TECHNICAL UNIVERSITY OF NORTH

FACULTY OF ENGINEERING IN APPLIED SCIENCES

ENGINEERING IN MECHATRONICS

DESIGN AND CONSTRUCTION OF A MACHINE PLANTER OF SEEDS OF TOMATO AND PEPPER IN TRAYS OF 50X28.2 cm IN THE SEEDLING PRODUCTION PROCESS

TECHNICAL REPORT

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2014

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Carlos Andres Acosta Jaramillo

OVERVIEW

This work is part of a research that will demonstrate the utility that presents a seed tray seeder machine, people engaged in farming, in where from sowing seeds are acquired plants already germinated to just be transplanted to the ground getting new plants which grow in proper places and conditions. This machine will save work, effort, and money.

The main objective of this project is automatic planting tomato seeds and pepper in trays of 200 cells is the problem that has been presented and a solution; given to which the implementation of a seeder machine starts with the design and dimensioning of mechanical components and control, such as sensors and actuators.

After making calculations materials were acquired and built each necessary mechanical element, then it was fully assembled the machine and control elements have been implemented.

Carried out the necessary tests found that machine placed the seeds in trays automatically and fast.

I. INTRODUCTION

Nowadays people manually sow seeds using long, human and economic resources. There are also automatic seeding machines of high cost not facilitating their acquisition.

In these circumstances it is going to build a seeder machine of seeds at a moderate cost that allows your purchase helping producers get advantages, which allow the saving of human and economic resources, facilitating their use and suitable employment.

This machine will be of great utility to make agricultural production more efficient, saving money, time and labor.

II. CONTENT

SEEDER MACHINE DESIGN

SUPPLIER OF SUCTION NOZZLES FOR CROP

For the design of the blower it is necessary to specify that the material which is to be built will be aluminum is a lightweight, hard corrosive material very important feature since the basis for the vacuum nozzles will be in direct contact with air and water particles. E supplier of suction is hollow like a flute; also there are holes in the back for the hole in the power vacuum and suction probes.
The technical requirements of the part are displayed in the following table:

Feature	Detail
Long	$280\ [\mathrm{mm}]$
Width	$20\ [\mathrm{mm}]$
High	$50\ [\mathrm{mm}]$
Material	Aluminum

Table 1. Characteristics of the tube for suction of seeds
Source: Author

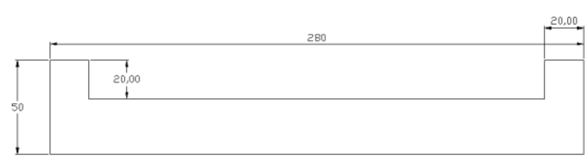


Figure 1. Front suction manifold $[mm]$
Source: Author

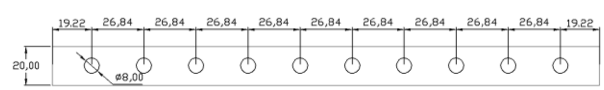


Figure 2. Bottom suction manifold view $[mm]$
Source: Author

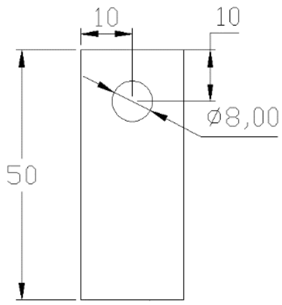


Figure 3 . The right side of the suction manifold$[\mathrm{mm}]$
Source: Author

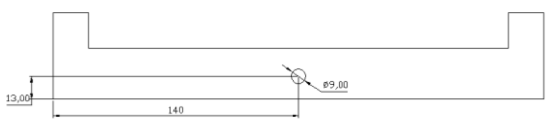


Figure 4. Rear view of the suction manifold$[\mathrm{mm}]$
Source: Author

Certain views of the piece to build, estimated the total size of the specimen to determine the mechanism that will allow the movement of the same and thus act as intended in the seeder machine.
The total volume of suction seed piece is then calculated:

The total theoretical volume of the distributor is:

$$V_{Distribuidor} = 128000\ [mm^3]$$

The distributor of seeds suction is a hollow piece and also has holes in which are placed the tips that suck the seeds, then to the calculated total is subtracted the volume of both of the holes in the piece as of the hollow section of the distributor.

Then, the total volume of the Distributor vacuum is the difference of the total volume already less calculated volumes of the existing holes in the piece.

$$V_{Dist\_Total} = V_{Distribuidor} - V_{orificios\ succión} - V_{orificios\_eje} - V_{orificio\_entrada\ de\ vacío} - V_{hueca}$$

Equation 1. Volume of vacuum real dealer

Where:
V_{Dist_Total} : Total volume of the distributor. $[mm^3]$
$V_{Distribuidor}$: Total theoretical volume of the Distributor. $[mm^3]$
$V_{orificios\ succion}$: Volume of suction holes. $[mm^3]$
$V_{orificios\_eje}$: Volume of the holes in the shaft. $[mm^3]$
$V_{orificio\_entrada\ de\ vacío}$: Volume of the vacuum inlet hole. $[mm^3]$
V_{hueca} : Volume of the hollow section. $[mm^3]$

Then:

$$V_{Dist\_Total} = 128000 - 2501.4931 - 2010.616 - 318.085 - 23758.29$$

$$V_{Dist\_Total} = 99411.51146\ [mm^3]$$

$$V_{Dist_{Total}} = 99.41151\ x\ 10^{-6}\ [m^3]$$

To determine the mass of the suction manifold, multiplies the value of the total size of the specimen by the value of the density of the material which is going to build this piece.
The mass of the distributor of suction is then calculated or vacuum:

$$m_{distribuidor} = \rho_{aluminio} \times V_{Dist\_Total}$$

Equation 2. Mass of the Distributor

Where:
$m_{distribuidor}$: Mass of the distributor. $[Kg]$
$\rho_{aluminio}$: Density of aluminum, the value is: $2698.4\ [Kg/m^3]$

Then:

$$m_{distribuidor} = 2698.4 \times 99.41151\ x\ 10^{-6}$$

$$m_{distribuidor} = 0.268252\ [Kg]$$

The weight that will mobilize the shaft of the Distributor vacuum, shall:

$$P_{distribuidor} = m_{distribuidor} \times Gravedad$$

Equation 3. Weight of the Distributor

Where:
$P_{distribuidor}$: Weight of the distributor. $[N]$

$Gravedad$: Gravitational interaction, the value is: 9.81 $[m/s^2]$
Then:

$$P_{distribuidor} = 0.268252 \times 9.81$$
$$P_{distribuidor} = 2.631552\ [N]$$

SUCTION NOZZLES

Suction nozzles (see figure 5) will be designed of aluminum for a lightweight material which is also a material that hardly is corroded; the vacuum nozzles will be in direct contact with air and water particles. These nozzles will be threaded so that they can be changed; the nozzles on the other side of the thread will also be cone-shaped and at the end will be a hole so that it only allows us to hold a seed.

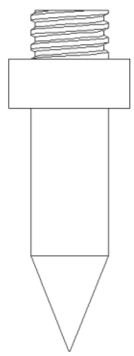


Figure 5. Suction nozzle
Source: Author

Technical requirements of the piece for the construction:

Feature	Detail
Diameter	8 [mm]
Knurled diameter	12.5 [mm]
High	35 [mm]
Material	Aluminum

Table 2. Features base nozzle
Source: Author

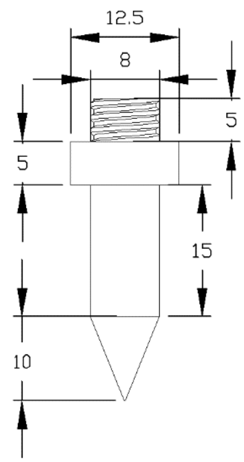


Figure 6. Suction in mm nozzle
Source: Author

For ease of calculation of the mass of the suction nozzles, each nozzle is separated into four areas (see Figure 7), each area with its respective volume, then add their volumes and multiplying by the density of the aluminum to find the mass of the nozzle.

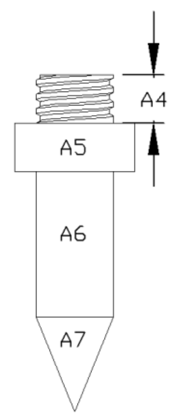


Figure 7. Areas of the suction nozzle
Source: Author

$$V_{Boquilla} = V_4 + V_5 + V_6 + V_7 - V_{hueco}$$
Equation 4. Total volume of the suction nozzle

Where:
$V_{Boquilla}$: Volume of the nozzle. $[mm^3]$

Then:

$$V_{Boquilla} = 251.327 + 613.59 + 753.98 + 167.55 - 6.8722$$
$$V_{Boquilla} = 1779.5748\ [mm^3]$$

We changed the units of $[mm^3]$ to $[m^3]$

$$V_{Boquilla} = 1.7795748\ x\ 10^{-6}\ [m^3]$$

Suction nozzles that make up the suction part of the machine are ten, therefore the volume obtained from the nozzle is multiplied by ten is suction.

Then:

$$V_{Boquillas} = V_{Boquilla}\ \times\ 10$$

Equation 5. Volume of suction nozzles

Where:

$V_{Boquillas}$: Volume of the nozzles. $[m^3]$

Then:

$$V_{Boquillas} = 1.7795748\ x\ 10^{-6}\ \times\ 10$$

$$V_{Boquillas} = 1.7795748\ x\ 10^{-5}\ [m]^3$$

To determine the mass of the nozzles, multiplies the value of the volume of the nozzles by the value of the density of the material which is going to build this piece.

