizar por técnicos especializados Garantir proximidade de um botão de emergência Requer autorização de trabalho

Equipamento: L11 - Cravadeira										
Nível	Atividades		Tarefas	Perigos principais	Riscos principais	Energias Identificadas	Energia/controlo			Comentários
	Produção	Manutenção					Independente	Partilhada	Detalhe partilha	
0	X		**Trabalho de operação normal**	n/a	n/a	n/a	n/a	n/a	n/a	
0	X		**alimentação de matéria prima** - pode ser realizada enquanto a maquina esta em funcionamento	Fadiga Entalamento Partes moveis	Entalamento Eletrização	Mecânica Eletrica	X	--	--	
0	X		**Limpeza Externa do Equipamento**	n/a	n/a	n/a	n/a	n/a	n/a	
0		X	**Verifficar Arrance, Disparo e Encerramento dos equipamentos**	Encerramento abrupto da maquina pode ainda deixar energias residuais	n/a	n/a	n/a	--	--	Check-list segundo as verificações

1	X	X	**Desencravamento/limpeza da Cravadeira**	Posicionamento e acesso difícil a alguns elementos Movimentação da cravadeira Presença de Energias e chapa	Esmagamento Entalamento Corte/ escoriações Eletrização	Mecânica Elétrica Pneumática	X	--	--	
2	X		**Endireitar sensor**	Entalamento Partes moveis Presença de eletricidade	Entalamento Eletrização	Mecânica Eletrica	n/a	n/a	n/a	Limpeza com ar comprimido pode lançar peças pequenas para pessoas dentro da cabine
2	X		**Limpar ou Substituir Filtros de Vácuo**	Pressão dentro dos tubos	Projeção de impurezas ou objectos	Pneumática	n/a	n/a	n/a	
2		X	**Limpeza Geral do Quadro Eléctrico**	Presença de Eletricidade	Eletrocussão/ Eletrização	n/a	n/a	--	--	

3	X	X	**Fazer alterações na Instalação Pneumática** -Verificar Fugas de Ar, Tubos de Ar comprimido, Escapes das Válvulas, Manómetros, Injectores , Reguladores, Vâlvulas, cilindros etc…)	Pressão dentro dos tubos	Projeção de impurezas ou objectos	Pneumática	X	--	--	
3		X	**Fazer alterações na Eletrovalvula**	Presença de Eletricidade Pressão dentro dos tubos	Eletrocussão/ Eletrização	Elétrica Pneumática	X	--	--	
3		X	**Intervensão/Substituição de componentes eletricos**	Presença de Eletricidade	Eletrocussão/ Eletrização	Elétrica	X	--	--	
3)	X	X	**Lubrificação Geral**	Dificil acesso a certos elementos Movimento de peças Manipulação de ferramentas	Esmagamento Entalamento Corte/ escoriações	Mecânica	X	--	--	
3		X	**Reapertar Parafusos expostos a alta carga / Ajuste de cabos eletricos**	Presença de Eletricidade Manipulação de ferramentas	Eletrocussão/ Eletrização	Elétrica	X	--	--	

3		X	**Intervenção/Substituição dos Motores; Correias, Suportes, Guias, Rolos, Peças mecanicas**	Arranque do motor ligado as peças Presença de Eletricidade Movimentação de peças Manipulação de ferramenta	Entalamento Corte/ escoriações	Mecânica Elétrica	X	--	--	O motor da tela de transporte do desperdicio pode ser cortada exteriormente sem desligar a maquina, ou bloqueio mecanico
3		X	**Reparação de sensores e cabos**	Posicionamento e acesso difícil a alguns elementos Movimentação da prensa Presença de Energias	Esmagamento Entalamento Corte/ escoriações Eletrização	Mecânica Elétrica Pneumática	X	--	--	
3		X	**Intervenção/ reparação no quadros elétrico do comando manual**	Presença de Eletricidade Manipulação de ferramentas	Eletrocussão/ Eletrização Corte/ escoriações Entalamento	Elétrica	X	--	--	
3		X	**Substituição / reparação de motores eletricos no interior do equipamento**	Presença de Eletricidade Manipulação de ferramentas Movimento da janela	Eletrocussão/ Eletrização Corte/ escoriações Entalamento	Mecânica Elétrica	X	--	--	

3		X	**Revisão Geral**	Pressão (ar) Movimento da prensa Movimento da mesa do elevador e alimentador Arranque de rolos Energia armazenada (pulmão) Trabalho em Altura >2m Manipulação de ferramentas	Entalamento Esmagamento Queda de peças Corte/ escoriações Queda em altura	Mecânica Elétrica Hidráulica Pneumática	X	--	--	
3		X	**Intervenção/ reparação no quadro elétrico ou cabos de potência**	Presença de Eletricidade Manipulação de ferramentas	Eletrocussão/ Eletrização Corte/ escoriações Entalamento	Elétrica	X	--	--	
3		X	**Substituir cabos**	Presença de Eletricidade	Eletrocussão/ Eletrização	Elétrica	X	--	--	
4		X	**Verificar folgas nas correias ou veios**	Arranque da prensa Movimentação de peças Manipulação de ferramentas Utilização de garibalde para desmontar e movimentar volante	Entalamento Esmagamento Queda de peças Corte/ escoriações Choque contra estruturas Atropelamento Queda em altura	Mecânica Pneumática	X	--	--	

4		X	**Análise Termográfica**	Funcionamento do Equipamento com o colaborador dentro da máquina	Entalamento Esmagamento Corte/ escoriações Eletrização	Mecânica Elétrica	X	--	--	É necessario ver a temperatura de um equipamento em funcionamento ao long do tempo
4		X	**Identificação de avarias**	Movimento da prensa Movimento da mesa do posicionador (cilindro) Movimento dos rolos	Entalamento Esmagamento Queda de peças Corte/ escoriações	Mecânica Elétrica Pneumática Hidraúlica	X	--	--	Tarefa a realizar por técnicos especializados Garantir proximidade de um botão de emergência Requer autorização de trabalho

Equipamento: L26 - Alimentador + Prensas										
Nível	Atividades		Tarefas	Perigos principais	Riscos principais	Energias Identificadas	Energia/controlo			Comentários
	Produção	Manutenção					Independente	Partilhada	Detalhe partilha	
0	X		**Trabalho de operação normal**	n/a	n/a	n/a	n/a	n/a	n/a	Por vezes os operarios desmontam os interlocks de segurança, porque demora demasiado tempo a desligar a maquina
0	X		**alimentação de matéria prima** - colocar folha na mesa - cortar as cintas, retirar filme estiravel, retirar a 1ª folha	Circulação empilhador/ operador Queda do balote Manipulação de ferramentas (corte de cinta e filme) Manipulação de folha de flandres	Atropelamento/ Choque contra Esmagamento Entalamento Corte/ escoriações	Mecânica Eletrica	X	--	--	

