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Automation of the Production of Paint Rollers by Thermofusion Method

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ABSTRACT

This document describes an automated system for the manufacture of paint rollers so that the plush can be attached to the support tube (thermofusion) in the presence of heat. The methodology was based on identifying the different activities performed in the manufacture of a paint roller and identifying which of these activities can be automated. We seek to create an alternative to manufacture paint rollers that can be implemented in the local industry with what was presented.

Keywords: Automation, Control, Inductive sensor, PLC, Thermofusion

1. INTRODUCTION

The economic and productive development of a country requires the implementation of technology at different levels of productivity to generate economic growth due to increased production, reduce operating costs and encourage the professional growth of operators and technicians involved in the various processes.

The country must stop being a consumer of machinery and automated processes brought abroad. Automation processes improve the quality of the final products and are also necessary for innovation and new employment opportunities at different production levels. Creating and implementing automated processes would greatly benefit, mainly reducing costs generated by imports and tariffs on this equipment [1]. If this is the case, the country can become a distributor in the region of specific equipment and products that are manufactured [2], [3].

By 2021, Colombia's degree of industrial automation should be between 25% and 30% [4]. This goal requires the gradual and constant development of different automation processes that benefit productivity in other industries in the country. The approach of an automated system can be implemented at different levels, which means that a limited and straightforward production process can be extrapolated and developed in a large industry [5]-[7].

In this paper, the development of an automated system is presented primarily and straightforwardly to be adjusted to different production requirements.

Basic parameters that will be considered in the manufacturing process of the paint rollers when programming the PLC. The programming of the PLC will be carried out and later, it will proceed to simulate using software and give validity to the carried out programming.

2. MANUFACTURING PROCESS OF ROLLERS

As in any automation process, the manufacturing process of rollers can be evaluated from three principles: measurement, evaluation and control. Identifying these principles can help to focus correctly on the automation process [8]-[10]:

- Measurement: An automated system must be able to evaluate physical changes in the system, either before, during or after the execution of the automated system.
- Evaluation: Based on the measurements made, these are evaluated to determine if the conditions established to carry out a specific activity are given or not.
- Control: In this principle, measurement and evaluation are integrated. For this reason, the control proceeds to execute what has been previously validated.

It is necessary to take into account that the production time is a determining factor when evaluating the manufacture of a component; in the different manufacturing processes of paint rollers, the time between the other methods is of vital importance when thinking about automating the manufacturing process [11]-[13].

In a manufacturing process of paint rollers cataloged as conventional in which glue is used to join the plush to the tube, it is necessary to wait up to 8 hours for the glue to dry to cut the tube with the plush in the required measures.

Among the various methods that can be used, the one that uses thermo infusion, also known as thermofusion, stands out. This method has the advantage of continuously carrying out the adhesion of the plush to the plastic support.

Using temperature allows the plush's adhesion to the roller's plastic support. Unifying these processes provides that it only remains to an assembly of the support with the handle in the following station, which is not considered in this automation process. Having continuous production allows us to eliminate the dead times that can be generated between the different processes and to be able to integrate several processes in a single station.

The method used to join the plush to the plastic tube can be identified in different ways, either thermo infusion or thermofusion for this case and the way it is used, it is that in the presence of heat, the plush can be joined to the tube.
The union by the action of the temperature is considered the most versatile and simple technique for the union of plastics. It can join small plastic components up to more significant parts such as pipes [14]-[19].

The parameters to be considered when joining components are the temperature and the heating time [20], [21].

It is necessary to mention that the contact of the flame with the plastic tube is temporary; for this reason, the speed of advance must be controlled thus to avoid those losses in the material being generated by the excess of heat that can be generated.

3. MATERIALS AND METHODS

3.1 Process variables

For the manufacture of the paint roller tube, it is necessary to consider specific parameters that must be controlled at the time of manufacture. For this reason, they must be taken into account when the respective programming is carried out in the PLC.

