Design Powder Coating Machine

By

Student name(s):

Yousef Mohsen **Laith Abu judeh**

Supervisor: Name(s):

Prof. Dr. Sameer Khader

Submitted to the College of Engineering
In partial fulfillment of the requirements for the degree of
Bachelor degree in Industrial-Automation Engineering

Palestine Polytechnic University

June 2021

الأهداء:

إلى من رسموا بدمائهم خارطة الوطن وطريق المستقبل وهندسوا .

إلى معلمنا وقائدنا وقدوتنا وحبيبنا وشفيعنا محمد صلى الله عليه وسلم.

بأجسادهم معاقل العزة والكرامة إلى من هم أكرم منا جميعا إلى شهداء الوطن الحبيب.

إلى الذين عشقوا الحرية التي تفوح منها رائحة الياسمين وتوارو خلف القضبان ليفسحوا لنا النور إلى أسرانا الأبطال.

إلى التي رآنا قلبها قبل عينيها واحتضنتنا أحشائها قبل يديها إلى التي تعجز الكلمات عن شكرها

إلى منبع الحنان وتاج الرأس ومن تنحني لها جباهنا، كيف لا والجنة تحت إقدامها أمهاتنا، الفضيلات.

إلى من وصلو النهار بالليل، و بذلو الغالي و النفيس من أجلنا، إلى مصدر فخرنا وعزنا، آبائنا الكرام.

إلى من يحملون في قلوبهم ذكرياتنا ويتقاسمون معنا أفراحنا وهمومنا ومن ساندونا،خوتنا وأخواتنا الأعزاء.

إلى من ضاقت السطور لذكرهم فوسعتهم قلوبنا، أصدقائنا الأعزاء.

إلى من علمونا حروفا من ذهب وكلمات من درر، إلى من جعلو أفكارهم منارة تنيرلنا الطريق، إلى محبي العلم والمعرفة، أساتذتنا الاكارم

إلى من رسم معنا خطوات هذا النجاح، إلى من بذل جهده ووقته وكان لنا مرشدا وناصحا وأخا إلى مشرفنا الحبيب البروفيسور سمير خضر

إلى صرحنا العظيم ومكمن فخرنا وصانع مجدنا إلى بيتنا الثاني التي قضينا فيها أجمل أيامنا جامعتنا الحبيبة.

إلى محفزنا الأول والأخير إلى قبلتنا ومقصد بوصلتنا إلى من احتضنتنا كل هذه السنين رغم أوجاعها إلى دولتنا الفلسطينية وجوهرتها القدس الشريف.

إلى الزملاء وكوادر جامعه بوليتكنك فلسطين.

Abstract

The painting process is one of the important and basic operations to preserve the pieces from damage, lose their properties and extend the life of the piece, hence the idea of the project. It is the design of a powder coating machine by immersion, unlike other methods of painting that are widely used in the Palestinian markets, most of which work by spraying, which proved its defects with many problems. Therefore, we designed a powder coating machine by immersion to cover the defects left by the spray painting method, which is automated. To fully compete with the Palestinian and international markets.

الملخص

تعد عملية الدهان من العمليات المهمة و الأساسية للحفاظ على القطع من التلف، و فقدان خصائصها و إطالة عمر القطعة، و من هنا جائت فكرة المشروع. وهي تصميم ماكنة دهان بالبودرة عن طريق التغطيس على خلاف طرق الدهان الأخرى و المستخدمة بالأسواق الفلسطينية بكثرة و التي تعمل غالبيتها عن طريق الرش، والتي اثبتت عيوبها بعديد من المشاكل لذلك قمنا بتصميم ماكنة دهان بالبودرة عن طريق التغطيس لتغطية العيوب التي خلفتها طريقة الدهان بالرش وهي مؤتمتة بالكامل لتنافس الاسواق الفلسطينية و العالمية .

List of Figure

List of Table

List of Equation

List of Appendix

Contents

1

Chapter one: Introduction.

1) **Overview**.
2) **Problem definition.**
3) **Project motivation.**
4) **Project Objectives**.
5) **Project Importance.**
6) **Time Schedule.**
7) **Cost estimation.**

1.1 Overview:

The paint is one of the most important and basic needs that must be added to the manufactured piece or the surfaces to be covered to add a cosmetic appearance to it in addition to achieving certain characteristics according to the piece to be painted and its field of use, as coating, is the thin layers of a covering substance, deposited or applied on a surface of any object, mainly to improve its critical properties and to create a protective barrier against deterioration of the surface due to its reaction with its environment.
Therefore, in this project, we will design a powder-coating machine to suit the goal to be reached, which we will clarify later.

1.1.1 Ways of powder coating Applying:

There is essentially two common ways of applying powder coating: by electrostatic spray and by fluidized bed powder coating. There are several other processes that have been developed, but they are far less used. These include flame spraying, spraying with a plasma gun, airless hot spray and coating by electrophoretic deposition. [1]

1. **fluidized bed:**

The fluidized bed is the original powder coating technique. It is still the primary technique used for the application of thermoplastic powder. The fluidized bed is also used for the application of some thermo set powders where high film build is required. Thermo set powders designed for electrical insulation often use the fluidized bed technique. The parts are pre-heated to a temperature significantly higher than the melting point of the powder. The parts are then immersed into a “fluidized bed” of the coating powder where the plastic powder is melted onto the part.

2. **Electrostatic spray:**

Electrostatic spray is the primary technique used for thermo set powder. The parties of powder are given an electrical charge in the powder coating gun. The target part is attached to a fixture that is grounded. The electrically charged powder particles are attracted to the grounded part and attach themselves like little magnets to the part. The particles build-up on the surface of the part until it is covered with charged particles and the part surface is charged. At this point the oncoming particles are actually repelled by the charged particles on the part and the coating process stops. This provides and even film thickness.

The part is then placed in an oven and the powder particles melt and coalesce to form a continuous film.

As in this project we will use the fluidized bed.

1.2 Problem definition:

1. The inability to paint the piece with an inner cavity even on parts with complex shapes.
2. Not achieving uniform coating thickness.
3. Failure to achieve electrical insulation in other methods and types of paints.

1.3 Project motivation:

The importance of the project lies in covering the defects and deficiencies that other painting methods leave us in terms of electrical insulation, moisture isolation, and the distribution of the paint layer to all areas of complex cutting.

1.4 Project Objectives:

The main project objectives are to overcome the up mentioned problems as following:

- Designing a powder coating machine to achieve the desired goals to reduce effort, time and automatic control.
- Exceptional abrasion resistance.
- Excellent resistance to alkaline and chlorinated hot water.
- Good UV resistance.
- External and internal coating in one single operation.

1.5 Project Importance:

The importance of the project is concentrated in the following points:

Providing a painting machine that is not available in the Palestinian markets in terms of efficiency and properties of the paint material in terms of electrical insulation for the fractured parts that must be electrically insulated and painted with a material that lasts long against climate fluctuations and humidity.

1.6 Time Schedule:

1.6.1 First semester:

Illustrates the tasks that we did and how long it takes weekly for each task.

Table (1. 1): First semester:

Tasks \ Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Finding Project Idea															
Proposal															
Collecting data															
Documentation															
Preparing for presentation															
Print documentation															

1.6.2 Second semester:

The following time table displays the project implementation-flow divided into fifteen weeks of the second semester as following.

Table (1. 2) Second semester:

Tasks \ Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Treatment and rectify the reviews command project															
Mechanical implementation															
Electrical implementation															
Calibration and adjustment															
Testing															
Report															

1.7 Cost estimation

Table (1. 3): shows the expected cost for the machine ±15%:

Item Name	No. of Items	Total Cost (NIS)
Emergency Switch	1	40
Double Acting Cylinder	1	150
Solenoid Valve	1	50
Air tools	7	100
3 phase Induction Motor	1	600
Gears	1	300
PLC	1	900
Contactor	2	150
Relay	1	50
MCB	5	200
Overload	1	100
Electric Panel	1	300
Earth Leakage	1	170
Convection oven	1	1500
Conveyor belt	1	200
Overall Machine Body	1	2500
Turning Works	1	1200
Photoelectric Sensor	1	150
Power Supply	1	100
Wires	-	150
Push Buttons	3	50
wheels	8	200
Total Cost		8080

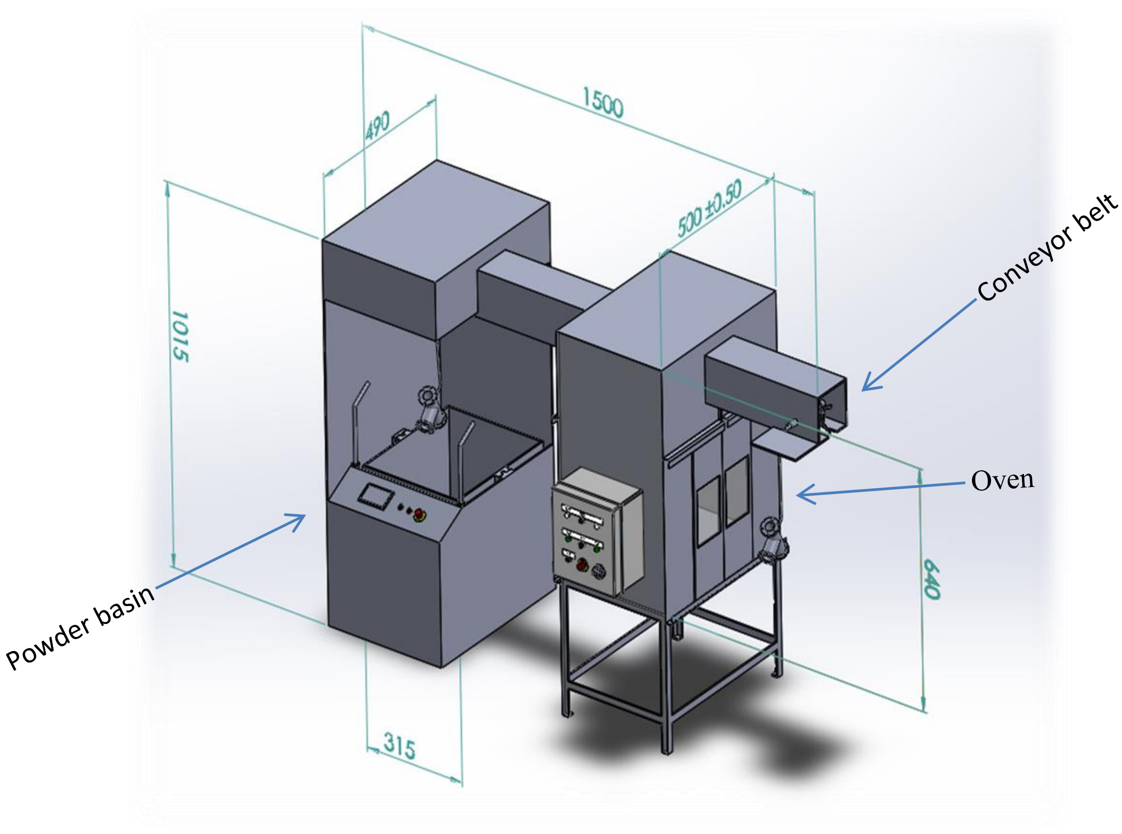
2

Chapter 2: Mechanical Design

1) **Introduction.**
2) **Process plan.**
3) **Mechanical Components.**
4) **Design and Selection.**

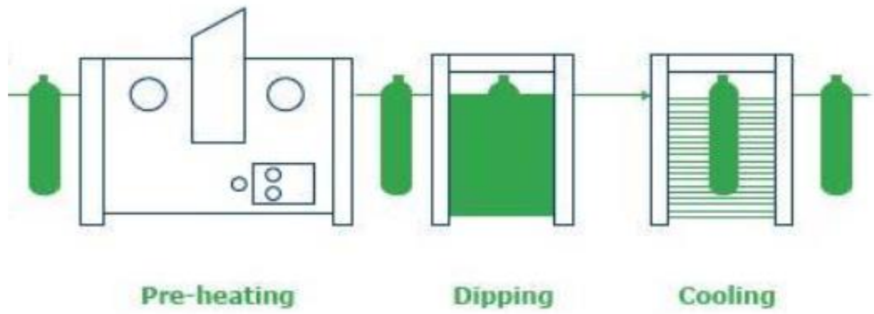
2.1 Introduction

In this part we will talk about how the powder coating machine as shown in Figure (2.1) works in general, where at the beginning of the process the finished and cleaned piece for the coating process is suspended on the conveyor belt where it is suspended by a snap and then the piece moves to enter the oven to be heated at a certain temperature and a certain time determined by the experiment method. The process in the next semester, and after the process of heating the piece, it comes out from the oven into the basin filled with paint powder, and the piece is dipped in the basin filled with the loose powder to be painted, and then it is exposed to air to be cooled and the process ends to be repeated on a new piece.



(a) Powder coating machine.

*** Units are in mm.**



(b) The path of the coating process.

Figure (2. 1): General view of the proposed machine.[2]

2.1.1 Problem statement

The followings are criteria for selecting this type painting: [2]

- **Thickness of the part:**

The process is particularly suitable for parts with a metal thickness of at least 3 mm. For small diameter wire articles, a post fusion operation may be required following the dip-coating Operation.

- **Thickness of coating desired:**

The process allows the application of Rilsan® coatings with a thickness from 250 to 500μm. For very massive parts, it is possible to apply thicker coatings by increasing dipping time, or by successive dipping operations. Datasheet in Appendix (Page65).

- **Size of the part to be coated:**

The dimension of the part determines the size of the tank. Very heavy or very long components (tubes) can be coated by this method, but will require specific handling equipment.

Furthermore, there are advantages [2] and disadvantages [3] of using such coating as follow:

- **Advantages of Fluidized Bed Dipping:**

  - External and internal coating in single operation.
  - Uniform coating thickness achieved, even on parts with complex shapes.
  - High flexibility in terms of part dimensions.
  - Simple production technology.
  - Very good productivity.
  - Easy process automation.
  - Very little powder wasted.