0	X		**Limpeza Externa do Equipamento**	n/a	n/a	n/a	n/a	n/a	n/a	
0	X	X	**Verifficar Arrance, Disparo e Encerramento dos equipamentos**	Encerramento abrupto da maquina pode ainda deixar energias residuais	n/a	n/a	n/a	--	--	Check-list segundo as verificações
1	X	X	**Desencravamento/limpeza das prensas, através da janela da entrada**	Posicionamento e acesso difícil a alguns elementos Movimentação da prensa Presença de Energias	Esmagamento Entalamento Corte/ escoriações	Mecânica Pneumática	X	--	--	
2	X		**Limpeza da zona interior do equipamento, e limpeza de elementos de corretes**	Fadiga Entalamento Partes moveis	Entalamento Eletrização	Mecânica Eletrica	n/a	n/a	n/a	Limpeza com ar comprimido pode lançar peças pequenas para pessoas dentro da cabine
2	X		**Limpar ou Substituir Filtros de Vácuo**	Pressão dentro dos tubos	Projeção de impurezas ou objectos	Pneumática	n/a	n/a	n/a	
2		X	**Mudar ou verificar o nivel de Óleo -Limpar ou Substituir Filtro Lubrificação Folha**	Pressão do óleo	Projeção de óleo ou impurezas	n/a	n/a	--	--	O óleo pode ser assedido sem primeiro desligar a pressão

2	X		**- Desencravar componentes do interior da maquina** **- Substituição de ventosas**	Movimentação da mesa do posionador Mudança de formato (peso e forma do cunho)	Esmagamento Entalamento Corte/ escoriações	Mecânica Elétrica Hidráulica Pneumática	X	--	--	
2		X	**Limpeza Geral do Quadro Eléctrico**	Presença de Eletricidade	Eletrocussão/ Eletrização	Elétrica	n/a	--	--	
3		X	**Fazer alterações na Instalação Pneumática** -Verificar Fugas de Ar, Tubos de Ar comprimido, Escapes das Válvulas, Manómetros, Injectores , Reguladores, Vâlvulas, cilindros etc…)	Pressão dentro dos tubos	Projeção de impurezas ou objectos	Pneumática	X	--	--	
3		X	**Fazer alterações em Eletrovalvula**	Presença de Eletricidade Pressão dentro dos tubos	Eletrocussão/ Eletrização	Elétrica Pneumática	X	--	--	

3		X	**Intervensão/Substituição de componentes eletricos**	Presença de Eletricidade	Eletrocussão/ Eletrização	Elétrica	X	--	--	
3	X		**Lubrificação Central da Prensa**	Movimento da prensa Movimento da mesa do elevador Movimento dos rolos Manipulação de ferramentas	Esmagamento Entalamento Corte/ escoriações	Mecânica Pneumática	X	--	--	
3	X		**Lubrificação Geral**	Dificil acesso a certos elementos Arrance não programado dos motores Movimento dos rolos Manipulação de ferramentas	Esmagamento Entalamento Corte/ escoriações	Mecânica	X	--	--	
3		X	**Reapertar Parafusos expostos a alta carga / Ajuste de cabos eletricos**	Presença de Eletricidade Manipulação de ferramentas	Eletrocussão/ Eletrização	Elétrica	X	--	--	

3		X	**Intervenção/Substituição de Motores Eletricos; Correias, Suportes, Guias, Rolos, Peças mecanicas**	Arranque do motor ligado as peças Presença de Eletricidade Movimentação de peças Manipulação de ferramenta	Entalamento Corte/ escoriações	Mecânica Elétrica	X	--	--	O motor da tela de transporte do desperdicio pode ser cortada exteriormente sem desligar a maquina, ou bloqueio mecanico
3		X	**Reparação de sensores e cabos**	Posicionamento e acesso difícil a alguns elementos Movimentação da prensa Presença de Energias	Esmagamento Entalamento Corte/ escoriações Eletrização	Mecânica Elétrica Pneumática	X	--	--	
3		X	**Trocar e ajustar correias do volante**	Arranque da prensa Movimentação de cilindro	Entalamento Esmagamento	Mecânica Pneumática	X	--	--	
3		X	**Substituir cilindros amortecedores**	Arranque da prensa Movimentação de peças Manipulação de ferramentas Utilização de plataforma Trabalho em Altura	Entalamento Esmagamento Queda de peças Corte/ escoriações Choque contra estruturas Atropelamento Queda em altura	Mecânica Pneumática	X	--	--	

3		X	**Intervenções/ substituições no sistema pneumático da prensa**	Pressão (ar) Movimento da prensa Movimento da mesa do elevador e alimentador Arranque de rolos Manipulação de ferramenta	Entalamento Esmagamento Corte/ escoriações	Pneumática Potencial	X	--	--	
3		X	**Intervenção/ reparação nos quadros elétricos de comando**	Presença de Eletricidade Manipulação de ferramentas	Eletrocussão/ Eletrização Corte/ escoriações Entalamento	Elétrica	X	--	--	
3		X	**Substituição / reparação de motor da janela de alimentação de balotes**	Presença de Eletricidade Manipulação de ferramentas Movimento da janela	Eletrocussão/ Eletrização Corte/ escoriações Entalamento	Mecânica Elétrica	X	--	--	
3		X	**Substituição/reparação de motores ou cabos elétricos dos transportadores de saída de produto**	Presença de Eletricidade Manipulação de ferramentas Movimento do transportador	Eletrocussão/ Eletrização Corte/ escoriações Entalamento	Mecânica Elétrica	X	--	--	
3		X	**Revisão Geral**	Pressão (ar) Movimento da prensa Movimento da mesa do elevador e alimentador Arranque de rolos Energia armazenada	Entalamento Esmagamento Queda de peças Corte/ escoriações Queda em altura	Mecânica Elétrica Hidráulica Pneumática	X	--	--	

