COMPRESSED AIR DISTRIBUTION AND AUTOMATION OF THE WOOD FASTENER OF THE LOG DOOR CAR OF A SAWMILL IN ITAMARANDIBA – MG

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Heitor Misael Alves Neves[1], Adriana da Silva Torres[2],Moisés de Matos Torres[3].

ABSTRACT

Due to the growing number of areas destined for reforestation and the demand for sawn wood, companies that provide this type of service need to improve production processes. The automation of the log carriage can influence the reduction of the time it takes to fix the wood to be sawn, increasing productivity. In addition, the pneumatic equipment used in the manufacturing processes will have greater robustness and useful life. Thus, the present work aims to distribute the compressed air and automate the wood fixer of the log door car of a sawmill, located in the city of Itamarandiba-MG. A *layout* of the company was made to demonstrate where the compressed air will be used and the path of the air through the company. To carry out this project, information obtained from the literature and data collected within the sawmill were used. Calculations were carried out using manuals and catalogs of equipment manufacturers for the dimensioning of the distribution lines, feed, compressor, actuators and reservoir volume. With this, the well-sized compressed air system will be able to meet the needs of the company's equipment, making the enterprise more profitable and competitive.

Keywords: Automation. Compressors. Distribution network sizing.

[1] Federal University of the Jequitinhonha and Mucuri Valleys
[2] Federal University of the Jequitinhonha and Mucuri Valleys
[3] Federal University of the Jequitinhonha and Mucuri Valleys

INTRODUCTION

According to the Brazilian tree industry report (IBA, 2017), Brazil totaled 7.84 million hectares of trees planted in 2016, due exclusively to the increase in areas with eucalyptus forestry. The areas with pine and other genera remained unchanged in the period. Eucalyptus plantations occupy 5.7 million hectares of the country's planted tree area and are located mainly in Minas Gerais (24%), São Paulo (17%) and Mato Grosso do Sul (15%).

The state with the largest area of planted forest in Brazil is Minas Gerais, with 1,880,538 hectares in 2016, with 98% of the genus *Eucalyptus*. Sawn wood increased production to 8,546,365 m³ (growth of 52.3%) (SNIF BULLETIN, 2017).

The Brazilian sawn wood activity is one of the biggest highlights among producers of solid wood derivatives. This activity is usually carried out by a certain segment of the market, the sawmills. In this type of market, the pieces are arranged by splitting logs into saws, which characterizes a type of primary transformation of wood (ABIMCI, 2009).

Sawmills are small industries that, most of the time, have small working capital, use machinery in poor conditions, low productivity and high waste of raw material.

In most of the enterprises in this sector, the splitting of wood occurs (an operation where the log is sawn longitudinally, generating the so-called planks or planks), and this activity is carried out only based on the experience of the employees, which most of the time is reflected in a low performance and quality (VITAL, 2008).

In 1896, the first saw powered by a motor powered by electric current appeared and since then sawmills have become large constructions, which can be built far from rivers (LATORRACA, 2004, apud BATISTA, 2006). With the improvement of machines for sawing wood and cutting elements, together with electric motors, the automation of industrial processes appears as necessary for serial production and consequently increasing production yields (BATISTA, 2006).

Compressed air plays an important role in automating many processes in a sawmill, whether it is used to move materials such as stacked logs, or employed to control the movement of logs as they are used in the band saw. The use of compressed air in industry is justified by the fact that it is a conductor of energy for various areas of industrial applications (PACCO, 2013).

With the growing number of renewable forests and a greater demand for the use of wood in the current market, there is a need for technologies that improve the unfolding of wood. However, new technologies also mean expensive expenses for the acquisition of this type of machinery and require a capital contribution.

In this sense, the automation of manual models (log door carts) could minimize costs, since the enterprise would only adapt the existing machinery. In this way, automation emerges as a great tool in increasing productivity by reducing hours worked/men to perform everyday activities, in addition to maintaining greater safety in the work environment, reducing costs and obtaining profits.

GENERAL OBJECTIVE

Automation of the wooden fastener of the log door car and distribution of compressed air with a focus on enabling greater productivity in the enterprise.

Specific objective

Determine which type of system would be the most suitable for sizing equipment such as compressors, piping, and actuators.

STATE OF THE ART

In this chapter, a brief description of the pneumatics linked to machines used in sawmills will be developed. In industrial automation, it is necessary to use technologies such as pneumatics and hydraulics to generate movements in machines. These sciences are the main ones used to replace manual work, such as opening bus doors and automotive brakes (PAVANI, 2011).

PNEUMATIC

The etymology of the word pneumatics comes from the Greek *pneuma,* which is synonymous with wind, blowing, in this way, this science deals with the movements and phenomena of gases (FIALHO, 2011). Which studies the behavior of compressed air, applied in engineering for the transmission of energy, for moving, fixing and transporting parts. The use of pneumatics has become a relatively cheap and simple means due to its properties (SILVA, 2002).

The production of compressed air is nothing more than the accumulation of energy for the activation of various devices in mechanical application, or for participation as a relevant member in the transformation of raw materials in industrial production processes (SCHULZ, 2002). The positive points of compressed air are the quantity (it can be found anywhere), transport (it is easy to be transported by pipes), storage (it can be stored and then used), temperature (it does not influence the work), safety (there is no danger of fire and explosion), cleanliness (possibility of being released anywhere without treatment), speed (allows the achievement of high working speeds and ease of maintenance) (FIALHO, 2011).

Among the negative points we have with pneumatics, there is the preparation of compressed air, where it is necessary that it does not present impurities and moisture, details that can lead to wear and tear on equipment and oxidation of pipes. In addition to the high cost of obtaining compressed air since the energy expenditure is high, this problem is minimized by the low installation cost and profitability of the work cycle. Force also appears as another problem, since it limits the use of maximum pressure to 1723.6 kPa, a small value when compared to the hydraulic system (FIALHO, 2011).

For the use of pneumatics, it is first essential that the air goes through a treatment and preparation process, as it consists of approximately 78% nitrogen, 21% oxygen and 1% other gases. The air also has contaminants in its composition such as water in the form of water vapor, oil and dust. The process begins with the air going through the phases of filtration, compression, cooling, drying, storage, distribution and treatment (SILVA, 2002).