- **Disadvantages:**

Table (2. 1): Main Disadvantages of powder dipping: [3]

DEFECT	CAUSE
1. **Poor adhesion.**	• Inadequate preparation of the surface. • Too little or too much primer. • Wrong preheating temperature and/or time.
2. **Bubbles.**	• Degassing of part. • Primer layer too thick. • Air inclusion due to excessively long dipping time.
3. **Clusters.**	• Poor fluidization of the powder. • Insufficient or inadequate motion during dipping.
4. **Black spots.**	• Contaminated powder. • Presence of impurities around the tank. • Pollution in post-fusion oven.
5. **Yellowing.**	• Preheating temperature too high. • Preheating time too long. • Dipping time too short.
6. **Pinholes at intersection of faces or wires.**	• Insufficient shaking during dipping. • Preheating temperature too low. • Dipping time too short.
7. **Poor edge coverage.**	• Preheating temperature too high. • Dipping time too short. • Post-fusion temperature too high and/or time too long. • Edges too sharp.

8. **Frosting or unmated powder.**	• Preheating temperature too low or/and time too short. • Excessive delay between preheating and dipping. • Dipping time too long. • Insufficient shaking after dipping.

❖ **Type of Powder Materials:-**

➢ There are two main types [4] :

1. *A thermoplastic powder coating:*

One that melts and flows when heat is applied, but continues to have the same chemical composition once it cools and solidifies. Thermo plastic powder exhibit excellent chemical resistance, toughness and flexibility. They are applied mainly by the fluidized bed application technique, in which heated parts are dipped into a vat where the powders are fluidized by air and are used in many thick film applications. They are generally applied to a surface that has been preheated to a temperature significantly higher than the melting point of the powder. As a thermo plastic powder material is applied to the hot surface it will melt to the surface and then "flow out" into a strong, continuous film. As the film cools it develops its physical properties Nylon powder coating materials are the most commonly used thermo plastic powder.

2. Epoxy

❖ **Easy and efficient processing reduces cost:-**

- Easy thermoplastic processing – unlike thermosets such as epoxy, thermoplastics do not need to undergo a chemical reaction to form a solid coating. This makes processing quicker and easier as you do not need precise cure times and temperatures.
- Parts can be formed or machined after coating – parts can be bent after coating and the coating can be selectively machined away to create metal contact points.
- Adhesion to a variety of substrates – steel, aluminum, copper, nickel, and more.

- Quick and easy masking – thanks to coating flexibility and the ability to use lower thicknesses for the same amount of dielectric protection.

❖ Construction of the propose automatic machine :

- The machine consists of :

1. Frame.
2. Conyver belt.
3. Oven.
4. Powder basin.
5. Cylinder.
6. Hook.
7. 3phase indaction motor.
8. Gearbox.
9. Pressure control valve.
10. Pneumatic compressor.
11. Flow control
12. PLC.
13. Temperature Controller.

2.2 Functional process plan:

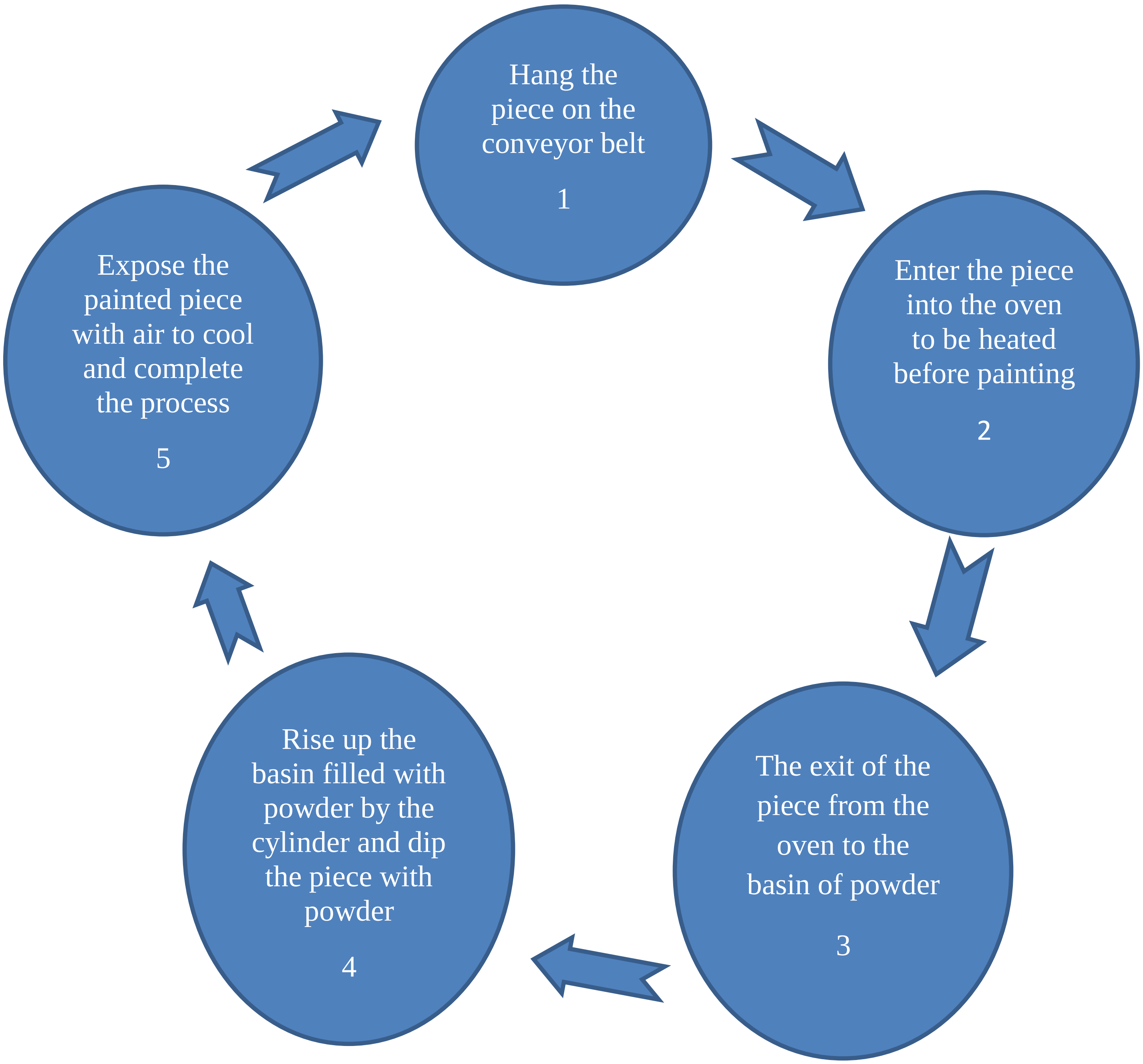


Figure (2. 2): Process plan Powder coating machine.

2.3 Mechanical components

This design contains the following parts as appears in Figure (2.1.A).

2.3.1 Frame

Material: Aluminum.

The propose frame is from aluminum and is steel welded in such a way that it can hold the equipment completely. Steel is strongly welded in welding to carry the entire machine equipment with the control unit, powder pan, belt conveyor, oven and ac motor.

2.3.2 Conveyor belt

Material: Chained steel.

This conveyor belt is used to transfer the piece to be painted inside the oven and then to the powder a motor as shown in Figure (2.3) moves bath and it.

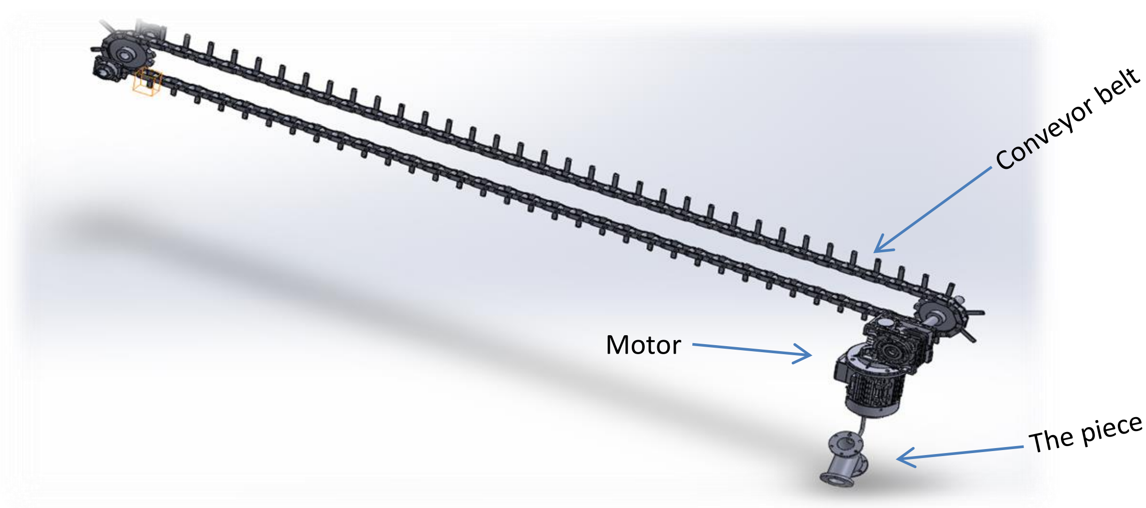


Figure (2. 3): Conveyor belt.

2.3.3 The Oven

Material: Galvanized Iron.

The oven is used to heat the metal piece to be painted, as it is heated at a certain temperature and time, depending on the thickness of the piece, and this is reached through practical experience in the next semester as shown in Figure (2.4).

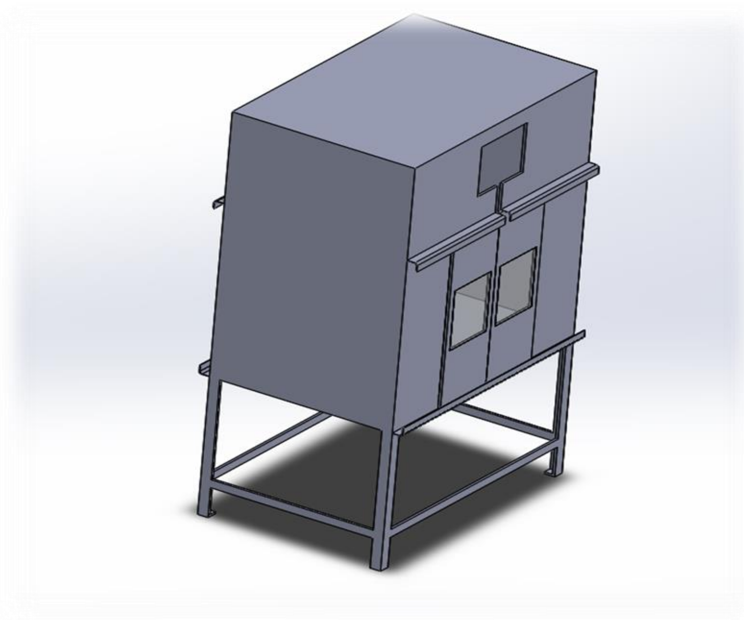


Figure (2. 4): Oven.

2.3.4 Powder basin

Material: Iron.

This is a basin for powder material inside it, whose particles are broken down by the air coming from the compressor as shown in Figure (2.5).

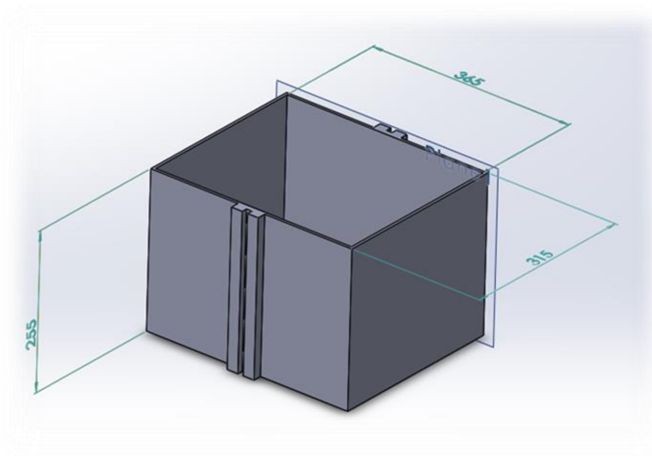


Figure (2. 5): Powder basin.

2.3.5 The Hook

Material: Iron.

The processed piece is hung should be hung on the hook as shown in Figure (2.6).

Figure (2. 6): Hook.

2.3.6 Pneumatic system

A pneumatic system is a system that compressed air is used to mix the powder and control the cylinder. [5]

❖ **The advantages of pneumatic systems:**

a) High efficiency to control the process.

b) Simple design.

c) Safety.

d) Easy selection of speed and pressure cylinder.

❖ **Main pneumatic components:**

Pneumatic components can be divided into two categories as shown in Figure (2.7):

1. Components that produce and transport compressed air.
2. Components that consume compressed air.

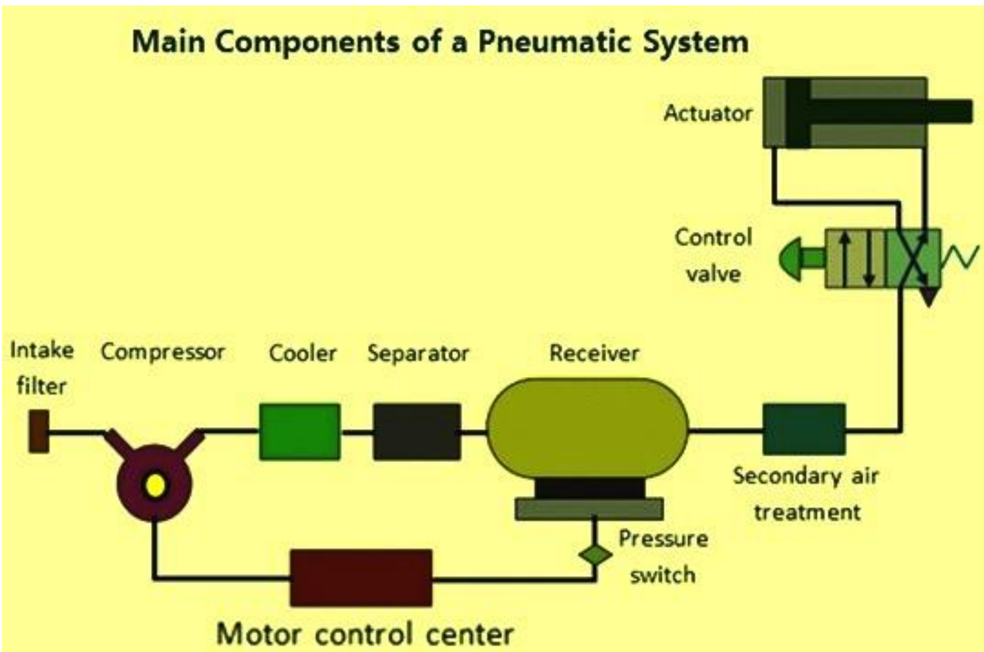


Figure (2. 7): Pneumatic system.