				(pulmão) Trabalho em Altura >2m Manipulação de ferramentas						
3		X	**Verificar/Reparar Cunho**	Movimento da prensa Movimento dos rolos Manipulação de ferramentas	Esmagamento Entalamento Corte/ escoriações	Mecânica Pneumática	X	--	--	
3		X	**Intervenção/ reparação no quadro elétrico ou cabos de potência**	Presença de Eletricidade Manipulação de ferramentas	Eletrocussão/ Eletrização Corte/ escoriações	Elétrica	X	--	--	
3		X	**Substituir cabos e esteira**	Presença de Eletricidade	Eletrocussão/ Eletrização	Elétrica	X	--	--	
4 (trabalhos de manutenção dentro da área de risco da máquina)		X	**Verificar folgas no Volante / correias / veios**	Arranque da prensa Movimentação de peças Manipulação de ferramentas Utilização de garibalde para desmontar e movimentar volante	Entalamento Esmagamento Queda de peças Corte/ escoriações Choque contra estruturas Atropelamento Queda em altura	Mecânica Pneumática	X	--	--	

4 (trabalhos de manutenção dentro da área de risco da máquina)		X	**Análise Termográfica**	Funcionamento do Equipamento com o colaborador dentro da máquina	Entalamento Esmagamento Corte/ escoriações Eletrização	Mecânica Elétrica	X	--	--	É necessario ver a temperatura de um equipamento em funcionamento ao long do tempo
4 (trabalhos de manutenção dentro da área de risco da máquina)		X	**Identificação de avarias**	Movimento da prensa Movimento da mesa do posicionador (cilindro) Movimento dos rolos	Entalamento Esmagamento Queda de peças Corte/ escoriações	Mecânica Elétrica Pneumática Hidraúlica	X	--	--	Tarefa a realizar por técnicos especializados Garantir proximidade de um botão de emergência Requer autorização de trabalho

APPENDIX D - SAFETY PROCEDURES

Anexo II - Plano de Consignação LoTo – L99 PRENSA E TRANSPORTADORES

NÍVEL 0 - Operar a máquina conforme procedimento operacional standard
NÍVEL 1 – Operar intercetando a barreira de segurança para acesso parcial
NÍVEL 2 – Aplicar bloqueio(s) para impedir a reinicialização. Chave única individual para cada pessoa exposta
NÍVEL 3 – Identificar as fontes de energia, desconectar as fontes de energia, bloqueio com cadeado pessoal adequado + etiqueta. Libertar energia armazenada
NÍVEL 4 – Permanecer em zona delimitada e sinalizada de segurança + uso da consola em modo manual + garantir acesso fácil ao botão de emergência. Condição de Risco Elevado

VERIFICAÇÃO DO ISOLAMENTO DAS ENERGIAS	**Nº de pontos LoTo: 20**
Verifique se todas as fontes de energia estão isoladas e num estado de energia zero, tentando iniciar um equipamento com os controlos normais.	
Se houver mais do que um interveniente, é necessário o bloqueio complexo existindo o coordenador de consignação, sendo o último a remover o bloqueio e a verificar a área a desconsignar.	

 M1 - porta lateral da mesa do posicionador (em frente ao E2)	 M2 – porta lateral do sistema pneumatico/ da mesa do posicionador	 M3 - porta lateral da mesa de elevação (junto ao alimentador)	 M4 – portal lateral de acesso a mesa do posicionador	 M5 – portal lateral de acesso a prensa

Anexo II - Plano de Consignação LoTo – L99 PRENSA E TRANSPORTADORES

M6 - janela de acesso à prensa

M7 - janela de alimentação de balotes

M8 - Calço do Cunho

M9 - Alavanca da mesa de elevação

EE1.L99 - Quadro elétrico Geral (Potência) junto ao A3

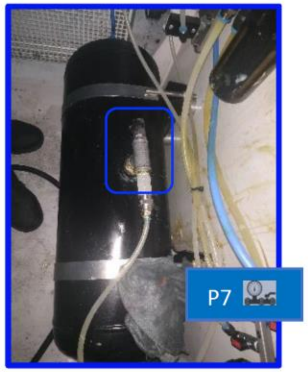
EE1.L99.1 - Quadro elétrico Parcial da prensa

EE1.L99.1.1 - Quadro manual do alimentador

P1 - Ar comprimido. Baixada L99 – Prensa

P2 - Ar comprimido. Baixada L99 – Prensa

P3 - Ar comprimido. Baixada L99 – Prensa (Bipass)

<table>
<tr><th colspan="5">Anexo II - Plano de Consignação LoTo – L99 PRENSA E TRANSPORTADORES</th></tr>
<tr>
<td>
P4 - Ar comprimido Para o sistema</td>
<td>
P5 - Ar comprimido para a Pistola de ar</td>
<td>
P6 – Sistema Central de destribuição de pressão da maquina</td>
<td>
P7 - Despressurização do Pulmão (despressurizar quando aturar nas almofadas da prensa)</td>
<td>
P8 - Despressurização da pressão do Óleo</td>
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Anexo II - Plano de Consignação LoTo – L99 PRENSA E TRANSPORTADORES

Tarefa	Pontos de energia a bloquear	Dispositivos LoTo a utilizar	Método de bloqueio	Informação Adicional	Nível LoTo
1. Alimentação de matéria prima: - Descer estrado vazio e retirá-lo pela M3; - Abrir janela M7; - Mover o balote para a mesa. Centrar balote e subir a mesa; - Fechar a janela M7;	M3 + M7	Operador	1. Avisar os colaboradores envolvidos; 2. Abrir a porta de acesso e colocar cadeado.	1. O ponto de energia mecânica a bloquear será sempre pela porta por onde se entra para o equipamento; 2. Posição da mesa de elevação ao mesmo nível do transportador de entrada;	**2**
2. Parametrização e afinação da mesa do posicionador; 3. Desencravar a folha na mesa; 4. Substituição de ventosas; 5. Limpeza das correias; 6. Ajuste do centramento; 7. Desmontar / montar cortantes; 8. Substituir parafusos do cunho; 9. Setup troca de cunho; 10. Lubrificação geral do equipamento; 11. Limpeza da linha no interior da cabine;	M1 ou M2 ou M3 ou M4	Operador Man. Eletr | Man. Mec.	1. Avisar os colaboradores envolvidos; 2. Para as tarefas 8, 9, 10 e 11 colocar em modo manual na consola;	1. Verificar se máquina esta em modo manual - energias suspensas (só pequenos movimentos são permitidos e controlados no interior da máquina); 2. Para as tarefas 10 e 11 colocar calço debaixo do cunho; 3. Para a tarefa 9 colocar calço debaixo do cunho sempre que não é necessário movimentar cabeçote manualmente; 4. Para a tarefa 11 desligar a ficha *Harting* antes de efetuar qualquer operação. 	**2**