Filtering

Filtration occurs with the use of an air filter that retains the particles of impurities and condensed water contained in the air, as shown in Figure 1. The filter works when the air enters it, forcing it to rotate through a directional slit. By centrifugal force and cooling caused by speed, the water condenses and is deposited at the bottom of the filter along with the solid particles that have been thrown against the filter wall. Subsequently, this residue is drained from the filter, which can be manually or automatically (MARINS, 2009).

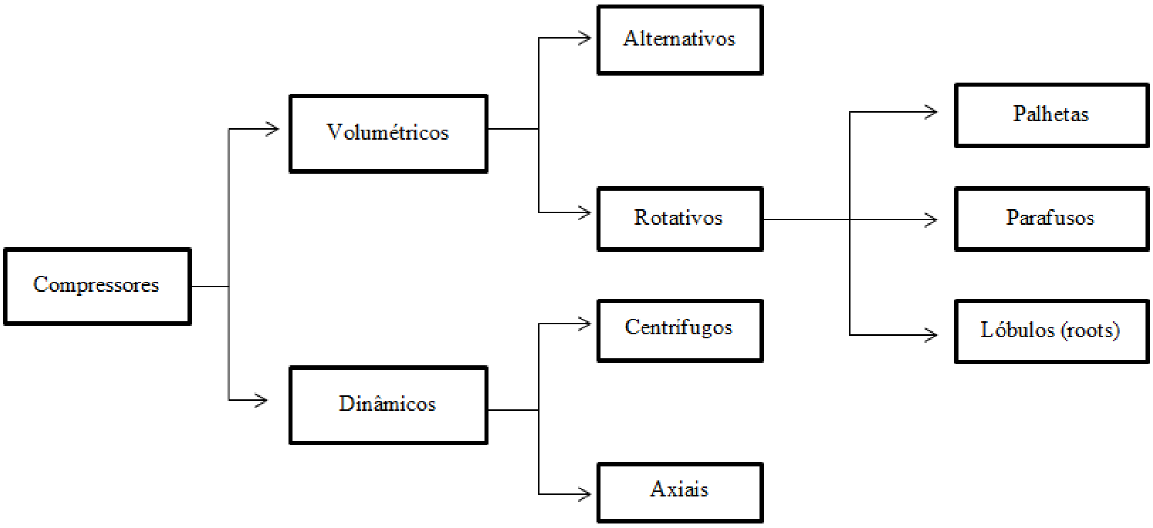
Figure 1: Air Filter

Source: PARKER TRAINING, 2006, p. 42.

Compression

In order to compress the air, machines called compressors are used, which are responsible for performing work on a compressible fluid when the pressure is raised as a result of the decrease in an air volume (PEIXOTO; INDRUSIAK, 2011). Compressors can be classified as positive (volumetric) or dynamic displacement, as shown in Figure 2. In cases of positive displacement (volumetric), the air is admitted into a chamber isolated from the medium, and its volume is compressed and pushed into the discharge pipe, and this type of compressor can be divided into reciprocating and rotary (PAVANI, 2011).

Figure 2: Classification of compressors.



Source: Adapted from FIALHO, 2011, pg. 42.

Reciprocating volumetric compressors use a piston (piston) that, coupled to a connecting rod and an eccentric shaft, performs alternating movements (up and down of the piston), which can be double- or single-acting, as can be seen in Figure 3 (PARKER TRAINING, 2000). Double-acting ones are those that have two compression chambers in the same piston, one above and one below. Another type of configuration is the use of multiple stages of compression, in which the compressed air in one combustion chamber passes through another combustion chamber thus increasing its pressure. Reciprocating compressors are indicated for the compression of toxic, corrosive and flammable gases, in addition to having a good relationship between suction and discharge temperatures (CACHONIS *et. al.,* 2011).

Figure 3: Piston compressor with reservoir and electric motor.

Source: SCHULZ, 2018

Rotary compressors can be screw, *scroll*, vane and piston type Screw compressors shown in Figure 4 are the most common, being composed of two screw-shaped rotors that, rotating in opposite directions within a housing, causes the air to travel through the screw, becoming more compressed. The pallet compressor, on the other hand, has an off-center rotor and blades that delimit the air space, in the rotation movement of the rotor, the blades, when having a radial movement, cause the air to be compressed in the direction of the rotor housing (SILVA, 2002).

Figure 4: Screw air compressor with reservoir and electric motor.

Source: SCHULZ, 2018

Dynamic compressors, on the other hand, are made up of two central parts: impeller and diffuser. In this type of compressor, pressure is obtained through the conversion of kinetic energy into pressure energy, when the air is accelerated by the impeller, which is a rotor made up of blades that transfers kinetic energy to the air when it passes through the diffuser, the organ responsible for transforming the kinetic energy of the gas into enthalpy (PARKER TRAINING, 2000).

Dynamic compressors are divided into centrifugal (radial) and axial. In the first type, the air flow is perpendicular to the axis, while in the second, both aspiration and discharge occur in the same axial direction parallel to the axis and acceleration occurs by means of propellers (PAVANI, 2011).

Cooling

The cooling step is necessary to avoid the expansion of the compressed air distribution line and this cooling process occurs by passing the hot and humid compressed air from the compressor to a heat exchanger, and this cooling leads to water condensation (FARGON, 2018). After cooling, it is necessary to use an equipment called an air dryer, which aims to dry the water vapor generated in the compressed air, by condensing and separating the condensed water (PEIXOTO and INDRUSIAK, 2011).

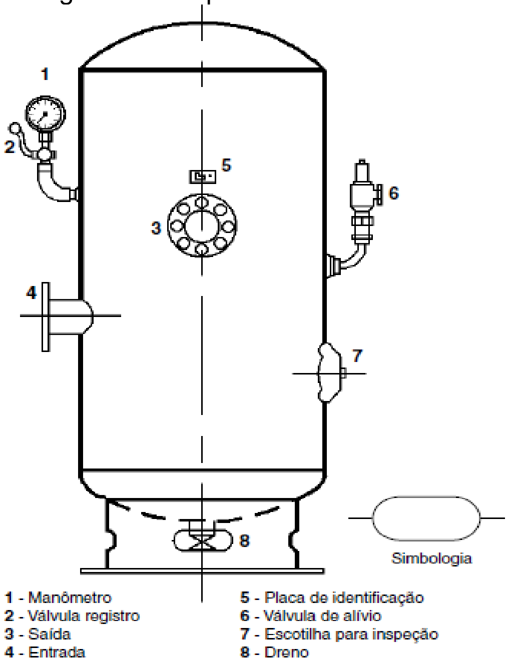
Drying

Among the main types of dryers, we can mention refrigeration dryers, in which a refrigeration cycle continuously retains an icy surface through which the flow of the mixture flows; by adsorption, by means of a physical process. Through this process, a substance of high hygroscopic capacity adds a body of water, by absorption, by means of a chemical substance also with great hygroscopic capacity incorporating a body of water. From this stage, another substance is generated that can be discarded; by membrane, using a special filter medium (FARGON, 2006).