All main pneumatic components can be represented by simple pneumatic symbols. Each symbol shows only the function of the component it represents, but not its structure. Pneumatic symbols can be combined to form pneumatic diagrams. A pneumatic diagram describes the relations between each pneumatic component, that is, the design of the system.

❖ **Compressor:**

A compressor can compress air to the required pressures. It can convert the mechanical energy from motors and engines into the potential energy in compressed air as shown in Figure (2.8):

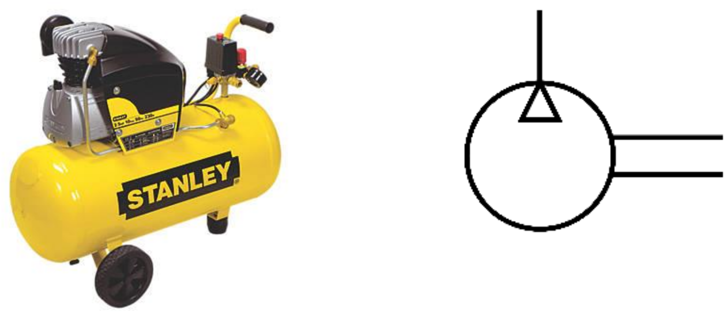


Figure (2. 8): Compressor and pneumatic symbol. [6]

- Pressure regulating component: Pressure regulating components are formed by various components, each of which has its own pneumatic symbol as shown in Figure (2.9):
- Filter: can remove impurities from compressed air before it is fed to the pneumatic component.
- Pressure regulator: to stabilize the pressure and regulate the operation of pneumatic components.
- Lubricator: To provide lubrication for pneumatic components.

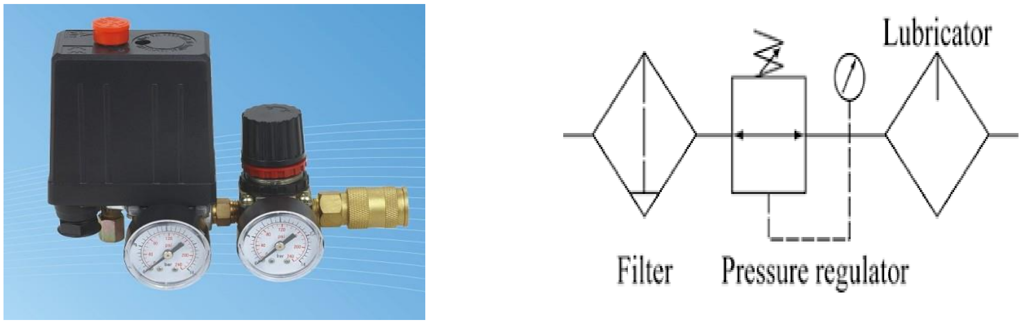


Figure (2. 9): Pressure regulation.

- Directional control valve: Directional control valves ensure the flow of air between air ports by opening, closing and switching their internal connections. Their classification is determined by the number of ports, the number of switching positions, the normal position of the valve and its method of operation. Common types of directional control valves include 2/2, 3/2, 5/2, etc. The first number represents the number of ports; the second number represents the number of positions as shown in Figure (2.10):

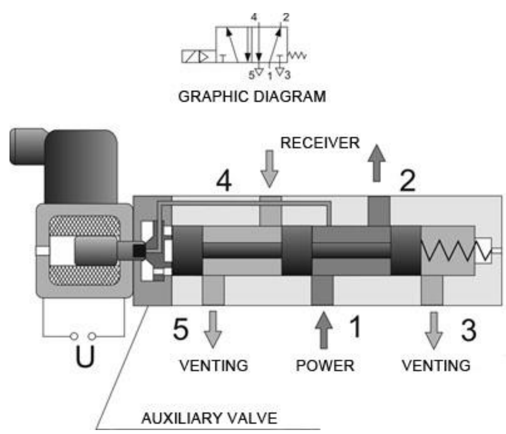


Figure (2. 10): Description of 5/2 valve. [7]

- 3/2 Directional control valve: A 3/2 directional control valve can be used to control a single acting cylinder as shown in Figure (2.11).The open valves in the middle will close until ‘P’ and ‘A’ are connected together. Then another valve will open the sealed base between ‘A’ and ‘R’ (exhaust). The valves can be driven manually, mechanically, electrically or pneumatically.

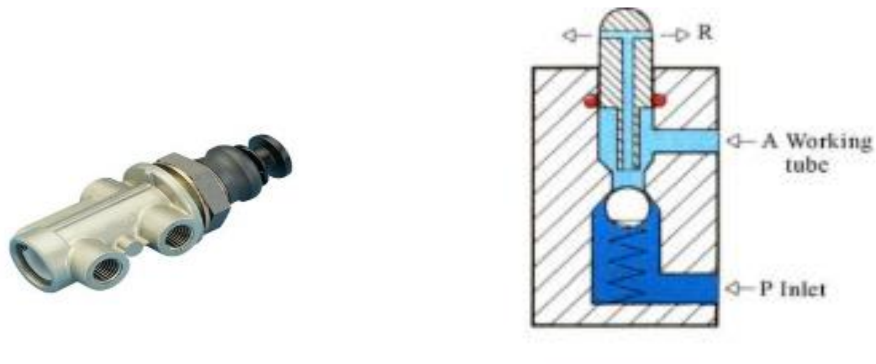


Figure (2. 11): 3/2 Direction and Ross section.

- **Flow control valve:**

Flow Control Valves are used to reduce the rate of flow In a section of a pneumatic circuit, resulting in a slower actuator speed.
Unlike a Needle Valve, a Flow Control Valve regulates air flow in only one direction, allowing free flow in the opposite direction as shown in Figure (2.12):

Figure (2. 12): Flow control valve and cross section. [8]

2.4 Design and Selection:

2.4.1 Mechanical design:

To calculate the dimensions required for the amount of powder needed to fill the fluid tank as well as choose the correct size air blower is calculated by the following equations**:**

- **The quantity of the powder mass (Mp) to use for this in design is accorder** as shown in Figure (2.5).

$$Mp = L * W * H * \rho d \qquad (2.1)$$

$$= 365 * 315 * 255 * 0.55$$

$$= 16125243 * 10^{-6}\, Kg$$

$$= 16.125\ Kg$$

Where

- L: Length (mm).
- W: Width (mm).
- H: Height of powder (mm).
- ρd: These density of use at rest (0.55 Kg/m^3) Datasheet in appendix (Page73).

- **Total mass (M_T):**

$$M_T = M_{tank} + Mp \qquad (2.2)$$

$$= 5 + 16.125$$

$$= 21.125\, kg$$

Where

- M_{tank}: is the tank mass with approximated weight of 5 (kg).

- **Area of the tank in m^2 (A) :**

$$A = L * W \quad (2.3)$$

$$= 0.365 * 0.315$$

$$= 0.1149\ m^2$$

- **Flow rate in m^3/h (D) :**

$$D = A * Number \quad (2.4)$$

$$= 0.1149 * 45$$

$$= 5.1705\ m^3/h$$

Where

- Number: (45 m/h) Subjects by the company. Datasheet in Appendix (Page73)

- **Powder pressure in the tank in Pa (P) :**

$$P = (Mp * g)/A \quad (2.5)$$

$$= \frac{(16.125 * 9.8)}{0.1149}$$

$$= 1375.32\ Pa$$

Where

- g: Acceleration of gravity (m/s^2).

- **To convert into (mill bar):** Datasheet in Appendix (Page73)

$$1\ mill\ bar\ =\ 1\ Pa/101.325 \quad (2.6)$$

$$P_{mill\ bar} = \frac{1375.32}{101.325} = 13.57\ milll\ bar$$

- **Safety factor :**

Because of the potential pressure drop in the porous tile and the connections, it is recommended to calculate with a safety factor of 3, i.e. powder pressure m Bar (P) x 3.

Datasheet in Appendix (Page73).

$$P_{millibar} = 13.57 * 3 \quad (2.7)$$

$$= 40.72\ mill\ bar$$

2.4.2 Cylinder calculation:

The dimension of flexing piston is calculated by the following equations: [9]

$$F = P * A \quad (2.8)$$

Where

- F: force (N).
- P: pressure(bar)=6 bar
- A: cross section area of the piston rod.

- **According to Newton second low, the force can be calculated by the following equations:**

$$F = M_T * a \quad (2.9)$$

$$= 207.025\ N$$

Where

- a: Acceleration of gravity (m/s^2).

- **The volume of tank can be calculated by the following equation:**

$$V = L * W * H \quad (2.10)$$

$$= 0.02931\ m^2$$

- **The cross section area of the piston rod (A) :**

$$A = \frac{P}{F} \quad (2.11)$$

$$= \frac{600}{207.025} = 2.89\ cm^2$$

- **The piston Rod thread can be calculated by the following equation:**

$$A = \frac{\pi}{4} * (d_1^2 - d_2^2) \quad (2.12)$$

On according in data sheet ($d_1 = 25\ mm$) : Datasheet in Appendix (Page67)

$$d_2^2 = d_1^2 - \frac{(A-4)}{\pi} \quad (2.13)$$

$$d_2^2 = d_1^2 - \frac{2.89 * 4}{\pi}$$
$$= 6.25 - 3.68$$
$$= \sqrt{2.57}$$
$$= 1.6\ cm^2$$

Where

- d_1 : Diameter.
- d_2 : Rod thread.

2.4.3 Conveyors motor:

Table (2.2) represents the main mechanical properties of the conveyor belt and some mechanical coefficients according as shown in Figure (2.3): [10]

Table (2. 2): mechanical properties of steel conveyor:

PROPERTIES	VALUE
Belt density	$8000\ kg/m^3$
Belt thickness	$2\ cm$
Belt width	$2\ cm$
Belt length	$150\ cm$
The diameter of the pulley	$10\ cm$
Fraction coefficient (μ)	0.35

- **The belt of volume (V_b):**

$$V_b = B_b * W_b * L_b \quad (2.14)$$

$$= 0.02 * 0.02 * 3$$

$$= 12 * 10^{-4}\ m^3$$

Where

- B_b: The belt thickness (m).
- W_b: The belt of width (m).
- L_b: The belt of Length (m).

- **Mass of the belt (Mb):**

$$Mb = Vb * \rho b \tag{2. 15}$$

$$= 12 * 10^{-4} * 8000$$
$$= 9.6 \; kg$$

Where

- ρb: Belt density (kg/m^3). Datasheet in appendix (Page71)

- **The pulley area (A_p) can be to determine as follow:**

$$A_p = 2\pi rh \tag{2. 16}$$

$$= 2 * 3.14 * 0.05 * 0.02$$
$$= 6.28 * 10^{-3} \; m^2$$

Where

- r: radius of pulley.
- h: High of pulley.

- **The mass of pulley (M_{pu}):**

$$M_{pu} = \rho b * A_P * length_{Pu} \tag{2. 17}$$

$$= 8000 * 6.28 * 10^{-3} * 0.02$$
$$= 1 \; kg$$

- **Total mass:**

$$\textbf{Total mass} = \textbf{Mb} + 2 * (M_{pu}) + M_d \quad (2.18)$$

$$= 9.6 + (2 * 1) + 1$$

$$= 12.6\ kg$$

❖ The mass of two pieces (M_d) moving together is around 1 kg.

- **Force:**

$$F = \textbf{Total mass} * a \quad (2.19)$$

$$= 12.6 * 9.8$$
$$= 123.48\ N$$

Where

- a: Acceleration of gravity (m/s^2).

- **Load pulley Inertia: [30]**

$$J_1 = \frac{1}{8} \times M_P \times D_P^2 \quad (2.20)$$

$$= \frac{1 \times 1 \times 0.1^2}{8}$$

$$= 0.0125\ Kg.m^2$$

Where

- M_P: *(suggested of mass) 1kg.*
- D_P: *Diameter of pulley.*

- **Belt Inertia and work*:***

$$J_2 = Mp\left(\frac{\pi \times 0.5}{2 \times \pi}\right)^2 \quad (2.21)$$

$$= 1(\frac{\pi \times 0.5}{2 \times \pi})^2$$

$$= 0.0625\ Kg.m^2$$

- **The total inertia:**

$$J_{tot} = J_1 + J_2 \quad (2.22)$$

$$= 0.075\ Kg.m^2$$

- **The torque of load (T_L):[31]**

$$T_L = \frac{F*Dp}{2*\eta} \quad (2.23)$$

$$= \frac{5.4*0.1}{2*0.9}$$

$$= 0.3\ N.m$$

Where

- F: The force
- η: Belt pulley efficiency.

After adding 1.25 for safety factor for equation (2.24) becomes:

$$T_L = 1.25 * T_L \quad (2.24)$$

$$= 0.375\ N.m$$

- **The torque is equal:**

$$T = \frac{F*Dp}{2*\eta} \quad (2.25)$$

$$= \frac{170.52 * 0.1}{2 * 0.9}$$

$$= 9.47\ N.m$$

After adding 1.25 for safety factor for equation (2.26) becomes:

$$\boldsymbol{T = 1.25 * T} \quad \textbf{(2. 26)}$$

$$= 1.25 * 9.47$$

$$= 11.8375\ N.m$$

- **linear Speed (V):**

$$\boldsymbol{V = D/t} \quad \textbf{(2. 27)}$$

$$= \frac{1.5}{10}$$

$$= 0.15\ m/s$$

Where

- D: The traveled Distance.
- t: Time.