Anexo II - Plano de Consignação LoTo – L99 PRENSA E TRANSPORTADORES

12. Desencravar folha ou componentes no cunho (atraves da janela M6); 13. Limpar o cunho na máquina (atraves da janela M6);	M6	Operador Man. Eletr Man. Mec.	1. Avisar os colaboradores envolvidos; 2. Abrir a janela M6.		3
14. Abastecer depósito de Oleo da mesa. 15. Limpar ou substituir filtro lubrificação folha	M1 ou M2 + P8	Operador Man. Mec. Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Abrir porta M1 ou M2 e colocar cadeado. 3. Fechar válvula do ar comprimido e colocar cadeado+ etiqueta sinalizadora de perigo;	1. Purgar a válvula de ar comprimido imediatamente e juzante de P8; 2. Verificar manómetro (pressão zero) ar comprimido no tanque antes da intervenção.	3
16. Eliminar folgas Volante; 17. Substituição / reparação de motor da janela de alimentação de balotes; 18. Troca/reparação de motores elétricos ou cabos elétricos dos transportadores; 19. Troca de telas no transportador (dentro e fora da cabine); 20. Intervenção/ reparação no quadro manual do alimentador; 21. Intervensão/Substituição de sensor, cabos eletricos e outros componentes eletricos dentro da cabine; 22. Intervenção/reparação nas Correias, Suportes, Guias, Rolos, e outros elementos mecanicos;	EE1.L99.1.1	Man. Eletr Man. Mec. Prestador de Serviços Operador	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo; 3. Pressionar botoneira START/STOP (para efeito de verificação).	1.Para as tarefas 17, 18 e 19, desligar fichas *Harting* do transportador; 	3
23. Intervenção/reparação das correias do volante; 24. Substituir veios x / y do Servomotor; 25. Substituir cilindros amortecedores; 26. Substituir rolo saca retalhos e correia; 27. Trocar telas dos transportadores;	EE1.L99.1.1 + P6	Man. Eletr Man. Mec.	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo;	1.Purgar a válvula de ar comprimido imediatamente a juzante de P6;	3

Anexo II - Plano de Consignação LoTo – L99 PRENSA E TRANSPORTADORES

28. Substituir fusíveis mecânicos e ajustar pressão da prensa; 29. Reparação de sensores, cabos e electroválvulas pneumáticas; 30. Intervenções/ substituições filtros de vácuo;		Prestador de Serviços	3. Fechar válvula do ar comprimido e colocar cadeado+ etiqueta sinalizadora de perigo; 4. Pressionar botoneira START/STOP (para efeito de verificação).	2. Verificar manómetro (pressão zero) ar comprimido antes da intervenção; 3. Para a tarefa 27 desligar ficha *Harting* antes de efetuar qualquer operação. 	
31. Intervenções/ substituições no sistema pneumático da prensa; 32. Intervenção no sistema de lubrificação central da prensa; 33. Intervenção /substituição do pulmão P7;	EE1.L99.1.1 + P6 + P7	Man. Eletr Man. Mec. Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo; 3. Fechar válvula do ar comprimido e colocar cadeado+ etiqueta sinalizadora de perigo; 4. Pressionar botoneira START/STOP (para efeito de verificação.	1. Verificar com multímetro a ausência de energia; 2. Purgar a válvula de ar comprimido imediatamente e juzante de P6; 3. Verificar manómetro (pressão zero) ar comprimido antes da intervenção; 4. Dissipar energias presentes - despressurizar pulmão P7	3
34. Revisão Geral.	EE1.L99.1 + P6	Man. Eletr Man. Mec. Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo; 3. Fechar válvula do ar comprimido e colocar cadeado+ etiqueta sinalizadora de perigo; 4. Pressionar botoneira START/STOP (para efeito de verificação).	1. Verificar com multímetro a ausência de energia; 2. Purgar a válvula de ar comprimido imediatamente e juzante de P1; 3. Verificar manómetro (pressão zero) ar comprimido antes da intervenção; 4. Dissipar energias presentes - despressurizar pulão P7.	3

Anexo II - Plano de Consignação LoTo – L99 PRENSA E TRANSPORTADORES

35. Substituição / reparação de motores laterais da mesa de elevação.	M3 + M9 + EE1.L99.1.1	Man. Eletr; Prestador de Serviços	Man. Mec.	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo; 3. Colocar alavanca M9 e colocar cadeado; 4. Pressionar botoneira START/STOP (para efeito de verificação).	1. Para a tarefa 34 desligar ficha *Harting* antes de efetuar qualquer operação. 	3
36. Intervenção/ reparação no quadro elétrico ou cabos de potência. 37. Limpeza Geral do Quadro Eléctrico 38. Alterar ou apertar parafusos expostos a alta carga 39. Mudanças no layout	EE1.L99.1	Man. Eletr	Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo; 3. Pressionar botoneira START/STOP (para efeito de verificação).	1. Verificar com multímetro a ausência de energia.	3
40. Substituição/ reparação do pulmão na zona dos transportadores de saída de produto acabado. Pulmão de ar comprimido nº4.	P6	Man. Mec.	Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Fechar válvula do ar comprimido e colocar cadeado+ etiqueta sinalizadora de perigo.	1. Purgar a válvula de ar comprimido do equipamento; 2. Verificar manómetro (pressão zero) ar comprimido antes da intervenção; 3. Dissipar energias presentes - despressurizar pulmão 4.	3

41. Identificação de avarias. 42. Análise Termográfica			1. Avisar os colaboradores envolvidos; 2. Colocação de barreiras e sinalização; 3. Colocação da máquina em modo manual; 4. Coordenação entre 2 técnicos; 5. Botão de emergência acessível.	1. Garantir que só pessoas habilitadas e formadas em LoTo podem executar esta operação; 2. Garantir proximidade de um botão de emergência; 3. Requer autorização de trabalho.	4

Anexo II - Plano de Consignação LoTo – L99 PRENSA E TRANSPORTADORES

Pontos de bloqueio	Foto do Bloqueio LoTo	Metodo de Bloqueio
M1 M2 M3 M4 M5 M6 M7		1. A abertura da porta/janela irá parar imediatamente a máquina; 2. A máquina só podera arrancar novamente quando a porta/janela estiver fechada;
M8		1. Remover o calço do seu suporte; 2. Colocar os calços em ambos os lados da prensa como representado nas figuras a esquerda.

Anexo II - Plano de Consignação LoTo – L99 PRENSA E TRANSPORTADORES

M9		1. Colocar alavanca na mesa; 2. Colocar cadeado.
EE1.L99.1		1. Desligar o disjuntor eletrico; 2. Colocar o equipamento de bloqueio no disjuntor, como mostrado na figura; 3. Apertar o parafuso de forma a bloquear o interruptor do disjuntor; 4. Fechar o equipamento de bloqueio, e colocar o cadeado.