The mass of the suction nozzles is then calculated:

$$m_{Boquillas} = \rho_{aluminio}\ \times\ V_{Boquillas}$$

Equation 6. Mass of the nozzles

Where:

$m_{Boquillas}$: Mass of the nozzles. $[Kg]$

$\rho_{aluminio}$: Density of aluminum. $[Kg/m^3]$

Then:

$$m_{Boquillas} = 2698.4\ \times\ 1.7864486\ x\ 10^{-5}$$

$$m_{Boquillas} = 0.048020046\ [Kg]$$

Then, the weight of the jets, will be:

$$P_{Boquillas} = m_{Boquillas}\ \times\ Gravedad$$

Equation 7. Weight of nozzles

Where:

$P_{Boquillas}$: Weight of the nozzles. $[N]$

$Gravedad$: Gravitational interaction, the value is: 9.81 $[m/s^2]$

Then:

$$P_{Boquillas} = 0.048020046\ \times\ 9.81$$

$$P_{Boquillas} = 0.471076651\ [N]$$

THE DISTRIBUTOR SHAFT AND NOZZLES

The shaft of the Distributor and nozzles is a load-resistant steel and is also resistant to corrosion; to contribute with the environment is used a recyclable printer axis, this axis is of thick. The movement of the shaft is held using a DC servomotor.

Feature	Detail
Diameter	$8\ [\mathrm{mm}]$
Long	$310\ [\mathrm{mm}]$
Material	Chrome-plated steel

Table 3. Characteristics of the shaft

Source: Author

$$P_{total} = P_{Boquillas} + P_{distribuidor}$$

Equation 8. Total weight of dispenser and nozzles

Where:

P_{total}: Total weight. $[N]$

Then:

$$P_{total} = 0.471076651\ + 2.631552$$

$$P_{total} = 0.471076651\ + 2.631552$$

$$P_{total} = 3.102628651\ [N]$$

To turn the shaft need a motor, calculations for the selection of the motor are shown in the following equation.

$$T_{motor} = F\ \times\ D$$

Equation 9. Engine torque

Where:

T_{motor}: Torque of the engine. $[Nm]$

F: Force applied on the shaft. $[N]$

D: Distance from Center shaft to the end tip of suction. $[m]$

Then

$$T_{motor} = 3.102628651 \times 0.07$$
$$T_{motor} = 0.217184 \; [Nm]$$

By precision turning needed is essential to use a servo motor, it is also readily available in our midst. Previous calculations the next operator is of 4.8 $[Kg\ cm]$ o 0.47 $[Nm]$.

Below are shown diagrams of cuts and moments of the forces acting on the shaft, the force that supports the axis is the weight of the suction manifold and nozzles with a torque that makes the engine of 0.47 $[Nm]$.

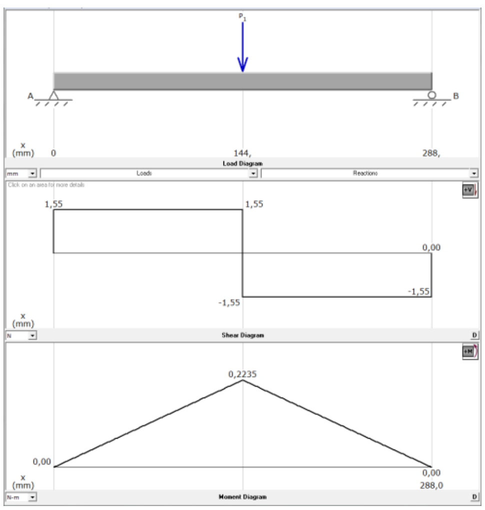


Figure 8. Diagram of cuts and moments of shaft
Source: MDSolids 3.5

Then the calculations necessary to determine the apparent diameter of the shaft are carried out:

$$\sigma_x = \frac{32\ M}{\pi \times d^3}$$

Equation 10. Normal effort exerted on the shaft

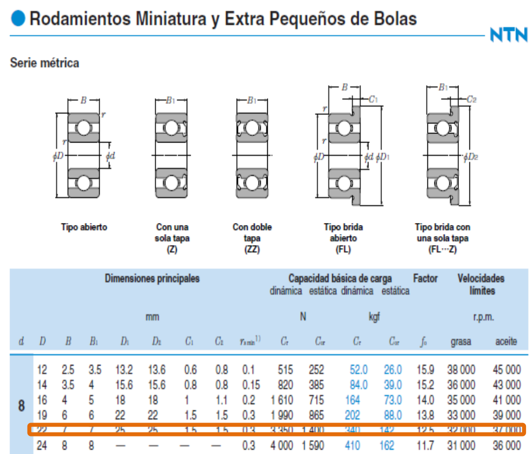
Where:
σ_x : Normal effort. $[Pa]$
M : Maximum moment exerted on the shaft. $[N-m]$
d : The diameter value to find. $[mm]$

With the value of the effort of von mises, clears the value of and as a result has the following value of the diameter:

$$d^6 = \frac{22.3719}{\sigma'^2}$$

$$d^6 = \frac{22.3719}{1.521 * 10^{16}}$$
$$d = 0.003372 \; [m]$$
$$d = 3.372289 \; [mm]$$

Shaft bearings are selected with reference to the following figure:



	Dimensiones principales								Capacidad básica de carga				Factor	Velocidades límites	
									dinámica	estática	dinámica	estática			
	mm								N		kgf			r.p.m.	
d	D	B	B1	D1	D2	C1	C2	rs min 1)	Cr	Cor	Cr	Cor	fo	grasa	aceite
8	12	2.5	3.5	13.2	13.6	0.6	0.8	0.1	515	252	52.0	26.0	15.9	38 000	45 000
	14	3.5	4	15.6	15.6	0.8	0.8	0.15	820	385	84.0	39.0	15.2	36 000	43 000
	16	4	5	18	18	1	1.1	0.2	1 610	715	164	73.0	14.0	35 000	41 000
	19	6	6	22	22	1.5	1.5	0.3	1 990	865	202	88.0	13.8	33 000	39 000
	22	7	7	25	25	1.5	1.5	0.3	3 350	1 400	340	142	12.5	32 000	37 000
	24	8	8	—	—	—	—	0.3	4 000	1 590	410	162	11.7	31 000	36 000

Figure 9. Diameters of bearings
Source: (NTN, 2009)

As the axis selected to perform the function of movement of the biting of seeds is a printer which is now disused; the shaft is of 8 $[mm]$ diameter and according to the characteristics presented in Figure 9 selected axis has the following main characteristics, which are represented in the following table:

Features	Data
Ball bearing	Open type
Inside diameter	8 mm
Outside diameter	22 mm
Width	7 mm

Table 2.4 Characteristics of bearings bearing
Source: (NTN, 2009)

BASE OF SEEDS

For the design of the base of seeds is referred to the magnitude of the radio which is obtained from the shaft to the ends of the nozzles of suction (Figure 10.), this value allows you to find the precise distance for suction nozzles to move freely in the tray containing the seeds and thus suction probes to absorb better seeds.
The material of which it is to be built will be the basis of seeds is galvanized tol since it is a material highly resistant to corrosion, main feature of selection since the base of the seeds will be usually in direct contact with air pressure and presence of water particles.

Technical requirements of the piece for the construction in the following table:

Feature	Detail
Long	280 [mm]
Width	100 [mm]
High	50 [mm]
Material	Galvanized tol
Thickness	1.27 [mm]

Table 2.5 Technical characteristics of the base of the seeds
Source: Author

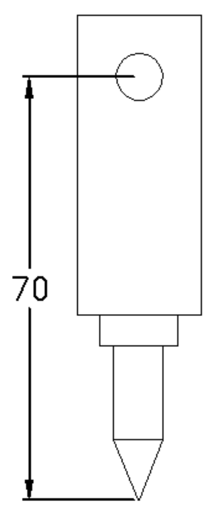


Figure 10. Radio seed base in $[mm]$
Source: Author

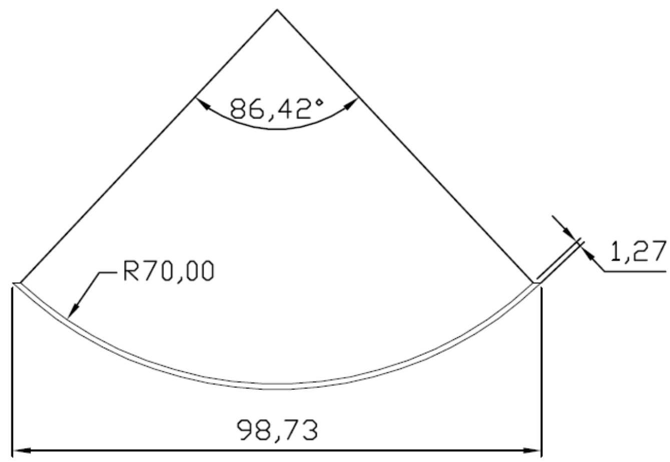


Figure 11. Radius of arc of the basis of seeds in $[mm]$
Source: Author

Here are the calculations necessary to determine the dimensions of base seeds:

$$L = \frac{2\,\pi\,r\,\alpha}{360°}$$

Equation 11. Arc length of the base of seeds

Where:
L : The arc length. $[mm]$
r : Radius of the arc. $[mm]$
α : Angle of the arc. [°]

Then:

$$L = \frac{2\,\pi\,(70)(86.42°)}{360°}$$
$$L = 105.581947\ [mm]$$

The side brackets on the base of the seeds are shown below:

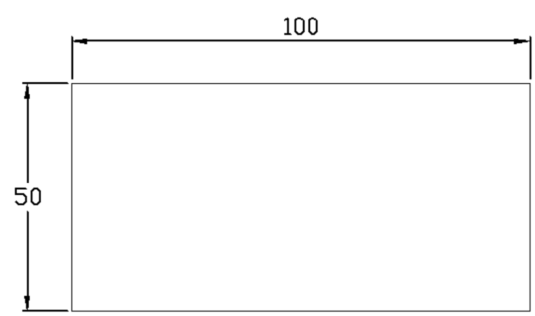


Figure 12. Left and right side bracket at the base of the seeds in $[mm]$
Source: Author

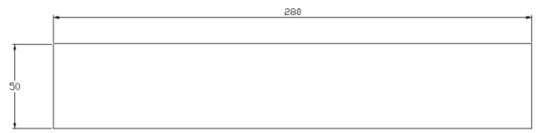


Figure 13. Front support from the base of the seeds in$[mm]$
Source: Author

The distributor of seeds will allow seeds to fall directly into each tray cells already dosed safely and accurately, is built of tol black like most of machine elements since its role within the process of seeding does not make that the distributor has a direct contact with the seeds, soil or water which can subsequently corrode the material.

The design of the distributor of seeds is below with their respective elements:

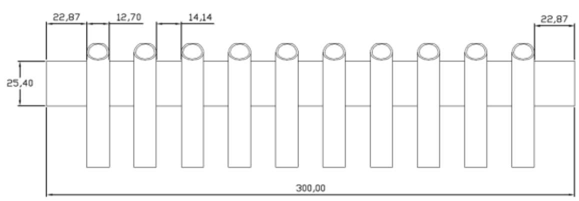


Figure 14. Distributor of seeds in $[mm]$
Source: Author

Based on seeds and the distributor of these are shown below:

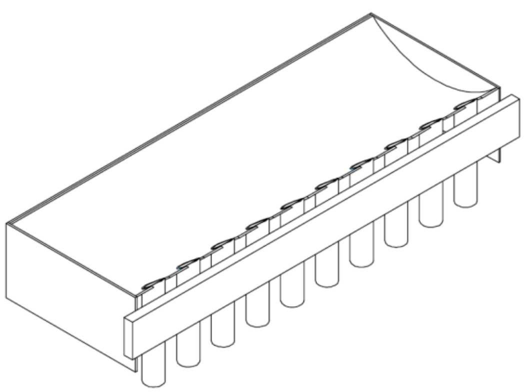


Figure 15. Base and distributor of seeds
Source: Author

SUPPORTING STRUCTURE OF SCATTERED ELEMENTS

Seeding elements supporting structure is designed referring to the conveyor belt support structure and standards for the construction of profiles, which is why DIPAC profiles catalogs are used.

The material of the supporting structure is the black tol, same structure of conveyor belt material.

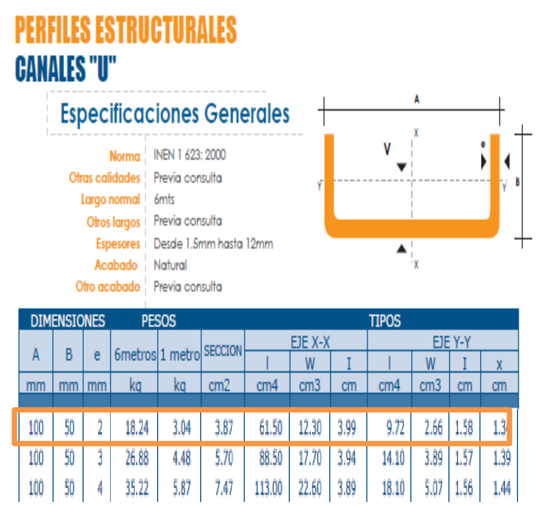
To build the structure of support of seeding elements listed below, the following table, the technical requirements of the piece:

Feature	Detail
High	$200\ [\mathrm{mm}]$
Long	$100\ [\mathrm{mm}]$
Width	$50\ [\mathrm{mm}]$
Thickness	$2\ [\mathrm{mm}]$
Material	Black tol

Table 5. Technical characteristics of the structure of seeder machine stand
Source: Author

SELECTION OF STRUCTURE

The following figure shows the different types of dimensions of "U" shaped channels used for the construction of the structure of support both seeder machine and conveyor belt:



DIMENSIONES			PESOS			TIPOS						
						EJE X-X			EJE Y-Y			
A	B	e	6metros	1 metro	SECCION	I	W	I	I	W	I	x
mm	mm	mm	kg	kg	cm2	cm4	cm3	cm	cm4	cm3	cm	cm
100	50	2	18.24	3.04	3.87	61.50	12.30	3.99	9.72	2.66	1.58	1.3
100	50	3	26.88	4.48	5.70	88.50	17.70	3.94	14.10	3.89	1.57	1.39
100	50	4	35.22	5.87	7.47	113.00	22.60	3.89	18.10	5.07	1.56	1.44

Figure 16. Types of dimensions of "U" shaped channels
Source: (DIPAC, 2014)

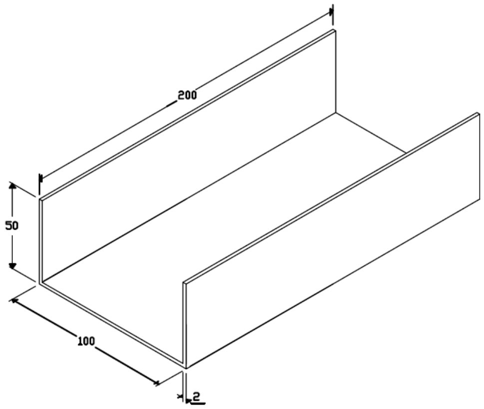


Figure 17. Structure for the sower of seeds in $[mm]$
Source: Author

PNEUMATIC ELEMENTS WHICH CONSTITUTE THE SEEDER MACHINE

VACUUM GENERATOR

To select the required working capacity of a vacuum generator, it is necessary to determine various characteristics of operation in relation to the function that will deliver.
Here is the calculation of the mass of the tomato seed:

$$m_{tomate} = \frac{\pi \times d_{t1} \times d_{t2} \times A_t \times \rho_{semilla\_tomate}}{4}$$

Equation 12. Calculation of the mass of tomato seed
Source: (SCHMALZ, 2014)

Where:
m_{tomate} : Mass of tomato seed. $[kg]$
d_{t1} : Diameter greater than the tomato seed. $[m]$
d_{t2} : Tomato seed diameter. $[m]$
A_t : Width of tomato seed. $[m]$
$\rho_{semilla\_tomate}$: Tomato seed density, its approximate value of: $6153.99\ [kg/m^3]$

The following figure details graphically dimensions of tomato seed, so their diameters greater and lesser as the width of the window:

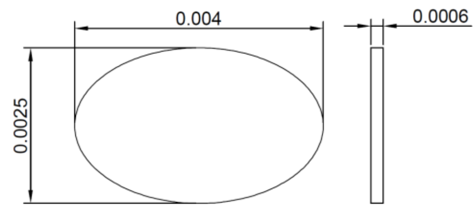


Figure 18. Dimensions of tomato seed in $[m]$
Source: Author

Then the tomato seed mass is as follows:

$$m_{tomate} = \frac{\pi \times 0.004 \times 0.0025 \times 0.0006\, x\, 6153.99}{4}$$

$$m_{tomate} = 0.000029\ [kg]$$

Here is the calculation of the mass of the pepper seeds:

$$m_{pimiento} = \frac{\pi \times d_{P1} \times d_{P2} \times A_P \times \rho_{semilla\_pimiento}}{4}$$

Equation 13. Calculation of the mass of the pepper seed
Source: (SCHMALZ, 2014)

Where:
$m_{pimiento}$: Pepper seed mass. $[kg]$
d_{P1} : Diameter greater than pepper seed. $[m]$
d_{P2} : Diameter smaller pepper seed. $[m]$
A_P : Width of pepper seed. $[m]$
$\rho_{semilla\_pimiento}$: Density of the seed of pepper, approximate value of: $7535.499\ [kg/m^3]$

The following figure details the dimensions of the seed of pepper, greater and lesser diameters and width:

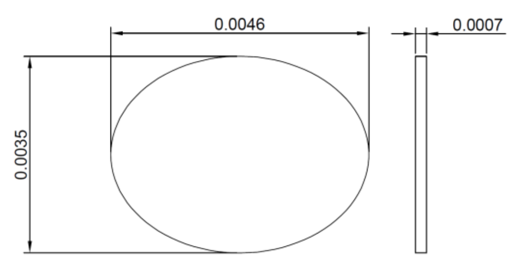


Figure 19. Diameters of pepper seed in $[m]$
Source: Author

Then the value of the pepper seed mass is:

$$m_{pimiento} = \frac{\pi \times 0.0046 \times 0.0035 \times 0.0007 \times 7535.499}{4}$$

$$m_{pimiento} = 0.0000667\ [kg]$$

Calculated the mass of seeds the holding force of the tips of suction, force that will allow to know if probes built to suck the seeds play well its role can be determined.

Theoretical suction probes retention force is then calculated:

$$F_{TH} = m \times (g + a) \times S$$

Equation 14. Suction probes theoretical holding force

Source: (SCHMALZ, 2014)

Where:

F_{TH} : Theoretical holding force. $[N]$

m : Mass. $[kg]$

g : Acceleration or gravity, equivalent to $[9.81\ m/s^2]$

a : Acceleration of the installation. $[m/s^2]$

S : Safety factor

To determine the strength of theoretical retention of the tomato, then it is necessary to give values to the acceleration of installation as the factor of safety, the given values are as follows:

$$a = 5\ [m/s^2]$$
$$S = 2$$

The theoretical force for the suction of the tomato seed is as follows:

$$F_{TH\_tomate} = m_{tomate} \times (g + a) \times S$$
$$F_{TH\_tomate} = 0.000029 \times (9.81 + 5) \times 2$$
$$F_{TH\_tomate} = 0.00085898\ [N]$$

The theoretical force for the suction of the seed of pepper is as follows:

$$F_{TH\_pimiento} = m_{pimiento} \times (g + a) \times S$$
$$F_{TH\_pimiento} = 0.0000667 \times (9.81 + 5) \times 2$$
$$F_{TH\_pimiento} = 0.00197565\ [N]$$

The suction force required to suck the seeds can be determined with the aid of the value obtained from the retaining strength.

Below is the calculation of the force of aspiration of the seeds:

$$F_S = F_{TH}/n$$

Equation 15. Suction force

Source: (SCHMALZ, 2014)

Where:

F_S : Suction force. $[N]$

F_{TH} : Theoretical holding force. $[N]$

n : Number of sucker.

Then the tomato seed suction force is as follows:

$$F_{S\_tomate} = F_{TH\_tomate}/n$$
$$n = 10$$
$$\rightarrow \textit{because they are ten tips suction}$$
$$F_{S\_tomate} = 0.00085898\ /10$$
$$F_{S\_tomate} = 0.000085898\ [N]$$

Then the pepper seeds suction force is as follows:

$$F_{S\_pimiento} = F_{TH\_pimiento}/n$$
$$n = 10$$
$$\rightarrow \textit{because they are ten tips suction}$$
$$F_{S\_pimiento} = 0.00197565\ /10$$
$$F_{S\_pimiento} = 0.000197565\ [N]$$

To define the vacuum generator that will be used to suck the seeds, it is necessary to determine the ability of suction of the same according to the distance it will be to find the seeds to be sucked up and mainly to the diameter of the tips of suction that are to be used, in this way can be a generator of vacuum based on existing requirements or needs to perform the function of suction of the seeds.

A table with the technical characteristics of vacuum generator work below is to be used in this project:

A suction cup suction capacity		
∅ Suction Cup	Suction capacity V_s	
$To\ 20\ mm$	$0.17\ m^3/h$	$2.83\ l/min$
$To\ 40\ mm$	$0.35\ m^3/h$	$5.83\ l/min$
$To\ 60\ mm$	$0.5\ m^3/h$	$8.3\ l/min$
$To\ 90\ mm$	$0.75\ m^3/h$	$12.7\ l/min$
$To\ 120\ mm$	$1.0\ m^3/h$	$16.6\ l/min$

Table 6. Suction of the vacuum generator capacity

Source: (CAMOZZI, 2008)

According to the table 6, if the diameter of the suction tips is less than or equal to $20\ [mm]$ then the suction probes aspiration capacity is: $2.83\ l/min$.

Suction capacity value obtained in table 6 is the value of only one suction capacity suction tip, so to determine the total suction capacity is necessary to multiply that value by ten which is the number of points that are to be used.

$$V = n \times V_S$$

Equation 16. Total suction capacity
Source: (SCHMALZ, 2014)

Where:
V : Total suction capacity. $[l/min]$
n : Number of suction suckers.
V_S : Single suction capacity. $[l/min]$

Then the total suction capacity is as follows:

$$V = 10 \times 2.83$$
$$V = 28.3\ [l/min]$$

The following figure shows the behavior of vacuum generators according to the suction capacity and working pressure.

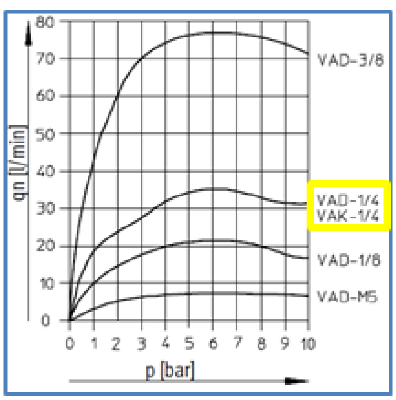


Figure 20. Behavior of generators vacuum VAD and VAK depending on the suction capacity and working pressure
Source: (FESTO, 2014)

With the result of the total suction capacity and the working pressure of 7 bar is to select the vacuum generator which is the VAD-1/4 of the FESTO brand.

Vacuum generator (figure 21) is the main element of the total machine performance enabling you to select a single seed for each end of suction and then deposited it in each one of the cells of the tray in which the seedlings are grown.

The following table lists the performance characteristics of vacuum generator selected:

Features	Data
Ambient and fluid temperature	$-20° C \sim 80° C$
Pressure range	$1.5 \sim 10\ bar$
Vacuum degree	80%
Fluid	Compressed air according to ISO 8573-1:2010 [7:4:4]
Nominal diameter of the nozzle	$1\ mm$
Material	Die-cast aluminium

Table 7. Features of vacuum generator
Source: (FESTO, 2014)

Figure 21. Vacuum generator
Source: (FESTO, 2014)

SELECTION OF THE MAINTENANCE UNIT

The maintenance unit (figure 22) is a very important element when there are pneumatic connections because delivers air lubricated and free of impurities, water particles also regulates the required air pressure which work with pneumatic elements.

The following table shows technical characteristics in the selected maintenance unit:

Features	Description
Operating temperature	$41 - 140\ [°F]$
Maximum pressure	$135\ [PSI]$

Table 8. Features of the maintenance unit
Source: (SNS PNEUMATIC, 2008)

Figure 22. Maintenance unit
Source: (SNS PNEUMATIC, 2008)

ELEMENTS OF THE CONTROL SYSTEM

The automatic system of seeder machine will consist of a conveyor belt, the motor that allows the movement of the conveyor belt, sensors and actuators, the elements of system protection, vibration mechanism and programmers who will control the entire process.

CONVEYOR BELT

The conveyor belt to be used for the realization of seedling production process is PVC since this material allows that trays adhere easily to the band trays to not cause displacement unforeseen in the course of the process of the seeds.

In the figure you can display the shape and color of the conveyor belt to use:

Figure 23. PVC conveyor belt
Source: (2014 REINRA)

The dimensions of the conveyor belt according to the capacity of trays to grow are: $5.4\ [m]$ long and $28\ [cm]$ wide. Therefore the structure for conveyor belt dimensions is: $2.4\ [m]$ long and $28.5\ [cm]$ wide.

In figure 24 shows the shape of the structure for the conveyor belt:

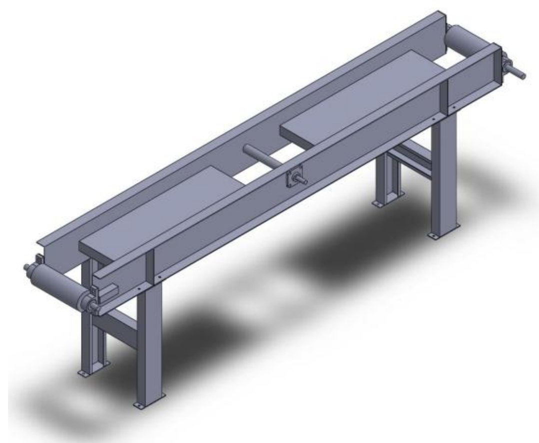


Figure 24. Structure of the conveyor belt
Source: Author

The conveyor belt structure is adopted a model of conveyor belt for the recycling of plastics.

The conveyor belt to be used for the transport of the trays throughout the seeding system is the band thickness Breda B12 CK type of $2.7[mm]$ and green for being an industrial and agricultural process.

The following table details the characteristics of the conveyor belt type Breda B12 CK:

Features	Data
Band type	Breda B12 CK.
Material	PVC.
Color	Green
Special features	Antistatic, resistant to mineral oils and grease and abrasion.
Thickness	$2.7\ [mm]$
Long	$5400\ [mm]$
Width	$280\ [mm]$
Weight	$2.95\ [kg/m^2]$

Table 9. Characteristics of the conveyor belt Breda B12 CK
Source: Bands and bands

MOTOR FOR CONVEYOR BELT

To determine the engine that will mobilize the conveyor belt it is necessary to determine the requirements for its operation.
The initial parameters of operation of the conveyor belt are the distance from the conveyor belt, which covers approximately $4\,trays$ throughout its length.