Storage and distribution

After the treatment of the compressed air, the next step is the storage and distribution process, in which the storage tank, represented in Figure 5, has as its main objective the stability of the distribution of the compressed air, not allowing pressure fluctuations to occur and reducing the energy consumption of the compressor. In the distribution process, a correct sizing and assembly of the pipes is required, as it requires regular maintenance and cannot be installed inside walls. Normally, distribution networks are made up of carbon steel or galvanized tubes (FIALHO, 2011).

Figure 5: Compressed air reservoir



Source: PARKER TRAINING, 2006, pg. 18.

According to Parker Training (2006), to size a reservoir it is necessary to use the following parameters:

- Piston compressors: the volume of the reservoir will be equal to 20% of the total flow of the system in m³/min.
- Rotary compressors: the volume of the reservoir will be equal to 10% of the total flow of the system in m³/min.

The distribution system has the task of conducting compressed air from compressors and/or reservoirs to the place of use, and the success of this system is related to the ability to transport compressed air with the lowest possible losses (OLIVEIRA *et. al.,* 2015).

The basic function of distribution is to make the interconnection between the generating equipment and the consumer, and this distribution network can be either open or closed circuit, and in the open circuit one must pay attention to an inclination of the circuit capable of draining the condensate formed. This type of network is widely used to bring air to distant points, but it prevents even distribution in the network. On the other hand, the closed distribution network has a uniform distribution that facilitates maintenance as it is not necessary to stop the process, but it does not present a direction for the flow of condensate. It is also possible to obtain a combined distribution network (open and closed) (PAVANI, 2011).

For pipe sizing, according to Fialho (2011), the minimum precise diameter to size the main compressed air piping is obtained through Equation 1. This equation is also used to estimate the inside diameter of the pipe and to design the diameter of the feed line. To use this equation, the values of the flow and length variables must be adjusted.

$$d = 10\left[\sqrt[5]{\frac{1{,}663785.10^{-3}Q^{1{,}85}Lt}{\Delta P.P}}\right] \quad (1)$$

Where:

- d = Internal diameter of the pipe, in mm;
- Q = Air volume (total flow of the equipment + future expansion, in m³/h);
- Lt = Total length of the line (sum of the linear length of the pipe and the equivalent length caused by the singularities (tees, curves, registers), in m);
- ∆P = Admitted pressure drop (pressure loss due to internal pipe friction and singularities, in kgf/cm²);
- P = Regime pressure (storage reservoir pressure, in kgf/cm²).

2.1.6. Treatment unit

Soon after the production, treatment and distribution process, the compressed air passes through the last improvement, passing through a conservation unit or preparation unit composed of a filter, a pressure regulating valve and the addition of a little oil for the lubrication of the mechanical parts of the pneumatic equipment (PAVANI, 2011). These treatment units, also known as "lubrefil", represented in Figure 6, are essential, as they allow good efficiency of the machinery, in addition to increasing its useful life, and can be used from the simplest to the most robust systems (BLOCH apud CORADI, 2011 and CORADI, 2011).

Figure 6: Lubrefil treatment unit.

Source: SCHULZ, 2018.

To carry out the work of compressed air, actuators are used that transform energy contained in the air into work (PARKER TRAINING, 2000). Of the existing types of actuators, there are linear actuators that transform pneumatic energy into rectilinear movement and are represented by pneumatic cylinders and rotary actuators that generate torsion moments and are widely used in pneumatic motors (PAVANI, 2011).

Actuators

Actuators can have models such as single-acting, in which compressed air is activated on one side and its return is made by means of a spring, causing the piston to return to its initial position, in this type of actuator, the work takes place only in one direction. Double-acting actuators, as shown in Figure 7, can perform work both in the advance and backward of the actuator, and are used in most cases where force is required in both directions (PARKER TRAINING, 2000). The actuators can have damping, widely used to avoid impacts at the end of the limit, thus increasing their useful life. There are other actuator configurations such as the double rod (through) where it has two rods connected in a piston, actuators formed by two pistons joined by the same rod and which have an independent air intake, where its force is the sum of the forces produced by each piston, thus presenting greater force in this type of actuator (PARKER TRAINING, 2000). The multi-position linear actuator consists of two double-acting actuators joined with air chambers (PAVANI, 2011).

Figure 7: Pneumatic actuator

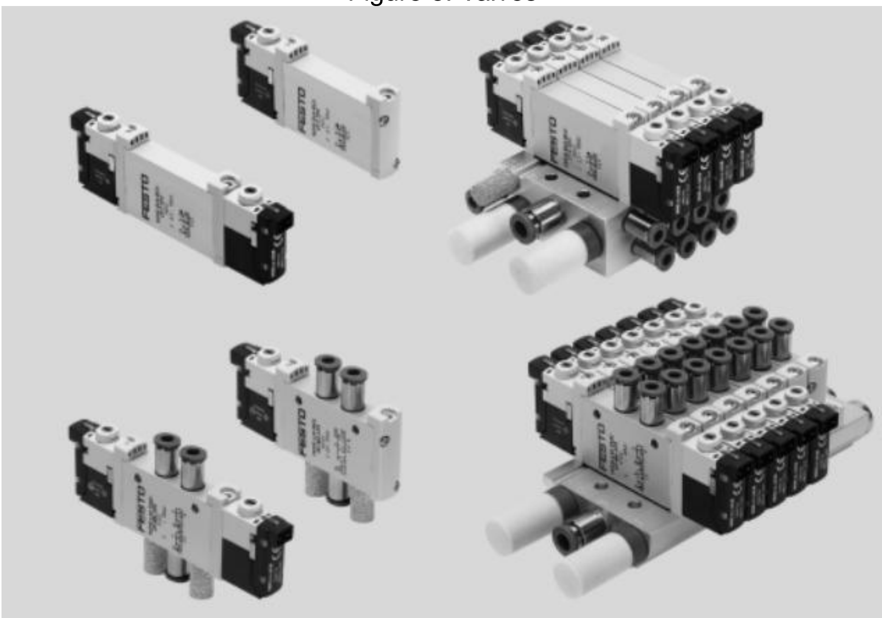
Source: FESTO, 2018.