Anexo II - Plano de Consignação LoTo – L99 PRENSA E TRANSPORTADORES

EE1.L99.1.1		1. Desligar o quadro eletrico ponto a alavanca na posição "OFF"; 2. Revelar a peça de bloqueio como mostrado na figura a esquerda; 3. Colocar e bloquear com o cadeado, como mostrado na figura.
P1 P2 P3 P4 P5		1. Purgar a válvula de ar comprimido; 2. Colocar e bloquear com o cadeado, como mostrado na figura.

Anexo II - Plano de Consignação LoTo – L99 PRENSA E TRANSPORTADORES

P6 		1. Purgar a válvula de ar comprimido; 2. Verificar no manómetro da válvula que o sistema de ar comprimido se encontra despressurizado (pressão zero) antes da intervenção; 3. Colocar e bloquear com o cadeado, como mostrado na figura.
P7 		1. Abrir a valvula do tanque de ar como mostrado na figura a esquerda; 2. Verificar no manómetro do tanque que o tanque se encontra despressurizado (pressão zero) antes da intervenção.

Anexo II - Plano de Consignação LoTo – L99 PRENSA E TRANSPORTADORES

		4. Mover a peça para baixo como indicado na figura a esquerda; 5. Verificar no manómetro do tanque que o tanque se encontra despressurizado (pressão zero) antes da intervenção.

PLANO DE DESCONSIGNAÇÃO

1. Assegurar que o trabalho foi realizado corretamente;
2. Verificar que ninguém se encontra no interior da zona de segurança;
3. Certificar-se de que a área de trabalho não contém ferramentas e materiais;
4. Retirar e guardar o(s) bloqueio(s) e etiqueta(s);
5. Verificar que os bloqueios e etiquetas foram removidos;
6. Informar todos os colaboradores que o equipamento irá ser testado;
7. Repor as fontes de energia e testar o equipamento.

Anexo II - Plano de Consignação LoTo – L11 Cravadeira

NÍVEL 0 - Operar a máquina conforme procedimento operacional standard

NÍVEL 1 – Operar intercetando a barreira de segurança para acesso parcial

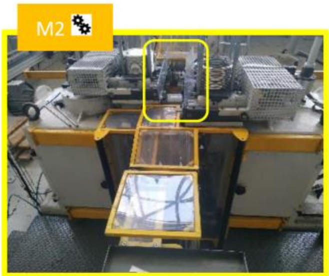
NÍVEL 2 – Aplicar bloqueio(s) para impedir a reinicialização. Chave única individual para cada pessoa exposta

NÍVEL 3 – Identificar as fontes de energia, desconectar as fontes de energia, bloqueio com cadeado pessoal adequado + etiqueta. Libertar energia armazenada

NÍVEL 4 – Permanecer em zona delimitada e sinalizada de segurança + uso da consola em modo manual + garantir acesso fácil ao botão de emergência. Condição de Risco Elevado

VERIFICAÇÃO DO ISOLAMENTO DAS ENERGIAS	**Nº de pontos LoTo: 13**
Verifique se todas as fontes de energia estão isoladas e num estado de energia zero, tentando iniciar um equipamento com os controlos normais.	
Se houver mais do que um interveniente, é necessário o bloqueio complexo existindo o coordenador de consignação, sendo o último a remover o bloqueio e a verificar a área a desconsignar.	

M1 – Janela frontal de acesso a Cravadeira

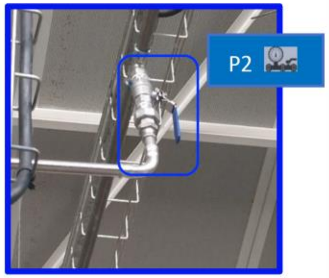


M4 – Barreira Superior da Cravadeira

M3 - Janela lateral direita, da entrada de latas

M2 – Janela lateral esquerda, da entrada de latas

EE1.L11.1 - Quadro elétrico Geral (Potência) junto ao ??

Anexo II - Plano de Consignação LoTo – L11 Cravadeira				
 EE1.L11.1.1 – Coffret de potencia dos transportadores	 EE1.L11.1.1 - Quadro elétrico dos transportadores	 EE1.L11.1.1 - Coffret de potencia da cravadeira	 EE1.L11.1.1.1 - Quadro eletrico da Cravadeira	 EE1.L11.1.1.1.1 - Comando manual da Cravadeira L11
 P1 – Valvula de ar comprimido, Baixada L11 – Cravadeira	 P1 – Valvula de comprimido. Baixada L11 – Cravadeira	 P2 – Sistema de ar comprido L11		

Anexo II - Plano de Consignação LoTo – L11 Cravadeira

Tarefa	Pontos de energia a bloquear	Dispositivos LoTo a utilizar	Método de bloqueio	Informação Adicional	Nível LoTo
1. Parametrização e afinação da maquina; 2. Retirada de latas e ou outros materiais que caem dentro da área de trabalho da máquina; 3. Limpeza interior a maquina; 4. Lubrificação geral do equipamento; 5. Inspeção visual dos elementos do equipamento;	M1 ou M2 ou M3 ou M4	Operador Man. Eletr Man. Mec.	1. Avisar os colaboradores envolvidos; 2. Abrir a porta/janela;		2
6. Fazer novo layout; 7. Troca/reparação dos motores elétricos; 8. Intervenção/reparação nas Correias, Suportes, Guias, Rolos, e outros elementos mecanicos; 9. Intervensão/substituição de sensores, cabos, e outros componentes eletricos dentro do equipamento 10. Intervenção na consola da maquina (EM1.D2.L11.2.1.1);	EM1.D2.L11.2.1	Man. Eletr Man. Mec. Prestador de Serviços Operador	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo; 3. Pressionar botoneira START/STOP (para efeito de verificação).	1. Verificar com multímetro a ausência de energia;	3
11. Intervenção módulo de alimentação do ar comprimido	P2 + P3	Man. Eletr Man. Mec Prestador de Serviços	1. Avisar os colaboradores envolvidos 2. Desligar equipamento. 3. Fechar a válvula e colocar cadeado 4. Acionar Start/ Stop na Consola e nos botões Restart - Marcha máquina ao lado das portas de acesso.	1. Verificar manómetro (pressão Zero) ar comprimido a montante e jusante antes da intervenção	3