The variables to be taken into account are:

- Tube Length: Refers to the distance from the tube over which the plush is to be joined. (Maximum 3 meters).
- Flameout Time: This is a unit of time in seconds, which the operator can modify. It acts as a delay so that the flame does not ignite immediately after starting the process.
- Flame Time: This is a unit of time defined in seconds and refers to when the flame will be lit.
- Tube Rotation Speed: This is defined in RPM and varies according to the length of the tube and the production requirements at the time.
- Blower Start-up Time: This activates the time in which a current of air passes through the tube and the plush and which will have two functions: to cool the tube and the plush to help the union and clean the plush of any dirt that it has on the surface.
- Working Speed Car: This can be configured and varies the speed with which the trolley moves parallel to the axis of rotation of the tube.
- Warm-up Time: This is used to check the flame's intensity, for example, when the gas supply hose is disconnected or the equipment needs to be prepared.

3.2 Logical operation diagram of the equipment

Figure 1 shows the operation sequence that the designed equipment will have.

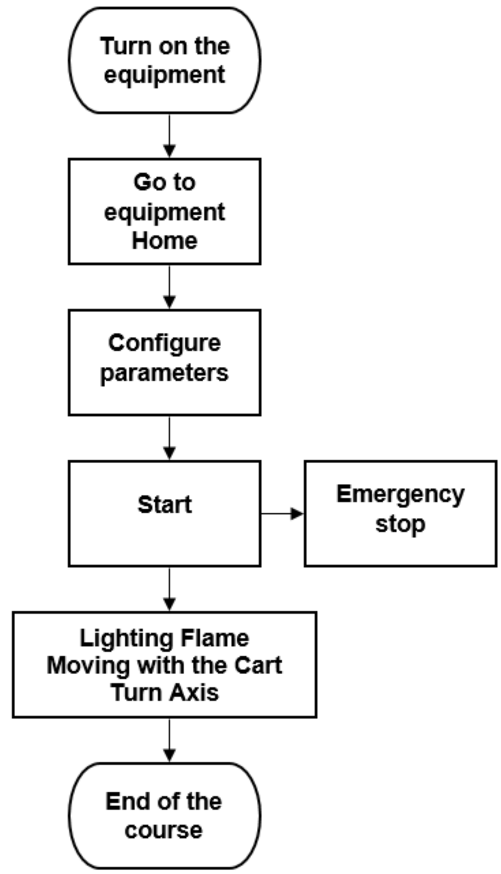

Figure 1: Process operation diagram

In practice, the movement that the equipment has to make to manufacture the rollers is effortless, a plastic tube is supported on an axis, a carriage moves parallel to the axis; this carriage is where the plush will be fed. A flame is located a few centimeters in front of the point where the plush is provided.

At the beginning of the process, the plush will be attached to the plastic tube and as the tube rotates and the trolley advances, this will determine the speed at which the plush is fed (See Figure 2).

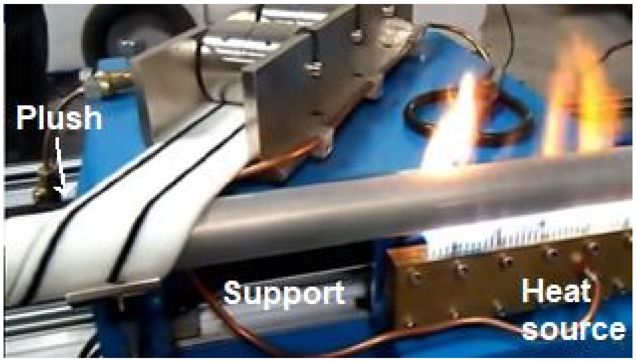

Figure 2: Plush to tube bonding by the presence of heat [22]

The operation process is straightforward to facilitate the development of programming.

When the equipment is turned on, the Reset button is pressed, which will move the trolley to the beginning of the route regardless of the location along with the equipment. The carriage will always move parallel to the axis of rotation.

Once the cart is at the beginning of the route, pressing the Set button allows you to program the process variables as they are: Tube Length, Flameout Time, Flame Time, Tube Rotation Speed, Blower Start-up Time, Warm-up Time.