Making a division in pneumatics into commands, the actuators are the working elements, we still have the signal and command elements, the latter having the purpose of controlling the flow of compressed air. These elements are known as valves (MARINS, 2009).

Valves

Valves can be classified according to their function, with the most commonly used: directional, blocking, flow control and pressure control valves. The valves are made up of symbols and squares, with squares being the positions and the ways are represented by arrows. The valves have the types of return command, which can be mechanical through rollers, which are limit switch valves, springs, while the manual requires muscle strength and through button, lever and pedal, the electric ones are made through electrical signals through solenoids (PAVANI, 2011). Figure 8 shows models of pneumatic valves.

Figure 8: Valves



Source: FESTO, 2018.

Electropneumatics emerges as an arm of pneumatics responsible for taking advantage of electrical energy, a very relevant aspect in the activation of directional and proportional valves, in addition to energizing various types of sensors (FIALHO, 2011).

AT THE SAWMILL

A sawmill is a type of establishment that generally has as its main objective the market for the unfolding of logs for the most diverse economic purposes.

The most used machinery in the unfolding are frame or alternative saws, circular saws, band saws and log carriages, these equipment are responsible for activities that generate products such as planks, boards, slats (DA SILVA, 2010, ROCHA, 2002).

Of the machines used in sawmills, we can list the band saw as the most used equipment, due to its great mobility in various jobs. It is basically composed of a continuous steel blade tensioned by two flywheels (ROCHA, 2002). As can be seen in Figure 9.

When the band saw is used in the main split, the log is usually attached to a mobile cart, equipment with the function of taking it to the band saw at a certain speed, and can be used in this equipment with manual or automatic control. This cart is known as a log carrier cart and usually has three to four claws that are fixed to the wood, and that move away and approach the saw together, as shown in Figure 10 (ROCHA, 2002).

Figure 9: Band saw Figure 10: Conventional log carrier carriage

Source: SHIFFER, 2018.

PROBLEM ANALYSIS

The present work was carried out in a small sawmill in Itamarandiba, located in the northeastern region of Minas Gerais. The company works exclusively with reforested wood logs of the genus *Eucalyptus* sp., which are unfolded into slats and planks.

The sawmill is composed of various machinery used in the cutting and finishing of wood, such as a band saw, manual log door carriage (its dimensions are 5 x 1 x 0.8 meters in length, opening and height respectively), bench band saw, circular saw and thickness. These machines have electric motors in addition to having a compressor used to varnish the manufactured parts. The company also has in its warehouse, electric machines, such as drill, screwdriver and sander, used in the finishing and assembly of the parts.

With the need to increase the productivity of the lumber company, and specifically of the sawn wood, it was noted that there is a certain delay in fixing the logs in the log carriage. It is known that automatic log carriages have ease and speed in fixing the wood, so a study was proposed with future implementation of the automation of the log carriage with the use of pneumatic actuators responsible for fixing the logs on the carriage that the enterprise already has. As a pneumatic system will be used in the automation of the log door carriage, air will be distributed throughout the company in order to change the electrical machinery for the pneumatic one.

METHODOLOGY

After a detailed analysis of the compressed air, its production, distribution and air preparation processes and the methodology that will be used, it was time to present the company's layout, sizing of the distribution lines, feeding and choice of compressor.

For a lower production cost in a company, compressed air is used in some cases. With a well-dimensioned air network, it is possible to reduce energy consumption and provide longer useful life to pneumatic equipment. Thus, it is essential to choose the best paths for the execution of the sizing of the compressed air system.

In this study, the equipment that makes use of compressed air will be surveyed, in addition to specifying the volume of air consumed, pressure necessary for operation and its location to trace the supply and distribution lines of the fasteners of the log carriage for a sawmill.

To carry out the calculations regarding the pipe diameters, first the pneumatic equipment that will be used in the sawmill was selected, which are listed below, as well as their function.

- 2 cleaning nozzles: used to remove particulate matter;
- 1 sander: used in finishing and removing burrs from wood;
- 1 spray gun: used to varnish wooden parts.

The flow value was followed according to the descriptions of the equipment contained in the manufacturer's manual.

Regarding the sizing of the actuators of the log carriage, the opening of the band saw will be taken into account. This has a distance between the handwheels of one meter in length and has the power to saw logs of up to 80 centimeters in diameter. Therefore, the following will be used:

- 4 actuators with 1 meter of displacement;
- 2 electric buttons to interchange the electropneumatic directional control valve;
- 1 pneumatic locking high button, 3-way and 2-position with spring return used in case of emergency;
- 1 5-way, 2-position electro-pneumatic directional control valve.

According to Fialho (2011), to calculate the air consumption of the actuator, Equation 2 is used:

$$Q = \frac{Ap.L.(Pt+1,013)}{T.1,013.10^6} \qquad (2)$$

Where:

Q = Air flow [l/sec].

Ap = Effective piston area [mm²]. $\frac{\pi.d^2}{4}$

L = Stroke [mm].

Pt = Working pressure [bar].

T= Time for a cycle in seconds [s].

Considering that the time spent to saw the wood is 30 seconds and that the actuator chosen was the double-acting linear actuator with a plunger diameter equal to 63 mm, theoretical force at 6 bar equal to 1682 N, according to the manufacturer's manual (FESTO, 2018). The flow rate value will be given by Equation 2.

$$Q = \frac{\frac{\pi.63^2}{4}.1000.(6+1{,}013)}{30.1{,}013.10^6} \qquad (3)$$

Q=0.72 l/s or 2.6 m³/h

Table 1 presents the pneumatic equipment that will be used in the company with their flow rates and pressures recommended by the manufacturer.

Table 1: Equipment and its flows and pressures used in the company.

Equipment	Quantity	Pressure (bar)	Unit Flow (m³/h)	Total Flow (m³/h)
Cleaning nozzle	2	5,89	25,2	50,40
Sander	1	6,00	33,98	33,98
Spray gun	1	3,40	24,64	24,64
Actuators	4	6,00	2,60	10,40
Total	8			119,42

Source: STEULA manufacturers' catalogues, 2014; V8BRASIL, 2018; MAXX TOOLS, 2018; FESTO, 2018.