Anexo II - Plano de Consignação LoTo – L11 Cravadeira

12. Reparação de sensores, cabos e electroválvulas pneumáticas. 13. Intervenções/ substituições do filtros de vácuo;	EM1.D2.L11.2.1 + P3	Man. Eletr Man. Mec. Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo; 3. Fechar válvula do ar comprimido e colocar cadeado+ etiqueta sinalizadora de perigo; 4. Pressionar botoneira START/STOP (para efeito de verificação).	1. Purgar a válvula de ar comprimido imediatamente a juzante de P3; 2. Verificar manómetro (pressão zero) ar comprimido antes da intervenção;	3
14. Intervenção nos transportadores da lata;	EM1.D2.L11.1.1	Man. Eletr Man. Mec. Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo; 3. Pressionar botoneira START/STOP (para efeito de verificação).	1. Verificar com multímetro a ausência de energia;	3
15. Intervenção no sistema pneumático dos equipamentos;	P3	Man. Eletr Man. Mec	1. Avisar os colaboradores envolvidos 2. Fechar a válvula e colocar cadeado 3. Acionar Start/ Stop na Consola e nos botões Restart - Marcha	1. Purgar a válvula de ar comprimido imediatamente a juzante de P3; 2. Verificar manómetro (pressão zero) ar comprimido antes da intervenção;	3

Anexo II - Plano de Consignação LoTo – L11 Cravadeira

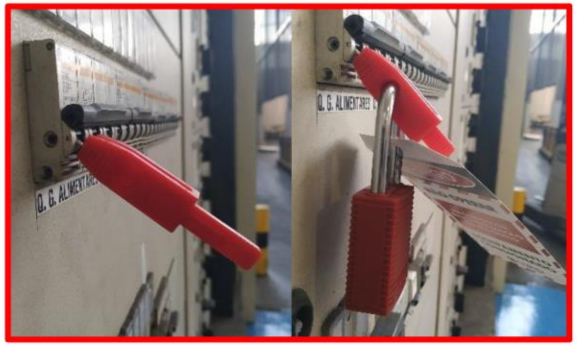
		Prestador de Serviços	máquina ao lado das portas de acesso.		
16. Revisão Geral.	EE1.D2 + P2 + P3	Man. Eletr Man. Mec. Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo; 3. Fechar válvula do ar comprimido e colocar cadeado+ etiqueta sinalizadora de perigo; 4. Pressionar botoneira START/STOP (para efeito de verificação).	1. Verificar com multímetro a ausência de energia; 2. Purgar a válvula de ar comprimido imediatamente e juzante de P1; 3. Verificar manómetro (pressão zero) ar comprimido antes da intervenção; 4. Dissipar energias presentes - despressurizar pulmões 1 + 2 + 3 + 4 + 5.	3
17. Intervenção/ reparação no quadro elétrico ou cabos de potência; 18. Limpeza Geral do Quadro Eléctrico.	EE1.L11.1	Man. Eletr Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo.	1. Verificar com multímetro a ausência de energia.	3

19. Identificação de avarias. 20. Análise Termográfica			1. Avisar os colaboradores envolvidos; 2. Colocação de barreiras e sinalização; 3. Colocação da máquina em modo manual; 4. Coordenação entre 2 técnicos; 5. Botão de emergência acessível.	1. Garantir que só pessoas habilitadas e formadas em LoTo podem executar esta operação; 2. Garantir proximidade de um botão de emergência; 3. Requer autorização de trabalho.	4

Anexo II - Plano de Consignação LoTo – L11 Cravadeira

Pontos de bloqueio	Foto do Bloqueio LoTo	Metodo de Bloqueio
M1 M2 M3 M4		1. O ponto de energia mecânica a bloquear será sempre pela porta por onde se entra para o equipamento; 2. Posição da mesa de elevação ao mesmo nível do transportador de entrada; 3. Atenção à sinalética na janela M5: Proibida a entrada com a máquina em funcionamento (não é ponto passível de bloqueio).
EM1.D2		1. Desligue o disjuntor; 2. Desparafuse o equipamento de bloqueio e coloque-o na parte superior do interruptor; 3. Aparafusar o equipamento de bloqueio, apertando a chave; 4. Coloque o cadeado no equipamento de bloqueio.

Anexo II - Plano de Consignação LoTo – L11 Cravadeira

EM1.D2.L11.1 EM1.D2.L11.2		1. Desligue o interruptor elétrico; 2. Encaixe o equipamento de bloqueio na chave como mostrado na figura ao lado; 3. Coloque o cadeado no equipamento de bloqueio.
EM1.D2.L11.1.1 EM1.D2.L11.2.1		1. Desligue a quadro eletrico; 2. Coloque o cadeado na seção exposta conforme a imagem; 3. Bloquear e marcar o cadeado.

Anexo II - Plano de Consignação LoTo – L11 Cravadeira

EM1.D2.L11.2.1.1		1. Pressionar o botão de emergencia ira desligar o equipamento.
P1 P2		1. Purgar a válvula de ar comprimido; 2. Colocar e bloquear com o cadeado, como mostrado na figura.

Anexo II - Plano de Consignação LoTo – L11 Cravadeira

P3		1. Purgar a válvula de ar comprimido; 2. Verificar no manómetro da válvula que o sistema de ar comprimido se encontra despressurizado (pressão zero) antes da intervenção; 3. Colocar e bloquear com o cadeado, como mostrado na figura.

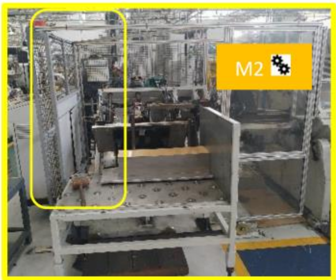
PLANO DE DESCONSIGNAÇÃO
1. Assegurar que o trabalho foi realizado corretamente; 2. Verificar que ninguém se encontra no interior da zona de segurança; 3. Certificar-se de que a área de trabalho não contém ferramentas e materiais; 4. Retirar e guardar o(s) bloqueio(s) e etiqueta(s); 5. Verificar que os bloqueios e etiquetas foram removidos; 6. Informar todos os colaboradores que o equipamento irá ser testado; 7. Repor as fontes de energia e testar o equipamento.

Anexo II - Plano de Consignação LoTo – L26 PRENSA E TRANSPORTADORES

NÍVEL 0 - Operar a máquina conforme procedimento operacional standard
NÍVEL 1 – Operar intercetando a barreira de segurança para acesso parcial
NÍVEL 2 – Aplicar bloqueio(s) para impedir a reinicialização. Chave única individual para cada pessoa exposta
NÍVEL 3 – Identificar as fontes de energia, desconectar as fontes de energia, bloqueio com cadeado pessoal adequado + etiqueta. Libertar energia armazenada
NÍVEL 4 – Permanecer em zona delimitada e sinalizada de segurança + uso da consola em modo manual + garantir acesso fácil ao botão de emergência. Condição de Risco Elevado

VERIFICAÇÃO DO ISOLAMENTO DAS ENERGIAS	**Nº de pontos LoTo: 22**
Verifique se todas as fontes de energia estão isoladas e num estado de energia zero, tentando iniciar um equipamento com os controlos normais.	
Se houver mais do que um interveniente, é necessário o bloqueio complexo existindo o coordenador de consignação, sendo o último a remover o bloqueio e a verificar a área a desconsignar.	