- **Speed (n):**

$$\boldsymbol{n = \frac{V*60}{2*\pi*r}} \quad \textbf{(2. 28)}$$

$$= \frac{0.15 * 60}{2 * 3.14 * 0.05}$$

$$= 28.6\ rpm$$

$$\textbf{Gear ration} = \frac{\mathbf{1450}}{\mathbf{28.6}} \quad \textbf{(2. 29)}$$

$$= 50$$

- Gear ration is 1: 50.

$$1450 * \frac{1}{50} = 29\ rpm$$

- **Angular speed (ω):**

$$\omega = 2 * \pi * n/60 \quad (2.30)$$

$$= \frac{2 * 3.14 * 29}{60}$$

$$= 3.03 \text{ Rad/sec}$$

- **Power :**

$$Power = T * \omega \quad (2.31)$$

$$= \frac{(11.8375 + 0.375) * 2 * 3.14 * 29}{60}$$

$$= 37 \quad Watt$$

Where

- n: speed of conveyer 29 rpm

- **Power converted to HP:**

$$Power_{HP} = \frac{power}{746} \quad (2.32)$$

$$= \frac{37}{746}$$

$$= 0.0495 \; hp$$

A single-phase induction motor is selected according to appendix C with main data , 60 Watt, single PHASE. Datasheet in Appendix (Page69).

3

Chapter 3: Electrical Design

3.1 Introduction.

3.2 Motor calculations.

3.3 Oven Design and Calculations.

3.4 Cylinder calculations.

3.5 Protection Circuit Sizing

3.6 Control element.

3.7 Temperature Controller.

3.8 PLC description.

3.9 Electrical Block Diagram

3.10 Flowchart.

3.11 State graph.

3.12 PLC Connection:

3.13 PLC Input-Output table.

3.14 Power circuit.

3.15 Pneumatic circuit.

3.1 Introduction:

This chapter contains the electrical component specifications (motor, sensor, overload, etc.), power and control circuit which will be used in our project.

3.2 Motor calculations:

An electric motor is an electrical machine that converts electrical energy into mechanical energy. In this section, the specifications of the electric motor that include the AC motor will be explained, as the motor will move the conveyor belt and it has been chosen for the machine to be used in industrial facilities.

- The conveyor motor that obtain by the equation (2.32).

Table (3. 1): Selected Motor Nameplate:

Name	Phase	Type	P/KW	V	A	RPM	F/Hz
Conveyer motor	**1Ø**	Squirrel cage	**0.06**	**220**	**1.09**	**1450**	**60**

3.3 Oven Design and Calculations:

The oven is one of the main parts used in this project. The oven is used to increase the temperature of the piece to be painted until the piece reaches the required temperature according to the thickness of the piece and the specifications of the powder in order to obtain the best results. In our project, the following parts were used in addition to the outer frame made of iron and lined with thermal wool to maintain the temperature inside the oven.

➢ The following element was used for heating:

- Heater element.

A typical heating element is usually a coil or tape (straight or corrugated) or a strip of wire, as shown in Figure (3.1), that emits heat like a filament for a lamp. When an electric current flows through it, it glows red and converts the electrical energy that passes through it into heat that radiates in all directions and gives a higher temperature than what is required, so Thermocouples sensor, as shown in Figure (3.7) were used to control the temperature.

Figure (3. 1): Heater Element. [11]

➢ We will be using 3 heating elements distributed on the sides of the oven.

$$P_{total} = N * P_{heater} \qquad (3.\ 1)$$

$$= (2 * 1200) + (1 * 800)$$
$$= 3200\ W$$

Where

- N: Number of heater element.
- P_{heater}: Power of heater element. Datasheet in appendix (Page81)

Table (3. 2): Selected Oven Nameplate:

Name	Phase	P/KW	Volt/V	Temp/C	F/Hz
Oven	**1∅**	**3.2**	**230**	**300**	**50**

3.4 Cylinder calculations:

The cylinder is used to raise and lower the basin, as its value was found in the last chapter. The following are the results according to the data sheet.

- The cylinder that obtain by the equation (2.11), (2.12).

Table (3. 3): Selected cylinder Nameplate:

Name	Stroke(mm)	Diameter(mm)	Rod thread	Max force (N)
Double acting cylinder	**250**	**25**	**M10*1.25**	**294**

3.5 Protection Circuit Sizing:

Power-system protection is a branch of electrical power engineering that deals with the protection of electrical power systems from faults through the isolation of faulted parts from the rest of the electrical network. The devices that are used to protect the power systems from faults are called protection devices which includes in this project.

3.5.1 Protection Devices:

1. Circuit breaker:

A circuit breaker is a switching device that interrupts the abnormal or fault current. It is a mechanical device that disturbs the flow of high magnitude (fault) current and in additions performs the function of a switch. The circuit breaker is mainly designed for closing or opening of an electrical circuit, thus protects the electrical system from damage, as shown in Figure (3.2). [12]

Figure (3. 2): Circuit breaker. [13]

2. Earth Leakage:

Earth leakage is electric current that finds its way to earth via an unintended path. There are two categories: unintentional earth leakage, which results from faulty insulation or equipment, and intentional earth leakage, which is a consequence of the way equipment is designed, as shown in Figure (3.3).

Figure (3. 3): Earth Leakage. [14]

3. Overload:

To protection the motor we used overload switches and it defined as overload relays are intended to protect motors against excessive heating due to long time motor over currents up to and including locked motor currents. Protection of the motor due to short circuits or grounds is a function of circuit breakers, or motor short-circuit protectors, as shown in Figure (3.4). [15]

Figure (3. 4): Overload. [16]

- **Conveyer Motor and Oven Protection Circuit:-**

- Overload

  OL=In
- MCB(Miniature Circuit Breaker)

  MCB= Next Standard$(1.25 \times In)$
- Contactor

  Contactor = Next Slandered$(1.1 \times \text{Pin})$

- The following table (3.4) shows the selected components ratings.

Table (3. 4): Selected Protection Components Ratings:

Name	Overload size(A)	MCB size(A)	MCB Type	RCD	Contactor size
Conveyer Motor	6	--	--	20	AC3-4KW
Oven	--	20	B	20	AC1-9KW

3.6 Control element:

3.6.1 Electrical Switches:

They are electromechanical devices used in electrical circuits to control power, detect when the systems are outside their operating ranges, and signal control devices for the locations of machine members and work pieces, and provide a means for manual control and automatic control of the functions of electrical machinery and equipment, as shown in Figure (3.5).

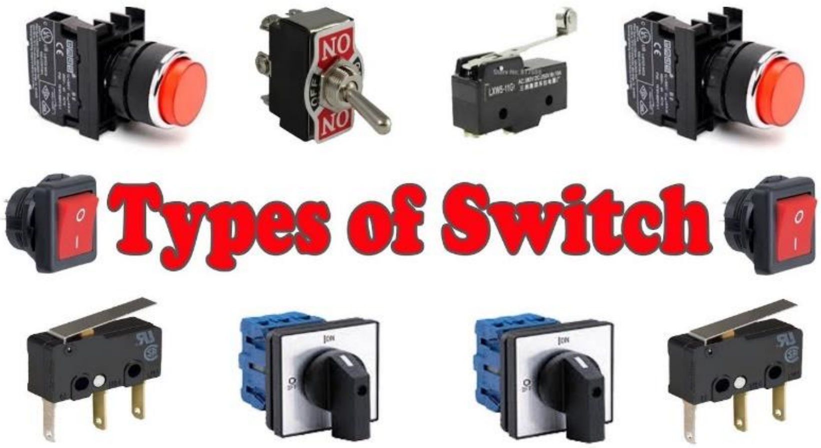


Figure (3. 5): Electrical Switches. [17]

3.6.2 Pushbutton switches:

Are momentary contact switches, where contacts change from their default state only when the button is pressed and held down, as shown in Figure (3.6), the two types of momentary contact switches are: [18]

- **Normally open (NO):** In a normally open switch, the default state of the contacts is open. When you push the button, the contacts are closed. When you release the button, the contacts open again. Thus, current flows only when you press and hold the button.
- **Normally closed (NC)**: In a normally closed switch, the default state of the contacts is closed. Thus, current flows until you press the button. When you press the button, the contacts are opened and current does not flow. When you release the button, the contacts close again and current resumes.

Figure (3. 6): pushbutton switches. [19]

3.6.3 Thermocouples sensor:

The Thermocouple sensor as shown in Figure (3.7) consists of two electrical conductors made of different metals that are joined at one end. Changes in temperature at the measurement junction induce a change in voltage between the other ends. [20]

Datasheet in appendix (Page74)

Figure (3. 7): Thermocouples sensor. [21]

Thermocouple are two groups, the base metal thermocouples J, K, T, E and N, and the precious metal thermocouples R, S and B.

In each type has a characteristic voltage against temperature curve and application range, as shown in Figure (3.8).

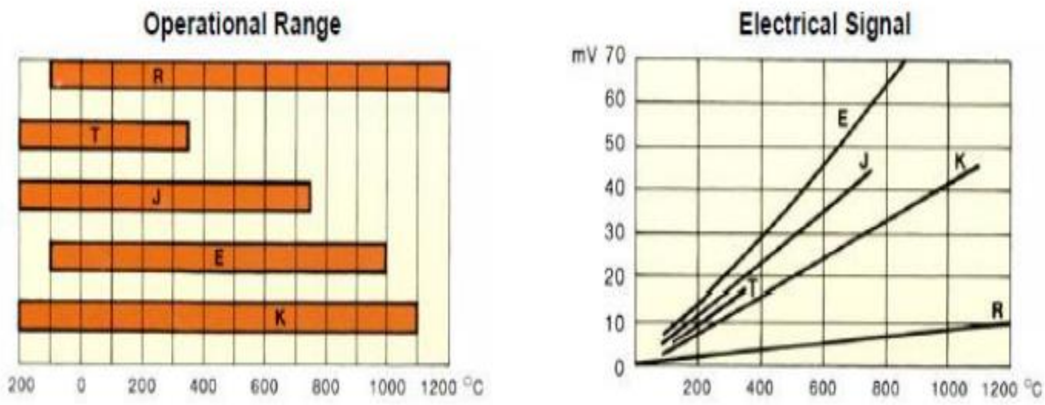


Figure (3. 8): Thermocouple Characteristic Curve.

A thermocouple sensor will be used to measure the oven temperature. The output voltage value of the thermocouple feeds this into the PLC input port. To close the temperature control loop.

3.6.4 Photoelectric sensor:

A self-contained photoelectric sensor contains the optics, along with the electronics. It requires only a power source. The sensor performs its own modulation, demodulation, amplification, and output switching. Some self-contained sensors provide such options as built-in control timers or counters. Because of technological progress, self-contained photoelectric sensors have become increasingly smaller.

Remote photoelectric sensors used for remote sensing contain only the optical components of a sensor. The circuitry for power input, amplification, and output switching are located elsewhere, typically in a control panel. This allows the sensor, itself, to be very small. Also, the controls for the sensor are more accessible, since they may be bigger, as shown in Figure (3.9).

Datasheet in appendix (Page79)**.**

Table (3. 5): Photoelectric sensor Specifications:

Model	Sensing Distrance	Operation voltage	Output		Response time	Sensing method
			Method	Mode		
G50-3A30NA	30cm 50cm	DC10-30V	NPN	NO	<2mS	Diffuse type
G50-3A30NB	30cm 50cm	DC10-30V	NPN	NC	<2mS	Diffuse type
G50-3A30NC	30cm 50cm	DC10-30V	NPN	NO+NC	<2mS	Diffuse type

Figure (3. 9): Photoelectric sensor. [22]

3.6.5 Contactors:

A contactor is an eclectically controlled switch used for switching a power circuit, similar to a relay except with higher current ratings.

A contactor is controlled by a circuit which has a much lower power level than the switched circuit.

Contactors come in many forms with varying capacities and features. Unlike a circuit breaker, a contractor is not intended to interrupt a short circuit current.

Contactors range from those having a breaking current of several amperes to thousands of amperes and 24 V DC to many kilovolts. The physical size of contactors ranges from a device small enough to pick up with one hand to large devices approximately a meter (yard) on a side. Contactors are used to control electric motors, lighting, heating, capacitor banks, thermal evaporators, and other electrical loads, as shown in Figure (3.10). [23]

Figure (3. 10): Contactors. [24]

3.6.6 Emergency switch:

Emergency Stop Button, as shown in Figure (3.11), provides safety for humans and the machine; it offers a wide range of safety components for the protection of humans, machine and production goods in emergency situations. It is the purpose of emergency-stop device to deflect or minimize the risk as quickly as possible and optimally in the event of an emergency arising.

Figure (3. 11): Emergency switch. [25]

3.6.7 Selector switch:

Limiter switches are available in versions of 2, 3 and 4 or more positions, and are often used when more than one control option is required. In general, the central position of the selector switch is the position of the starting camera. Left position presses the left plunger in the selector switch. Shifting the selector switch to the right causes the right plunger to be depressed as shown in Figures (3.12), a three-position selector switch is used to open or close two circuits, "manual", "off" and "automatic", of the coating machine. It works in the following way.

Table (3. 6): principle of selector switch:

Select 0	Machine off
Select 1	Manual operation
Select 2	Automatic operation

Figure (3. 12): selector switch. [26]

3.7 Temperature Controller:

As the name implies, a temperature controller is an instrument used to control temperatures, mainly without extensive operator involvement. A controller in a temperature control system will accept a temperature sensor such as a thermocouple or RTD as input and compare the actual temperature to the desired control temperature, or set point. It will then provide an output to a control element, as shown in Figures (3.13). [27]
Datasheet in appendix (Page80)

Figure (3. 13): Temperature Controller. [28]

3.8 PLC description:

Programmable Logic Controller (PLC) is a digital computer used for automation of electromechanical process, such as control of machinery on factory assembly lines, PLCs are used in many industries and machine. Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery backed-up or non- volatile memory.

The PLC used in this machine is **Delta PLC (DVP-14SS2)**, as shown in Figure (3.14). Datasheet in appendix (Page75).