According to the table, it is possible to notice that the total flow corresponds to a value of 119.42 m³/h. According to Parker (2006), after obtaining the total flow of the equipment, a factor between 20% and 50% should be determined for future expansions of the project. Starting from the conception of an analysis of the maximum growth of the company in the future facilities, a percentage of 50% increase was adopted. Passing the flow to an approximate value of 179.13 m³/h, to be used for the sizing of the pipes. The pipes will be divided into two lines, the distribution line, responsible for taking the air from the compressor to the feed line and will have a length of 75 meters, while the feed line, responsible for taking the air from the distribution line to the equipment, has a length of 3 meters.

For the actuators of the log carriage, a longer line length will be necessary, as the carriage is dislodged both forward and backward. In this way, a length of 10 meters will be used to the steering control valve. It is observed that all the dimensions defined here take into account the size of the existing log carrier car that will be automated. The singularities of the bends, registers and means of pipe connections (tees) of the distribution and feed lines were obtained for their equivalent lengths. As the compressed air suffers a pressure drop along the pipe due to friction and other singularities, a good line sizing should adopt an admissible pressure drop of 0.3 kgf/cm² (FIALHO, 2011).

A regime pressure (pressure at which the air is stored in the reservoir) varies from 6 kgf/cm² to 12 kgf/cm², so in this work a regime pressure of 10 kgf/cm² will be adopted, sufficient for a working pressure of 6 kgf/cm² (FIALHO, 2011).

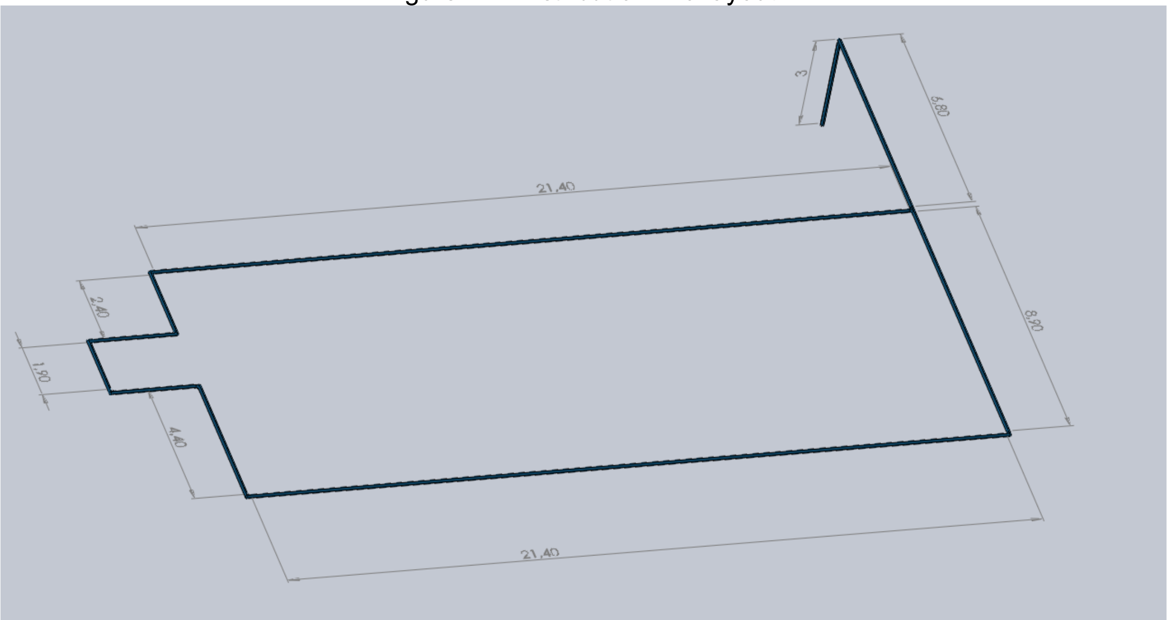
RESULTS AND DISCUSSION

To size the pneumatic air network according to the company's needs, it was necessary to develop its *layout*. Thus, several measurements were carried out in order to determine the shortest path of the pipes and thus the definition of the path taken by the air network.

To define the layout, the best circuit (closed or open) for the system was taken into account, when analyzing the advantages and disadvantages of each one. We chose the closed circuit, as this type of circuit allows the air to flow to both sides, standardizing the supply. In addition to favoring the installation of other unforeseen consumption points, since the network runs throughout the company.

The *layout* of the distribution and power lines was developed with the help of *Autodesk Inventor* software. The distribution line that connects the compressor to the supply line is shown in Figure 11.

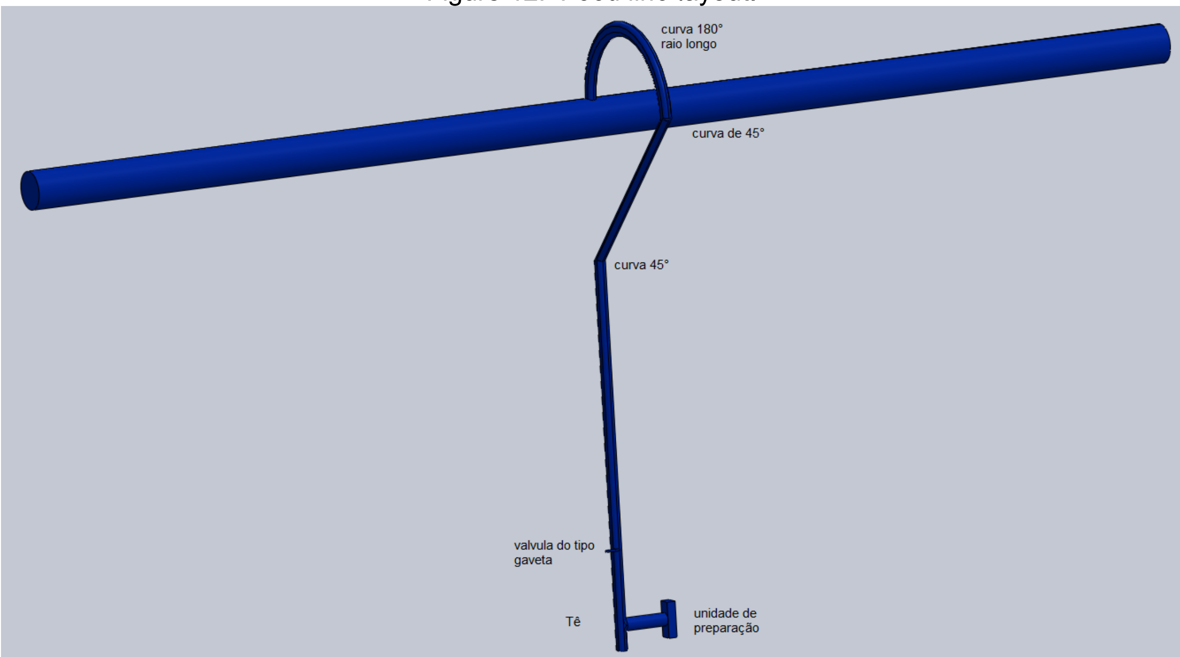
Figure 11: *Distribution line* layout.



Source: Author himself.

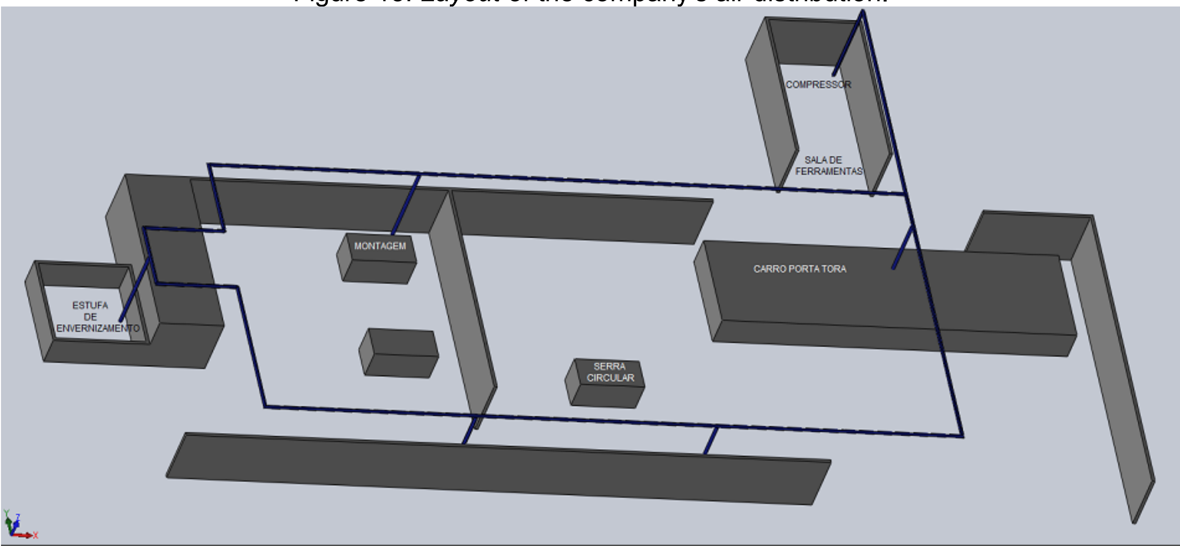
The power line, responsible for connecting the distribution line to the equipment as shown in Figure 12. The project foresees that the power line has a record for maintenance of the preparation unit without it disconnecting the distribution line, it is also emphasized that the air is supplied through the upper part of the distribution line piping, to prevent condensate formed from going to the supply line. Figure 13 shows the drawing of how the feeding and distribution lines should be located in the sawmill in Itamarandiba - MG.

Figure 12: *Feed line* layout.



Source: Author himself.

Figure 13: *Layout* of the company's air distribution.



Source: Author himself.

For the sizing of the distribution line, the distribution line that will conduct air from the compressor to the supply line is first dimensioned. The parameters collected from the line are:

- Linear pipe length: 75 meters;
- Admitted pressure drop: 0.3 kgf/cm²;
- Regime pressure: 10 kgf/cm²;
- Air volume with future expansion: 179.13 m³/h;
- Uniqueness (to be calculated);
- 5 threaded gate valves;
- 8 threaded long-radius 90° bends;
- 1 thread of flow in branch;
- 5 threaded tees of in-line flow;

Calculation of pipe diameter by Equation 1.

$$d = 10\left[\sqrt[5]{\frac{1{,}663785.10^{-3}179{,}13^{1{,}85}75}{0{,}3.10}}\right] \qquad (4)$$

D=36.1mm

The main line can be made of galvanized or black steel tube according to ASTM A-120 Schedule 40, however for the diameter of 36.1 mm it was not possible to find corresponding values in this standard (FIALHO, 2011). In this way, a larger value will be used, 1.1/2 inches, which corresponds to 40.9 mm of internal diameter. This data will be used to calculate the equivalent length, where it considers all singularities (added value referring to curves, registers, tees) existing in the distribution line. Table 2 below shows the values of the singularities of the distribution line.

Table 2: Singularities of the distribution line.

Singularity	Qty	Comp. Equi. (m)	Total (m)
Threaded gate valves	5	0,37	1,85
Threaded long-radius 90° bend	8	1,00	8,00
Threaded tee with branch flow	1	3,00	3,00
Threaded tee with in-line flow	5	1,70	8,50
Total	19		21,35

Source: FIALHO, 2011, pg. 290 and 291.

With this data, the total length of the distribution line Lt is obtained, it will be:

$$Lt = L1 + L2 = 75 + 21.35 = 96.35 \text{ m}$$

Applying Equation 1 to the diameter.

$$d = 10\left[\sqrt[5]{\frac{1{,}663785.10^{-3}179{,}13^{1{,}85}96{,}35}{0{,}3.10}}\right] \quad (5)$$

d= 37.9 mm

When redoing the calculations with the length of the singularities, the value of the diameter found will be 37.9 mm, a value lower than that referring to 1.1/2 inches (40.9 mm). Thus, the nominal diameter of the distribution line adopted for this case will also be 1.1/2 inches.

For the sizing of the feed line, the same principle used for the calculation of the distribution line is followed, in which the total flow will first be divided by the number of feed lines (FIALHO, 2011).

$$\frac{179{,}13\ m^3/h}{5} = 35{,}82\ m^3/h$$

The feed line has the following characteristics:

- Linear pipe length: 3 m;
- Regime pressure: 10 kgf/cm²;
- Admitted pressure drop: 0.3 kgf/cm²;
- Air volume: 35.82 m³/h.