M1 – Mesa de alimentação da maquina



M2 – Portal lateral de acesso a alimentação

M3 – Janela de acesso a primeira prensa

M4 – Calço do cunho da primeira prensa

M5 – Janela de acesso a segunda prensa

Anexo II - Plano de Consignação LoTo – L26 PRENSA E TRANSPORTADORES

M6 – Calço do cunho da segunda prensa

EE1.D3 - Quadro elétrico Geral (Potência) junto ao A3

EE1.D3.L26.1 - Coffret de potencia dos transportadores

EE1.D3.L26.1 - Quadro elétrico dos trasportadores

EE1.D3.L26.1 - Coffret de potencia da primeira prensa

EE1.D3.L26.1.1 - Quadro elétrico da primeira prensa

EE1.D2.L26.1.1.1 – Comando manual da primeira prensa

EE1.D2.L26.2 - Coffret de potencia da segunda prensa

EE1.D2.L26.2.1 – Comando manual e quadro eletrico da segunda prensa

P1 - Ar comprimido. Baixada L99 – Prensa

Anexo II - Plano de Consignação LoTo – L26 PRENSA E TRANSPORTADORES

P2 - Ar comprimido. Baixada L99 – Prensa

P2 - Ar comprimido. Baixada L99 – Prensa

P2 - Ar comprimido. Baixada L99 – Prensa

P2 - Ar comprimido. Baixada L99 – Prensa

P3 - Ar comprimido. Baixada L99 – Prensa (Bipass)

P2 - Ar comprimido. Baixada L99 – Prensa

P2 - Ar comprimido. Baixada L99 – Prensa

Anexo II - Plano de Consignação LoTo – L26 PRENSA E TRANSPORTADORES

Tarefa	Pontos de energia a bloquear	Dispositivos LoTo a utilizar	Método de bloqueio	Informação Adicional	Nível LoTo
1. Alimentação de matéria prima: - Adicionar folha em cima da mesa; - Descer a mesa da máquina; - Empurrar a folha para o interior da maquina pela mesa M1;	M1	Operador	1. Avisar os colaboradores envolvidos; 2. Abrir a porta de acesso e colocar cadeado.	1. O ponto de energia mecânica a bloquear será sempre pela porta por onde se entra para o equipamento; 2. Posição da mesa de elevação ao mesmo nível do transportador de entrada;	2
2. Desencravar folha ou componentes das prensas (através da janela M3 ou M4); 3. Limpar o cunho na máquina (através da janela M3 ou M4); 4. Desmontar / montar cortantes; 5. Substituir parafusos do cunho; 6. Setup troca de cunho; 7. Lubrificação geral das prensas;	M3 ou M4	Operador Man. Eletr / Man. Mec.	1. Avisar os colaboradores envolvidos; 2. Abrir a janela M3 ou M4.	1. Caso a intervenção seja na prensa da primeira operação, abrir a janela M3; 2. Caso a intervenção seja na prensa da segunda operação, abrir a janela M4;	2
8. Parametrização e afinação da mesa de alimentação; 9. Desencravar a folha da mesa; 10. Substituição de ventosas; 11. Limpeza das correias; 12. Ajuste do centramento;	M1 ou M2	Operador Man. Eletr / Man. Mec.	1. Avisar os colaboradores envolvidos; 2. Para as tarefas 8, 9, 10 e 11 colocar em modo manual na consola;	1. Verificar se máquina esta em modo manual - energias suspensas (só pequenos movimentos são permitidos e controlados no interior da máquina);	

Anexo II - Plano de Consignação LoTo – L26 PRENSA E TRANSPORTADORES

13. Troca/reparação de motores elétricos ou cabos elétricos dos transportadores; 14. Troca de telas nos transportador;	EE1.D3.L26.1.1 + EE1.D3.L26.2.1 + EE1.D3.L26.3.1	Man. Eletr Man. Mec. Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo; 3. Pressionar botoneira START/STOP (para efeito de verificação.	1. Verificar com multímetro a ausência de energia; 2. Ter cuidado com a ativação das prensas quando interage com os transportadores.	3
15. Substituição / reparação de motor da janela de alimentação de folha; 16. Intervenção/ reparação no quadro manual da primeira prensa: 17. Intervensão/Substituição de sensor, cabos eletricos e outros componentes eletricos da primeira prensa; 18. Intervenção/reparação nas Correias, Suportes, Guias, Rolos, e outros elementos mecanicos; 19. Limpeza da linha no interior da prensa;	EE1.D3.L26.2.1	Man. Eletr Man. Mec. Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo; 3. Pressionar botoneira START/STOP (para efeito de verificação.	1. Verificar com multímetro a ausência de energia; 2. Para a tarefa 15 desligar fichas *Harting* do transportador; 	3
20. Intervenção/ reparação no quadro manual da segunda prensa: 21. Intervensão/Substituição de sensor, cabos eletricos e outros componentes eletricos da segunda prensa; 22. Intervenção/reparação nas Correias, Suportes, Guias, Rolos, e outros elementos mecanicos;	EE1.D3.L26.3.1	Man. Eletr Man. Mec. Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo; 3. Pressionar botoneira START/STOP (para efeito de verificação.	1. Verificar com multímetro a ausência de energia;	3