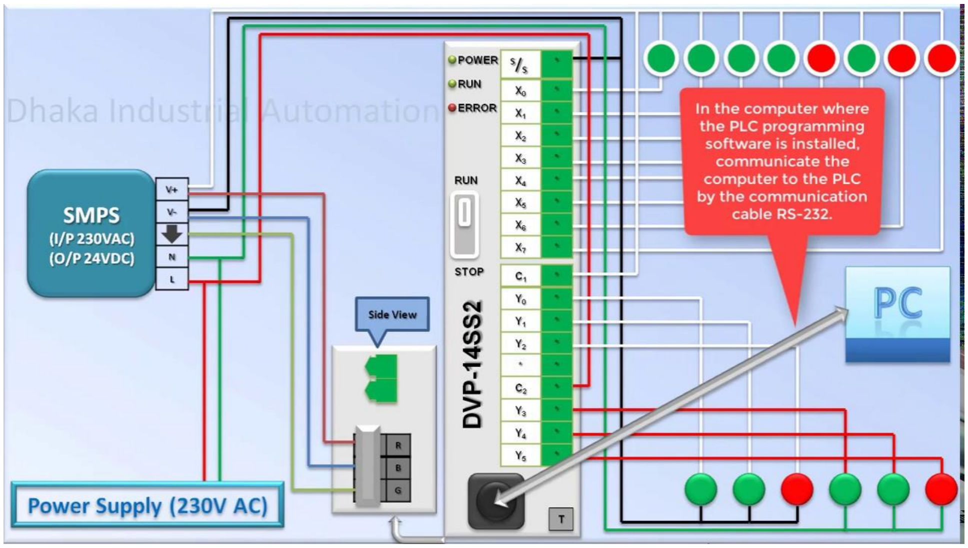


Figure (3. 14): model Connection. [29]

3.9 Electrical Block Diagram :

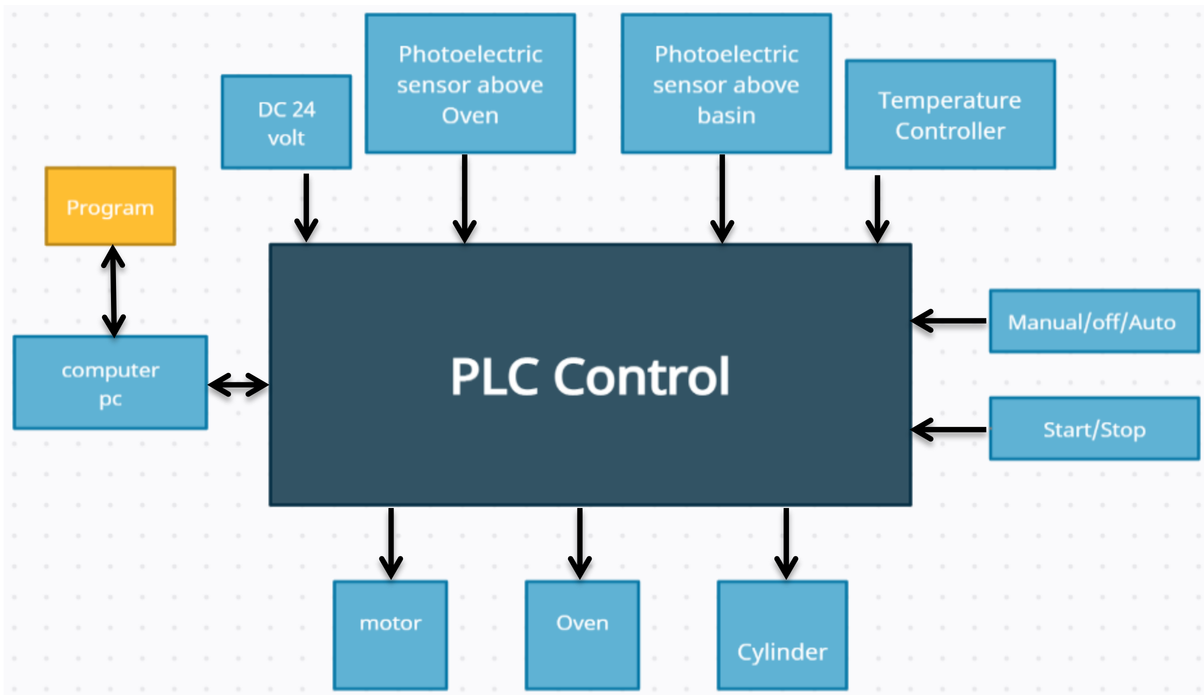
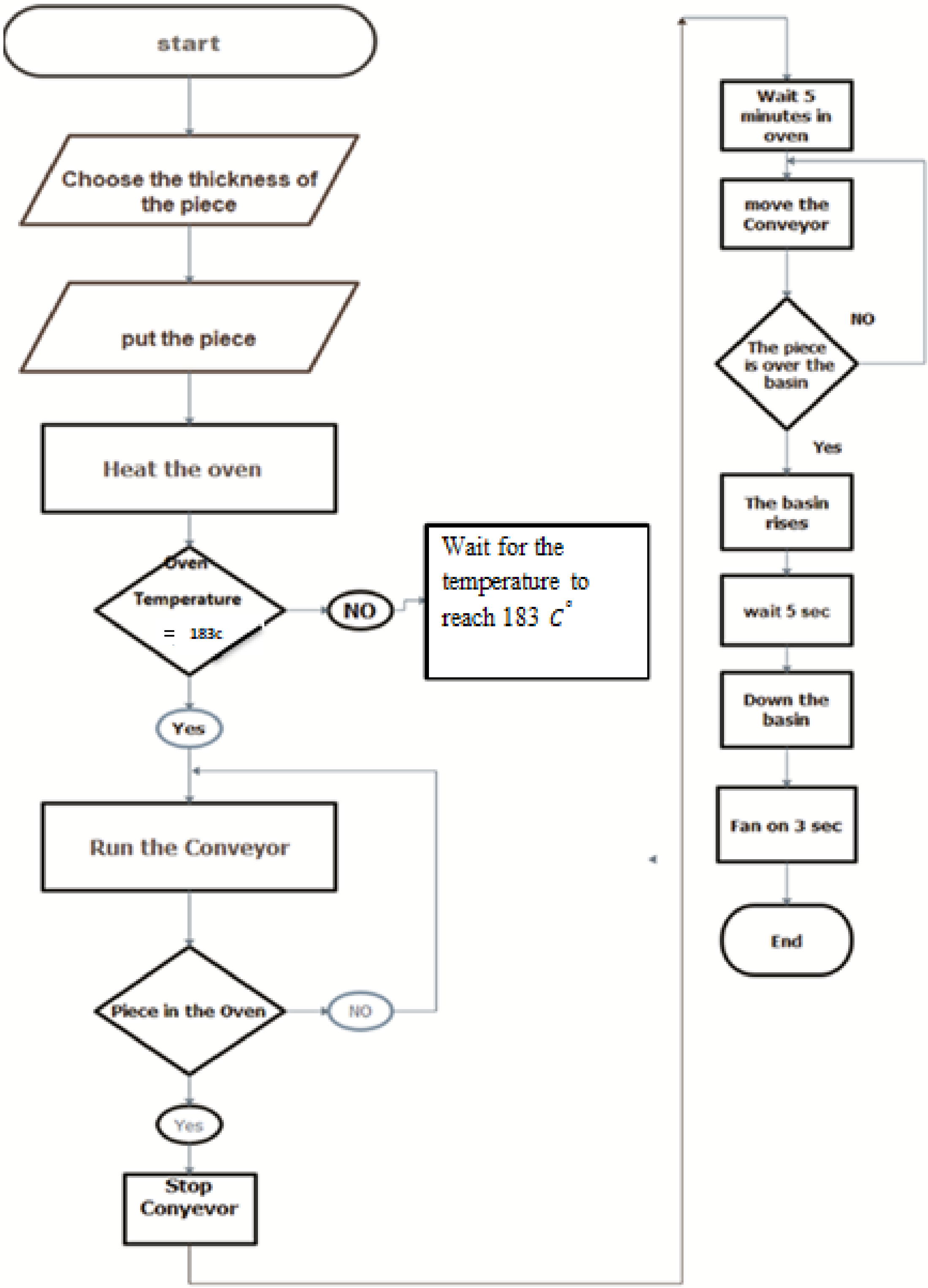


Figure (3. 15): Electrical Block Diagram.

3.10 Flow chart:



3.11 State graph:

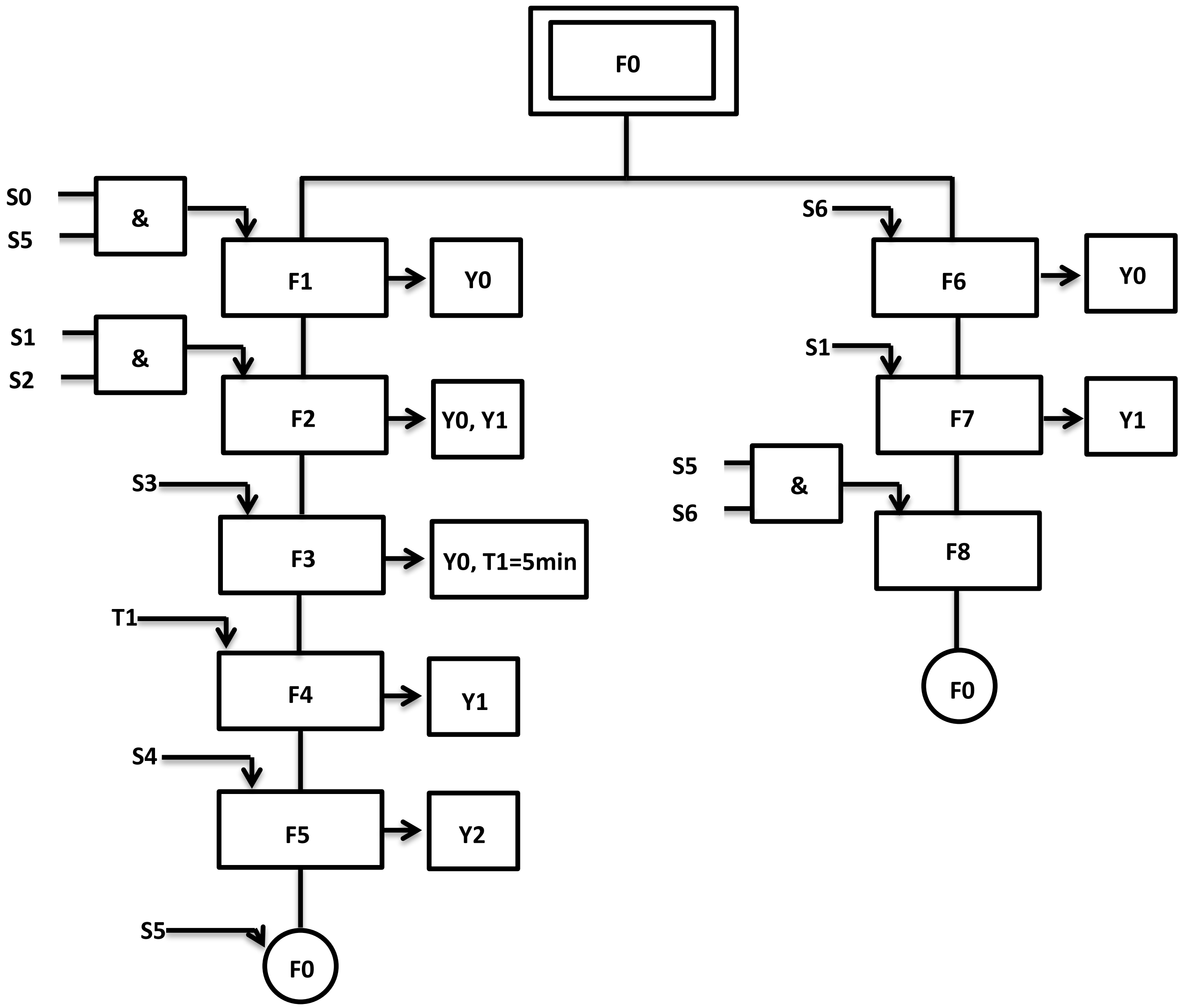


Table (3. 7): Output PLC signal.

Symbol	Function	Address
S0	Automatic	Input
S1	Start	Input
S2	Temperature Controller	Input
S3	Up oven sensor	Input
S4	Up Powder basin sensor	Input
S5	Stop	Input
S6	Manual	Input
T1	Timer	Input
Y0	Oven	Output
Y1	Conveyor motor	Output
Y2	Cylinder	Output

3.12 PLC Connection:

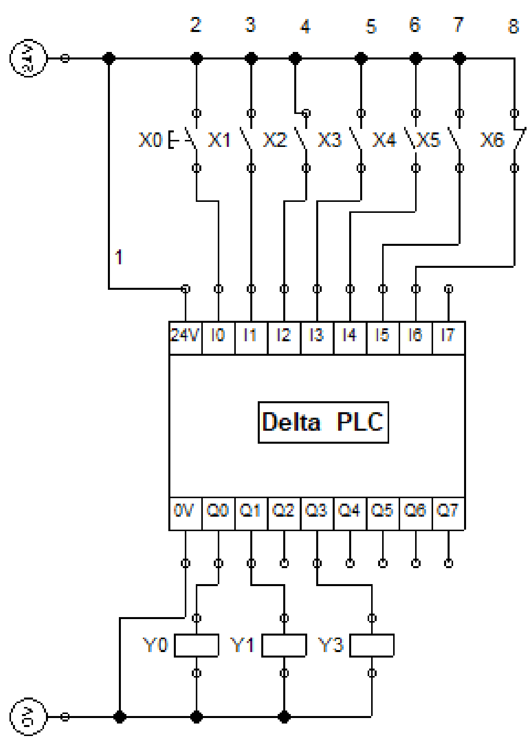


Figure (3. 16): PLC Connection.

3.13 PLC Input-Output table:

Table (3. 8): PLC Input-Output:

Symbol	Function	Address
Inputs		
Auto	Auto control	**X0**
S1	start	**X1**
Temp	Temperature Controller	**X2**
P1	Photoelectric sensor above Oven	**X3**
P2	Photoelectric sensor above basin	**X4**
S0	stop	**X5**
Manual	Manual control	**X6**
Output		
OV	Oven	**Y0**
M0	Conveyor motor	**Y1**
C1	Cylinder basin	**Y2**

3.14 Power circuit:

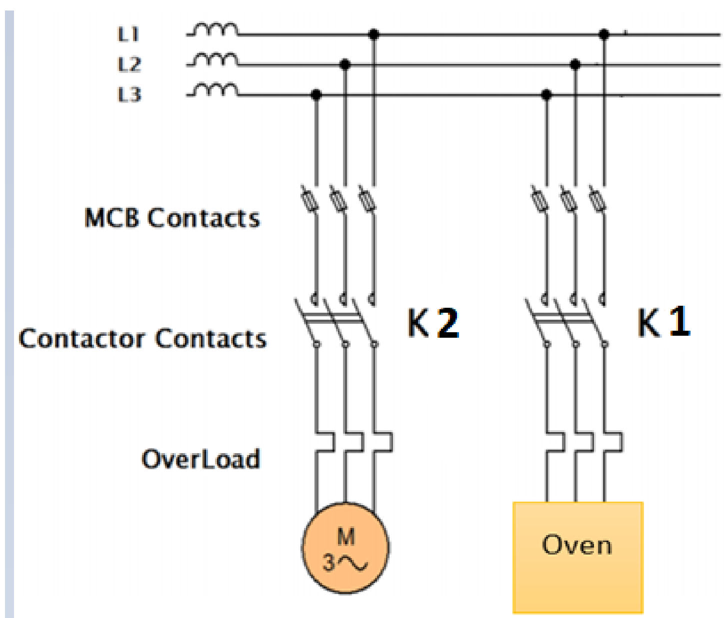


Figure (3. 17): Power Circuit.

