

Auto Agriculture Irrigation Tower System Design

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Abstract

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Title of the thesis Auto Agriculture Irrigation Tower System Design		
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Abstract <p>The objective of the thesis was to design integration of the auto irrigation system into the agriculture tower, which contributes to protecting the environment through reducing the consumption of water and fertilizer in the agriculture industry.</p> <p>In general, the thesis focused on two main things: the design and manufacturing of the tower spare parts and the automation system design. The spare parts were drawn with draft, then it was adjusted until the component met requirement for planting space. The 3D-modeling and manufacturing drawing were edited by SOLIDWORKS program to optimize the space for planting and water circulation inside the tower. The automation irrigation system was designed based on the solenoid valve normally closed mechanism which was controlled by a circuit board and drive-by receiving the signal from soil moisture sensor. The research and design were sourced from internet data, books, and articles.</p> <p>The result of the thesis showed the manufacturing method, the material selection of the tower, structure of the agriculture tower and how to combine the agriculture tower with the automation irrigation system.</p>		
Keywords Sensor, Agriculture, Tower, System, Irrigation, Molding		

Contents

1	Introduction.....	1
1.1	The Effect of Agriculture Industry on Natural Environment.....	1
1.2	Aim of study case	1
2	Different moister system and the applying method agriculture	2
2.1	Smart Agricultural Technology.....	2
2.2	Automatic irrigation and fertilization ssystem using a microcontroller with soil moisture sensor and ph sensor	4
2.3	Analysis and Comparison between the Systems	5
3	Manufacturing.....	7
3.1	Material.....	7
3.1.1	Fluoropolymer.....	7
3.1.2	Properties and Application.....	7
3.2	Injection Molding.....	9
3.3	Rotation Molding.....	15
4	Tower Design	19
4.1	General Information and Specification	19
4.2	Rotary motion mechanism	21
4.3	Tank and filter.....	23
4.4	Tower floor	25
4.5	Compost tube, Normal Tube and Cap.....	26
5	Auto Irrigation system	28
5.1	General information about Auto Irrigation system	28
5.1.1	Moisture Sensor	28
5.1.2	Solenoid Valve.....	29
5.1.3	Water Pump Booster: Wilo PB 201 EA	31
5.1.4	IRF 520 MOSFET Driver module.....	32
5.1.5	Arduino Nano.....	33
5.2	Net pipe	35
5.2.1	Major Pipe	36
5.2.2	Minor Pipe	39
5.2.3	Round Soaker Hose	39
6	Conclusion.....	40
	Figures	41
	Table	42

References43

1 Introduction

1.1 The Effect of Agriculture Industry on Natural Environment

Generally, Agricultural industrial emits a lot of the carbon emission and other chemical effluents. Irrigation in agricultural sector is one of largest consumption of fresh water which is about four times the domestic consumption. In addition, chemicals are used in agriculture, which negatively affects environment such as water and soil of certain industrial areas. A study in Japan indicates that the agricultural activity emits various kinds of the chemical effluents which originate from the chemical fertilizers and pesticides and damages source of water and soil such as Kali, Chloride and Sulfate (Nakano et al. 2007.) According to research in Journal of Research in Environmental Health, it demonstrates that agricultural effluents have poor quality and affect river water quality because the amount of Nitrate in agricultural effluents was higher than river water in all stations. Also, it was found that agricultural drains reduce the quality of river water due to traditional paddy cultivation and the use of chemical and organic fertilizers. Moreover, nitrogen and phosphorus as nutrients, if not controlled, will pose a nutritional risk. (Sadeghi et al. 2015.) Therefore, well-designed agriculture tower and irrigation system is potential for an agriculture method which consumes less water and put bio waste into recycling, which can replace chemical fertilizer. As a result, this system is definitely a solution for reducing waste and saving water in agriculture, which is likely to enhance natural environment.

Auto Agriculture Irrigation Tower is the combination between agriculture tower and auto irrigation system. Agriculture tower is a product contributing to optimizing the agriculture area even with small area such as apartment balcony together with recycling bio waste from households. Auto Irrigation system is an automation irrigation method reducing the wasted water with the application of moisture sensor.

1.2 Aim of study case

The auto irrigation system tower is the solution to reduce fertilizer and water in the plant growth process for individual garden and vegetable farm. The system contributes to minimizing the amount of excess water consumption in irrigation process and auto irrigating if necessary without supervision. Design of the tower must be suitable to create a recycle life inside tower, which is similar to habitat of earth worm in order to decompose the bio waste instead of chemical fertilizer. Moreover, design of the tower is solution for the excess water problem, which can collect the excess water to reuse for irrigation. Consequently, the auto irrigation system tower is a new solution to create bio vegetable farm with low cost.

2 Different moister system and the applying method agriculture

2.1 Smart Agricultural Technology

The Automation of soil moisture sensor-based basin irrigation system was a system proposed in 2022, connected wirelessly to the automatic check gate and soil moisture sensors that can be controlled remotely and adjusted based on the ground soil moisture level in real time. A cloud-based system was also tested as a part of the system in loamy soil conditions. The network layout can be observed in figure 1, which demonstrates the dataflow of the system via a central gateway connected to the cloud. (Monalisha Pramanik et al. 2022.)

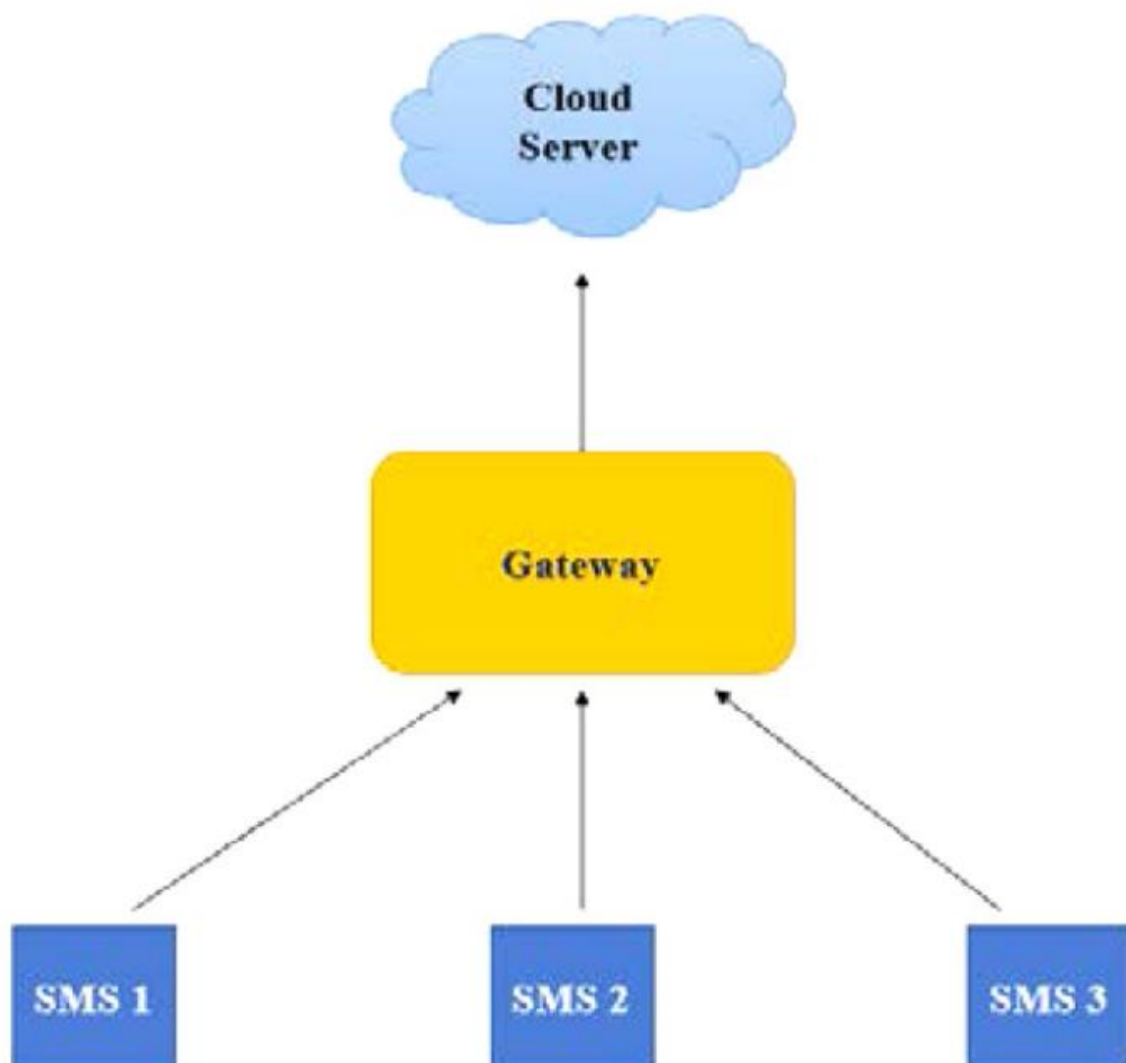


Figure 1. Mock-up of the cloud based IOT wireless system (SMS) (Monalisha Pramanik et al. 2022)

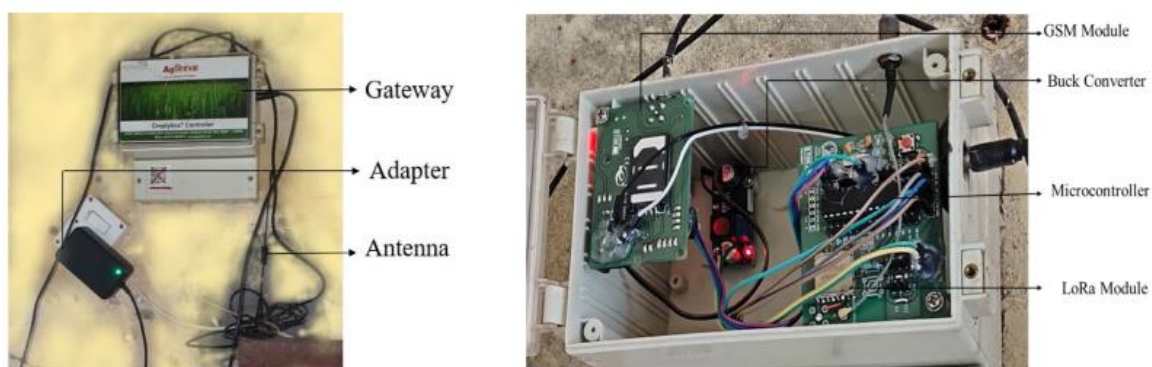


Figure 2. Gateway and its different component (Monalisha Pramanik et al. 2022)

The gateway includes a micro-controller, LoRa module, global system for mobile (GSM) module and buck converter (Figure 2). The LoRa module enables sensors and gateways to communicate wirelessly over long distances via an online wireless connection. The LoRa module sent soil moisture data to the gateway every 3 minutes. To save energy, the system went into periodic sleep mode. The data is also saved on a specialized cloud server and transmitted to the gate via GSM. According to crop condition/demand, users could program the automatic check gate to open at predetermined maximum and minimum soil moisture levels. The prototype basin measures 60 m x 14 m in size, with a slope of 0.0005 m/m. Three capacitance-based SMSs are located at 37.5 cm (1st sensor) 15 cm (second sensor), and 7.5 cm (3rd sensor) soil depths, respectively, at 25%, 50%, and 75% of the field length. A solar-powered automatic-check gate was installed at the field's inlet, connected to an external water supply channel that can control the inflow to the basin layout and enables or stops the water intake on demand. Finally, an ultrasonic flow meter (Model Unidata 6526E) was installed at the entrance to allow for remote flow rate monitoring. (Monalisha Pramanik et al., 2022).

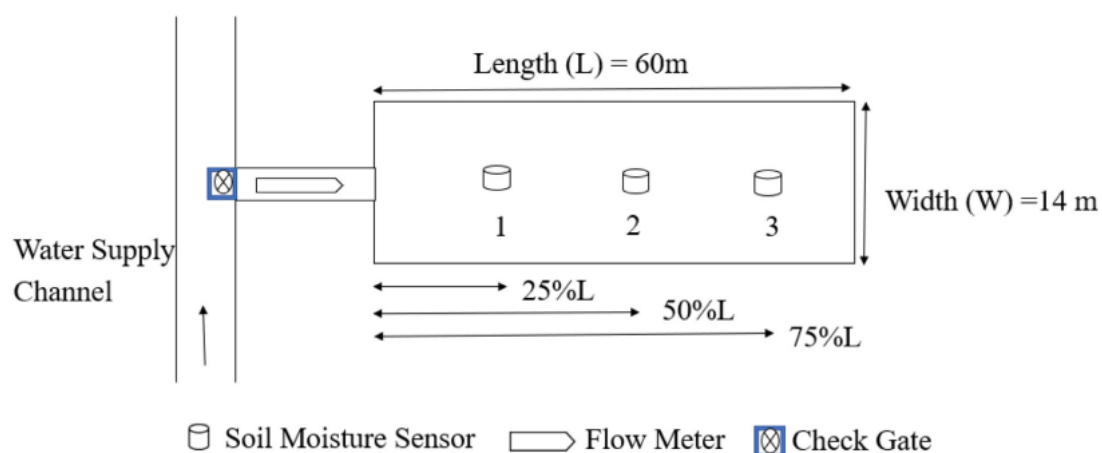


Figure 3. Experimental field layout diagram (Monalisha Pramanik et al. 2022)

2.2 Automatic irrigation and fertilization system using a microcontroller with soil moisture sensor and pH sensor

The system is designed to be responsive to underground water uses, which allows them to keep track of ground moisture levels and preserve water when necessary and control the water consumption rates to prevent excess. Tensionmetric and volumetric techniques are the most fundamental and are used to regulate soil moisture irrigation, however they are tied to a specific soil type's water curve. (R Sruthi et al. 2021.)

The fertility of the soil is a crucial factor in determining its eminence, as it reflects its plant life. The presence of macro- and micronutrients, H₂O levels, pH, and other factors influence soil fertility. Soil nutrients are depleted with each crop and must be replenished. If necessary, fertilizers are supplied into the system to correct for nutritional deficiencies. In the end, farmers prefer to manually adjust the fertilizer level. Maintaining the correct level of fertilizer in the soil is critical because excessive or insufficient fertilizer addition can harm the plant and reduce yield patterns. Despite a variety of pre-programmed systems for planting, weeding, field reaping, and so on, no strategy for retaining soil fertility has been invented or applied. having been in use for some time now. By measuring the amount of nutrients available, the proposed scheme aim to aid in the replenishment of various minerals such as nitrogen, phosphorous, and potassium in the soil composition. Chemical processes use sensors to detect the presence of nutrients and count them. The automated system takes charge of administering regulatory input of fertilizer to balance the system and prevent an excess or deficit of nutrients and minerals. Three different sensors are linked to the Arduino circuit board input : humidity, rain, and pH. Because the circuit board's ADC is an analogue moisture sensor, its digital resistance (0-1023) is converted. Dry soil has the most resilience, whereas moist soil has the lowest. If the soil is dry, the moisture sensor resistance value is high, and if it exceeds the threshold, the system is activated, and a

switch is turned on and off. In contrast, this is true of damp soil. The pH sensor measures the pH of the soil and recommends the right amount of fertilizer. (R Sruthi et al. 2021.)

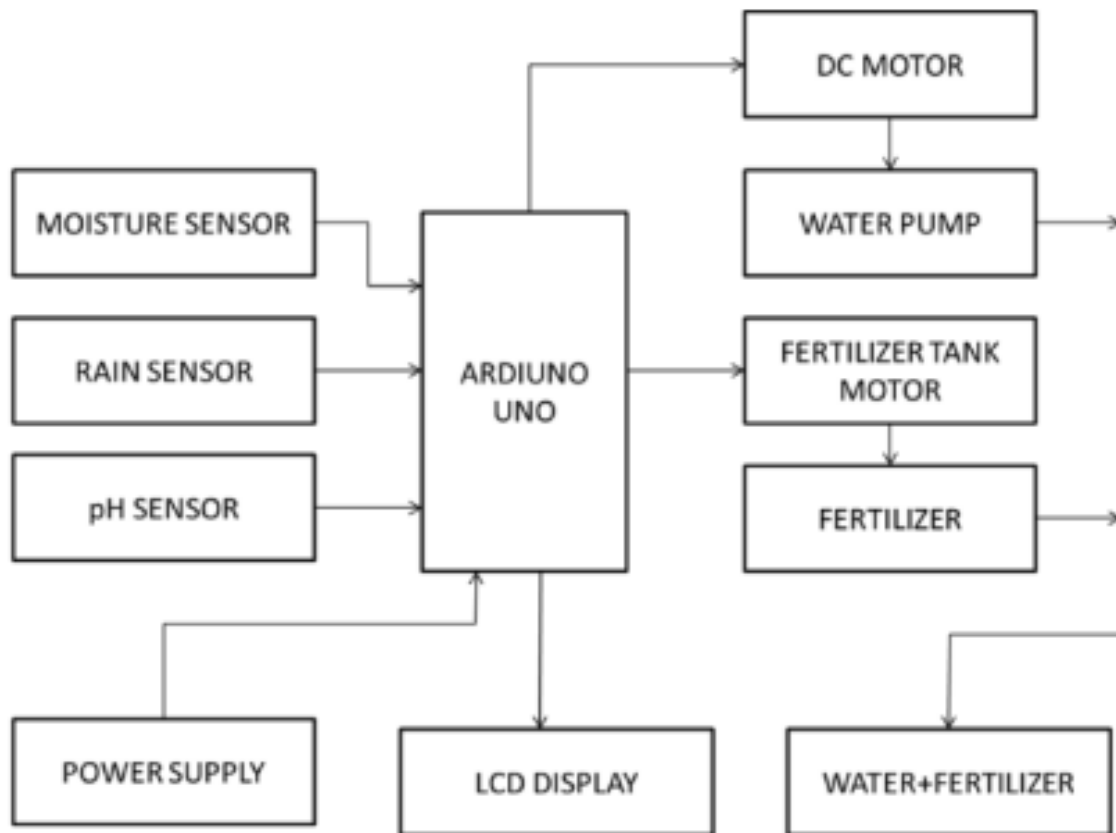


Figure 4. Block Map of the system proposed (R Sruthi et al. 2021)

2.3 Analysis and Comparison between the Systems

The table below shows evaluation criteria of the agriculture system, it is clearly to be seen that the objective of each system is different. In the table, Auto Irrigation Agriculture Tower is an effective solution for vegetable farm by reducing fertilizer in process. Beside that, The system is a sustainable agriculture solution, helping recycle bio waste without effect to the environment. However, Other systems can be applied to a wider range of plants.

- Smart Agricultural (1)
- Automatic irrigation and fertilization system using a microcontroller with soil moisture sensor and ph sensor (2)
- Auto Irrigation Agriculture Tower (3)

Table 1. Comparison of different systems

	(1)	(2)	(3)
Using Fertilizer	N/A	Yes	No Need
Recycle Bio Waste	N/A	N/A	Yes
Water control	Yes	Yes	Yes
Different type of plants	Long term crops, pasture and fodder crops	Almost of agriculture plants	Vegetables, Flower and small garden plants

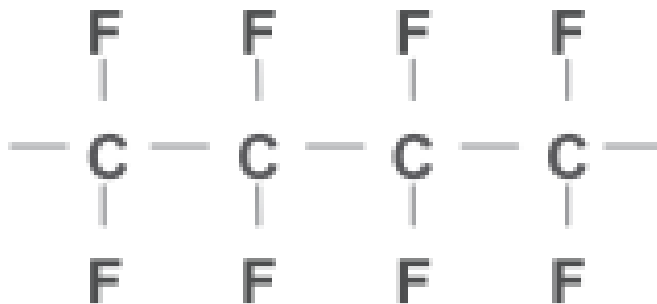
3 Manufacturing

3.1 Material

Overall, due to humidity of the tower operation environment, the material must be anticorrosive. In the case of food industry, the tower carries the weight and exposes to sunshine and organic chemistry so the material must be durable, chemically inert and have high-temperature resistance. Moreover, the manufacturing requires the material to be molding and laminate.

3.1.1 Fluoropolymer

In general, A fluoropolymer or fluoroplastic is traditionally defined as a polymer composed of carbon (C) and fluorine (F). Perfluoropolymers are sometimes used to distinguish them from partly fluorinated polymers, fluoroelastomers, and other polymers that include fluorine in their chemical structure. Fluorosilicones, fluorinated polyimides, and fluoroacrylates, for example, are not commercially referred to as fluoropolymers. Tetrafluoroethylene polym is an example of a linear fluoropolymer:



3.1.2 Properties and Application

Table 2 and table 3 show characteristics of fluoropolymer which meet the requirements mentioned in 3.1. The notable thing is the material selection in the design is a research of concept because the strength analysis after production has not been done and the material selection is preliminary.

Table 2. The Fundamental Properties of Polytetrafluoroethylene (Ebnesajjad & Khaladkar 2017)

<ul style="list-style-type: none">• High melting point (342°C)• High thermal stability• Useful mechanical properties at extremely low and high temperatures• Insolubility• Chemical inertness• Low coefficient of friction• Low dielectric constant/dissipation factor• Low water absorptivity/adsorptivity• Excellent weatherability• Flame resistance• Purity

Table 3. The Useful Attributes of Perfluoropolymers (Ebnesajjad & Khaladkar 2017)

<ul style="list-style-type: none">• Stability• High continuous use temperature• Excellent weatherability• Excellent chemical resistance• Excellent fire properties• Low surface energy• Good release properties• Biological inertness• Low friction• Cryogenic properties• Retains flexibility• Electrical properties• Low dielectric constant• Low dissipation factor

Table 4. Fluoropolymers Applications (Ebnesajjad & Khaladkar 2017)

Industry/Application Area	Key Properties	Typical Uses
Chemical processing	Chemical resistance, good mechanical properties, thermal stability, cryogenic properties	Gaskets, vessel liners; valve, pipe, and fitting liners; T's, bellows, spacer, high-pressure hoses tubing; coatings and fluid handling systems
Electrical and communications	Low dielectric constant, high volume/surface resistivity, high dielectric breakdown voltage, flame resistance, thermal stability	Connectors, insulation of signal and electric wire and cable, coaxial cable, automotive wiring harness and electronic wiring harness, thermocouple wire, multicore instrumentation cable, jacketing, high-temperature automotive and aerospace wire
Automotive and office equipment	Low coefficient of friction, good mechanical properties, cryogenic properties, chemical resistance	Seals and rings in automotive power steering, transmission, and air-conditioning; copier roller and food processing equipment covering
Housewares	Thermal stability, low surface energy, chemical resistance, purity	Domestic and commercial cookware and bakeware coatings
Medical	Low surface energy, purity, excellent mechanical properties, chemical resistance	Cardiovascular grafts, heart patches, mesh grafts for hernia repair, ligament replacement, vent and intravenous infusion membranes, microporous polytetrafluoroethylene tubing for drug dispersion
Architectural fabric	Excellent weatherability, flame resistance, low surface energy	Coated fiberglass fabric for tension and air structures, tents, stadium and airport roofs, exhibition halls, super shopping malls, entertainment complexes

3.2 Injection Molding

Injection molding operates on a simple concept. The polymer-based compound is heated to a liquid form before being subjected to high pressure and molded to form the shape of the final product. As long as the temperature and pressure levels are maintained, the compound will stay viscous within the confines of the mold and can later be cooled down to harden into the final product. The process is straightforward in theory, but in order to maintain the necessary conditions for the injection and molding to take place, heat transmission and pressure flow are vital to maintain the operation of the system. The machine used in which process is known as the injection molding machine and employs the use of a cast mold, otherwise known as a tool or die. (Ebnesajjad 2003.)

Injection molding involves heating a thermoplastic polymer beyond its melting point, at which the viscosity of the substance drops below the solid point and becomes a molten polymer fluid that is much more susceptible to shaping and molding. The liquid compound

is then pumped into a cast mold, which forms the product's shape, thus the namesake injection molding. Due to the inherent low viscosity of the substance itself, it can easily be injected and fill the mold completely as long as it stays liquid. The object within the mold will cool down and solidify as soon as the temperature and pressure are reduced, thus allowing it to be removed from the mold. The chilling process will be taken at a predetermined rate and will be closely monitored so as to regulate the crystallinity of the polymer substance, thus controlling the mechanical properties and appearance of the final product upon its removal from the mold. (Ebnesajjad 2003.)

An injection molding machine is made up of six parts as can be observed from figure 5. The mold, which is constructed of at least two sections to allow ejection (demolding) of the molded part via the separation of the 2 mold halves, is the most significant aspect of the machine. Six phases comprise the injection molding process. Table 5 presents the main functions of each step.

Table 5. Process Steps of Injection Molding (Ebnesajjad 2003)

Steps	Function
1. Beginning of plastification	Screw transports the melt to the reservoir where it is heated
2. End of plastification	The screw is switched off after the reservoir is filled
3. Closing the mold	Clamping unit actuates closure of the mold
4. Beginning of injection	Forward axial motion of the screw starts the flow of the melt into the mold until filled
5. Mold cooling and end of injection	The mold begins to cool and additional melt is injected to compensate for the part shrinkage
6. Ejection of the molded part	The part is ejected and the screw retracts for a new cycle

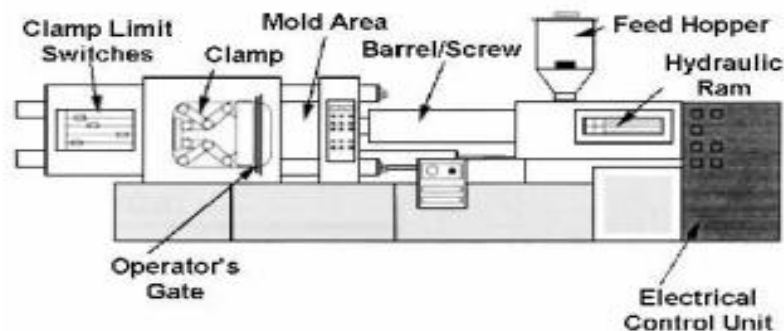


Figure 5. Injection molding machine example (Ebnesajjad 2003)

Fluoropolymer is best suited to injection molding via a screw machine. However, a plunger and ram delivery system will also be possible and can be implemented for the material family. With that on the table, the former still offers more perks which can be summed up in table 6. As can be seen from the illustration, the machine method entails 3 interwoven processes, the perks of which are highlighted below. (Ebnesajjad & Khaladkar 2017.)

Table 6. Advantages of Screw-Type Injection Molding Machine (Ebnesajjad & Khaladkar 2017)

Process	Advantage
Heat transfer	Uniform melt temperature and thorough plastication.
	Higher melt temperature possibility.
	Less thermal degradation.
Mass transfer	Better additives and pigments dispersion in the melt.
Material flow	Shorter hold-up times.
	Less resin stagnation in the barrel.
	Efficient pressure transmission to the melt.
	Efficient mold filling.

Fluoropolymer plastication properties, although fairly similar to other thermoplastics, would entail a number of additional parameters to consider and these considerations should be manifested into the screw design specialized for the family of polymer. Apart from these additional considerations, conventional parameters for injection molding will still be applied as do all cases of thermoplastics. (Ebnesajjad & Khaladkar 2017.)

The plastication process refers to the mixing and melting of the polymer and the additives that aid in the plastication process into a homogeneous blend, which is then pressurized, and fed to the transfer section of the cylinder via the check valve. Plastication will only occur at relatively high temperatures (230°C - 400 °C) depending on the type of the plastic in production and family of material used for the input, with PVDF on the lower end of the spectrum and PFA at its highest end. (Ebnesajjad & Khaladkar 2017.)

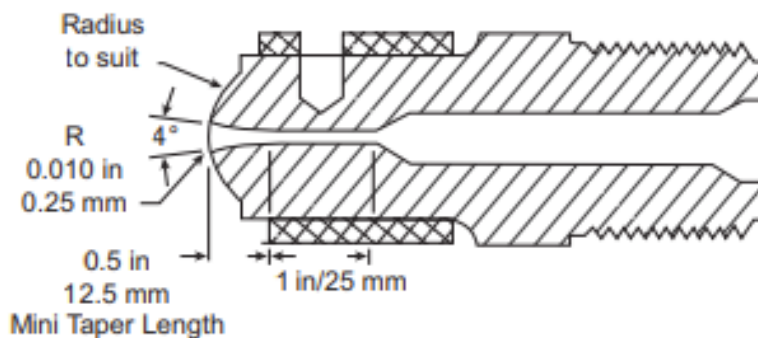


Figure 6. Schematic of a conventional reverse (Ebnesajjad & Khaladkar 2017)

For FEP, PFA, and ETFE, a conventional nozzle with a reverse taper (Figure 6) may be employed. The width of the bore will be a factor influencing the consistency and speed of the melting process and, thus, should be as large as possible so as to ease said process. The length of the sprue should be sufficient so that it may reach far enough into the nozzle (13 - 25 mm) and prevent cold slug development during the plastication process. The sprue removal from the shot can also be aided in part by incorporating a 4-degree angle to the entry point. Meanwhile, the exit point should employ rounded edge nozzle orifices so as to minimize the chance of peening (e.g., with a radius of 0.25 mm) (see "Glossary" for a description). Sensory capability for the nozzle should also be a consideration via built in independent temperature control. Finally, for a smooth material flow throughout the process, the bore and adaptor must be compatible in design, which will also prevent clumping and interruptions in the molten flow. (Ebnesajjad & Khaladkar 2017.)

During the injection process, the melt should not be allowed to return to the cylinder which can be achieved via the use of a nonreturn check ring valve, which can help prevent reverse flow into the injection chamber, as can be seen in figure 7. In order to pack the melt, the ram can be left in the extended position after filling the mold, which will apply pressure to the fluid substance which can maintain a high density for the final product and prevent void and air bubbles that can be caused by a partially filled mold. Mold packing time is defined as the length of time from the moment the mold is injected to the point of the ram's retraction. A smear head can also be employed to prevent overpacking, whereas a smooth polymer flow between the valve and the screw can prevent clumping and material retention in the seams which can be done using a pointed screw tip. (Ebnesajjad & Khaladkar 2017.)

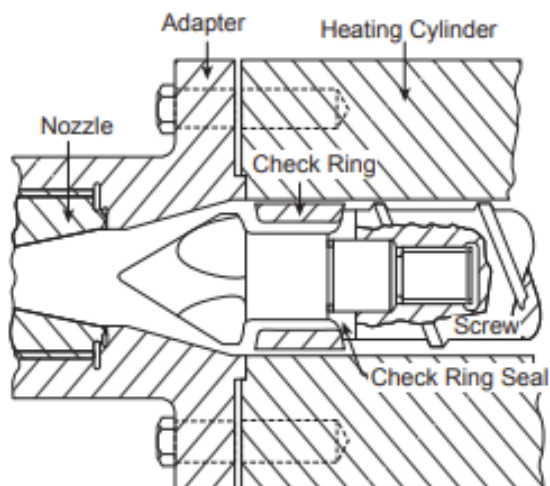


Figure 7. Schematic of a combination of a check (Ebnesajjad & Khaladkar 2017)

A smear head (Figure. 8), an alternative to the check ring valve, employs the use of a tiny opening in the diameter over a substantial length. The design prevents melt backflow as the injection phase is underway. During the retraction process, the screw turns, orienting the flow of material through the tiny annular area. The shear force will increase the temperature of the compound, thus lowering the viscosity of the polymer and allowing for easier mixing as well as a lower overall pressure within the chamber. There are some advantages to pick a smear head over a nonreturn valve, namely, a lower likelihood of overpacking, a lower likelihood of streak formation in the part, and less abrasion due to the lack of metal-to-metal contact. Check ring valves could be required for lower viscosity melts. (Ebnesajjad & Khaladkar 2017.)

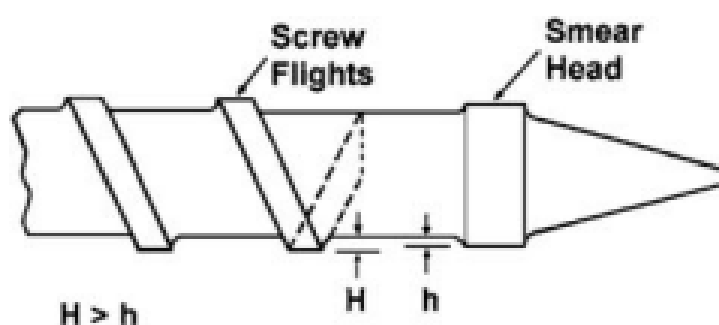


Figure 8. A smear head design (Ebnesajjad & Khaladkar 2017)

Controlling temperature and speed in the plastication unit is critical to manufacturing a high-quality item. Compartmentalization can assist in temperature control, and the cylinder is often divided into three zones. The adapter and the nozzle are controlled via different controllers located at different zones within the cylinder. Processing high-viscosity fluoropolymers requires full range temperature control over a 430°C spectrum, which

equates to a heater output of up to 6.2 W/cm². The hydraulic system is required to deliver a large assortment of uniformed and unanimous ram speeds, from as low as 60 s/shot to very fast. The weight all components, melt density (Figure 11), and clamp tonnage should all be considered when sizing the plastication unit. To mold all fluoropolymers, a tonnage of 69 N/mm² (5 T/in²) should be sufficient. (Ebnesajjad & Khaladkar 2017.)

Table 7. Fluoropolymers' Melt Density (Ebnesajjad & Khaladkar 2017)

Polymer	Melt Density (kg/m ³)
Fluorinated ethylene propylene	1492
Perfluoroalkoxy polymer	1492
Ethylene tetrafluoroethylene	1298
Ethylene chlorotrifluoroethylene	1362
Polyvinylidene fluoride	1740

Corrosion-resistant metals should be used to make mold cavities. A moderate amount of Alkaline solution should be used to cleanse a mold without a protective plating in place. The mold should be de-moisturized and covered in an antioxidant coating to avoid rust during long periods of storage. In order to keep the mold functional for longer use, a smooth, thin (0.01 - 0.03 mm thickness) chrome and nickel plating on the steel should be used. The sprue bushing's diameter should be at least 1.6 mm greater than the main runner's diameter and slightly larger than the nozzle aperture. A standard taper of 4-6 mm/m is a good rule-of-thumb choice. Runner design should be oriented towards minimizing the amount of pressure and heat loss during operation. In order to achieve this, it is advisable to employ the use of full-round runners with a large diameter and minimal length. Another notable contender for ease of machining are trapezoidal runners, which should also be taken into consideration when picking out the right runner specifications. As for the runner-gate connection, the pathway needs to be smooth and clear of all potential hindrance for the runner to pass through. During the molding process, the larger the molded item, the shorter the runner should be and the larger the cross section of said runner should be as a result. For ease of measurement, a 6 mm in diameter runner should be perfectly suited for items up to a thickness of 13 mm. This basically means the runner diameter should correspond to an approximate of 50% to 100% of the thickness of the part being molded, depending on the thickness of the part above 13 mm, with thicker parts veering more towards the 100% thickness to diameter ratio. (Ebnesajjad & Khaladkar 2017.)

3.3 Rotation Molding

Rotating molding (otherwise referred to as rotomolding or rotational casting) is a molding method with a specific purpose of manufacturing hollow plastic components such as cylindrical tanks or containers. The process calls for a thin metal mold to be heated with

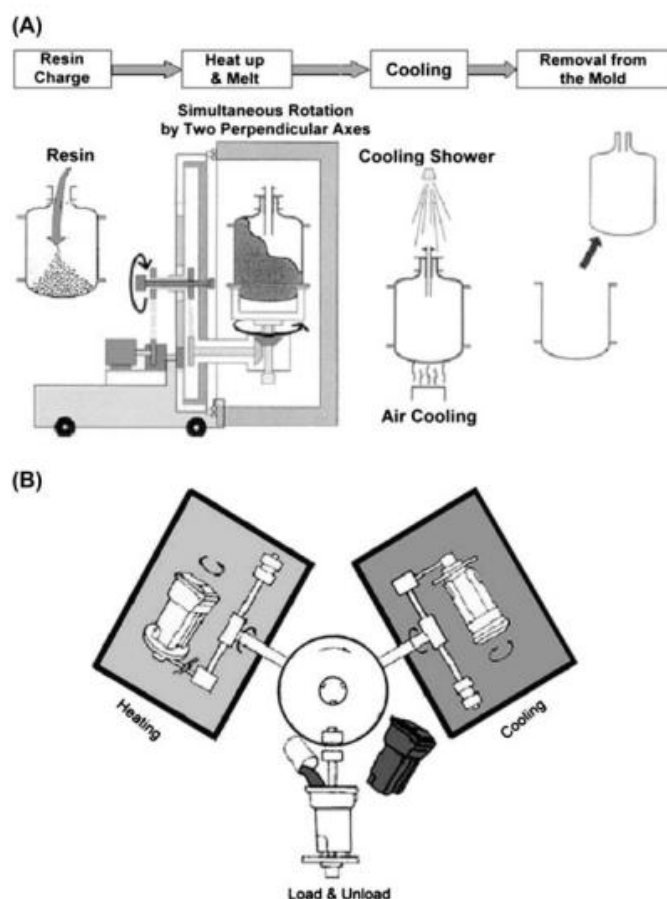


Figure 9. Schematic diagram of rotational molding (Ebnesajjad & Khaladkar 2017)

polymer powder deposited inside of the mold chamber. As temperature rises above polymer's melting point, the aforementioned powder melts and coats the inner walls of the mold. The mold is rotated continuously on its axis throughout the entire heating process, thus equally distributing the melted polymer compound over the mold's walls partly via the centrifugal force of the spinning mold, thus why it is called rotation molding. However, the centrifugal force enacting on the melted compound is lower in this method than other rotational methods, which will be discussed further in the following segments. In the case of fluoroplastics, the mold is then cooled, allowing the portion to solidify and crystallize. Finally, the part is removed, and the process begins a new with another batch of polymer powder. (Ebnesajjad & Khaladkar 2017.)

A wide range of seamless hollow plastic objects are manufactured using rotational molding. Rotolining processing issues are identical to rotomolding with the sole exception of permanent polymer melt sticking to the inner walls of the mold cavity. A predetermined amount of plastic powder, granules, or liquid is charged inside a mold cavity in this procedure. The mold cavity is sealed and heated in a high temperature oven while being turned in multiple directions (usually two axes). A biaxial rotomolding machine is depicted in Figure 10. The primary axis is the centerline of the mold's arm. The mold is rotated perpendicular to the major axis by the minor axis. The minor axis typically circles four times for every one rotation of the major axis. In another arrangement, the molds "rock and roll," rotating 360 degrees about one axis and swaying about a perpendicular axis. In most of these applications, heated air was used a source for this convection heating process. (Ebnesajjad & Khaladkar 2017.)

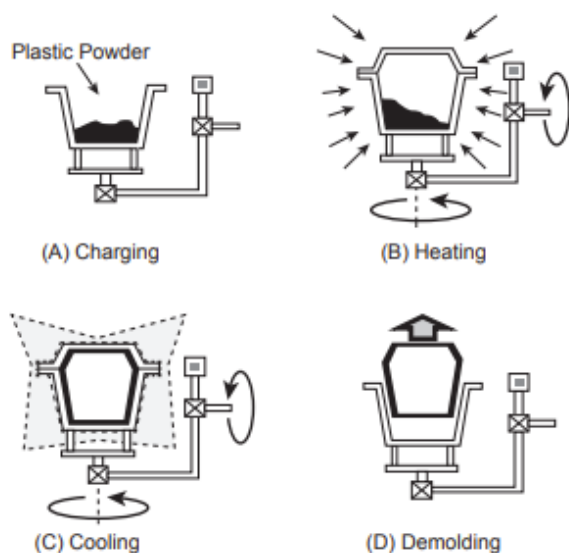


Figure 10. Biaxial rotational molding sample process diagram (Ebnesajjad & Khaladkar 2017)

During the heating process, the heated air in the oven transfers its heat to the polymer powder adhering to the mold's outer and inner walls and melts it (Figure 11). As the mold is rotating, this melt forms an even layer of viscous polymer over the inner walls of the mold. To maintain uniform wall thickness, the mold is cooled while being rotated. After the mold has cooled down to a solid state, the part is then removed from the mold cavity while a vent port is used to remove volatile material formed during the heating process. Throughout the process, the rotation rate, temperature, heating rate, and cooling rate are all controlled. (Ebnesajjad & Khaladkar 2017.)

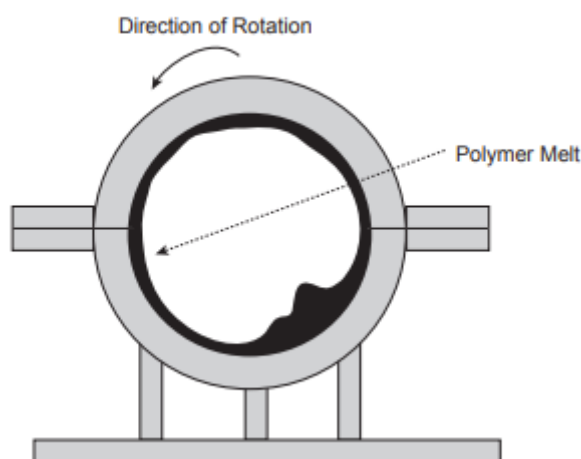


Figure 11. Scheme for adhesion of polymer melt to the wall and part formation (Ebnesajjad & Khaladkar 2017)

The rotomolding process is distinguished from spin-casting or centrifugal casting by its relatively low rotation speed, which is typically in the 1-20 rpm range although all these molding methods make use of the centrifugal force of a rotating body, rotomolding relies more on gravity to shape the polymer. Rotation speeds on the minor axis for this method can reach 40 rpm and 12 rpm on the major axis. Due to this fairly low speed of rotation, a controllable level of centrifugal force is maintained throughout the process without risk of significant force manifesting, meaning gravity is the main force acting on the substance inside. The entire process is divided into two stages. The polymer melts, sinters, and densifies during the first stage, where convection heating is introduced via an enclosed oven heating the mold and its polymer contents. During the second stage, the melted polymer is allowed to flow onto the walls and fills the mold's inner walls, coating all cavities and preserve the original geometry of the mold's walls and shape the final product. Gravity is the primary force acting on the polymer because centrifugal forces are negligible due to the low rotation speed. In the absence of significant shear, the melt's filling action is aided by introducing a higher temperature in order to lower the melt's viscosity, thus easing the filling process overall, as more viscous polymer is harder to fill and shape. This method is best suited for casting spherical shapes, but the outer shape can be modified using special techniques, nonetheless. The material of choice for the mold is usually metal, and the mold should be made available to spin in 3 axes, namely horizontal, vertical and inclined. The main purpose of the centrifugal force in this method of molding is to maintain the

substance's homogeneity and retain accuracy, rather than a shaping force for the polymer. (Ebnesajjad & Khaladkar 2017.)

Table 8. Thermoplastic Polymers Molding Techniques pros and cons (Ebnesajjad & Khaladkar 2017)

Molding Technique	Advantages	Disadvantages	Typical Process Shear Rate (s^{-1})
Injection molding	The most precise control of shape and dimensions; highly automatic process; fast cycle time; the widest choice of materials.	High capital cost; is only good for large numbers of parts; large mold pressures (140 MPa).	1000–10,000
Compression molding	Lower mold pressures (7 MPa); does minimum damage to reinforcing fibers (in composites); large parts are possible.	Requires more labor; longer cycle than injection molding; less shape flexibility than injection molding; each charge is loaded by hand.	<1
Transfer molding	Good for encapsulating metal parts and electronic circuits.	Some scrap with every part and each charge is loaded by hand.	1–100
Blow molding	Can make hollow parts (such as bottles); stretching action improves mechanical properties, fast cycle; requires low labor.	No direct control over wall thickness; cannot mold small details with high precision; requires a polymer with high melt strength.	—
Rotational molding/lining	Labware that is shatterproof and will not contaminate samples; small to very large lined vessels; valve lining; bellows; items with complex geometry; containers	A slow process; requires labor and involves numerous moving parts. A great deal of cleaning and surface conditioning is necessary.	<100
Extrusion	Used for films, wraps, or long continuous parts (i.e., pipes).	Must be cooled below its glass transition temperature to maintain stability.	100–1000

4 Tower Design

4.1 General Information and Specification

In this case, the design is a concept study, which means that material thickness can be changed, strength analysis has not been done and all dimensions visible are preliminary.

The component of agriculture tower includes Tower base (1), Rotation Ball (2), Floor base (3), Compost Tube (4), Tower floor (5), Tube (6), Cap (7), Tank (8), Filter (9).

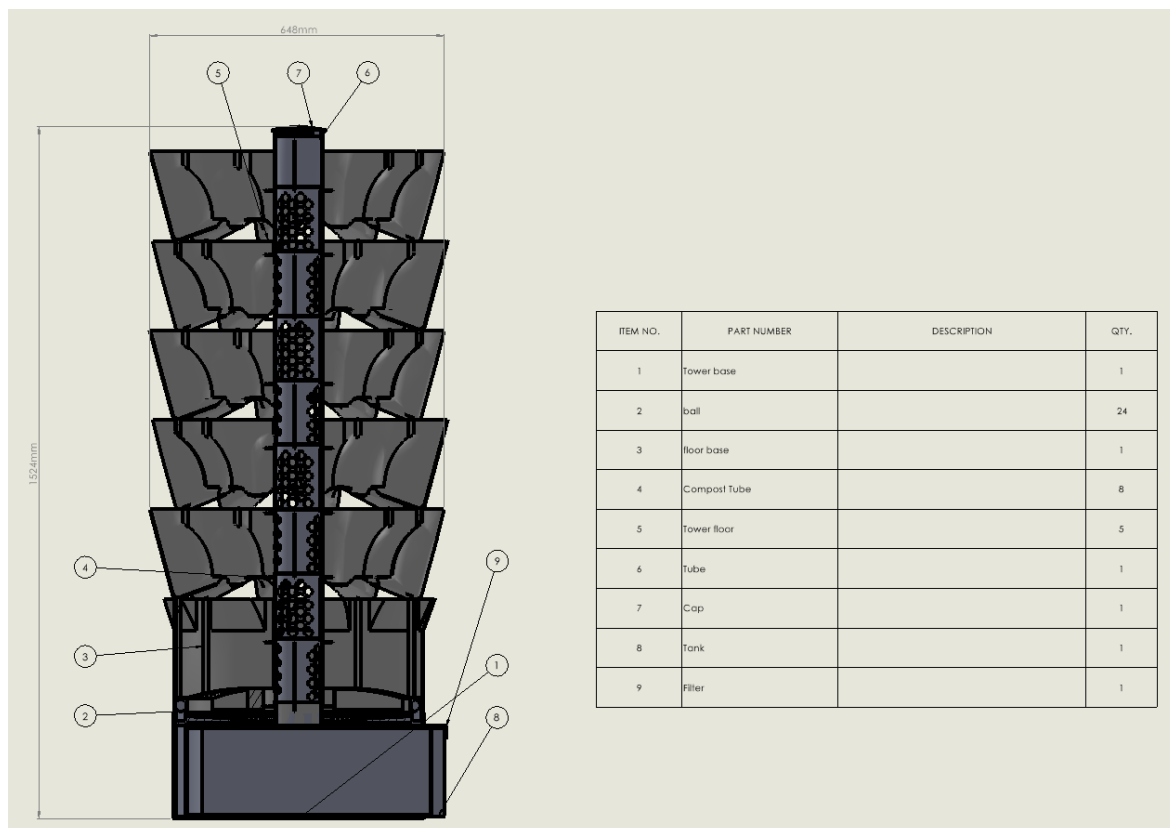


Figure 12. Agriculture Tower Section View

The diameter of the tower is 648 mm and the maximum height is 1524 mm. The height of the tower can be adjusted by reducing the number of compost tubes and tower floors suitable for users' demands. Tower body is constructed by tower floors and compost tube sections with holes. Tower body can make maximum 54 curved planting pockets.

The objective of the tower design is to create the circle life which recycles bio waste inside the tower. The pipe was formed by compost tubes (4) which are joined together to contain organic waste and keep soil not falling inside. According to the research, one of the biggest earthworm species in the world is 20 mm in diameter. (Taylor et al. 2004.) Therefore, the compost tube has 20 mm holes around the tube which helps earthworm move through hole, mixing and digging. This activity of earthworm improves the decomposition process of organic

waste, which will become fertilizer and provide nutrition for plants and make soil looser. Irrigation water passes through the soil, fertilizer, and a filter (9) before flowing down to the tank (8), which generates worm tea solution that is used to water plants because they give a lot of nutrients, nitrogen, and good probiotics for plants. Cap (7) on the top of tower protects centre of the hole from flooding which derives from the rain. The circle life is summarized as flow chart below:

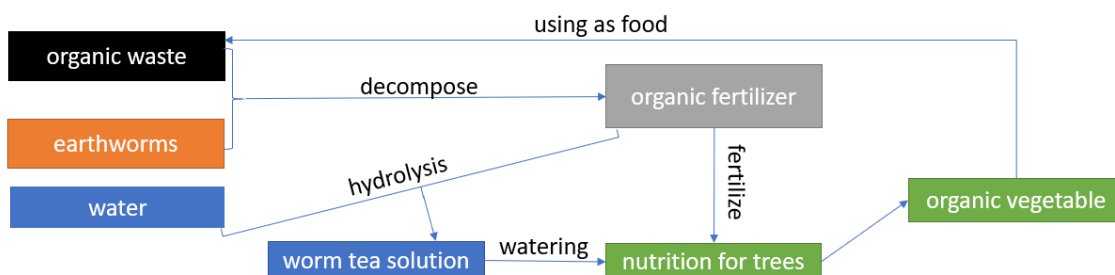


Figure 13. Circle life

The base tower is the most complicated part of the tower, including rotary motion mechanism, the filter, the tank, and the feet.

Table 9. Specifications

Weight	Approx. 16kg
Height	1524 mm
Width	648 mm
Material	Fluoroplastic
Rotation 360	Yes
Planting Pockets	54 max.

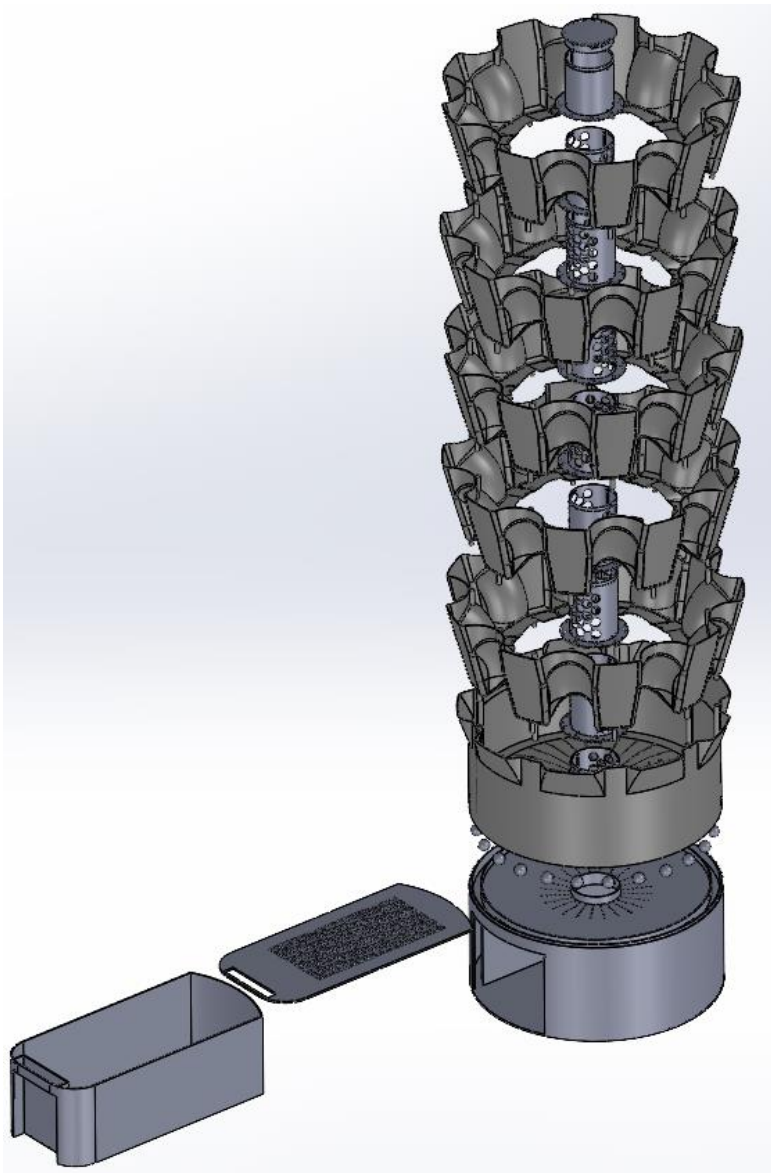


Figure 14. Explored View of Tower

4.2 Rotary motion mechanism

The rotary motion mechanism is created by 3 parts:

- 1) Base tower has groove to contain rotation balls and drawers for tank and filter. There are several 2 mm holes on top of the base tower and the center hole for draining the bio fertilizer after decomposition process when releasing filter and collecting in the tank. According to the design and the table 8, Rotation Molding can be applied to produce the base tower.

- 3) Rotation ball which is solid plastic ball with 26 mm in diameter

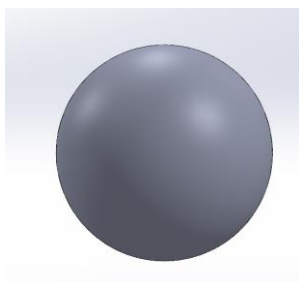


Figure 17. Rotation Ball

There is a trench above the base tower and under base floor for rotation ball, which makes the rotary motion mechanism work as a bearing. It helps tower rotate 360 degrees.

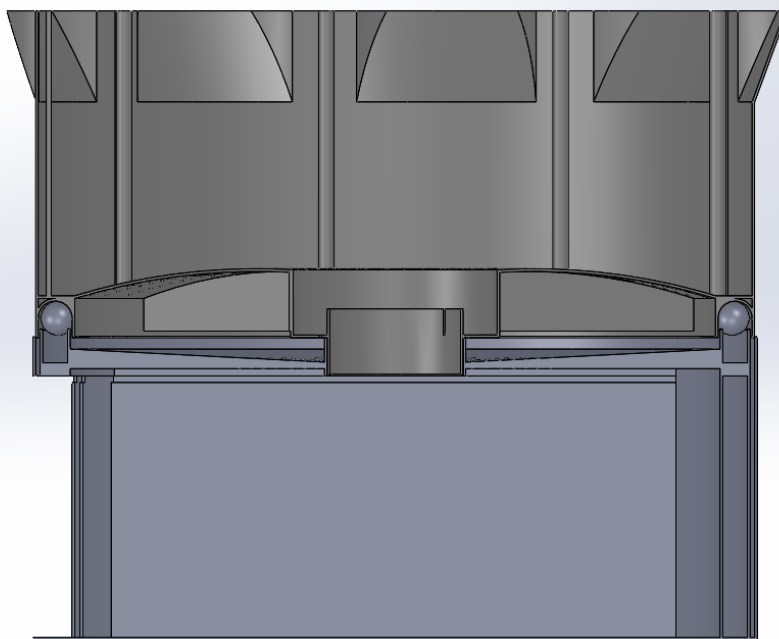


Figure 18. Rotary motion mechanism (section view)

4.3 Tank and filter

The tank is removable compost/nutrient tea drawer that collects about 25 liters of nutrient enriched water for another pass by plant roots. Filter is a release gate for compost, allowing seasonal removal of finished compost and provides for aeration of the vermicompost from below.

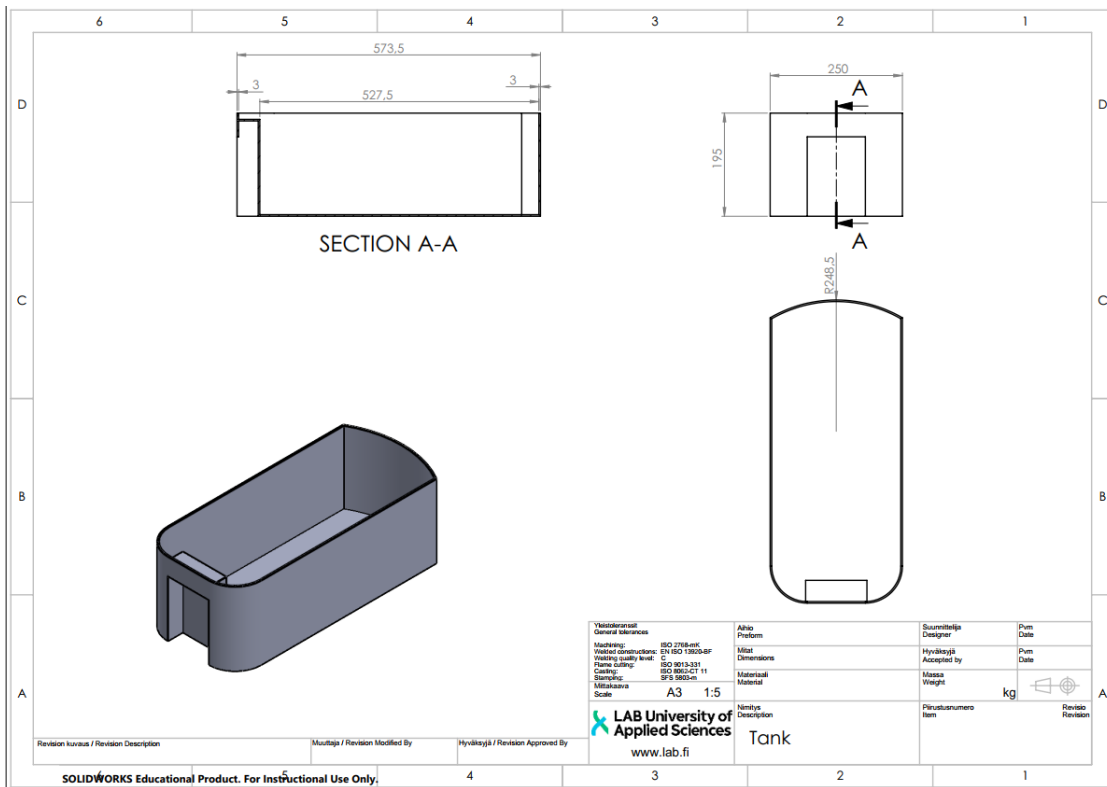


Figure 19. Tank Drawing

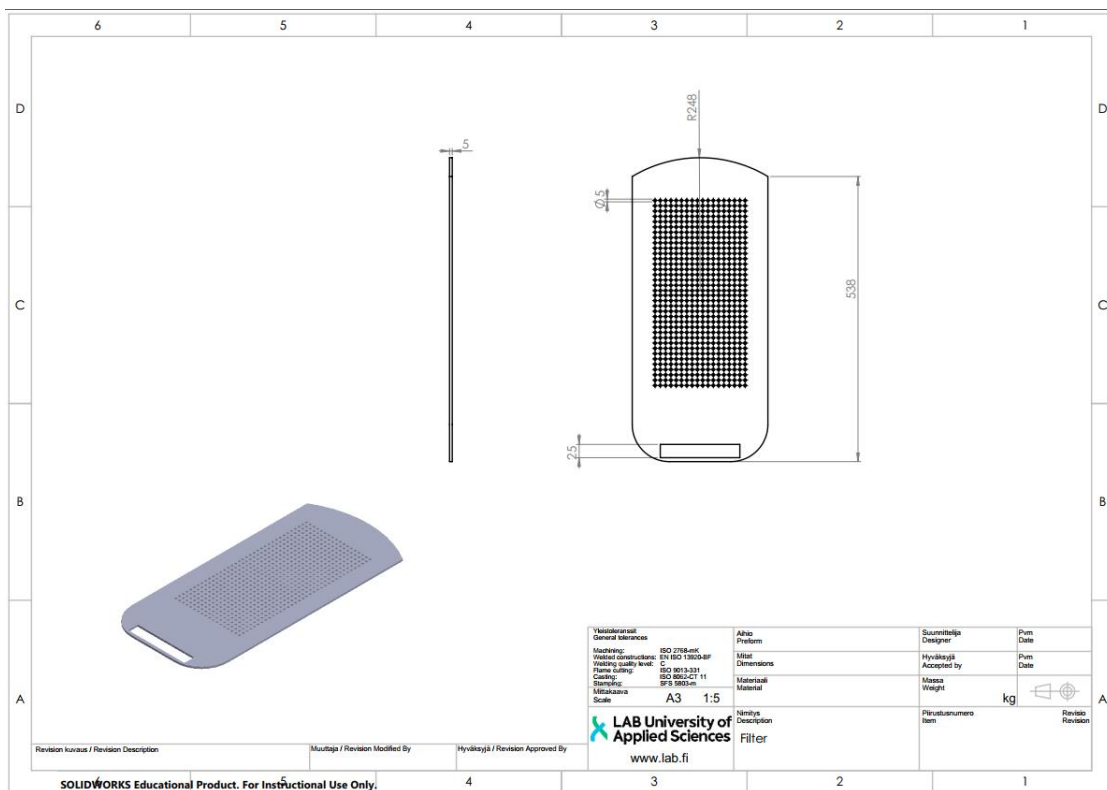


Figure 20. Filter Drawing

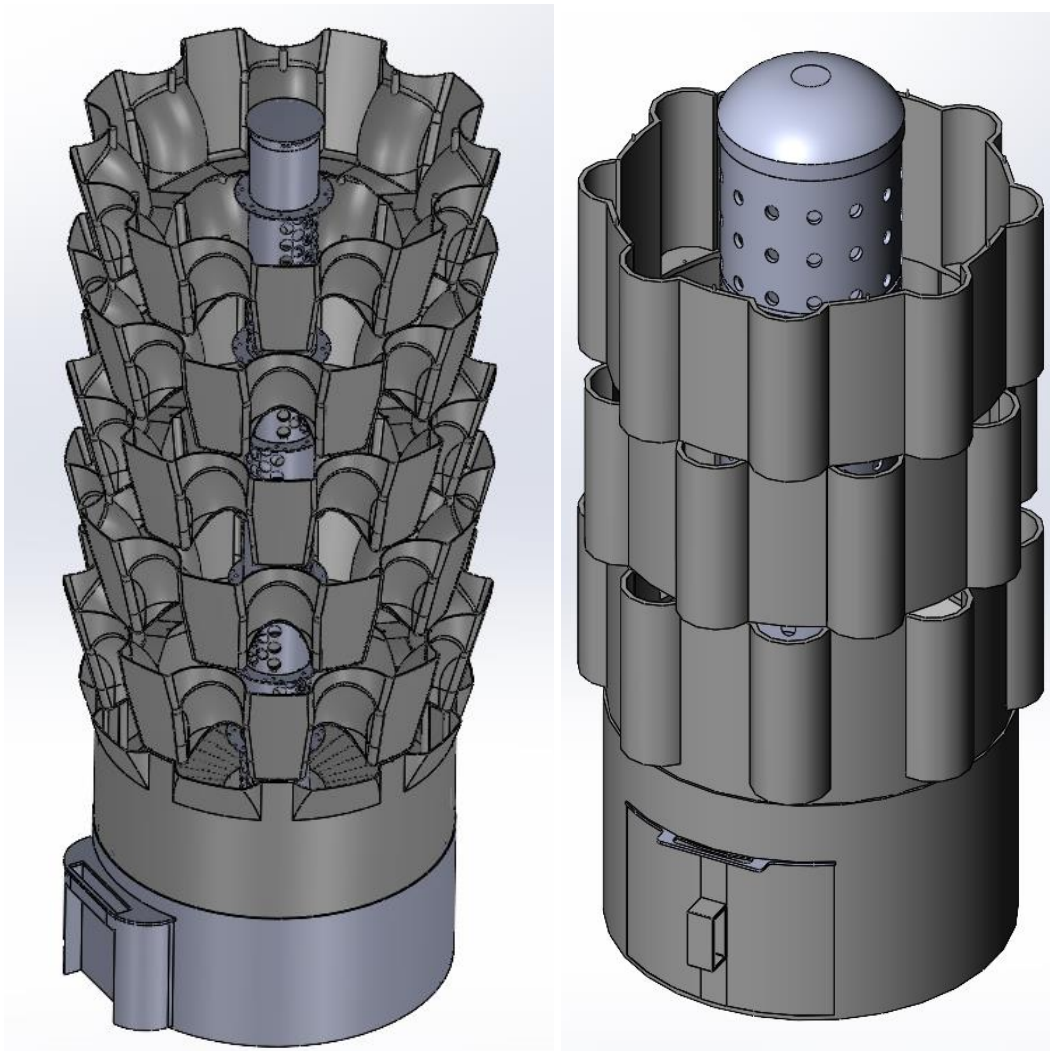


Figure 22. The final design (left) and the original design (right)

4.5 Compost tube, Normal Tube and Cap

Compost tube has many holes for worms and air can move around inside tower. The normal tube and the cap are only on the top of the tower, which covers the compost space from rain or other things are not bio waste.

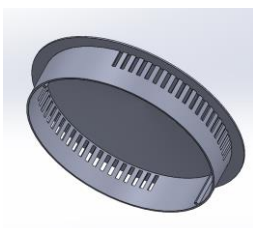


Figure 23. Cap

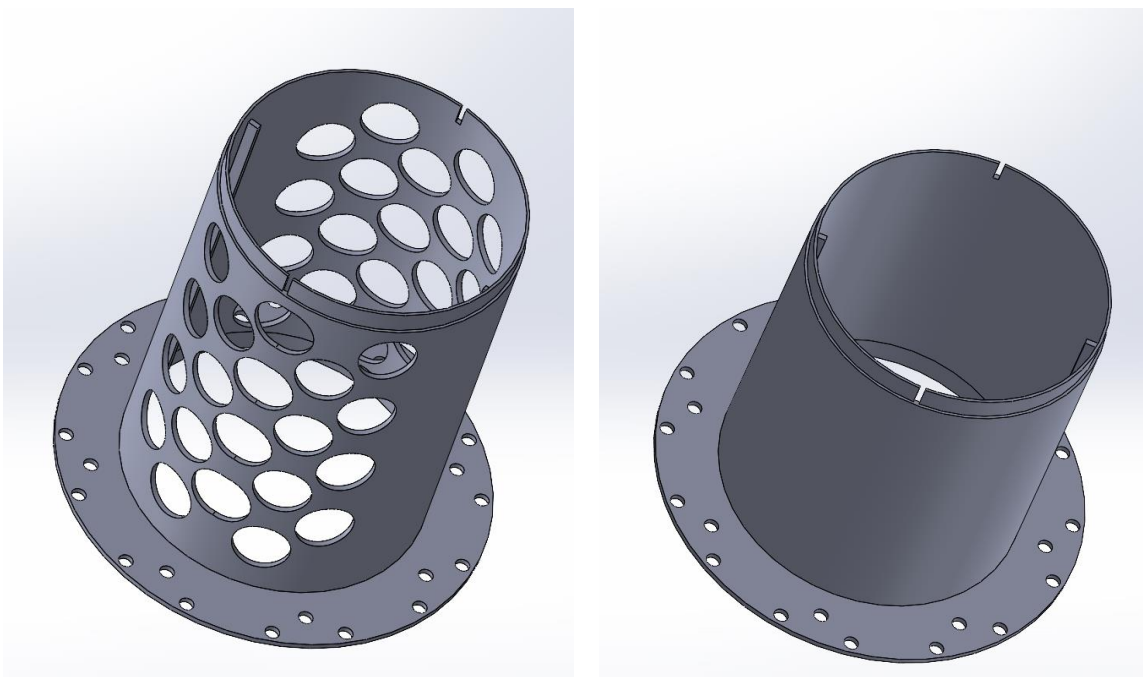


Figure 24. Compost Tube (left) and Normal Tube (right)

5 Auto Irrigation system

5.1 General information about Auto Irrigation system

Auto Irrigation system work based on input and output of the soil humidity sensor. The soil moisture sensor is put into soil to measure soil moisture and transfer signal to turn on pump for watering plant when humidity under level was set before. There is a soil moisture sensor in every tower, each sensor has a number from 1 to N+1 corresponding to each tower and solenoid valve from 1 to N+1. If the sensor receives signal soil moisture lower than the range set, the valve of this tower will be opened. The water pump booster will be turned on when the pressure reduces because valves are opened.

5.1.1 Moisture Sensor

The 250-40561 MAS-1 Soil Moisture Sensor has a 4-20 milliamp output, which is commonly used by PLCs and irrigation controllers. Cable lengths of over 76 meters (250 feet) are feasible with the 4-20 mA interface. (NovaLynx n.d.)

Dielectric constant of the material is measured by the MAS-1 through utilizing capacitance/frequency domain technology with the aim of determining volumetric water content (VWC). The sensor operates at a frequency of 70 MHz, which reduces salinity and textural effects and allows the MAS-1 to be used practically in any soil or soilless medium. Mineral soils, potting soils, and rockwool all have factory calibrations. (NovaLynx n.d.)

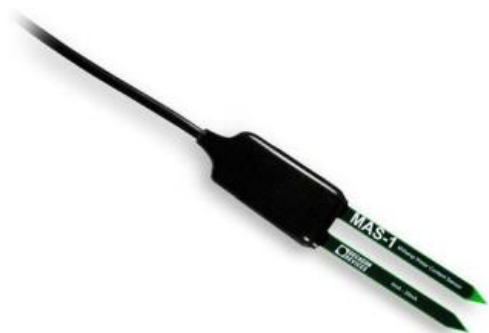


Figure 25. 250-40561 MAS-1 Soil Moisture Sensor (NovaLynx n.d)

Table 10. 250-40561 MAS-1 Soil Moisture Sensor Specification (NovaLynx n.d)

Interface	4-20 mA
Supply voltage	12-32 Vdc
Output current	4-20 mA
Overvoltage protection	Yes
Setting time	4s
Red Wire	(+) supply
Black Wire	(-) output: 4-20 mA
Sensor Type	Volumetric Water Content (VWC)
Sensor measurement interval	1s
Range	0-100% VWC typica
Accuracy	± 6%
Operating temperature	-40° to 60° C
Dimension	89 mm x 18 mm x 7 mm

5.1.2 Solenoid Valve

Solenoid valves aid in the control of liquid or gas flow. The plunger of a typically closed solenoid valve is down when the valve is unpowered, effectively shutting the valve, and stopping liquid or gas flow. The magnetic field causes the plunger to rise after the normally closed solenoid valve is triggered or energized. (TAMESON n.d.)

Solenoid Valve DF-SA 3/4" brass EPDM 0-6bar 12V DC refers to a semi-direct working 2-way solenoid valve from JP Fluid Control with G 3/4-inch threads and a 12 V DC coil. The valve has a brass housing with EPDM sealing and a 20 mm (about 3/4 inch) aperture. The solenoid valve will only open when a voltage is applied to the system as it runs on a closed circuit. (TAMESON n.d.)

The valve's pressure threshold ranges from 0 to 6 bar (0 to 87 psi) and must be kept below 120° C (248° F). The valve has a Kv-value of 6.48 m³/h, or 108.02 l/min at 1 bar differential pressure (for water). In imperial units: Cv = 7.49, which is 7.49 GPM at 1 psi pressure drop. (TAMESON n.d.)

Table 11. Solenoid Valve Specification (TAMESON n.d)

Series	Direct Flow (DF)			
Function	2/2 way			
Operation	Semi-direct (S)			
Position	Normally closed (A)			
Body	Brass (B) / Nylon 66 (N) / Stainless Steel 304 (S)			
Seal & Media Temperature	NBR (N)	-10..80°C (0..80°C Nylon 66)		
	EPDM (E)	-30..120°C (0..80°C Nylon 66)		
	FKM (F)	-10..120°C (0..80°C Nylon 66)		
Thread	BSPP / NPT (N)			
Ambient Temperature	Max 50°C			
Min. Pres. Difference	0 bar			
Max. Pressure	Brass & Stainless Steel: 10/6 bar (AC/DC)	Nylon: 8/6 bar (AC/DC)		
Coil series	CS2 / CS8 (>1")			
Voltage	380V AC 50Hz (380AC)			
	230V AC 50/60Hz (230AC)			
	120V AC 60Hz (120AC)			
	24V DC (024DC)			
	24V AC 50/60Hz (024AC)			
	12V DC (012DC)			
Insulation Class	Class F			
Power	22 W / 45VA (≤1"), 45 W / 65 VA (>1")			
Duty Cycle	100% ED			
Connector	EN 175301-803 (formerly DIN 43650A)			
Protection Class	IP 65 (with cable plug)			
Circuit Diagram				
Pipe (P)	Orifice (D)	Kv (m3/h)	AxBxH (mm)	Response time (Open/Close)
3/8" (038)	16 mm (160)	4.09	69x57x106	80/300 ms
1/2" (012)	16 mm (160)	4.09	69x57x106	80/300 ms
3/4" (034)	20 mm (200)	6.48	73x57x114	90/550 ms
1" (100)	25 mm (250)	10.24	99x77x121	100/800 ms
1 1/4" (114)	32 mm (320)	20.47	112x87x150	100/800 ms
1 1/2" (112)	40 mm (400)	24.74	123x94x160	110/1100 ms
2" (200)	50 mm (500)	40.94	168x123x183	120/1300 ms

5.1.3 Water Pump Booster: Wilo PB 201 EA

Single-stage centrifugal pump with no self-priming for automatic water supply/pressure boosting from a tank (e.g., elevated tank) to extraction points beneath it. (Wilo 2018.)



Figure 26. Wilo PB 201 EA (Wilo 2018)

A built-in flow switch allows for automatic activation and deactivation. The water flows out of the tank into the pump when the extraction point is open. The flow switch is built into the pressure port, activating the pump when the volume flow is created. Due to a lack of volume flow, the pump turns off when the extraction point is closed. (Wilo 2018.)

Table 12. Specification Pump Booster (Wilo 2018)

Specification	PB-201EA
Maximum operating pressure	2.2 bar (2.2 x 10 ⁵ Pa)
Maximum suction pressure	0.7 bar (0.7 x 10 ⁵ Pa)
DN of suction connection	3/4"
DN of pressure connection	3/4"
Fluid temperature range	+5°C to +80°C
Ambient temperature	max. +40°C
Motor protection rating	IPX4
Insulation class	F ₁₅₅
Frequency	50 Hz 220 V - 230 V
Voltage	50 Hz 220 V - 230 V
Speed in RPM	~ 2900

5.1.4 IRF 520 MOSFET Driver module

The PWM (Pulse Width Modulation) approach is used by the IRF 520 MOSFET Driver module to drive DC motors. A constant input voltage is converted to a variable voltage by modules. The speed of a DC motor may also be regulated by varying the voltage across it. PWMs have a fixed frequency and an adjustable engine speed through varying the amount of time the pulse is HIGH (Duty Cycle). (Amir Mohammad Shojaei n.d.)

The sensor has 7 pins which are shown in the diagram below:

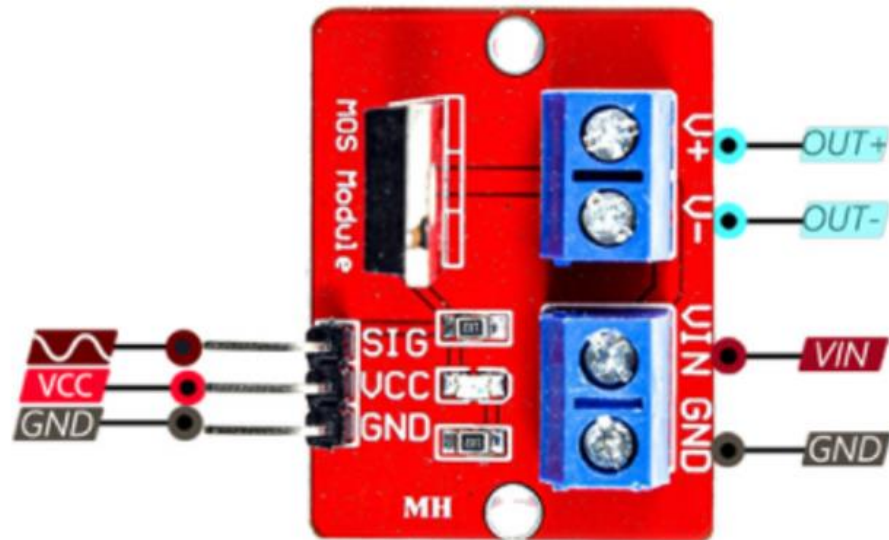
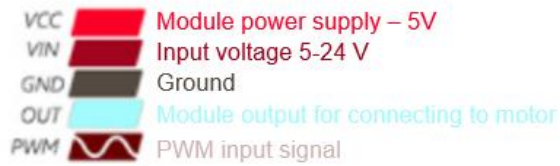


Figure 27. IRF 520 MOSFET Driver module (Amir Mohammad Shojaei n.d)

5.1.5 Arduino Nano

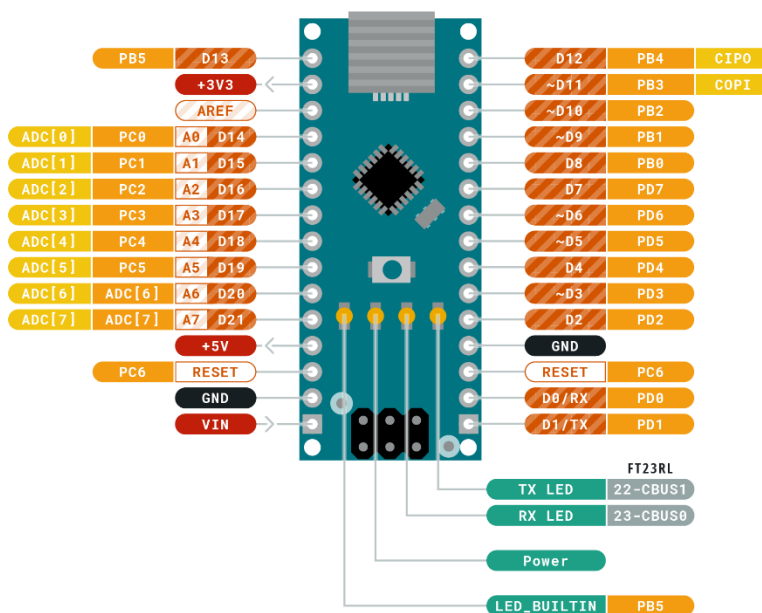
The ATmega328P microprocessor is utilized in the Arduino Uno microcontroller board. It has 14 digital I/O pins, 8 analog I/O pins, a USB connector, and a reset button. The function of the microcontroller board is receiving and transferring from sensor to solenoid valve. In addition, the microcontroller board can be set up with the different of the moisture levels by computer in order to be suitable for the plant species. (Arduino n.d.)

Table 13. Technical Specification Arduino Nano (Arduino n.d)

Board	Name	Arduino® Nano
	SKU	A000005
Microcontroller	ATmega328	
USB connector	Mini-B USB	
Pins	Built-in LED Pin	13
	Digital I/O Pins	14
	Analog input pins	8
	PWM pins	6
Communication	UART	Yes
	I2C	Yes
	SPI	Yes
Power	I/O Voltage	5V
	Input voltage (nominal)	7-12V
	DC Current per I/O Pin	20 mA
Clock speed	Processor	ATmega328 16 MHz
Memory	ATmega328P	2KB SRAM, 32KB flash 1KB EEPROM
Dimensions	Weight	5gr
	Width	18 mm
	Length	45 mm



ARDUINO NANO



Ground	Internal Pin	Digital Pin	Microcontroller's Port
Power	SWD Pin	Analog Pin	
LED	Other Pin	Default	

ARDUINO.CC

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Figure 28. Connector Pinouts (Arduino n.d)

5.2 Net pipe

Net pipes include the water pump booster connecting with water tank from suction connection of the water pump booster through major pipe. Pressure connection of the water pump booster is connected to solenoid valves to control water running through minor pipe to the agriculture tower. Water is split inside the agriculture tower by soaker hose.

The pipe of solenoid valve, the suction connection and the pressure connection in the pressure booster have the same size is 3/4 inch. Therefore, the size of major pipe should be 3/4 inch to simplify. The size of minor pipe and soaker hose is 1/2 inch, the adaptor 3/4 inch

and ½ inch must be used to connect major pipes and minor pipes. Minor pipes and soaker hoses are connected by hose repairer ½ inch.

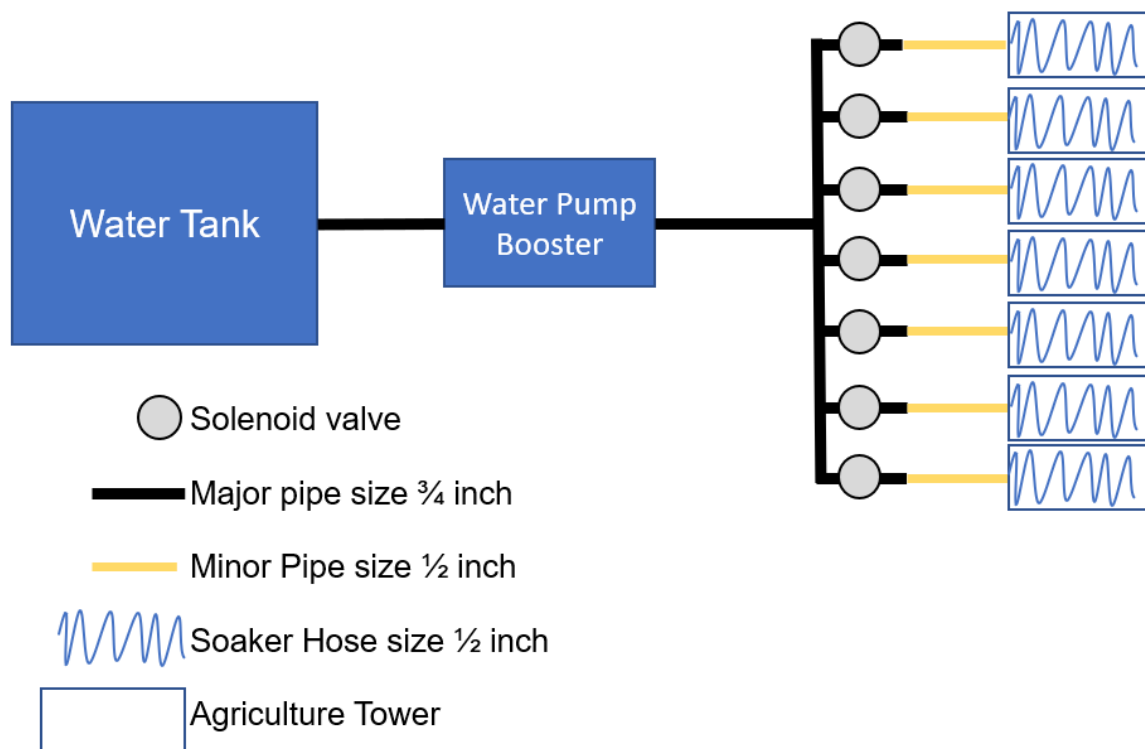


Figure 29. Net Pipe

5.2.1 Major Pipe

Specification of the major pipe must stand with pressure at least 8 bars or more and the thickness is from 2,8 mm to 3 mm. During operation period, the pressure in major pipe is heavy, the material must be durable. There are two materials to select for this case, including HDPE and PVC.

HDPE is a thermoplastic polymer manufactured from petroleum. It is one of the most adaptable plastics. It is employed in a wide range of applications such as bottles, crockery, toys, chopping boards, and piping that all made with it. Its tremendously tensile strength is its most notable feature. It also has a high melting point and has a very strong resistivity. It has various applications in the food industry. Wood-plastic composites are also made with it. It is also employed in medical procedures such as plastic surgery, particularly face and skeletal reconstruction. Show boards and 3-D printing applications also take advantage of it. HDPE is also commonly used in the food and beverage industry. It features a textured surface that makes it easier to grab HDPE items. Food-grade quality contains it as well. Low-maintenance, safe, and long-lasting items are manufactured from it. As a result of their superior quality, the products have a longer lifespan. Its high ductility and malleability are

some of the advantages and reasons for its strong commercial demand. HDPE is manufactured from the ethylene monomer. It is also known as alkathene and polythene when it is used in pipes. It has a high density-to-strength ratio. Therefore, it is commonly employed in the production of bottles, and it is corrosion resistant. (Tang et al. 2003.)

PVC is a thermoplastic synthetic plastic polymer. PVC is produced more than 40 million tons per year. Pipes, as well as the construction of doors and windows, contain them. Food-safety sheets are one of the most common uses for this PVC. Their ductility and malleability have made them a popular choice for a variety of items. PVC is commonly utilized in the manufacturing of high-quality pipes as well as in the medical industry. It is also utilized to insulate cables and medical devices. It is both economically and qualitatively affordable. It is also used in the construction industry. These are used to make door and window profiles. It is white in color and brittle in texture. It is available in both granules and powder form. It has outstanding features of durability, low cost, and ease of processing, all of which have led to PVC being utilized as a replacement component in building materials and construction applications, as well as being used in place of wood, concrete, ceramics, rubber, and even metals. PVC comes in a variety of shapes and sizes. Plasticized or flexible PVC, rigid or unplasticized PVC, chlorinated PVC, modified PVC, and molecularly orientated PVC are a few of them. High stiffness, flame retardant qualities, superior chemical resistance, dimensional stability, and insulating capabilities are some of the benefits of these PVCs. It does, however, have several drawbacks, such as difficulties meeting because of its high melting point. Its solvent cracking resistance is insufficient. (A. Craggs et al. 1974.)

Table 14. Comparison table HDPE and PVC

Parameters of Comparison	HDPE	PVC
Definition	High-density polyethylene (HDPE) is semi-crystalline and expensive.	Polyvinyl chloride (PVC) is inexpensive, affordable, and is amorphous.
Surges	High-density polyethylene (HDPE) has the capacity to dampen and also absorb the waves to prevent the system from being affected by reducing the surges.	Polyvinyl chloride (PVC) does not reduce surges.
Areas of Applications	High-density polyethylene (HDPE) is best suited to be employed in lower pressure areas.	Polyvinyl chloride (PVC) is best suited in trenchless regions and also in burial areas.
Properties	High-density polyethylene (HDPE) is resistant to heat and abrasion.	PVC is best known for its high durability and sturdiness.
Usage	High-density polyethylene (HDPE) is the most popularly used plastic for commercial purposes.	PVC is ranked three among the popularly used types of plastics.

Both types of plastics are robust and well-known for their long lifespan. Their pressure capacity varies due to differences in their strength and characteristics. Based on their qualities, both types of plastics have different needs and requirements.

Though both are used to make pyrotechnics, HDPE is a much safer alternative because it can propel and launch the fireworks to a safe distance. PVC has the potential to explode inside the container, and HDPE has the same potential. After all, HDPE is selected for major pipe and minor pipe.

5.2.2 Minor Pipe

For minor pipe, the PVC pipe is selected for project because the technical requirement is less than Major pipe. Using the PVC pipe helps to reduce cost. The size of the minor pipe must be ½ inch.

5.2.3 Round Soaker Hose

Soaker hoses which are made of recycled rubber, polyurethane, and flexible polyvinyl chloride (PVC) allows water to soak straight into the soil around the plants through microscopic perforations. Round soaker hoses are more adaptable since they may be snaked around various bushes and trees in straight rows without kinking. Round soaker hoses are more flexible and long-lasting.

Table 15. Technical specification Soaker Hose

TECHNICAL SPECIFICATION	
Pipe diameter	1/2"
working pressure:	0,5-2 bar
Material	rubber

Table 16. Hydraulic Feature Soaker Hose

HYDRAULIC FEATURES	
BAR	L/H X M
0,5	14
1	22
1,5	28
2	32

6 Conclusion

After developing all of the components of the Agriculture Tower and Auto Irrigation System, the thesis research is completed. The thesis includes some principal specifications of the material, manufacturing, and the machine that reader can follow and get information from the design.

In general, the advantages of the system are flexible to change spare parts, user and environmental friendly, fitting with many sizes of area, reducing the volume of the water and fertilizer. Also, the tower can rotate 360-degree, which helps all of tower sides can easily expose to sunshine. However, it also has some limitation such as only suitable for small plants, vegetable, and flowers. The agriculture tower needs setting up in the airy place and lots of sunshine reach to all the floor towers.

In the process, the most important thing of thesis is to design to simplify system and fully functional. Auto Irrigation system takes a lot of time to figure out references, checking specification of the parts, simplify and optimized system. The tower design was improved after editing general design from project plan.

However, there are several times the design had to be delayed with innovated design because of the mistakes from previous tower and system design, data misunderstanding together with lack of technical drawings skill for real-life machine design.

Figures

Figure 1. Mock-up of the cloud based IOT wireless system (SMS) (Monalisha Pramanik et al. 2022).....	2
Figure 2. Gateway and its different component (Monalisha Pramanik et al. 2022)	3
Figure 3. Experimental field layout diagram (Monalisha Pramanik et al. 2022).....	3
Figure 4. Block Map of the system proposed (R Sruthi et al. 2021).....	5
Figure 5. Injection molding machine example (Ebnesajjad 2003).....	11
Figure 6. Schematic of a conventional reverse (Ebnesajjad & Khaladkar 2017).....	12
Figure 7. Schematic of a combination of a check (Ebnesajjad & Khaladkar 2017)	13
Figure 8. A smear head design (Ebnesajjad & Khaladkar 2017)	13
Figure 9. Schematic diagram of rotational molding (Ebnesajjad & Khaladkar 2017).....	15
Figure 10. Biaxial rotational molding sample process diagram (Ebnesajjad & Khaladkar 2017)	16
Figure 11. Scheme for adhesion of polymer melt to the wall and part formation (Ebnesajjad & Khaladkar 2017)	17
Figure 12. Agriculture Tower Section View	19
Figure 13. Circle life.....	20
Figure 14. Explored View of Tower	21
Figure 15. Base Tower.....	22
Figure 16. Base Floor	22
Figure 17. Rotation Ball	23
Figure 18. Rotary motion mechanism (section view)	23
Figure 19. Tank Drawing.....	24
Figure 20. Filter Drawing.....	24
Figure 21. Tower floor design	25
Figure 22. The final design (left) and the original design (right).....	26
Figure 23. Cap.....	26
Figure 24. Compost Tube (left) and Normal Tube (right).....	27
Figure 25. 250-40561 MAS-1 Soil Moisture Sensor (NovaLynx n.d)	28
Figure 26. Wilo PB 201 EA (Wilo 2018)	32
Figure 27. IRF 520 MOSFET Driver module (Amir Mohammad Shojaei n.d)	33
Figure 28. Connector Pinouts (Arduino n.d)	35
Figure 29. Net Pipe.....	36

Table

Table 1. Comparison of different systems	6
Table 2. The Fundamental Properties of Polytetrafluoroethylene (Ebnesajjad & Khaladkar 2017)	8
Table 3. The Useful Attributes of Perfluoropolymers (Ebnesajjad & Khaladkar 2017)	8
Table 4. Fluoropolymers Applications (Ebnesajjad & Khaladkar 2017)	9
Table 5. Process Steps of Injection Molding (Ebnesajjad 2003)	10
Table 6. Advantages of Screw-Type Injection Molding Machine (Ebnesajjad & Khaladkar 2017)	11
Table 7. Fluoropolymers' Melt Density (Ebnesajjad & Khaladkar 2017)	14
Table 8. Thermoplastic Polymers Molding Techniques pros and cons (Ebnesajjad & Khaladkar 2017)	18
Table 9. Specifications	20
Table 10. 250-40561 MAS-1 Soil Moisture Sensor Specification (NovaLynx n.d).....	29
Table 11. Solenoid Valve Specification (TAMESON n.d)	31
Table 12. Specification Pump Booster (Wilo 2018)	32
Table 13. Technical Specification Arduino Nano (Arduino n.d).....	33
Table 14. Comparison table HDPE and PVC	38
Table 15. Technical specification Soaker Hose.....	39
Table 16. Hydraulic Feature Soaker Hose	39

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