Anexo II - Plano de Consignação LoTo – L26 PRENSA E TRANSPORTADORES

23. Intervenções/ substituições no sistema pneumático da prensa. 24. Intervenção no sistema de Lubrificação Central da Prensa 25. Substituir cilindros amortecedores; 26. Substituir fusíveis mecânicos e ajustar pressão da prensa; 27. Reparação de sensores, cabos e electroválvulas pneumáticas; 28. Intervenções/ substituições filtros de vácuo;	EE1.D3.L26.3.1 + P3 + P4 ou EE1.D3.L26.2.1 + P5 + P6 + P7	Man. Eletr Man. Mec. Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo; 3. Fechar válvula do ar comprimido e colocar cadeado+ etiqueta sinalizadora de perigo; 4. Pressionar botoneira START/STOP (para efeito de verificação.	1. Verificar com multímetro a ausência de energia; 2. Purgar a válvula de ar comprimido imediatamente e juzante de P3 ou P2 dependendo da pressa; 3. Verificar manómetro (pressão zero) ar comprimido antes da intervenção; 4. Dissipar energias presentes - despressurizar pulmão P4 para a segunda prensa, e P7+P6 para a primeira prensa	3
29. 3Revisão Geral.	EE1.D3 + P5 + P6 + P7	Man. Eletr Man. Mec. Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo; 3. Fechar válvula do ar comprimido e colocar cadeado+ etiqueta sinalizadora de perigo; 4. Pressionar botoneira START/STOP (para efeito de verificação).	1. Verificar com multímetro a ausência de energia; 2. Purgar a válvula de ar comprimido imediatamente e juzante de P1; 3. Verificar manómetro (pressão zero) ar comprimido antes da intervenção; 4. Dissipar energias presentes - despressurizar pulmões P4, P6, P7	3

Anexo II - Plano de Consignação LoTo – L26 PRENSA E TRANSPORTADORES

30. Intervenção/ reparação no quadro elétrico ou cabos de potência. 31. Limpeza Geral do Quadro Eléctrico	EE1.D3	Man. Eletr	Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Desligar quadros elétricos e colocar cadeado + etiqueta sinalizadora de perigo.	1. Verificar com multímetro a ausência de energia.	3
32. Substituição/ reparação dos pulmões da primeira prensa	P5 + P6 + P7	Man. Mec.	Prestador de Serviços	1. Avisar os colaboradores envolvidos; 2. Fechar válvula do ar comprimido e colocar cadeado+ etiqueta sinalizadora de perigo.	1. Purgar a válvula de ar comprimido do equipamento; 2. Verificar manómetro (pressão zero) ar comprimido antes da intervenção; 3. Dissipar energias presentes - despressurizar pulmão P6 e P7	3
33. Substituição/ reparação dos pulmões da segunda prensa	P3 + P4	Man. Mec.	Prestador de Serviços	3. Avisar os colaboradores envolvidos; 4. Fechar válvula do ar comprimido e colocar cadeado+ etiqueta sinalizadora de perigo.	1. Purgar a válvula de ar comprimido do equipamento; 2. Verificar manómetro (pressão zero) ar comprimido antes da intervenção; 3. Dissipar energias presentes - despressurizar pulmão P4.	3

34. Identificação de avarias. 35. Análise Termográfica			1. Avisar os colaboradores envolvidos; 2. Colocação de barreiras e sinalização; 3. Colocação da máquina em modo manual; 4. Coordenação entre 2 técnicos; 5. Botão de emergência acessível.	1. Garantir que só pessoas habilitadas e formadas em LoTo podem executar esta operação; 2. Garantir proximidade de um botão de emergência; 3. Requer autorização de trabalho.	**4**

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Pontos de bloqueio	Foto do Bloqueio LoTo	Metodo de Bloqueio
M1 M2 M3 M4 M5 M6 M7		1. A abertura da porta/janela irá parar imediatamente a máquina; 2. A máquina só podera arrancar novamente quando a porta/janela estiver fechada;

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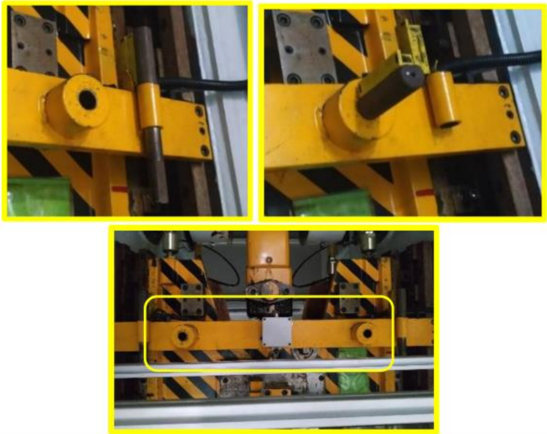
M8 M9		1. Remover o calço do seu suporte; 2. Colocar os calços em ambos os lados da prensa como representado nas figuras ao lado;
EE1.D3		1. Desligue o disjuntor; 2. Desparafuse o equipamento de bloqueio e coloque-o na parte superior do interruptor; 3. Aparafusar o equipamento de bloqueio, apertando a chave; 4. Coloque o cadeado no equipamento de bloqueio.

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EE1.D3.L26.1 EE1.D3.L26.2 EE1.D3.L26.3		1. Desligue o interruptor elétrico; 2. Encaixe o equipamento de bloqueio na chave como mostrado na figura ao lado; 3. Coloque o cadeado no equipamento de bloqueio.
EE1.D3.L26.1.1 EE1.D3.L26.2.1 EE1.D3.L26.3.1		1. Desligue a quadro eletrico; 2. Coloque o cadeado na seção exposta conforme a imagem; 3. Bloquear e marcar o cadeado.

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EE1.D3.L26.2.1.1		1. Pressionar o botão de emergencia ira desligar o equipamento.
P1 P2 P5		1. Purgar a válvula de ar comprimido; 2. Colocar e bloquear com o cadeado, como mostrado na figura.

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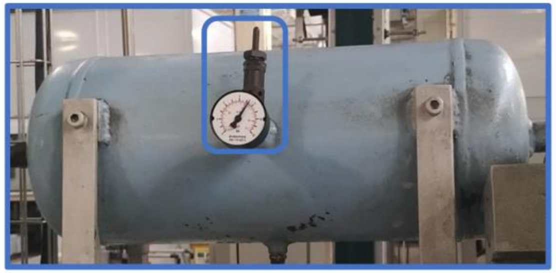
P3 P6		1. Purgar a válvula de ar comprimido; 2. Verificar no manómetro da válvula que o sistema de ar comprimido se encontra despressurizado (pressão zero) antes da intervenção; 3. Colocar e bloquear com o cadeado, como mostrado na figura.
P4 P7 P8		1. Abrir a valvula do tanque de ar como mostrado na figura a esquerda; 4. Verificar no manómetro do tanque que o tanque se encontra despressurizado (pressão zero) antes da intervenção.

PLANO DE DESCONSIGNAÇÃO

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1. Assegurar que o trabalho foi realizado corretamente;
2. Verificar que ninguém se encontra no interior da zona de segurança;
3. Certificar-se de que a área de trabalho não contém ferramentas e materiais;
4. Retirar e guardar o(s) bloqueio(s) e etiqueta(s);
5. Verificar que os bloqueios e etiquetas foram removidos;
6. Informar todos os colaboradores que o equipamento irá ser testado;
7. Repor as fontes de energia e testar o equipamento.