The end of travel is activated by the action of an inductive sensor, by generating a magnetic field in the coil when energizing this using electricity, when a metallic element approaches, they produce a magnetic field different from the direction of the magnetic field that is created in the coil, this alteration is the one that indicates the presence of an object and indicates that it is the end of travel [23]. Figure 3 shows how the inductive sensor detects an object.

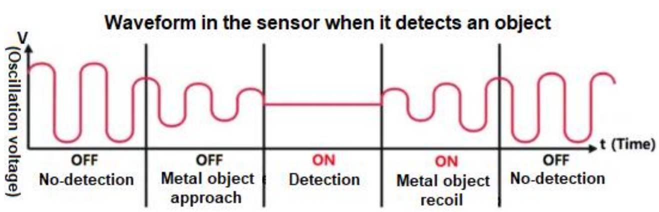

Figure 3: Operation of the inductive sensor [24]

When the end of the race is reached, the process will end and a counter will be activated, in which it is possible to keep track of how many tubes and plush have been joined.

3.3 Programming

Programming is the communication between the user and the PLC. Generally, there are two types of programming, one is graphic and the other is using code lines, in this case, programming will be done utilizing graphics where the sequence of actions to be carried out by the PLC to achieve a particular task [8], [25] can be represented.

The programming used for the development of the manufacturing process of paint rollers is Ladder-type which has as a characteristic:

- The input instructions are located on the left side.
- Output instructions are located on the right side.
- More than one output is allowed on each line in most PLCs, also known as a Rung.
- The processor or controller tracks from top to bottom and left to right.

In the case of the signal connections and the programming, standards may vary a little among the different manufacturers and models of PLCs, but in general, they have the same logic for their operation, thus having that the programming, as well as the power supply, are usually very generic, so much so that the input variables are named with the letter X and the output variables with the letter Y.

According to the logic of the process, where they identify the sequences that must be made to achieve the manufacture of paint rollers, we proceed to make the programming in the software (TIA Portal V15), for this case, we used a trial version that allows programming and validating that the programming, this for 21 days.

For programming, it is necessary to establish the variables. Figure 4 shows the list of variables related to the programming of the equipment.