3.15 Pneumatic circuit:

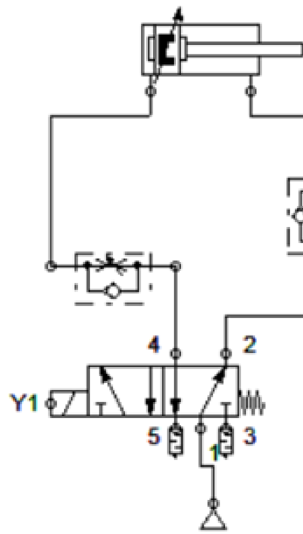


Figure (3. 18): Pneumatic Circuit.

4

Chapter 4: Implementation and Results.

4.1 Introduction.

4.2 Overall System.

4.3 Machine Testing.

4.4 Payback time and review.

4.5 Results.

4.6 Recommendations.

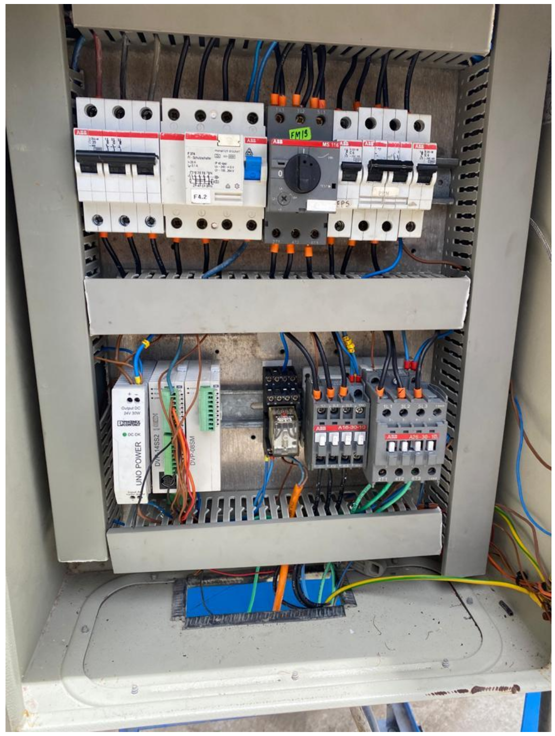
4.1 Introduction:

This chapter provides work implementation, experimental result and some recommendations from work we learned. We listed some goals hope to be accomplished or to be considered for the future project.

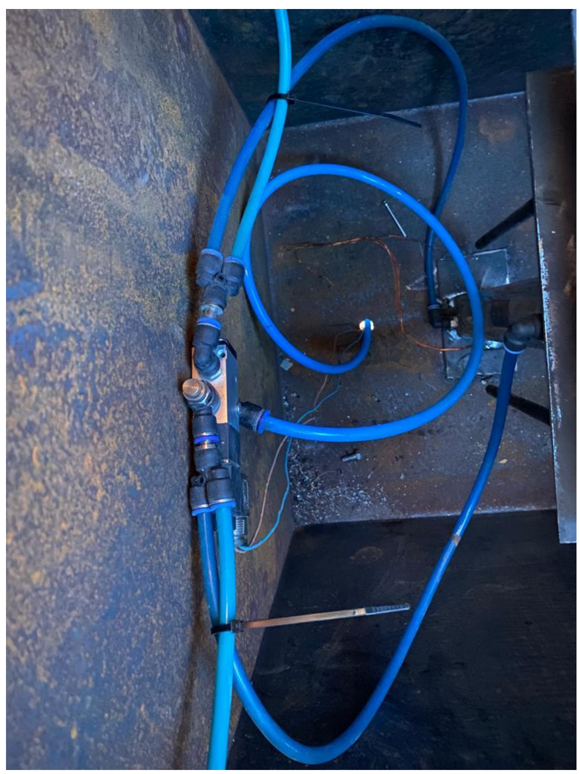
4.2 Overall System:

Figure (4.1) presents overall shape of the machines with parts illustrated as followers:

a) Control Board.



b) Internal electrical installation in the prod.



c) Air Selector.

d) The Oven.

e) Basin

f) The final machine.

Figure (4. 1): Overall shall of the machine.

4.3 Machine Testing:

In this part, few tests were conducted for path cases for manual and automatic mode as follows

In this mode peas of metal (range) is heated for 200° C and then dept. In the powder for certain values of time as illustrated in table (4.2), where it's indicated that the time of 15 min is the optimized time for fully covering and uniform pit distribution.

This time (15 min) is taken and inserted in the PLC program as processing time.

Table (4. 1): The relationship between the heating time and the pint quality (Efficiency) was in the oven and the Efficiency of its coating:

Reading No.	1	2	3	4
Time (min.)	3	5	10	15
Efficiency (%)	0	30	60	90

According to the previous table, we conclude that the optimized heating time is 15 min that is used as input parameter for automatic control mode.

4.4 payback time and review:

- Price powder (Pp.) = 20$
- Electricity consumption within an hour =3.57 KWH
- Price KWH = 0.65₪
- 1$ = 3.25₪

If it was assumed that 4 pieces could be brought into the oven in one cycle, then 16 would be produced within an hour.

- Daytime production (D_p):

$$\mathbf{D_p = 16\ pieces * 10\ hours} \qquad (4.1)$$

$$= 160\ pieces\ per\ day$$

- Month time production (M_p):

$$\mathbf{M_p = 160\ pieces * 24\ days} \quad \mathbf{(4.2)}$$

$$= 3840\ pieces$$

If each piece needs 10 g of powder.

$$\mathbf{Quantity\ of\ powder = 3840\ pieces * 10\ g} \quad \mathbf{(4.3)}$$

$$= 38400\ g$$

$$= 38.4\ Kg$$

- The cost of coating ($):

$$\mathbf{cost\ of\ coating = 38.4\ Kg * 20\ \$} \quad \mathbf{(4.4)}$$

$$= 768\ \$$$

- Electrical cost in month (E_m):

$$\mathbf{E_m = 3.57\ KWH * 10\ hours * 24\ days * 0.65₪} \quad \mathbf{(4.5)}$$

$$= 556.92₪$$

$$in\ dollar = 171.36\$$$

- Total cost:

$$\mathbf{Total\ cost = 171.36\$ + 768\$} \quad \mathbf{(4.6)}$$

$$= 975\$$$

The price per piece is plated = 0.5$

- The sale price of all the pieces (S_p):

$$\mathbf{S_p = 0.5\$ * 3840\ picese} \quad \mathbf{(4.7)}$$

$$= 1920\$$$

- Profit per month:

$$\mathbf{Profit\ per\ month = 1920\$ - 975\$} \quad \mathbf{(4.8)}$$

$$= 945\$$$

- The time required to complete the project cost is about three months.

4.5 Results:

In final test and after conducting the needed calibration and adjustment, the machine is operated in automatic mode where the oven temperature is adjusted to 200 ° C, for 15 minutes, and then the piece is exposed to coating powder for 3 seconds.

The following conclusions can be done:

1) The piece is completely painted (coated) uniformly without any areas that are not covered by the paint layer.
2) The coated piece is electrical insulated insulation.
3) Unlike with spray painting, paint power method reduces the powder waste.
4) The estimated time for one cycle of the machine is 16 minutes.
5) The estimated cost of the machine is around …..
6) The machine productivity is ….pieces/hour
7) 1kg of powder is capable to paint around 100 pieces of medium size)
8) The cost of coasting one piece is around

4.6 Recommendations:

In order to improve and in Hans the machine productivity and coating quality

The following is recommended can be proposed for future design:

1. Adding a Human Machine Interface (HMI) to the machine with purpose smooth and accrete control and motoring.
2. Adding PLC Extension contains analog signal to control temperature and time through HMI.
3. In order to reduced heating time an additional heaters is needed for increasing the heating temperature.
4. Adding a suitable air pumping system under the powder to be dismantled in the appropriate and required form for the process.

References :

http://textilescommittee.nic.in/writereaddata/files/Powder%20Coating.pdf?fbclid=IwAR3-89jFv6pEcZjypQwf6T5YsaKXRdR1vsBgLafDM4kmc6oTM9V7m2kfG0w[1]

https://www.rilsanfinepowders.com/en/processing/fluidized-bed-dipping/?fbclid=IwAR0UKVRlLwWN8mZujR8Nx5krxFOxk8Aeb-dpDvcz50n30-o4qHL78K_iJRY[2]

https://www.extremematerials-arkema.com/export/sites/technicalpolymers/.content/medias/downloads/brochures/rilsan-fine-powders-brochures/rfp-br-rilsan-coating-application-methods-and-recommendations-electrostatic-spraying-process-optimized.pdf?fbclid=IwAR0BVo3MCJMJlJgLzOaJSC18XbmSJxiFD85QOau-Mzym16TVxvjqQ4wJOrA[3]

https://coatings.specialchem.com/selection-guide/powder-coatings-formulation-tips?fbclid=IwAR0tgATF-W72Bzs1Pufcf6aGouMf-ZxznLbqTvwAfmLShV69jeg__0BRab8[4]

https://nptel.ac.in/content/storage2/courses/112103174/pdf/mod6.pdf?fbclid=IwAR1SZYTfBUcY4fRUnlO-8vKAsMC1V-wFdFc9WAM17_5mJR6BQLi-UJ2d3Jw[5]

https://www.google.com/search?q=Compressor+&tbm=isch&ved=2ahUKEwiiqpud8vbwAhVD-4UKHS69DfcQ2-cCegQIABAA&oq=Compressor+&gs_lcp=CgNpbWcQAzICCAAyAggAMgIIADICCAAyAggAMgIIADICCAAyAggAMgIIADICCABQ9x9YtiJg4yloAHAAeACAAZIBiAGvA5IBAzAuM5gBAKABAaoBC2d3cy13aXotaW1nwAEB&sclient=img&ei=VGW2YKKwB8P2lwSu-ra4Dw&bih=696&biw=1519&hl=en[6]

https://www.google.com/search?q=Description+of+5%2F2+valve&tbm=isch&ved=2ahUKEwjt-4Dy8vbwAhVH5IUKHZMKDvYQ2-cCegQIABAA&oq=Description+of+5%2F2+valve&gs_lcp=CgNpbWcQA1DgyQFY4MkBYMPSAWgAcAB4AIABigGIAYoBkgEDMC4xmAEAoAEBqgELZ3dzLXdpei1pbWfAAQE&sclient=img&ei=BWa2YK3lOcfIlwSTlbiwDw&bih=696&biw=1519&hl=en[7]

https://www.google.com/search?q=Flow+control+valve+and+cross+section&tbm=isch&ved=2ahUKEwiRrMP_8vbwAhUC_BoKHVTyABEQ2-cCegQIABAA&oq=Flow+control+valve+and+cross+section&gs_lcp=CgNpbWcQA1Dl7gRY5e4EYMP6BGgAcAB4AIABmQGIAZkBkgEDMC4xmAEAoAEBqgELZ3dzLXdpei1pbWfAAQE&sclient=img&ei=Ima2YJGTEoL4a9Tkg4gB&bih=696&biw=1519&hl=en[8]

https://www.engineeringtoolbox.com/pneumatic-cylinder-force-d_1273.html?fbclid=IwAR3o3iu-LUB7gZ1dVaKkbizGSWjeqKJ5Vx3OWM0NAB0f1Zb9DZrRG4hNR1U[9]

https://www.generatorjoe.net/html/motorformula.html?fbclid=IwAR1MQuGjKrkVRxE3FvZ20X0ERcnq3_4knHagTVhsbez-rqLAhQcTTPj8v40[10] https://www.google.com/search?q=Heater+Element&tbm=isch&ved=2ahUKEwjyhvGm8_bwAhVM-YUKHXAdDqYQ2-cCegQIABAA&oq=Heater+Element&gs_lcp=CgNpbWcQAzICCAAyAggAMgIIADICCAAyAggAMgIIADICCAAyAggAMgIIADICCABQ4qoTWOKqE2CcsRNoAHAAeACAAaYBiAGmAZIBAzAuMZgBAKABAaoBC2d3cy13aXotaW1nwAEB&sclient=img&ei=dGa2YPL8MszylwTwuriwCg&bih=696&biw=1519&hl=en[11]

https://circuitglobe.com/circuit-breaker.html?fbclid=IwAR3tbyEav_v5JI1l5W7B6bJFC-kynIoLUwtRQFv0y5benv93PcSejwez_LY[12]

https://www.google.com/search?q=Circuit+breaker+abb&tbm=isch&ved=2ahUKEwj974CB9fbwAhWE0oUKHfVtBYwQ2-cCegQIABAA&oq=Circuit+breaker+abb&gs_lcp=CgNpbWcQAzICCAAyAggAMgYIABAFEB4yBggAEAUQHjIGCAAQBRAeMgYIABAFEB4yBggAEAUQHjIGCAAQBRAeMgYIABAFEB4yBggAEAgQHjoECAAQQ1CpIFi2K2DtL2gAcAB4AIABpAGIAdQEkgEDMC40mAEAoAEBqgELZ3dzLXdpei1pbWfAAQE&sclient=img&ei=Pmi2YP3YEISllwT125XgCA&bih=696&biw=1519&hl=en[13]

https://www.google.com/search?q=)%3A+Earth+Leakage+abb&tbm=isch&ved=2ahUKEwjH6MuE9fbwAhUSShoKHR-ACjwQ2-cCegQIABAA&oq=)%3A+Earth+Leakage+abb&gs_lcp=CgNpbWcQAzIECAAQHjIGCAAQCBAeMgYIABAIEB5Q4fkCWNmDA2CrhgNoAHAAeACAAfQCiAGyB5IBBzAuNC4wLjGYAQCgAQGqAQtnd3Mtd2l6LWltZ8ABAQ&sclient=img&ei=RWi2YIeyMJKUaZ-AquAD&bih=696&biw=1519&hl=en[14]

https://www.c3controls.com/white-paper/what-is-overload-protection/?fbclid=IwAR2ZdmEjimmMyJES7foBmHaYKZbGaWGDxtcb2RpQGl-X2iSmAQF3gB7t4x0