Applying Equation 1 to the diameter of the feed line.

$$d = 10\left[\sqrt[5]{\frac{1{,}663785.10^{-3}35{,}82^{1{,}85}3}{0{,}3.10}}\right] \quad (6)$$

d= 10.4 mm

For the diameter of 10.4 mm, no reference values were found according to the ASTM A-120 Schedule 40 Standard, for black or galvanized steel pipe (FIALHO, 2011). Therefore, a larger value will be used, 3/8 of an inch, which corresponds to 12.6 mm of internal diameter. Then the equivalent length of the singularities is calculated, as there are no equivalent values for a 3/8 inch singularity, equivalent values will be used for a pipe with a diameter of 1/2. Table 3 below shows the values of the singularities of the feeding line.

Table 3: Singularities of the feeding line.

Singularity	Qty	Comp. Equi. (m)	Total (m)
180° long radius threaded bend	1	1,10	1,10
Threaded 45° bend	2	0,21	0,42
Threaded gate valve	1	0,17	0,17
Threaded branch flow tee	1	1,30	1,30
Total	5		2,99

Source: FIALHO, 2011, pg. 290 and 291.

The total length of the Lt feed line is obtained, it will be:

$$Lt = L1 + L2 = 3.00 + 2.99 = 5.99 \text{ m}$$

Applying Equation 1 to the diameter.

$$d = 10\left[\sqrt[5]{\frac{1{,}663785.10^{-3}35{,}82^{1{,}85}5{,}99}{0{,}3.10}}\right] \quad (7)$$

d= 12 mm

When recalculating taking into account the singularities and their head losses for 1/2 inch pipe, a diameter of 12 mm is found, a value smaller than that referring to the 3/8 inch (12.6 mm) for black or galvanized steel pipe. In this way, the nominal diameter of the power line adopted also for this case will be 3/8 inch.

For the log carrier carriage, hoses will be used instead of rigid tubes, as there is displacement and it is necessary that the line length is also displaced. As the log carrier carriage has a length of 10 m of line, it will be essential to size the diameter of the hose, a flow of 35.82 m³/h will be used, a value equal to the supply line. Applying Equation 1 we have the diameter of the hose.

$$d = 10\left[\sqrt[5]{\frac{1{,}663785.10^{-3}35{,}82^{1{,}85}10}{0{,}3.10}}\right] \quad (8)$$

d= 13.3 mm

To find the nominal and internal diameter of the flexible tube, the sizing was done with the help of a manufacturer's website and in this way it will be adopted for internal diameter equal to 18 mm (FESTO, 2018). The connections described in Table 4 will be used to power the network. Table 4 below shows the values of the singularities in relation to a diameter of 1/2 inch.

Table 4: Singularities of the line that feeds the log carrier carriage.

Singularity	Qty	Comp. Equi. (m)	Total (m)
Threaded long-radius 180° bend	1	1,10	1,10
Threaded gate valve	1	0,17	0,17
Total	2		1,27

Source: FIALHO, 2011, pg. 290 and 291.

After calculating the singularities, the new equivalent length Lt is obtained, it will be:

$$Lt = 10 + 1.27 = 11.27 \text{ mm}$$

Using Equation 1 to calculate the diameter with the new length, we have:

$$d = 10 \left[\sqrt[5]{\frac{1{,}663785.10^{-3} 35{,}82^{1{,}85} 11{,}27}{0{,}3.10}} \right] \quad (9)$$

d=13.6 mm

By recalculating for the inclusion of singularities, a new internal diameter equal to 13.6 mm is obtained. The flexible hose model PAN-R-22X2-SW with an outer diameter of 22 mm and an inner diameter of 18 mm is suitable for feeding the actuators (FESTO, 2018).

The log door carriage to be automated is shown in Figures 14 and 15, it can be seen the representation of the log fastener, where it will be maintained by means of pneumatic actuators as soon as automation is employed.

Figure 14: Log fastener in the log holder car

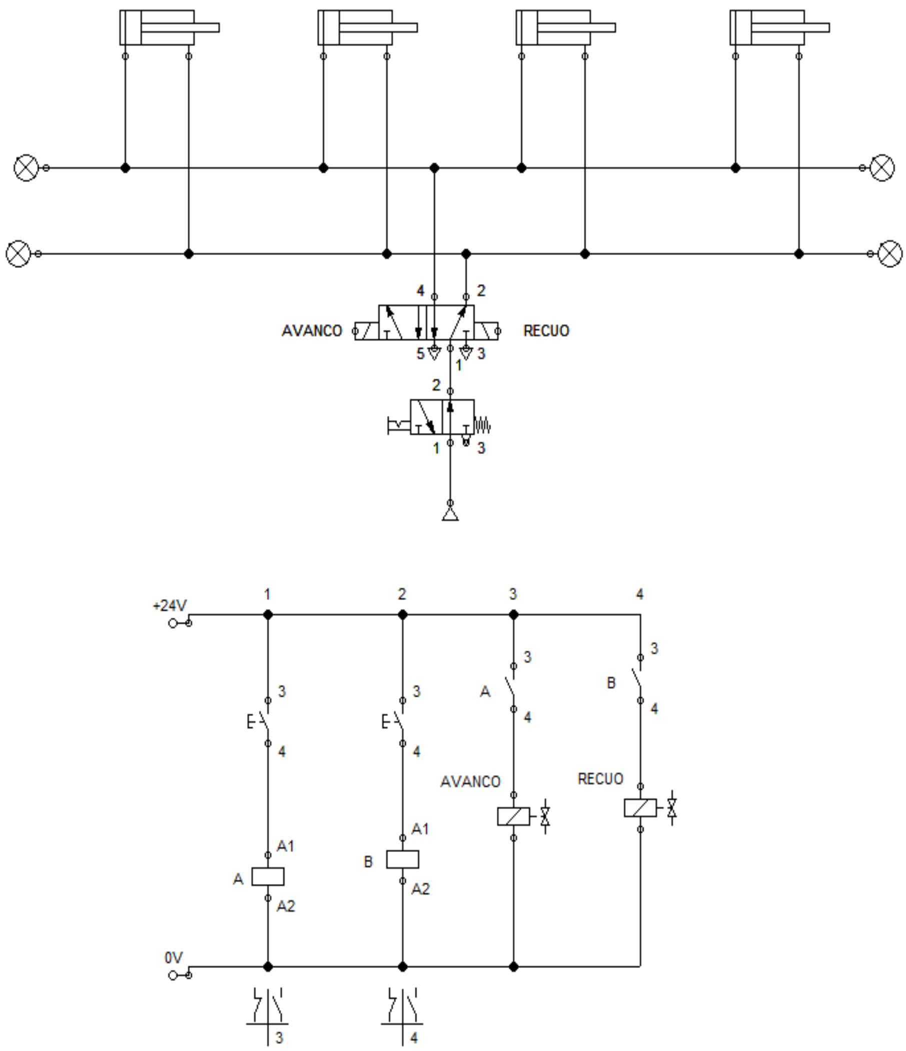
Source: Author himself.

Figure 15: Fastener detail

Source: Author himself.

The automation system will be carried out by electric buttons and valves as shown in Figure 16, being developed with the help of the *Fluidsim software* from the manufacturer Festo. Automation is represented through an electropneumatic scheme that will consist of two buttons, one for forward and the other for the retreat of the actuator that will fix the wood.

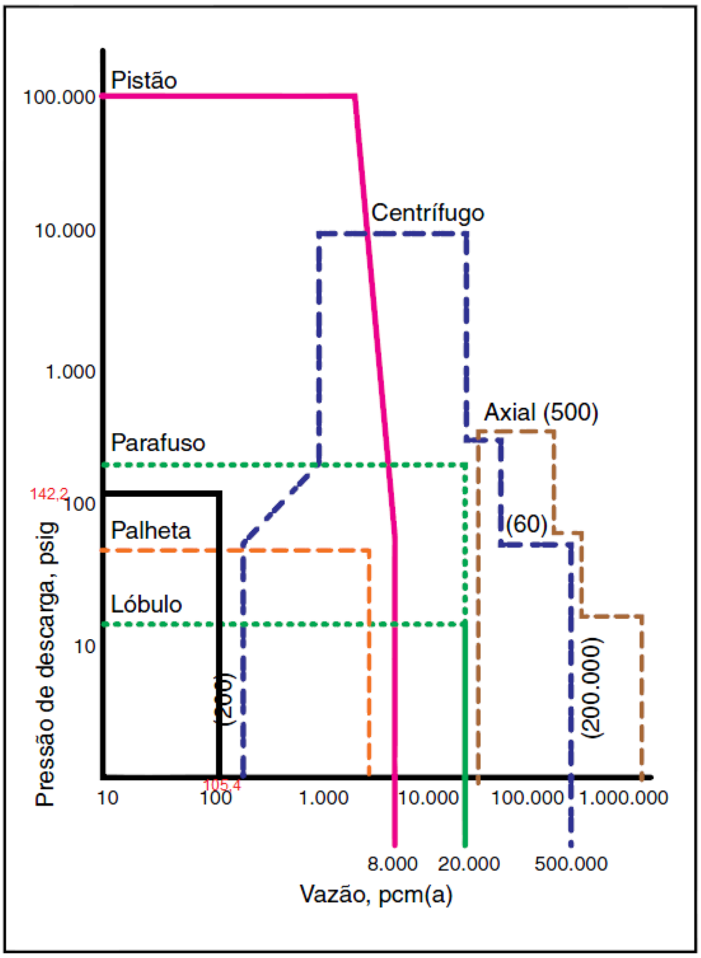
Figure 16: Automation scheme of the log door car fastener.



Source: Author himself.

To select the compressor, the calculated values of total system flow, 179.13 m³/h and regime pressure of 10 kgf/cm² will be used. For this analysis, it is necessary to convert the flow rate from m³/h to pcm and the pressure from kgf/cm² to psi, thus corresponding to 105.4 pcm and 142.2 psi, as the compressor selection diagram works in these units. In Figure 17, where the graph of the flow as a function of pressure is presented, it is possible to determine which types of compressors would be used in the case discussed here.

Figure 17: Diagram for compressor selection.



Source: Adapted from PARKER, 2006, pg. 17.

According to the diagram above, we have two compressor options that would satisfy the system, being the reciprocating piston type or rotary screw type compressor. In this case, the screw one will be used. According to Geralmaq (2018), screw compressors consume less energy, produce less noise and higher performance compared to piston-type compressors.

According to Parker Training (2006), in relation to the sizing of air reservoirs, a value equal to 20% of the total flow is adopted for piston compressors and for rotary compressors (screw) a value equal to 10%, and the total flow is given in m³/min. To size the reservoir for the screw compressor, the total flow of the system proposed here will be 179.13 m³/h, which is equivalent to 2.9855 m³/min, so 10% will be equal to 0.298 m³, with the necessary volume of the air reservoir corresponding to 298 liters.

With all the data presented here and the sizing of all equipment, as well as distribution and power lines, it will be possible to change the wood fixing system on the log carriage. Currently this process is carried out by employees, in order to fix the log by means of levers. With the adoption of an automated system, by pressing a button on the electrical panel, it will be possible to fix the wood automatically, precisely and uniformly, optimizing this process. Figure 18 shows an automated log door carriage that has a pneumatic actuator with clamps at its ends for fixing the wood to be sawn.

Figure 18: Automated log door carriage.

Source: Author himself.

CONCLUSION

Currently, the job market is more competitive and customers are looking for cheaper and faster delivery products. In this way, companies must always improve the manufacturing processes of their products. For this, in this work it was proposed a dimensioning of the compressed air by the company and automation of the log door carriage, since it does not have such a system. This method is essential for automation and finishing processes in product manufacturing.

For a good dimensioning of the compressor, reservoir and compressed air distribution networks and the application of automated processes, one must have a good knowledge of engineering techniques with the ability to analyze and interpret the company's needs. To avoid low equipment performance and oversizing, which could lead to a high investment, it is necessary to take into account future expansions that may occur in the project.

For further work, it is suggested to develop the modeling of a log feeder. Currently this work is done manually by using the unevenness of the terrain to facilitate the feeding of the wood.

Another suggestion for future work is the improvement of the log carrier carriage, using an equipment already available on the market called the log turning arm. This equipment is used next to the log carrier carriage in order to rotate the wood.

Finally, it should be noted that the field of automation is very promising both to find problems and to find solutions that can leave the empirical field and win the commercial market of small and medium-sized enterprises.

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