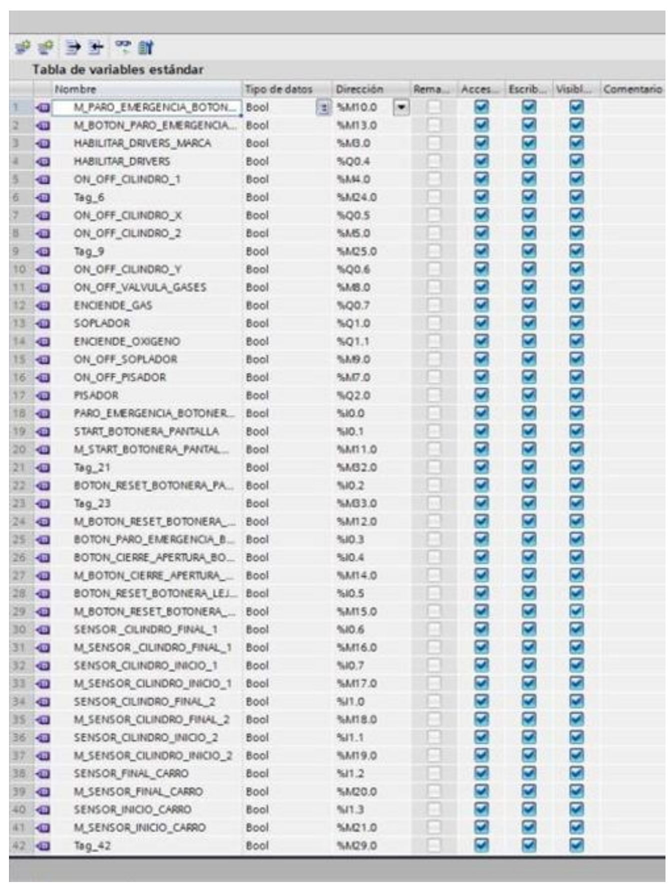

Tabla de variables estándar

	Nombre	Tipo de datos	Dirección	Rema...	Acces...	Escrib...	Visibl...	Comentario
1	M_PARO_EMERGENCIA_BOTON...	Bool	%M10.0	☐	☑	☑	☑	
2	M_BOTON_PARO_EMERGENCIA...	Bool	%M13.0	☐	☑	☑	☑	
3	HABILITAR_DRIVERS_MARCA	Bool	%M3.0	☐	☑	☑	☑	
4	HABILITAR_DRIVERS	Bool	%Q0.4	☐	☑	☑	☑	
5	ON_OFF_CILINDRO_1	Bool	%M4.0	☐	☑	☑	☑	
6	Tag_6	Bool	%M24.0	☐	☑	☑	☑	
7	ON_OFF_CILINDRO_X	Bool	%Q0.5	☐	☑	☑	☑	
8	ON_OFF_CILINDRO_2	Bool	%M5.0	☐	☑	☑	☑	
9	Tag_9	Bool	%M25.0	☐	☑	☑	☑	
10	ON_OFF_CILINDRO_Y	Bool	%Q0.6	☐	☑	☑	☑	
11	ON_OFF_VALVULA_GASES	Bool	%M8.0	☐	☑	☑	☑	
12	ENCIENDE_GAS	Bool	%Q0.7	☐	☑	☑	☑	
13	SOPLADOR	Bool	%Q1.0	☐	☑	☑	☑	
14	ENCIENDE_OXIGENO	Bool	%Q1.1	☐	☑	☑	☑	
15	ON_OFF_SOPLADOR	Bool	%M9.0	☐	☑	☑	☑	
16	ON_OFF_PISADOR	Bool	%M7.0	☐	☑	☑	☑	
17	PISADOR	Bool	%Q2.0	☐	☑	☑	☑	
18	PARO_EMERGENCIA_BOTONER...	Bool	%I0.0	☐	☑	☑	☑	
19	START_BOTONERA_PANTALLA	Bool	%I0.1	☐	☑	☑	☑	
20	M_START_BOTONERA_PANTAL...	Bool	%M11.0	☐	☑	☑	☑	
21	Tag_21	Bool	%M32.0	☐	☑	☑	☑	
22	BOTON_RESET_BOTONERA_PA...	Bool	%I0.2	☐	☑	☑	☑	
23	Tag_23	Bool	%M33.0	☐	☑	☑	☑	
24	M_BOTON_RESET_BOTONERA_...	Bool	%M12.0	☐	☑	☑	☑	
25	BOTON_PARO_EMERGENCIA_B...	Bool	%I0.3	☐	☑	☑	☑	
26	BOTON_CIERRE_APERTURA_BO...	Bool	%I0.4	☐	☑	☑	☑	
27	M_BOTON_CIERRE_APERTURA_...	Bool	%M14.0	☐	☑	☑	☑	
28	BOTON_RESET_BOTONERA_LEJ...	Bool	%I0.5	☐	☑	☑	☑	
29	M_BOTON_RESET_BOTONERA_...	Bool	%M15.0	☐	☑	☑	☑	
30	SENSOR _CILINDRO_FINAL_1	Bool	%I0.6	☐	☑	☑	☑	
31	M_SENSOR _CILINDRO_FINAL_1	Bool	%M16.0	☐	☑	☑	☑	
32	SENSOR_CILINDRO_INICIO_1	Bool	%I0.7	☐	☑	☑	☑	
33	M_SENSOR_CILINDRO_INICIO_1	Bool	%M17.0	☐	☑	☑	☑	
34	SENSOR_CILINDRO_FINAL_2	Bool	%I1.0	☐	☑	☑	☑	
35	M_SENSOR_CILINDRO_FINAL_2	Bool	%M18.0	☐	☑	☑	☑	
36	SENSOR_CILINDRO_INICIO_2	Bool	%I1.1	☐	☑	☑	☑	
37	M_SENSOR_CILINDRO_INICIO_2	Bool	%M19.0	☐	☑	☑	☑	
38	SENSOR_FINAL_CARRO	Bool	%I1.2	☐	☑	☑	☑	
39	M_SENSOR_FINAL_CARRO	Bool	%M20.0	☐	☑	☑	☑	
40	SENSOR_INICIO_CARRO	Bool	%I1.3	☐	☑	☑	☑	
41	M_SENSOR_INICIO_CARRO	Bool	%M21.0	☐	☑	☑	☑	
42	Tag_42	Bool	%M29.0	☐	☑	☑	☑	