[15]

https://www.google.com/search?q=Overload+abb&tbm=isch&ved=2ahUKEwjKxfmc9fbwAhUN9BoKHaanCFIQ2-cCegQIABAA&oq=Overload+abb&gs_lcp=CgNpbWcQAzICCAAyBggAEAgQHjIGCAAQCBAeMgYIABAIEB4yBAgAEBgyBAgAEBg6BAgAEEM6BggAEAUQHlCP7whYk_cIYNz5CGgAcAB4AIABvAKIAawHkgEHMC40LjAuMZgBAKABAaoBC2d3cy13aXotaW1nwAEB&sclient=img&ei=eGi2YMqpNY3oa6bPopAF&bih=696&biw=1519&hl=en[16]

https://www.google.com/search?q=Electrical+Switches+&tbm=isch&ved=2ahUKEwj28rXj9fbwAhUFdxoKHZvVAXMQ2-cCegQIABAA&oq=Electrical+Switches+&gs_lcp=CgNpbWcQAzICCAAyAggAMgIIADICCAAyAggAMgIIADICCAAyAggAMgIIADICCAA6BggAEAgQHjoECAAQGFCY4gRYh-8EYK3xBGgBcAB4AIABogGIAbgDkgEDMC4zmAEAoAEBqgELZ3dzLXdpei1pbWfAAQE&sclient=img&ei=DGm2YPa8KIXuaZurh5gH&bih=696&biw=1519&hl=en#imgrc=LB1Q9lAeiYekcM[17]

https://opentextbc.ca/basicmotorcontrol/chapter/switches-and-pushbuttons/?fbclid=IwAR1R4iktBI2zYBLfqFnn-Z3e911WUpyrjpvT_dWmWDlpgU8DP7lmxoW5C-0[18] https://www.google.com/search?q=pushbutton+switches&tbm=isch&ved=2ahUKEwjPxJyK9vbwAhXO44UKHeFvC2oQ2-cCegQIABAA&oq=pushbutton+switches&gs_lcp=CgNpbWcQAzIECAAQQzICCAAyAggAMggIABAFEAoQHjIGCAAQBRAeMgYIABAFEB4yBggAEAgQHjIECAAQGFCZpgdYmaYHYJGwB2gAcAB4AIABrAGIAawBkgEDMC4xmAEAoAEBqgELZ3dzLXdpei1pbWfAAQE&sclient=img&ei=Xmm2YM-dAs7HlwTh363QBg&bih=696&biw=1519&hl=en[19]

https://l.facebook.com/l.php?u=http%3A%2F%2Fwww.hyper-sense.com.tw%2Ffront%2Fbin%2Fdownload.phtml%3FPart%3DThermocouple%26Nbr%3D61247%26Category%3D0%26fbclid%3DIwAR0tgATF-W72Bzs1Pufcf6aGouMf-ZxznLbqTvwAfmLShV69jeg__0BRab8&h=AT2iqu7-Tbc5x1QkGZDHFOlps3QhH-w6FpGGHLtaPEB0IJ0XH1QClkIIXL1YGC5cob8qxxXDboOFTcK9VRAfwMirc8lMexHlJbtdZUxFGyQnKh0L8X251lQdGS4qDJc9qSHdeg[20]

https://www.google.com/search?q=Thermocouples+sensor.&tbm=isch&ved=2ahUKEwjCjrPE9vbwAhUD4oUKHYRqAsYQ2-cCegQIABAA&oq=Thermocouples+sensor.&gs_lcp=CgNpbWcQAzIECAAQHjIGCAAQCBAeUJzSDVic0g1g1dYNaABwAHgAgAHIAogByAKSAQMzLTGYAQCgAQGqAQtnd3Mtd2l6LWltZ8ABAQ&sclient=img&ei=2Gm2YMLCAoPElwSE1YmwDA&bih=696&biw=1519&hl=en[21]

https://www.google.com/search?q=Photoelectric+sensor&tbm=isch&ved=2ahUKEwiCvuiv9_bwAhULNxoKHa_zBcsQ2-cCegQIABAA&oq=Photoelectric+sensor&gs_lcp=CgNpbWcQAzIECAAQQzICCAAyAggAMgIIADICCAAyAggAMgIIADICCAAyAggAMgIIAFCc9gNYnPYDYMKABGgAcAB4AIABtAGIAbQBkgEDMC4xmAEAoAEBqgELZ3dzLXdpei1pbWfAAQE&sclient=img&ei=uWq2YML9EovuaK_nl9gM&bih=696&biw=1519&hl=en#imgrc=sYjz2cPQ7QttiM[22]

https://www.quisure.com/blog/faq/common-question-answer-of-contactor?fbclid=IwAR16-dHsIlkmTvXZOsWO1jZTxVKdXVLobUzCKRlF0ShRdI3pZWeF-n8vfgs[23]

https://www.google.com/search?q=Contactors.+abb&tbm=isch&ved=2ahUKEwjJl6aE-PbwAhUR-BoKHb7hB-MQ2-cCegQIABAA&oq=Contactors.+abb&gs_lcp=CgNpbWcQAzIGCAAQCBAeMgYIABAIEB4yBggAEAgQHjoECAAQHlDzHFjhJ2CiLmgAcAB4AIABuQGIAYMFkgEDMC40mAEAoAEBqgELZ3dzLXdpei1pbWfAAQE&sclient=img&ei=amu2YMm6HZHwa77Dn5gO&bih=696&biw=1519&hl=en[24]

https://www.google.com/search?q=Emergency+switch&tbm=isch&ved=2ahUKEwiR_9OH-PbwAhUI8xoKHaLbDfQQ2-cCegQIABAA&oq=Emergency+switch&gs_lcp=CgNpbWcQAzICCAAyAggAMgIIADICCAAyAggAMgIIADICCAAyAggAMgIIADICCABQuswCWLrMAmCE0wJoAHAAeACAAa4CiAGuApIBAzMtMZgBAKABAaoBC2d3cy13aXotaW1nwAEB&sclient=img&ei=cWu2YNGCIIjma6K3t6AP&bih=696&biw=1519&hl=en[25]

https://www.google.com/search?q=selector+switch&tbm=isch&ved=2ahUKEwiBgfuc-PbwAhWj8IUKHX-NABsQ2-cCegQIABAA&oq=selector+switch&gs_lcp=CgNpbWcQAzIECAAQQzIECAAQQzICCAAyAggAMgIIADICCAAyBAgAEEMyBAgAEEMyAggAMgIIAFCNhgNYjYYDYNWKA2gAcAB4AIABrQKIAa0CkgEDMy0xmAEAoAEBqgELZ3dzLXdpei1pbWfAAQE&sclient=img&ei=nmu2YIG6DKPhlwT_moLYAQ&bih=696&biw=1519&hl=en#imgrc=TJ6plT-63IYHNM[26]

https://www.omega.com/en-us/resources/temperature-controllers[27]

https://www.google.com/search?q=Temperature+Controller&source=lnms&tbm=isch&sa=X&ved=2ahUKEwiXj4LR-PbwAhUMlRQKHRs8At0Q_AUoAXoECAEQAw&biw=1536&bih=696[28]

https://www.google.com/search?q=Delta+PLC+(DVP-14SS2)&tbm=isch&ved=2ahUKEwivzKr--PbwAhUPYRoKHVp4AjcQ2-cCegQIABAA&oq=Delta+PLC+(DVP-14SS2)&gs_lcp=CgNpbWcQAzIGCAAQCBAeMgYIABAIEB5Q5fYCWOX2AmDR_AJoAHAAeACAAdACiAHQApIBAzMtMZgBAKABAaoBC2d3cy13aXotaW1nwAEB&sclient=img&ei=amy2YK_vGI_CadrwibgD&bih=696&biw=1536#imgrc=0al9rjr6gnIVjM[29]

https://blog.orientalmotor.com/motor-sizing-basics-part-2-load-inertia?fbclid=IwAR25rIE7VHx_k8EYriZWvGhKjls34zEODaxqdm4xEFF3D2UAgpmR0oXXmpo[30]

https://blog.orientalmotor.com/motor-sizing-basics-part-1-load-torque[31]

Appendix A:

RILSAN® T YELLOW 7379 MAC

Rilsan® 7379 Yellow MAC Fluid Bed Powder

Rilsan® fluid bed powders are thermoplastic polyamides obtained from renewable resources.

Outstanding characteristics: abrasion resistance, corrosion resistance, impact resistance, sound reduction, flexibility, low coefficient of friction.

MAIN CHARACTERISTICS

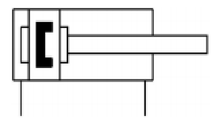
POWDER PROPERTIES	VALUE	UNIT	TEST STANDARD
Melting Temperature	183 - 188	°C	ISO 1218
Specific Gravity of Coating, 20°C	1.19	-	ISO 1183
Water Absorption, 24h	≤ 1	%	ISO 62-1
Median Particle Size	100 - 130	μm	ISO 13320
Abrasion Resistance, Wheel CS 17, load 1 kg, 1000 cycles	13	mg	ISO 9352
Impact Resistance	≥ 2	J	ASTM G14
Dielectric Stress, 350 - 450μm	30	kV/mm	ASTM D149
Persoz Hardness	280	-	ISO 1522
Covering Efficiency, 300μm	0.35	kg/m²	-
Fluidized Density	0.5	-	-
Tapped Density	0.69	-	ISO 1068
Non Tapped Density	0.57	-	ISO 1068

Appendix B:

ISO cylinder
DSNU-25-250-P-A

Part number: 19227

FESTO



Data sheet

Feature	Value
Maritime classification	See certificate
Stroke	250 mm
Piston diameter	25 mm 25 mm
Piston rod thread	M10x1.25 M10x1.25
Type code	DSNU DSNU
Cushioning	Elastic cushioning rings/pads at both ends Elastic cushioning rings/pads at both ends
Mounting position	Any Any
Conforms to standard	CETOP RP 52 P ISO 6432 CETOP RP 52 P ISO 6432
Piston rod end	External thread
Design	Piston rod Piston Cylinder barrel Piston Piston rod Cylinder barrel

Appendix C:

KⅡ Series

60 W (1/12 HP)

Frame Size: □90 mm (□3.54 in.)

Specifications – Continuous Rating

Product Name		Output Power	Voltage	Frequency	Current	Starting Torque	Rated Torque	Rated Speed	Capacitor	Overheat Protection Device
Terminal Box Type	Lead Wire Type	W (HP)	VAC	Hz	A	mN·m (oz-in.)	mN·m (oz-in.)	r/min	μF	
5IK60UAT2-□A	**5IK60UA-□A**	60 (1/12)	Single-Phase 110	60	1.09	320 (45)	405 (57)	1450	16	TP
			Single-Phase 115		1.09	320 (45)	405 (57)	1450		
5IK60UCT2-□A	**5IK60UC-□A**	60 (1/12)	Single-Phase 220	60	0.53	320 (45)	405 (57)	1450	4.0	
			Single-Phase 230		0.52	320 (45)	405 (57)	1450		

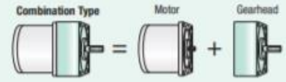
● The values in the table are characteristics for the motor only.

TP: This indicates that there is a built-in thermal protector (automatic return type). If a motor overheats for any reason, the thermal protector is activated and the motor is stopped. When the motor temperature drops, the thermal protector closes and the motor restarts automatically. Be sure to turn the power supply off before inspecting.

Product Line

Combination Type

Motor and gearhead are delivered pre-assembled. The combination of motors and gearheads can be changed and they are also available separately.
In addition, the gearhead can be removed and the assembly position can be changed in 90° increments.



● Combination Type Price includes motor and gearhead.

◇Terminal Box Type

Product Name	Gear Ratio	List Price
5IK60UAT2-□A	**5, 6, 7.5, 9, 12.5, 15, 18**	$245.00
	25, 30, 36, 50, 60, 75, 90, 100	$256.00
	120, 150, 180	$266.00
	250, 300	$300.00
5IK60UCT2-□A	**5, 6, 7.5, 9, 12.5, 15, 18**	$250.00
	25, 30, 36, 50, 60, 75, 90, 100	$261.00
	120, 150, 180	$271.00
	250, 300	$305.00

◇Lead Wire Type

Product Name	Gear Ratio	List Price
5IK60UA-□A	**5, 6, 7.5, 9, 12.5, 15, 18**	$224.00
	25, 30, 36, 50, 60, 75, 90, 100	$235.00
	120, 150, 180	$245.00
	250, 300	$279.00
5IK60UC-□A	**5, 6, 7.5, 9, 12.5, 15, 18**	$228.00
	25, 30, 36, 50, 60, 75, 90, 100	$239.00
	120, 150, 180	$249.00
	250, 300	$283.00

Appendix D:

Material	Density (ρ) kg/m³
Aluminum	2,705
Brass	8,587
Cast Iron	7300
Copper	8,944
Gold	19,320
Iron	7,860
Lead	11,343
Mercury	13,570
Mild Steel	7,850
Platinum	21,425
Silver	10,497
Stainless Steel	7,982
Tin	7,260
Titanium	4,520
Tungsten	19,450
Zinc	7,068