Table 9 gets the weight of conveyor belt, which is used in the calculation of the power of the engine the same as that listed below:

$$\mathrm{HP} = \frac{(\mathrm{W}+\mathrm{w})(\mathrm{f})(\mathrm{s})}{33000}$$

Equation 17. Calculation of the power of the engine

Where:
HP : Engine power. $[HP]$
W : Pthat load. $[lb]$
w : Weight of band. $[lb]$
f : Coefficient of friction.
s : Speed. $[ft/min]$

$$\mathrm{HP} = \frac{(50+0.0049)(0.4)(6)}{33000}$$

$$\mathrm{HP} = 0.00363672\ [\mathrm{HP}]$$

The gear ratio is:

$$4.8872\ \left[\frac{rev}{min}\right]$$

Then, the torque that will be working the motor is:

$$T = \frac{63000\ HP}{n}$$

Equation 18. Calculation of the torque of the motor

Where:
T : Torque of the motor. $[Nm]$
n : Transmission ratio. $[rpm]$

$$T = \frac{63000 \times (0.00363672)}{4.8872}$$

$$T = 46.88\ [lb \cdot in]$$
$$T = 5.29\ [N \cdot m]$$

The following table details the technical characteristics that have the selected motor, according to the value of the calculated torque:

Features		Description
Engine type		AC servo motor
Model		SMH80S-0075-30AAK-3LKH
Voltage $[V]$		220
Power range $[W]$		750
Speed range $[rpm]$		3000
Torque $[Nm]$	Nominal	2.39
	Maximum	7.17
	Stop	2.63
Current $[A]$	Nominal	3.9
	Maximum	11.7
	Stop	4.4

Table 10. Characteristics of the actuator
Source: (Kinko, 2013)

Figure 25. Actuator Kinco
Source: (Kinko, 2013)

The selected actuator has a driver that allows controlling the actuator using several configuration commands.

The following table details the technical characteristics that have the driver that allows control of the selected actuator:

Features	Description
Type of driver	Servo driver CD 420
Voltage $[VAC]$	220
Elements of the driver	Power supply for the control of 24 $[VDC]$
Features	**Description**
Elements of the driver	7 digital inputs
	Pulse signal input
	2 analog inputs
	4 current outputs $100\ [mA]$
	Digital outputs of $24\ [V] y\ 100 [mA]$
	Brake control outputs
	The encoder input/output

Table 11. Selection of motor for conveyor belt
Source: (Kinko, 2013)

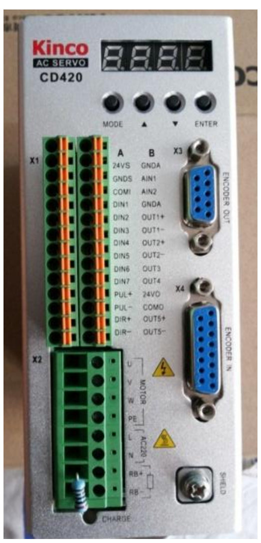


Figure 26. Servo-driver
Source: (Kinko, 2013)

SENSORS AND ACTUATORS

Sensors and actuators will be used in the seeding process are detailed in the following table:

Sensor	Quantity	Use
End of career	1	Detection of presence of the sown trays
Actuators	Quantity	Use
Solenoid valve	1	Activation of the vacuum generators
Actuator	1	Activation of the mechanism of seed suction
DC motors	2	Activation of the eccentric Motors (vibrators)

Table 12. Selection of sensors and actuators
Source: Author

END OF CAREER

Limit sensor will allow detecting if the tray is located in the exact position just below the seeder to absorb the seed and then exactly release seeds in the cells of the tray.
Below are the following table limit sensor specifications:

Features	Description
Material	Resin, plastic and metal
Head	Lever with roll
Contact settings	1 NC + 1 NO
Amperage/voltage	$5\ [A]\ -\ 110\ [VAC]$
	$0.4\ [A]\ -\ 115\ [VDC]$

Table 13. Final career characteristics
Source: Camsco

Figure 27. End of career
Source: Camsco

SOLENOID VALVE

The solenoid valve to be used in the process of the seeds will allow activation of the vacuum generator at the moment in that tray position under the planter to initiate the process of seeding, limit switch which activate the solenoid valve to suck the seeds and place them in the tray.
The following table details the technical characteristics of the solenoid valve to be used:

Features	Description
Type of valve	$5/2$
Operation voltage	$24\ [VDC]$
Operating pressure	$1.5 \sim 8\ [bar]$
Power	$3\ [W]$
Degree of protection	IP65
Port size	$1/4$ "

Table 14. Characteristics of the solenoid valve
Source: (SNS)

Figure 28. Electrovalve 5/2
Source: (SNS)

ACTUATOR

Selected a direct current servo motor by the precision needed in the movement of the nozzles at your destination in addition this actuator is easily accessible in our midst.
DC servomotor is shown in the following figure:

Figure 29. Servo HITEC HS-485HB
Source: (Servocity, 2014)

The following table shows the characteristics of the HITEC servo's $4.8\ [Kg\ cm]$ selected to move the seeder machine nozzles:

Feature	Description
Control system	+ pulse width of $1500\ [\mu sec]$ neutral
Required pulse	$3 - 5\ [VDC]$ peak-to-peak square wave
Operating speed $(4.8V)$	$0.22 sec/60°$ without load
Operating speed $(6.0V)$	$0.18 sec/60\ °$ without load
Torque $(4.8V)$	$4.8\ [kg\ cm]$
Maximum torque $(6.0V)$	$6\ [kg\ cm]$
Current consumption $(4.8V)$	$160\ [mA]$ no load operation
Current consumption $(6.0V)$	$180 [mA]$ no load operation
Width of dead band	$8\ [\mu sec]$
Engine type	3 Pole ferrite Motor

Table 15. Characteristics of the servo motor
Source: (Servocity, 2014)

DC MOTORS

Two motors selected dc and it transformed them into eccentric engines to generate a small vibration in the base of the seeds, vibration will help distribute the seeds evenly so that they can be absorbed easily.

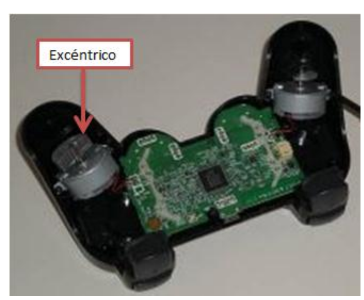


Figure 30. Engines eccentric lever Play Station
Source: Author

Figure 31. Engines eccentric seeds tray
Source: (aliexpress, 2014)

The following table details the characteristics of the selected engines:

Features	Description
Voltage range	$8{\sim}12\ [VDC]$
Speed	$6600\ [rpm]$
Current	$0.786\ [A]$
Torque	$7.27\ [Nm]$
Power	$5.04 [W]$

Table 16. Characteristics of eccentric Motors
Source: (aliexpress, 2014)

PILOT LIGHTS

The following table details the pilot lights to be used with their respective characteristics and their respective function:

LIGHT PILOT	TECHNICAL SPECIFICATIONS	FUNCTION
	$110\ [VAC]$ Color: Red	Indicates that the machine is powered, but it is not working.
	Voltage: $24\ [VDC]$ Current: $20\ [mA]$ Color: Green	Indicates that the machine is operating correctly.
	Voltage: $24\ [VDC]$ Current: $20\ [mA]$ Color: yellow	It indicates that there is some failure in the process which must be reviewed.

Table 17. Control panel pilot lights
Source: Camsco

BUTTONS

The flush type switches are best suited to meet the characteristics of direct interaction of the user with the machine.
The following table details the buttons to be used in the control system:

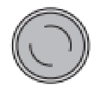
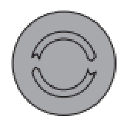
PUSH BUTTON	TECHNICAL SPECIFICATIONS	FUNCTION
	Type: flush Contact: NC  $110\ [VAC]$	Turn off the machine and allows that it is again to be turned on by pressing the power button.
	Type: flush Contact: NO  $24\ [VDC]$	It began operating the machine.
	Type: mushroom Contact: NC  $24\ [VDC]$	Turn off the machine and not allow that this can be activated if before is not unlock the emergency stop.

Table 18. Push buttons for control panel
Source: Camsco

The buttons for the power-machine are flush type with the aim of preventing that by any mistake or rubbing the user enable or disable the machine without any intention.

SELECTION OF DRIVERS

PLC PROGRAMMABLE CONTROLLER

The activation of the solenoid valve for vacuum generator activation is performed via a PLC relay type output.

The following table details the technical features of the PLC LOGO!:

Features	Description
Name of the PLC	LOGO! 12/24RC
Tickets	8 (4 analogue)
Outputs	4 (type relay)
Permissible range	$10.8\ [V]$ ... $28.8\ [V\ DC]$
"0" logical	Max. $5\ [V\ DC]$
logical "1"	Min. $8.5\ [V\ DC]$
Intensity of input	$0.1\ -\ 1.5\ [mA\ ]$

Table 19. Features of the PLC LOGO!
Source: *(Siemens, 2012)*

Figure 32. Programmable controller LOGO!
Source: (Siemens, 2012)

ARDUINO CONTROLLER

To control the movement of a certain angle suction nozzles to another plate was selected as the Arduino mini pro, by its low price and their PWM, PWM outputs these outputs control to DC servomotor.

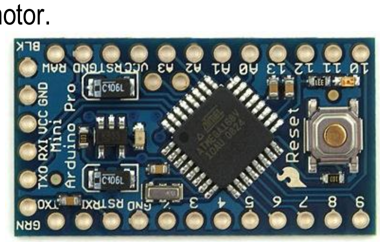


Figure 33. Arduino mini pro
Source: (ARDUINO, 2014)

The following table shows the features of the Arduino mini pro:

Feature	Description
Microcontroller	$ATmega168$
Operating voltage	$5\ [VDC]$
Input voltage	$5-12\ [VDC]$
Digital pin E / S	14 (6 of which have a PWM output)
Analog input pins	6
Maximum intensity by E/S	$40\ [mA]$
Flash memory	$16\ [KB]$
SRAM	$1\ [KB]$
EEPROM	$512\ [byte]$
Clock speed	$16\ [MHz]$

Table 20. Characteristics of the Arduino pro
Source: (ARDUINO, 2014)

To feed the Arduino mini pro was selected a source of $5\ [VDC]$ with an input voltage of $12\ [VDC]$ since using the same source of the vibrators, that source is displayed below:

Figure 34. Power of the Arduino mini pro
Source: (Current-Logic, 2008)

The following table shows the features of the power supply for the Arduino mini pro:

Feature	Description
Input voltage	$12\ [VDC]$
Output voltage	$5\ [VDC]$
Output current	$3\ [A]\ máx$
Power consumption	$5\ [W]$

Table 21. Characteristics of the source of
Source: (Current-Logic, 2008)

CONTROL SYSTEM

FLOWCHART OF THE PLC

When goes over on the conveyor belt tray is detected by the limit switch that is located under the seeder, that sensor emits a signal to the Arduino and this at the same time processing the information obtained and stops the conveyor belt, then activates the tray vibration and suction probes are mobilized by the actuator to the position where the distributor of seeds that allow them on each row of cells of the tray; at the moment in which the vibration is activated, the solenoid valve is also activated and nozzles absorb seeds that will be placed in the tray.

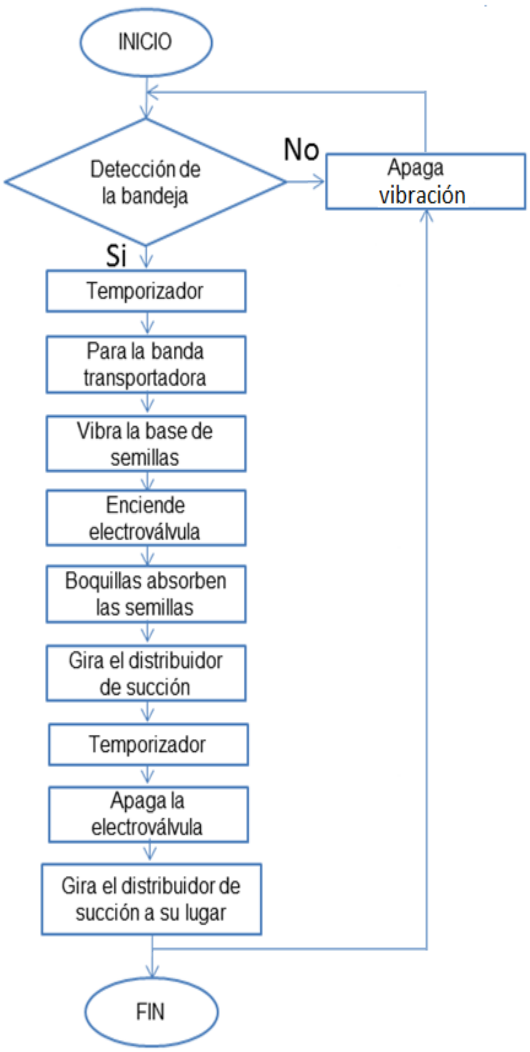


Figure 35. Flowchart of the PLC
Source: Author

TABLE OF VARIABLES

The variables to be used in the program of the PLC and the Arduino are those indicated in the following table:

Address PLC	Name	Symbol	Description
AI4	Input engine	M1	Activation of the vibrators (eccentric engines)
AI8	Input position	P1	Position of the distributor of suction
Arduino address	**Name**	**Symbol**	**Description**
I6	Limit 5	val	Presence of the sown trays
O9	Output Motor	motorpin	Input of the PLC for activation of vibrators
O7	Output position	estado	The PLC input to give the position of the suction manifold
O10	PWM output	myservo	PWM output that controls the actuator to turn the distributor of suction

Table 22. Variables used in PLC and Arduino controllers.
Source: Author

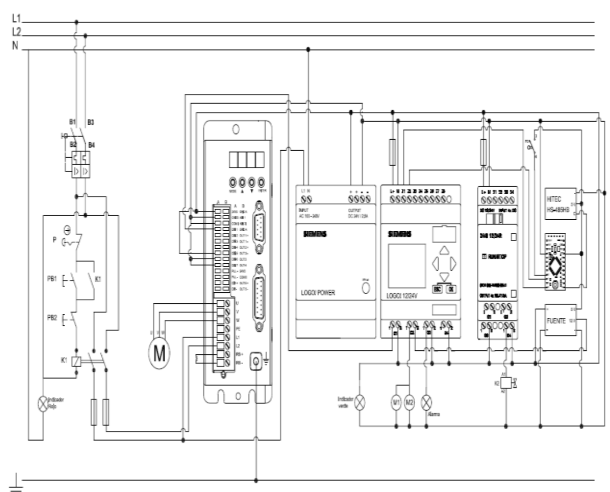


Figure 35. Electrical wiring diagram
Source: Author

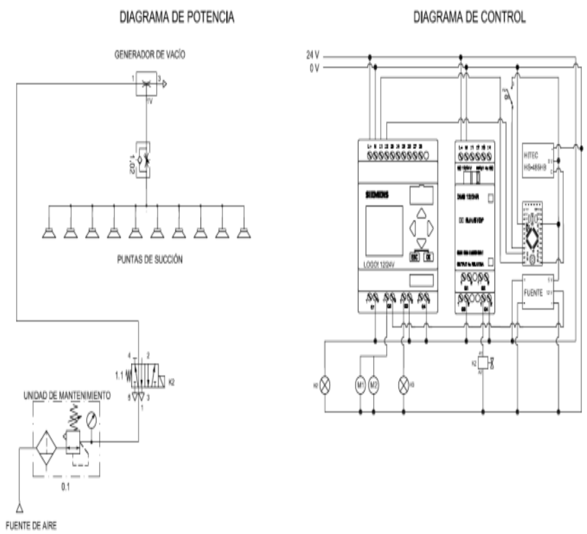


Figure 37. Pneumatic connection diagram
Source: Author

PLC PROGRAM

The PLC was programmed by the activation of the solenoid valve and vibrators engines by receiving the analog signal of the seeder:

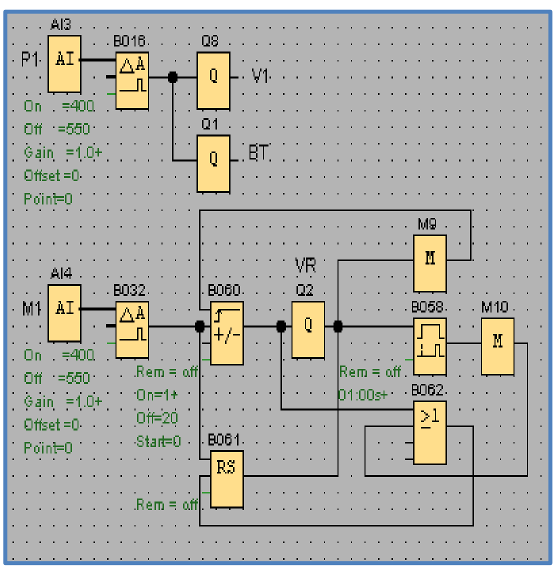


Figure 38. PLC program
Source: Author

THE ARDUINO PROGRAM

```
#include <Servo.h> // Carga la librería para controlar el servomotor
Servo myservo;  // Crea un objeto para controlar al servomotor
int pos = 180;    // Variable para almacenar la posición del servo
int final_de_carrera = 6;  // Asigna el pin 6 a la variable final_de_carrera
int inicial; // Se declara la variable inicial
int vibradores = 7; // Asigna el pin 7 a la variable vibradores
int estado = 9; // Asigna el pin 9 a la variable estado
void setup()
{
 myservo.attach(10); // Asigna el pin 10 para control del servo
 pinMode(final_de_carrera, INPUT); // Variable final_de_carrera como entrada
 pinMode(vibradores,OUTPUT); // Variable vibradores como salida
 pinMode(estado,OUTPUT); // Variable estado como entrada
}
void loop()
{
 myservo.write(pos); //Inicializa servo en la posición dada(pos=180°)
 inicial = digitalRead(final_de_carrera); //Lee estado de final_de_carrera y se asigna a la variable inicial
 digitalWrite(vibradores,LOW); // Apaga vibradores
 if(inicial==HIGH) // Final de carrera estado alto
 {
  delay(50); //Espera  50ms para correcta lectura
  inicial = digitalRead(final_de_carrera); //Lee estado de final_de_carrera y se asigna a la variable inicial
  digitalWrite(vibradores,HIGH); // Prende vibradores
  if(inicial==LOW) // Final de carrera estado bajo
  {
   digitalWrite(estado,HIGH); // Envía estado alto al PLC para prender electroválvula
   delay(1000); // Espera  1000ms para que absorba las semillas
   for(pos = 180; pos >= 129; pos-=1)     // Va de 180 grados  a 129 grados
   {
     myservo.write(pos);           // Dice al servo ir a la posición de la variable pos
   }
   digitalWrite(estado,LOW); // Envía estado bajo al PLC para apagar electroválvula
   digitalWrite(vibradores,LOW); //Apaga vibradores
   delay(1000); // Espera  posición (pos=129°) 1000ms
   for(pos = 129; pos <= 180; pos += 1)  // Va de 129 grados  a 180 grados
   {
     myservo.write(pos);          // Dice al servo ir a la posición de la variable pos
   }

   delay(1000); // Espera  1000ms

  }
 }
}
```

Figure 39. Program the Arduino
Source: Author

IMPLEMENTATION OF THE MACHINE

To represent the activities of implementation of machine technology operations are listed for the elements that are part of the seeder machine, the following table:

Number	Operation
1	Layout
2	Material cutting
3	Bent
4	Cast
5	Grinding
6	Drilling
7	Threaded
8	Turning
9	Roll
10	Soldier
11	At anchor
12	Painted
13	Polished

Table 23. Machining operations
Source: Author

The standard American Society of Mechanical Engineers, American Society of mechanical engineers (ASME) is in charge of normalizing flowcharts of machining symbols, the following table detailed each of the symbols used in the machining of the seeder machine:

Symbology	Interpretation	Description of the activity
○	Operation	It indicates the phases of the process
⇨	Transport	Indicates the movement of material or element from one place to another
▭	Inspection	It indicates the inspection of quality or quantity
▽	End process	Indicates the end of the process

Table 24. Standard the flowchart symbols
Source: *Norm ASME*

Below is each of the flowcharts of the activities carried out for the construction of the seeder machine:

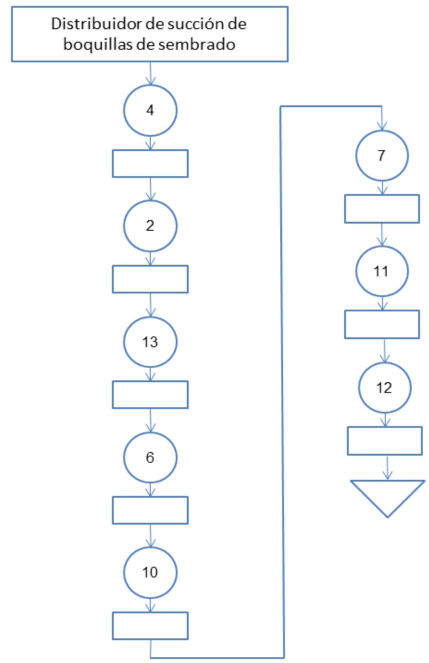


Figure 40. Construction of suction nozzles seeding distributor
Source: Author

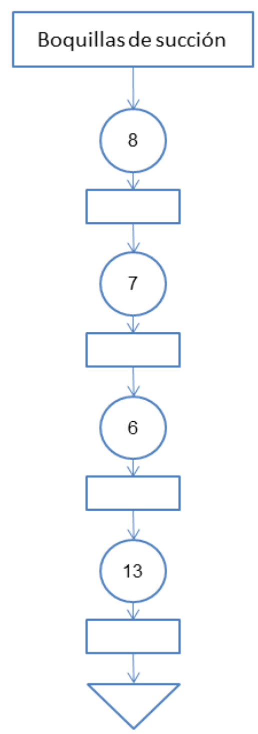


Figure 41. Construction of suction nozzles
Source: Author

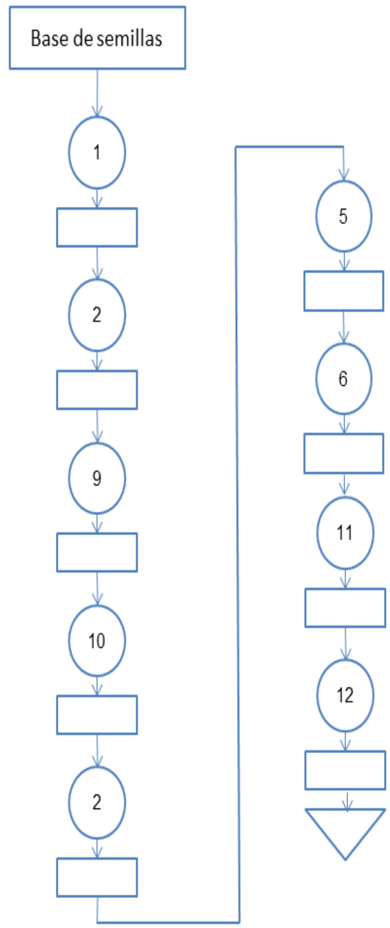


Figure 42. Construction of seed base
Source: Author

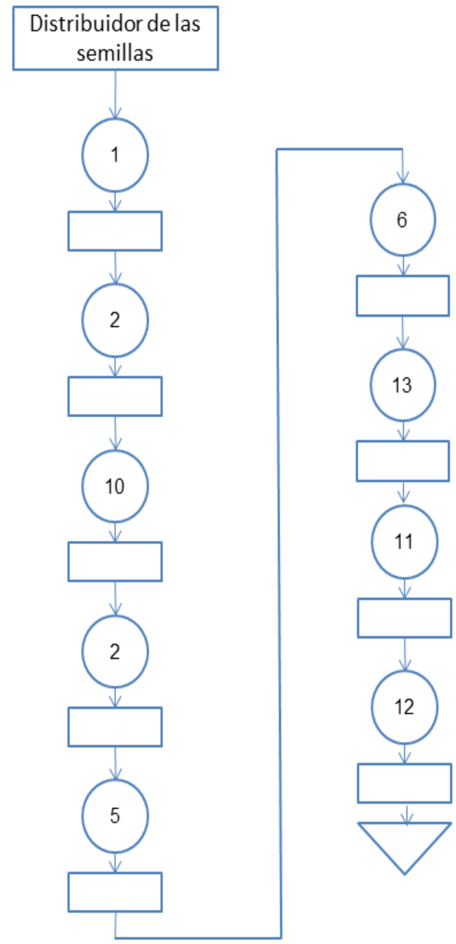


Figure 44. Construction of the distributor of seeds
Source: Author

Figure 43. Base of seeds
Source: Author

Figure 45. Distributor of seeds
Source: Author

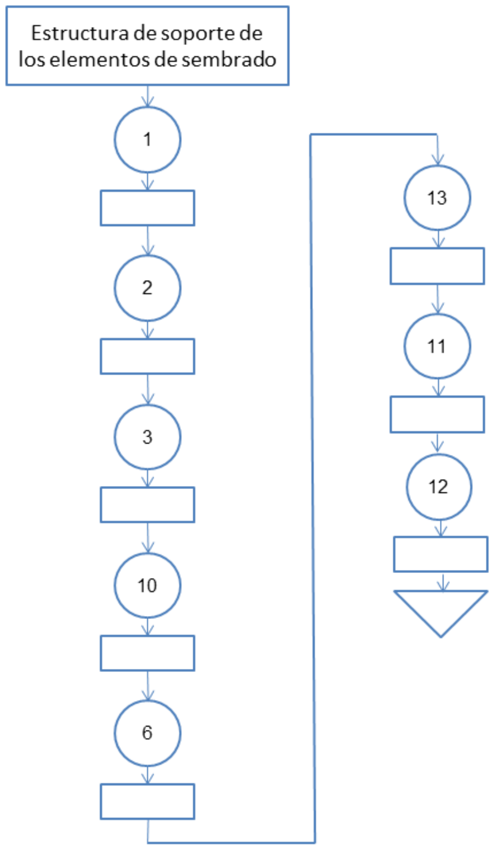


Figure 46. Construction of support of scattered elements
Source: Author

Figure 47. Supporting structure of scattered elements
Source: Author

ASSEMBLING MACHINE

Assembly of the machine details the activities of implementation of items that constitute each of the systems that allow the correct operation of the machine.
The symbolism of the ASME standard is also used to represent the Assembly of the elements that are part of the machine and each one of the activities is represented by a code.
The following table shows the activities of Assembly with its respective code:

Code	Activity
E1	Installation of the conveyor belt structure
E2	Installation of bearings
E3	Installation of conveyor belt rollers
E4	Installation of the conveyor belt
E5	Installation of elements for crop support structure
E6	Installation of seeds
E7	Installation of the distributor of seeds
E8	Installation of the supplier of suction suction nozzles
E9	Installation of shaft bearings
E10	Installation of shaft and suction distributor
E11	Installation of the electronic Board of control and dc servomotor
E12	Installation of AC servomotor.
E13	Control box installation

Table 25. Activities of assembling machine
Source: Author

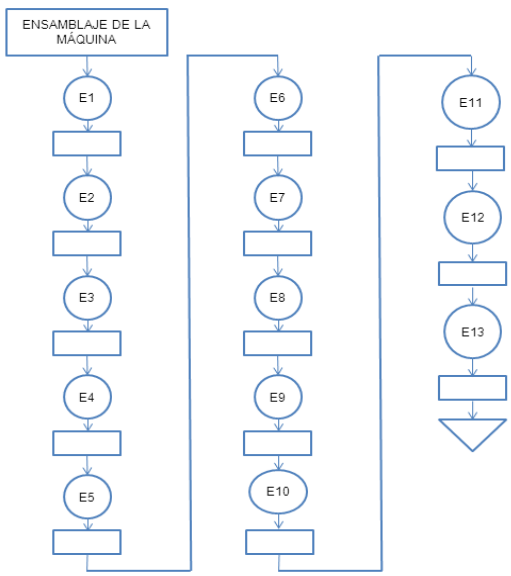


Figure 48. Flowchart of the elements of the machine Assembly
Source: Author

IMPLEMENTATION OF THE MACHINE CONTROL SYSTEM

The following table shows the implementation of the Board of control of the machine which details the activities to be carried out and its code:

Code	Activity
1	Selection of the box
2	Placement of rail
3	Placement of protection elements
4	Placement of the source of the PLC
5	Placement of the PLC
6	Placement of the expansion module
7	Placement of the 12 V supply
8	Placement of terminals
9	Connection of signal elements
10	Connection push-buttons and emergency stop
11	Connection of sensors
12	Connection of actuators
13	Labeling of cables
14	Energization of the elements

Table 26. Construction of the control board activities
Source: Author

IMPLEMENTATION OF THE CONTROL BOARD

The following are activities undertaken in the implementation of the Board of control in the following flowchart:

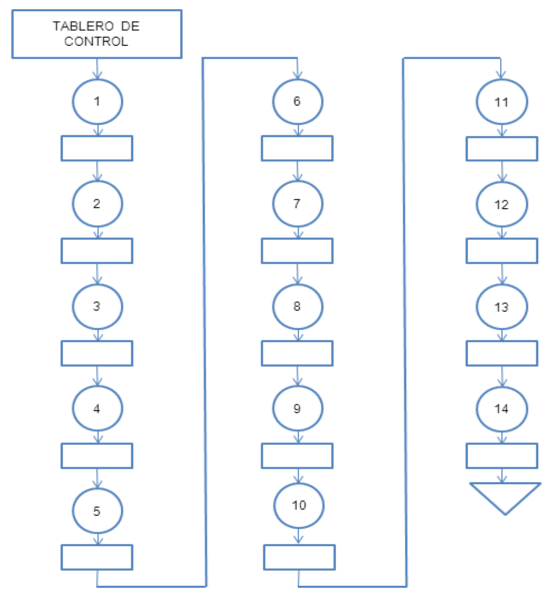


Figure 49 Flowchart of the control Panel Assembly
Source: Author

IMPLEMENTATION OF MACHINE-TIRE SYSTEM

The following table shows the implementation of the elements that compose the pneumatic system of the machine with its respective code.

Code	Activity
1	Solenoid valve placement
2	Vacuum generator placement
3	Placement of the maintenance unit
4	Placement of fittings and silencers
5	Solenoid valve connection
6	Connections of hoses to the pneumatic elements
7	Compressor connection
8	Labeling of cables and hoses

Table 27. Activities of implementation of pneumatic system
Source: Author

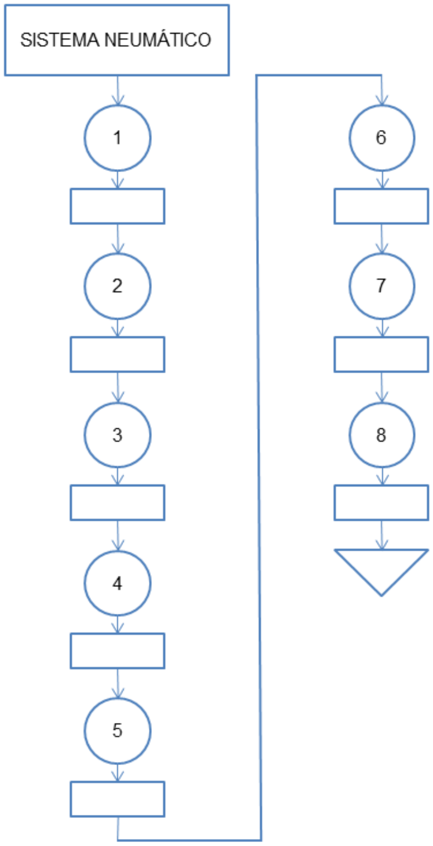


Figure 50. The implementation of the pneumatic system flow diagram
Source: Author

TESTS AND RESULTS

EVIDENCE OF THE MECHANICS OF THE MACHINE STRUCTURE

With respect to the failure of the mechanical structure of the machine are:

- Friction of the conveyor belt with the structure.
- Misalignment of conveyor belt rollers.
- Height of the machine for production of seedlings.
- Loose screws by vibration
- Dirt in the suction nozzles

SEEDING TESTS

Seeding tests several parameters were taken into account, or operating, these main features main features are as follows:

- Operation of the actuator
- Displacement of conveyor belt
- Absorption of seeds
- Sown from seed

OPERATION OF THE ACTUATOR

Velocidad [rpm]	Detección de sensores
1	SI
2	SI
3	SI
4	SI
5	SI
6	NO
7	NO
8	NO
9	NO

Table 28. Testing the speed of the actuator
Source: Author

According to the tests in the table above was obtained a proper speed depending on final race sensors detecting giving a speed of 5$[rpm]$taking into account that all the rows in the tray would be detected.

DISPLACEMENT OF CONVEYOR BELT

For the movement of the conveyor belt it is very necessary to check the leveling since if it is not level the band can out of position by colliding with the walls of the structure in addition to making him force on the actuator, the conveyor belt must be stretched not maximum $[cm]$ because it can break and cause damage to persons.

ABSORPTION OF SEEDS

Table 29 shows adjustment of vacuum flow tests so seeder machine to absorb only a seed, according to the results of the tests the flow control valve to absorb a seed is 50% giving a vacuum of - 0.4 [bar].

Regulación	Presión	Vacío	Semillas Absorbidas
0%	7	0	0
25%	7	-0,2	0
50%	7	-0,4	1
75%	7	-0,6	3
100%	7	-0,8	4

Table 29. Regulation of vacuum flow tests
Source: Author

SOWN FROM SEED

In the following figure shows the production of seedlings planted manual and automatic, the result obtained from auto-seeding is 48%, higher than the manual seeding; also the number of employees was reduced to 50%. Automatic machine used a maximum of two workers for its operation.

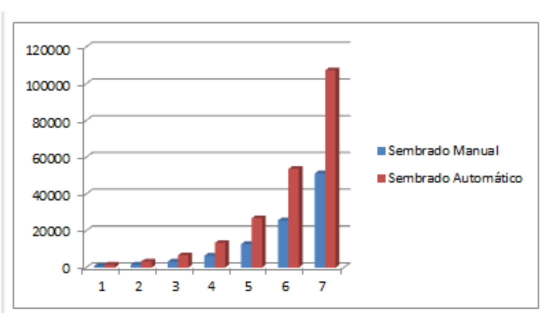


Figure 51 Production of seedlings with a seeded manual and automatic
Source: Author

The following figure shows the times manual and automatic, seeding the result obtained from the seeded automatic is 48%, better than the scattered manual; also the number of employees was reduced to 50%.

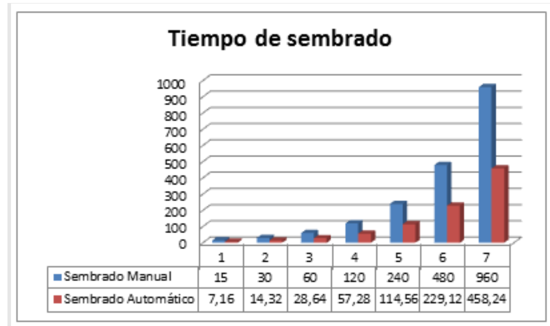


Figure 52 Production of seedlings with a seeded manual and automatic
Source: Author

The seeder machine was protected with acrylic (Figure 53) to prevent dirt from the atmosphere and other factors affecting the performance of the same.

Figure 53. Protection of the seed drill machine acrylic
Source: Author

The following figure shows sown seeds, some tray tray holes there is more than one seed due to different factors such as: seeds are attached, the nozzles absorbed cross-shaped seeds, poor distribution by the vibrator to the seeds, also in some holes not sown because of the following causes: the suction nozzle is covered by some dirt, there was not enough seeds.

Figure 54. Test dotted
Source: Author

With the help of the application of cell Smart Tools could know the noise level produced by the machine planter with a result of 84 dB, according to the World Health Organization (who) the human ear can tolerate 55 decibels without any damage to their health, noise above 60 decibels can cause physical discomfort, so it is recommended the use of earmuffs.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

- With the operation of the machine automatic planter of seeds of tomato and pepper managed to increase production by 48% as set out in the performance tests for such reason was met with the aim of producing more seedlings with automatic machine.

- The implementation of seed planter machine allows to reduce the cost of production on the labor of 4 workers who manually planted 3200 pylons per hour; the machine need two people and 6704 pylons are produced per hour according to performance tests.

- The production time of seedlings with the seeder machine improved dramatically in 48% more than the seeding manual according to performance tests.

- The selected actuator generated short accelerations of the conveyor belt during operation which caused problems at the time of seeding since the speed at which moved trays is altered continuously to others at the time of stop band conveyor for sowing caused an inertia that towards the band back out between $5 \text{ y } 10\ [\mathrm{mm}]$ which was also a problem for the seeding of trays for that reason became mechanized a ratchet that will ensure the engine not back out and continue getting properly.

- According to machine tests established that the vacuum flow to absorb the seeds is of - 0.4 [bar] so that suction probes can absorb only a seed; to increase that value suction probes absorb up to three seeds and to reduce that value suction probes do not maintain suction of seeds and drop them easily.

- According to the machine tests determined height optimal suction of seeds is of $4\ [\mathrm{mm}]$ with this height the vacuum generated in the suction probes allow to reach seeds that are on the tray.

- According to the machine tests determined that automatic machine has a 96% efficiency in the sown seeds in trays.

RECOMMENDATIONS

- Should be implement an automatic dosing of seeds for seeding process.

- A SCADA system can be implemented to monitor and control the production of seedlings, also have a history of production and failure thus improving productivity.

- An automatic process of seed coat should be implemented.

- An automatic process of irrigation can be implemented.

- It is recommended to level the machine before being installed.

- It is recommended before using machine since suction probes may cover seeds of any dirt base should be cleaned.

- It is recommended before using machine check operating pressure that is 7 bars.

- It is recommended before using the machine check that electrical and pneumatic connections are not disconnected.

- Earmuffs are recommended since the machine produces a noise of 84 dB which is harmful to health.

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