Figure 4: Programming variables

3.4 HMI display

To enable communication between the operator and the equipment and to operate the equipment and vary its parameters to operate it, HMI screens were developed to allow for this communication.

The sequence of the screens is shown below. In Figure 5, the initial screen is shown when the equipment is turned on.

Figure 5: Main screen

Figure 6 shows the operation buttons of the equipment:

- Reset button: Returns the cart to its initial position to start working.
- Start button: Starts the rotation of the shaft, the advance of the trolley where the plush is fed and lights the flame, this according to the selected configuration.
- Set button: Opens the screen where the parameters to be worked with can be modified.
- Monitor Button: Pressing this button will display both the inputs and outputs of the programming, indicating which are active or not.
- At the bottom of this screen, there is a counter, which keeps track of each of the rollers that have been manufactured.

Figure 1: Operation buttons

Figure 7 shows the system parameter configuration window, which can be changed depending on the work done.

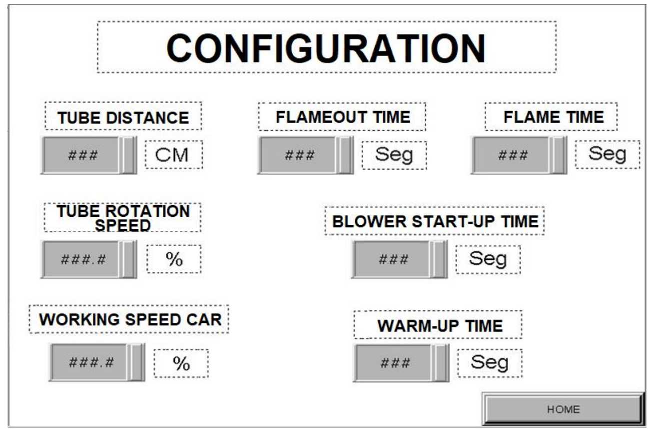

Figure 7: Parameter settings

Figure 8 shows the status of the Inputs and Outputs for the entire system.

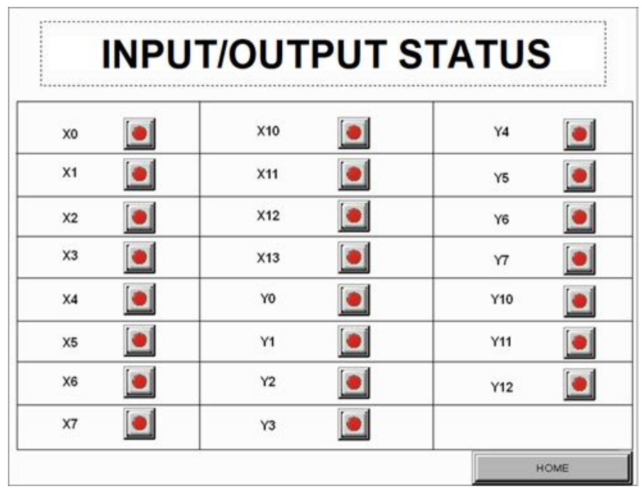

Figure 2: Inputs and outputs

4. RESULTS AND ANALYSIS

4.1 Simulation

The programming and simulation were developed for a Siemens 1214C PLC. In Figure 9, the beginning of the simulation is shown where each of the segments or lines of programming is.

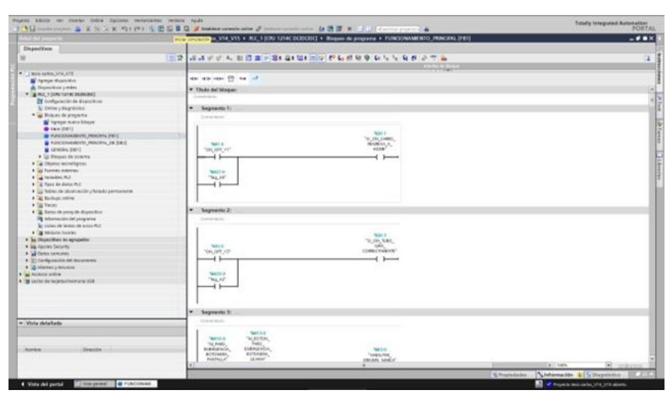

Figure 3: Start simulation

The software presents a preliminary list of all programming lines that can be loaded and configured. The software allows the programming to be loaded and compiled by previewing this process.

When loading and compiling the programming lines, the program allows the display of the lines highlighted in green, where it is validated that there are no errors and if the connection with the PLC is made, this should not present any problem.

Figure 10, Figure 11 and Figure 12 show the results of the validation of the programming carried out in the PLC used.

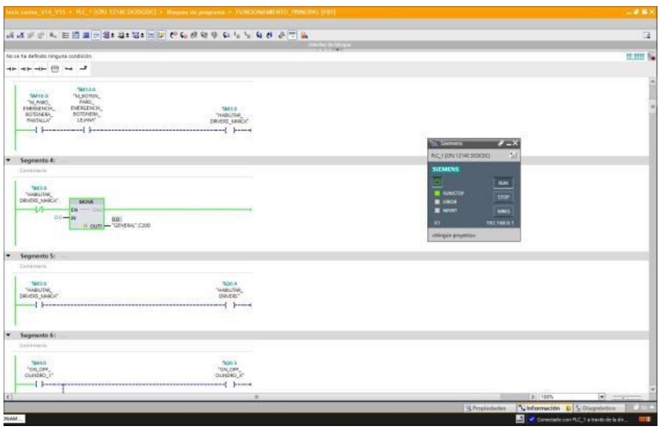

Figure 10: Programming validation

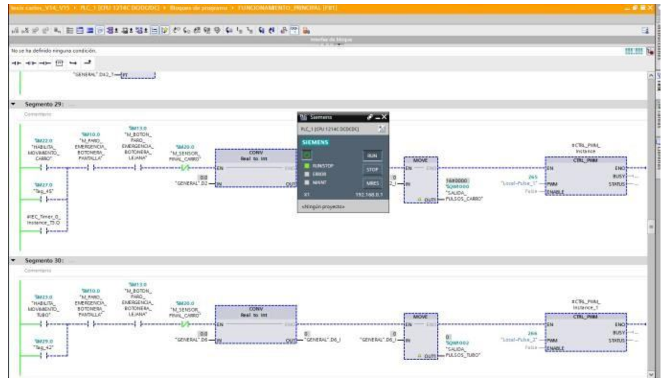

Figure 4 Programming validation

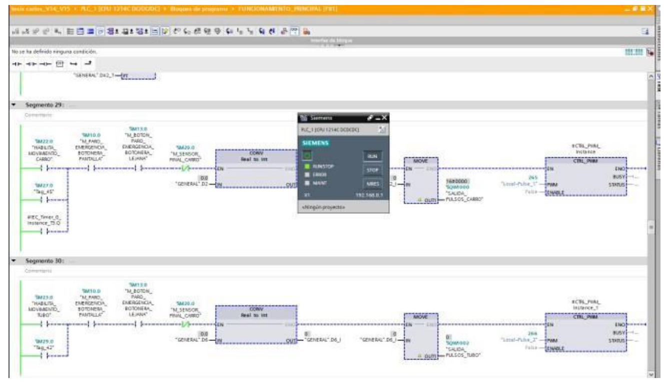

Figure 5 Programming validation

4.2 Electrical plans

Bearing in mind that the simulation was carried out correctly and did not present any problems, we proceeded to make the electrical plans to make the connections in the equipment.

Initially, only the drawings of the inputs and outputs are taken into account to identify each of the variables that appear on the implemented HMI screen and are shown in Figure 8.

Figure 13 and Figure 14 show the electrical drawings of the inputs and outputs of the entire implemented and tested system.

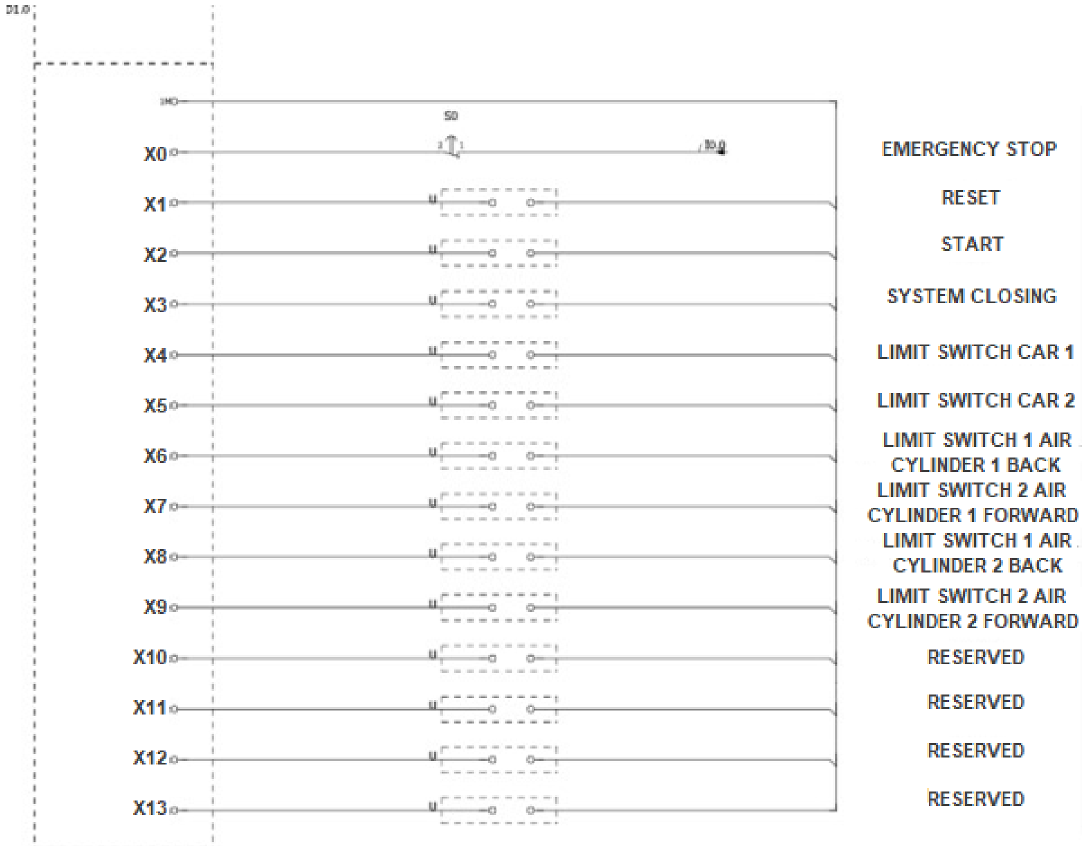

Figure 13: Electrical plan of the inputs

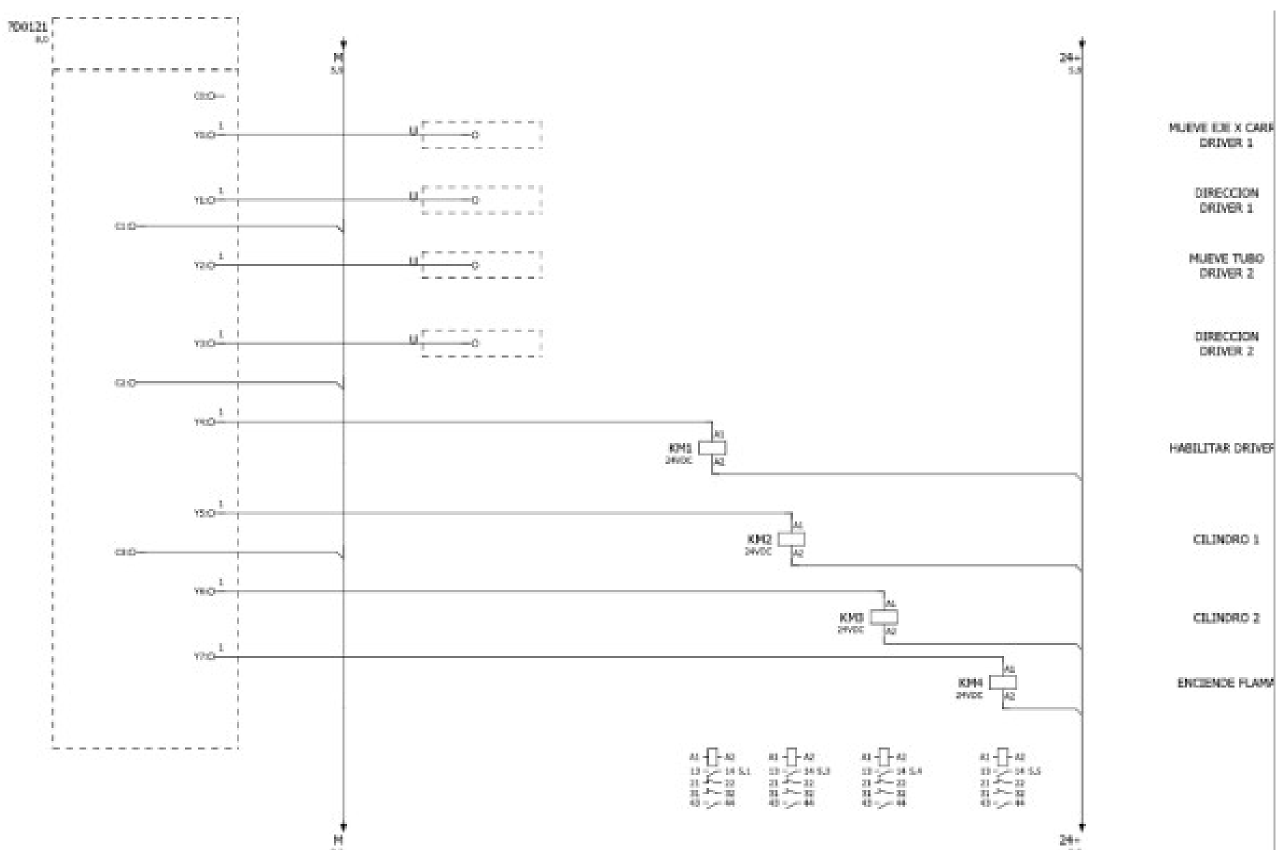

Figure 6 Electrical plan of the outputs

6. CONCLUSIONS

It is possible to change the methodology for manufacturing paint rollers manually and with glue to a thermo-infusion process automated.

The thermofusion technique can be applied using an electric resistance, but it can be easier to control the temperature utilizing a flame.

The programming mode allows us to make the change in some lines of the code to be able to install a second flame source of heat to generate the union between the plush and the tube if the configuration of new equipment requires it.

By validating that the programming allows the proper communication with a PLC, it could be possible to manufacture the equipment and by modifying some of the programming parameters, it could be adapted to the requirements of the local industry.

Currently, there are some similar types of equipment for the manufacture of paint rollers of Chinese origin, with the programming and the results obtained, it could be possible to start the construction of prototypes and thus introduce in the market a product of the local manufacturer.

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