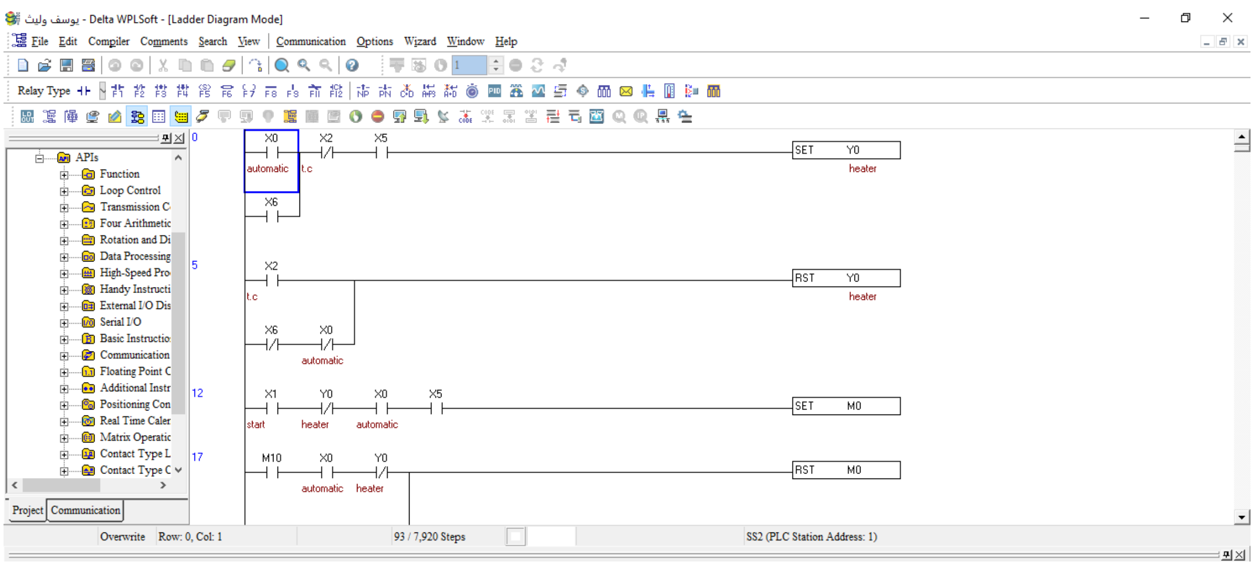
Appendix E:

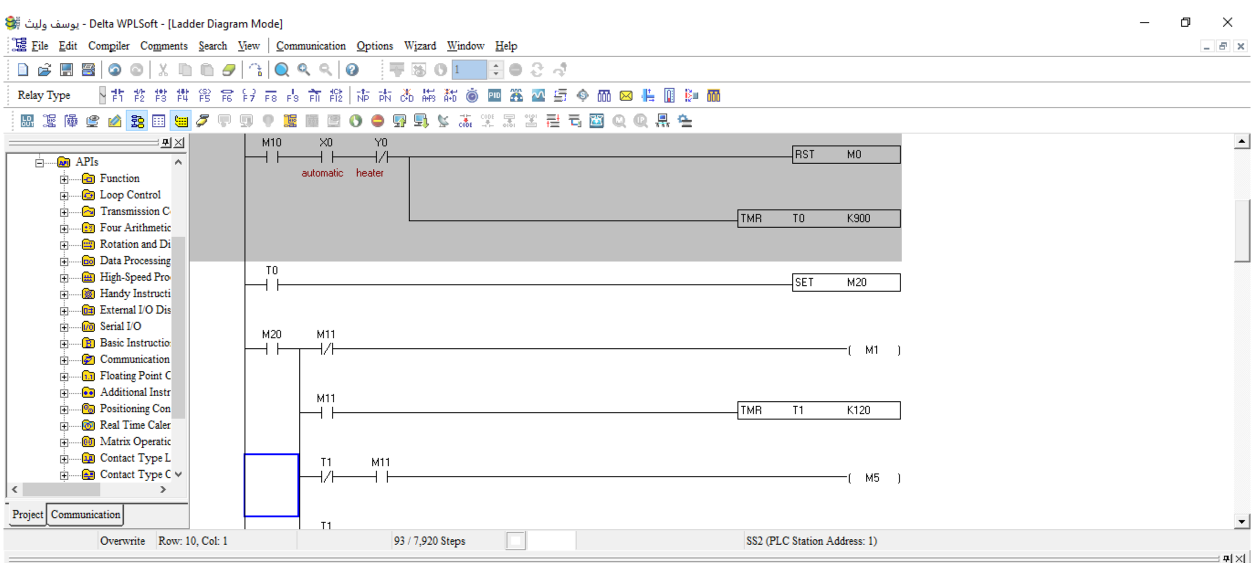
Appendix F:

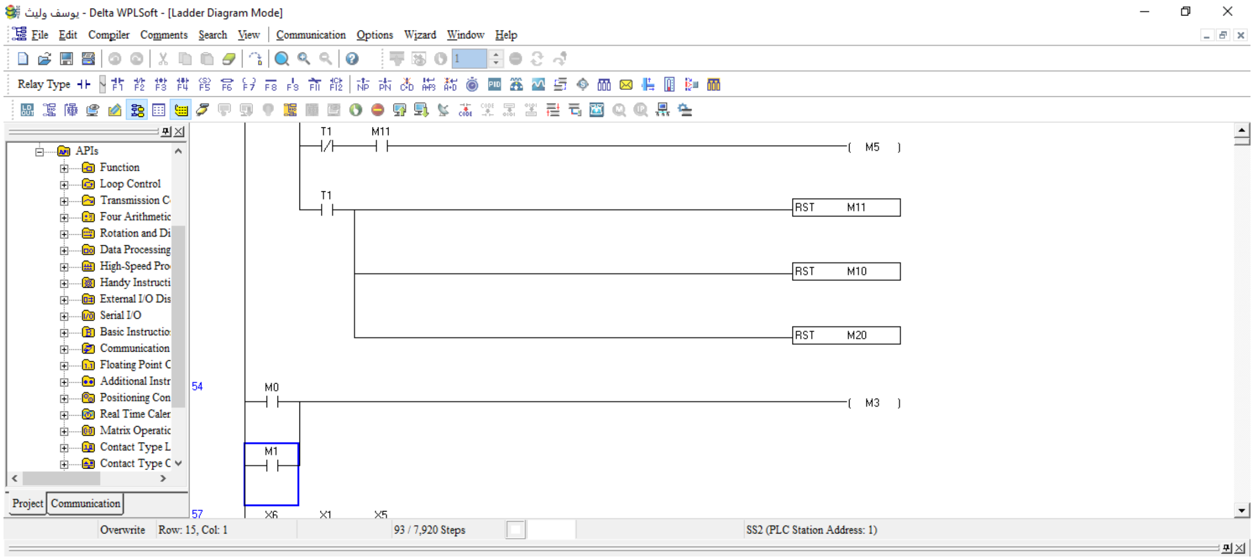
Appendix G:

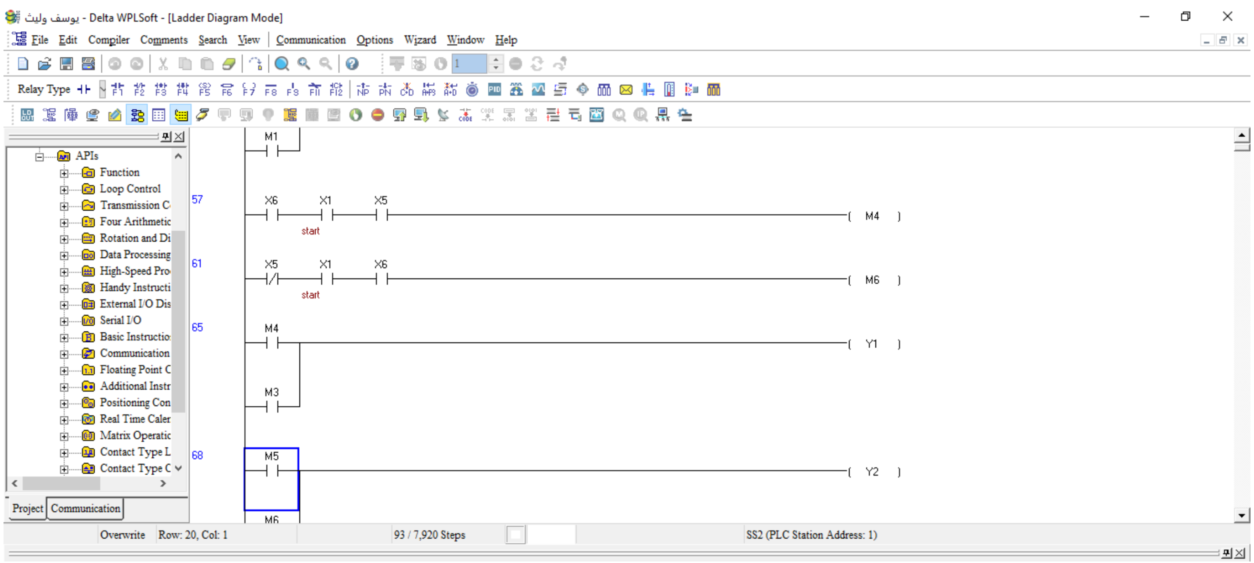
Appendix H:

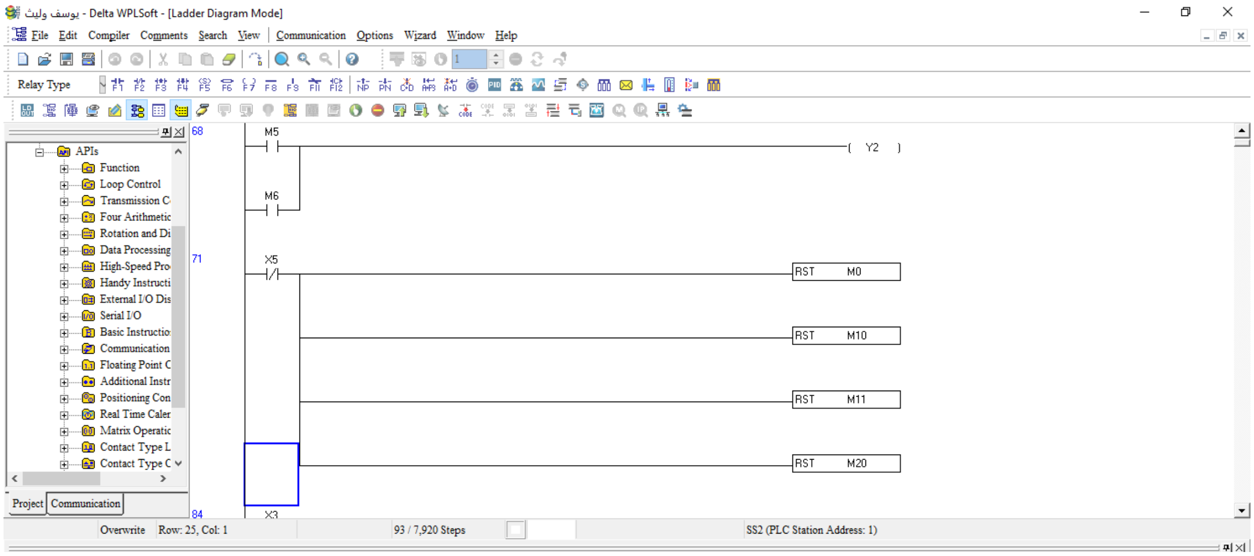
PLC Code

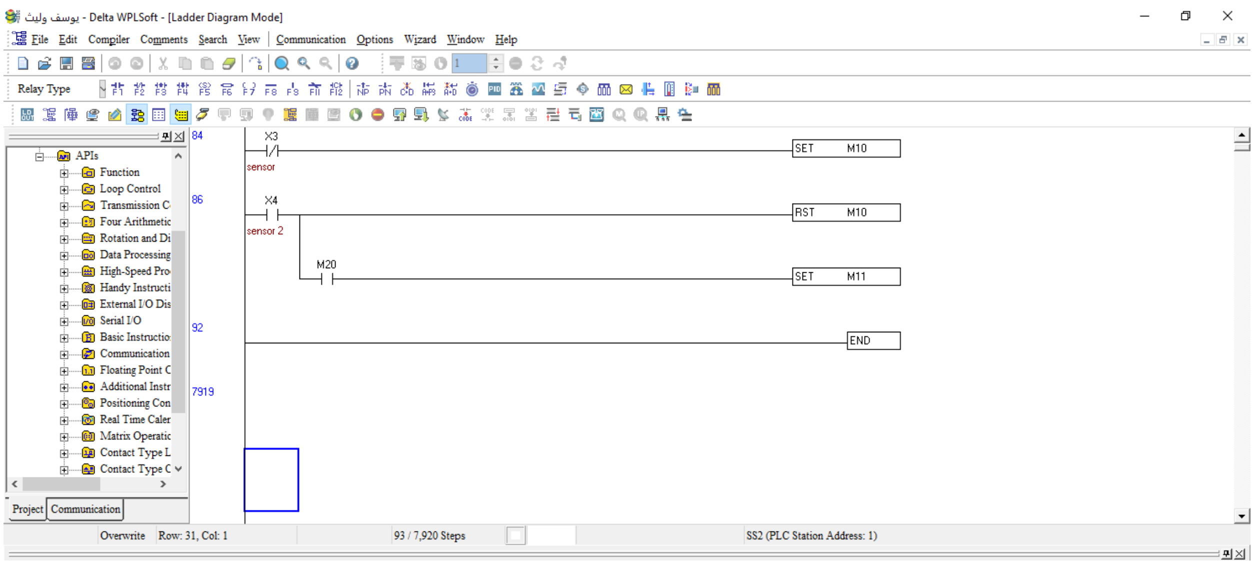





يوسف وليد - Delta WPLSoft - [Ladder Diagram Mode]
T1
M11
M5
RST M11
RST M10
RST M20
54
M0
M3
M1
57
Overwrite
Row: 15, Col: 1
93 / 7,920 Steps
SS2 (PLC Station Address: 1)


يوسف وليد - Delta WPLSoft - [Ladder Diagram Mode]
M1
57
X6 X1 X5
M4
start
61
X5 X1 X6
M6
start
65
M4
Y1
M3
68
M5
Y2
M6
Overwrite
Row: 20, Col: 1
93 / 7,920 Steps
SS2 (PLC Station Address: 1)


يوسف وليث - Delta WPLSoft - [Ladder Diagram Mode]
File Edit Compiler Comments Search View Communication Options Wizard Window Help
68
M5
Y2
M6
71
X5
RST M0
RST M10
RST M11
RST M20
84
X3
Overwrite Row: 25, Col: 1
93 / 7,920 Steps
SS2 (PLC Station Address: 1)


يوسف وليث - Delta WPLSoft - [Ladder Diagram Mode]
File Edit Compiler Comments Search View Communication Options Wizard Window Help
84
X3
sensor
SET M10
86
X4
sensor 2
RST M10
M20
SET M11
92
END
7919
Overwrite Row: 31, Col: 1
93 / 7,920 Steps
SS2 (PLC Station Address: 1)

Appendix I:

Appendix J:

Appendix K: