International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 07 | July 2021 www.irjet.net p-ISSN: 2395-0072

Pod shape structure of Aeroponics [For Space Cultivation]

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Abstract - *For many years scientist at NASA have been sending rockets to ISS[International Space Station] for supplying necessary food items and other supplies to the astronauts , but this project would be very helpful in saving millions of dollars by eliminating the problem of supplying food supplies to astronauts. The Aeroponic system of production is adopted in the project in which the plants are grown in a mist medium where nutrient water is sprinkled upon the roots of the plants, considering the fact that ISS couldn't adopt a large 50 meters rectangular field or 10 feet cylindrical walls for carrying out the process the POD shape has been adopted providing larger base radius for storing water, the whole POD would be enclosed in a cylindrical case with sliding doors along the circumference of bottom platform supporting POD* ***[discussed in brief in structure]*** *The concept of nutrient water has been adopted to overcome the problem of avoiding. unwanted exothermic reaction[by dissolving macro and micro nutrients{which are generally highly reactive metals }] the concept of infusing IONS by dissolving ionic compounds so that no unwanted reaction could take place****[learn more about nutrient water in working[external agents]]****. Moreover speaking the kind of material used is a strong polymer of plastic called PTFE the polymer provides various advantages to the project, only providing essential gases and nutrient water wont help in stimulating the process of photosynthesis in plants providing the right spectrum of light to helps in promoting the overall growth of the plants, specialized light sources such as high pressure sodium bulbs and Metal halide lamps in series have been attached along the interior of the cylindrical case to provide the right light to the plants****[in structure Materials used]****. This design of including innovative designing of the whole structure with advanced level of engineering with use of high-level technology takes the concept of Aeroponics to a complete new level waving flag for further space cultivation projects.*

1.INTRODUCTION

For many years till now the scientist at NASA have been spending millions of dollars for sending the food and other necessary supplies to the space (ISS) to supply astronauts with all the necessary items, but now with the new design of Aeroponics which has been designed to overcome all the problems relating to space cultivation has been arrived. The POD is a structure of a curved cone similar to that of the re-entry module in which astronauts return. The Pod shaped structure has been chosen for the project as it can solve many problems related to the environment of the ISS as the POD offers a larger base radius at the base therefore providing more area for storage unit for the nutrient water, the radius narrows down as it moves up and it provides area for the small plants at the top as if the small plants are grown in the bottom rays the area might get wasted so the top rays will provide the area for them, the POD is connected to a motor at the bottom which is again attached to a platform with less thickness and larger base radius than the POD along the circumference of the platform a cylindrical wall is raised which would cover the whole structure maintaining some distance so that while rotating the pod the structure wont crash into the cylindrical casing. The POD here is being rotated because to generate artificial force of gravity. Gravity is extremely important for growing plants as they play a major role in holding the plants. The motor attached at the bottom of the pod will be rotating the pod at particular RPM so that the gravity can be produced **mentioned in Structure[external]**. The function of the cylindrical casing is that the case will be acting as a protective layer that too the made up of the hard glass. There are 2 input shafts present on the sides of the cylindrical casing to let the essential gases such as carbon di oxide and oxygen let in the case explained in greater detail in **Structure[external]** the cylinder also has a series of light sources attached along the internal side vertically **mentioned in Structure[internal].** On the interior side the most area of the bottom part of POD would be given for the storage of nutrient water in which nutrient water is placed**[in structure internal]** , from the storage unit a pipe emerges extending towards the top the pipe however has major role to play as it is the transportation of the nutrient water to the sprinklers, the pipe placed is made up of a very special polymer of plastic **[mentioned in structure[internal]].** The interior also consists of the sprinklers which are placed accordingly to the placement of the rows present on the slant height of the POD the sprinklers are meant to sprinkle the nutrient water on the roots of the saplings of the plants they will sprinkle the water by turning them into

atomised water droplets for certain period of time depending on the plants which are being grown

1.1 Structure:

STRUCTURE[EXTERNAL]:

The following would be discussed in the external section:

1) POD structure specifications
2) Materials used in preparation

POD STRUCTURE SPECIFICATIONS:

The POD structure as mentioned in the Abstract section offers a larger base radius which would solve the problem of storing the nutrient water and as it narrows downs going along up. This model has been adopted to overcome the problem of reducing the area which the structure would take and maintaining the productivity throughout the process and obtain high nutrient value food because its impractical of laying 50m long rectangular field or raising 10 to 15 feet tall cylinders.

The POD is situated above a platform supported by a motor and cased in a glass cylinder.

Functions:

The platform at the bottom provides a circumference for the glass cylinder which would be casing the pod. The plate also provides area for motor which would be situated and attached to the POD which would rotate the POD at specified RPM at particular speed so that artificial force of gravity can be generated. Artificial gravity here is being generated so that the water in the storage unit in the POD would not float in the POD and scatter here and there. This would also help in proper sprinkling of water to the roots.

Artificial gravity [RPM] = 9.55 * root(g/r)

g- Gravity of earth [9.8 or 10 approx.]

r- Radius of pod(base)

The cylindrical casing however provides an environment for releasing essential gases such as CO2 and exposing them to the plants, the casing also has a sliding part where from the astronauts can open the case and extract the grown plants, the cylinder also has a major role as series of light sources such as High pressure bulbs and Metal halide lamps are placed inside the case so that they would provide the right spectrum light for the plant growth[read more about lights in **Structure[internal]]** the cylinder acts as a protective gear to the POD as it covers the POD and the glass used to make the POD is also made up of a hard substance resistant to heat and durable , apart from supplying. On the outer side of the POD there are several rows of plants attached and these rows are adjustable so that the plant can be fixed so that the force of artificial gravity wouldn't spit them out. The whole POD is both external and internal parts are automated for their purposes in the system as the manual functioning is quite hard and all the necessary process have to take place at specified time and at certain speed, hence there is a computer screen on the cylindrical shield which gives the information regarding the constituents of the POD and if there is any deficiency found in the structure, this information would be provided to the astronauts and it will also contain a section where astronauts could carry out the process and plan the growth of plants in advance. The platform at the bottom is supplied with electricity and sensors to detect any sort of threat to the POD. The POD has some minute holes in an large number at the storage area of water such that the water would not flow out but the oxygen which would be passed into the container would enter the POD so that the roots would get oxygen as it is required by the plants.

How stable can be the POD:

This is one of the most important question and the answer for this question is pretty simple if the size of the POD is quite small then the RPM to be programmed would be pretty high to bring the optimum force of gravity in the POD, However when size is increased the RPM also decrease descent RPM without any unwanted movements is necessary, the weight of the POD should also be considered so that no excess amount of weight is placed which would again lead to increasing the RPM and increasing the movement, therefore considering the measurements and weight of the POD is extremely important. For solving the weight problem there are sensors on the platform which can detect the weight and indicate the astronauts about the weight[whether under or over weight]. The stability also depends upon the interior part of the POD the plastic pipe used in transporting the water to the sprinklers is at the critical situation where a slight damage could cut the supply of nutrient water to the plants. As mentioned all this inter defects and any external injuries can be fortunately detected by sensors and be displayed on the computer screen.

But are there any chances for internal or external damage to the POD?

the answers to this question can be said as that it depends. If the sensors present in the POD are damaged there are chances for quick demolition of POD but as long as the sensors are fine it is ok to say that everything and process can be carried out without any problem, the external injury particularly when an external force is acted upon the chances of damage are considerably low as the material used in POD[PTFE or Teflon] and type of glass for cylindrical casing are very strong and have very high extreme points but this can potentially disturb the placement of objects in POD which would be problem, but in overall examining the POD can stand pretty hard against any potential damage causing actions.

What makes this POD unique?

The shape itself is a vary advantage to the POD which redefines the working of aeroponic and the compact design containing almost everything to carry out photosynthesis in the harsh space condition and the ability to detect any potential damage threats to the POD and the automated system which would carry out all the essential process from the sprinkling of water to spinning and supplying the essential gases with providing the right spectrum of light takes the production level to a new whole next level with maintaining the productivity of the plants.

Materials used:

The material and type of substance we are going to use in preparation of the POD should be considered to very deep

levels considering all the potential damaging threats to the POD, therefore the materials to used be in the POD are considered by taking all the points related to mobility and light weight with strong nature.
The body of the POD is designed to be made of **PTFE or Tefflon**
This polymer of plastic offers a great variety of characteristics such as:

1) High flexural strength
2) Chemical resistivity
3) High melting and boiling points
4) It is a soft plastic
5) It is a low friction plastic polymer
6) The polymer is also insoluble in most solvents and chemicals

So why exactly are we going to use a plastic polymer which is chemical resistant and a low friction plastic polymer, It's because the nutrient water used here is infused with NH4Cl which is a ionic compound and there is release of ions when the compound is dissolved in water, to prevent the electric flow because the structure is well supplied by electric circuits this plastic is being used the low-friction offers a more free movement of POD as the POD would be rotating at particular RPM to maintain the force of gravity. As for the cylinder case any sort of hard and high tension taker glass would be enough.

1.2 Structure Internal:

Apart from providing a really good shape and high rugged form of plastic with advance level use technology and engineering is involved the POD would not still be suffice of giving out plants.
The right amount of supplying of essential materials to promote growth is important, which is what exactly this section is about.
Constituents:

1) Nutrient water.
2) Sprinkler system.
3) Flow of water from storage unit to sprinklers.
4) How would you store plants?
5) The amount and time gases would be released in the case.
6) The lighting system.

Nutrient water:
The water which is the whole game of the **Aeroponic system** and the ultimate source of nutrient to the plants. The concept of water which would here provide nutrient to the plant has some amazing application of chemistry.
We know that there are some list of **macro and micro nutrients** required by the plants in order to grow, the following list consist of macro and micro nutrients;
Macro-Nutrients:

1) Nitrogen.
2) Phosphorous.
3) Potassium.
4) Magnesium.
5) Sodium.
6) Calcium.
7) Sulphur.

When we observe these nutrients, we come to know that there are some highly reactive metals when dissolved in water that too from some metals special conditions have to be made so that the metals can dissolve.
When doing this process the reaction taking place would be Metal and water which would be generally a exothermic reaction (for high reactive metals), but we do not require any kind of exothermic reaction to take place and separate conditions cannot be made for dissolving some, However when the POD will be rotating there are high chances of this metals to lose their nutrient value.

Plants take nutrients by **Osmosis** through roots**. Roots use the nutrients as ions in water as positively or negatively charged ions**. The primary nutrients which are required are generally products of ammonia [keep in mind that separate amounts of ammonia should be added in order to escalate the growth during the period of cultivation]. The produce of ammonia is really thought to have some great impact and growth of plants. Then dissolving ammonia directly into the water also seems quite difficult so one of the ionic compound of ammonia which is NH4CL can be used to bring out the ions,[note that as NH4CL is a ionic compound it can be easily dissolved in the water], the reaction taking place would release small amount of heat which is negligible, when dissolving the solution release Cl- and NH4+ ions the CL- ions gives a slight acidic medium to the solution and it would also help in smoothening of water which is again helpful to promote growth, the NH4+ ions are having high concentration of Ammonia which is helpful in stimulating growth. Note that amount of ammonia has to be checked because plants would require the amount of nutrient that is ammonia according to the need.
How effective is using ION infused water going to be useful in the process of growing plants?
when there is reaction of NH4CL and the water the PH value of the water automatically decreases which is required because in ISS the PH value of water ranges from 6.5 to 8.5, the water becomes optimum for growth of plants.
apart from PH the also value to be considered is the PPM which is the amount of nutrients present in the liquid this can be easily detected by a **Electric conductivity by a meter,** when the Ph decreases and there is release of IONs the liquid can transfer electricity [note that there won't be any kind of flowing of current through the nutrient water] this would also help in the growth of plants.
In an experiment carried out in Brazil in year 2006, where Sodium Chloride has been used as fertilizers in an area of 135m^2 where 15 m long rows 1.5m apart the results of the experiment where the productivity had exponentially increased, and the results were far better [1]. therefore, when the compound dissolved in the water this would help the plants to grow to their full potential.


NH4CL growth graph

https://www.scielo.br/j/rbcs/a/L8WYSNcJfKhhkytH9qQmbVg/?lang=en
the given above link is the graph showing the growth of plants with the help of NH4Cl fertilizers.

Sprinkler system:
The aeroponic equipment involves the use of sprayers, misters, foggers, or other devices to create a fine mist of solution to deliver nutrients to plant roots. the key to root development in an aeroponic environment is that size of droplet, water droplet size is very crucial as it has to go hand in hand with oxygen available, if the droplet is too big then there is less space for oxygen hence the optimum size of the droplet can be said to be as 6 micron droplet, this would be a perfect amount for plants and there would be room for oxygen. The problem arises in making these sprinklers as they would have to work for a very long time that too with spraying appropriate size of droplets, the answer to this question is very simple that this is not a very good question as the type of sprinkler depends upon plant grown, root density and width of growing bed. However, ice or cone sprayers are most suitable for the sprinkling. This settles that some sort of sprinklers should be used based upon the plant grown. Therefore, a complete set of sprinklers are necessary and should be available on the station the implanting of the sprinklers in the POD won't be a hard job it would just be a minute's work. Apart from using sprinklers the misters and foggers can also be used as these products would not require any kind of specifications.
The placements of the sprinklers or misters or foggers also has a big role to play, the right placement of the products should be done aligned to that of the rows of plants present on the outer layer so that the contact of water droplets to the plant's roots can be made as easy as possible. The droplets have to be sprinkled at regular intervals of time so that the plants can absorb the nutrient water and as it is a basic principle of Aeroponics. The water can be sprayed in 2 ways as in short term method or long-term method.

Short-term method:
In this method the nutrient water can be sprinkled at a rate so that in one minute 6 seconds the water can be sprinkled out and reaching the surface of roots, the disadvantage is that plants would not get enough time to soak all the moisture even though they are atomized the chances of actually complete absorption of the water molecules are quite less. The short-term method also makes it difficult for the pipe which would be transporting the water from storage unit to the sprinklers for every short interval of time [Note: the time taken here is just an example real working and spraying of nutrient water may differ]

Long-term method:
In this method the water droplets are sprayed for one minute for every 10 minutes, unlike in the short term method the time for absorption of nutrient water is far more greater then, hence the plants would have more time for better absorption of the nutrients, thereby increasing the chances of growth of plants to their full potential [Note: the time period taken here is just an example real working and spraying of nutrient water may differ]

Flow of water from storage unit to the sprinkler system:
The flow of water from the storage unit to the sprinkler system is also a very important place to consider, the pipe present in the centre of the storage unit and moving up to the vertex of the POD has been appointed this job, the job is quite difficult as the sucker present in the pipe has to suck the water from the curves of storage unit as the water gets accumulated there due to action of artificial force of gravity and after collecting the water from the end curves the water has to be transported to the sprinklers safely , considering that this job would also be done by the automated system we still will have to consider that if any sort of damage has been occurred to the POD due to the external triggers and if the pipe somehow gets detached the water probably wont flow out as the gravity would be flowing through the curves but the pipe might damage sprinklers and parts of plants as we go up to the top and as the radius decreases the chances of pipe coming in contact with the plant roots are high so proper fixing with the appropriate use of suckers present in the pipe is necessary to maintain the cycle of transporting the nutrient water to the roots of the plants.
The pipe is made up of thin layer of plastic which could take up to the cool temperature and are strong with low density and being light at the same time with chemical resistant , this characters are needed so that the no harm could potentially harm the plastic and the POD and the process of transportation can be carried out smoothly
The plastic which can be used as pipe can be considered as LDPE [Low Density Polyethylene]
Low-density Polyethylene (LDPE) is **high** clarity and chemically inert **polymer** that is widely used, owing to **its** flexibility, barrier **properties**, good impact strength, and stress crack resistance.
This polymer of plastic is perfect for the pipe we desire to build.

Samples	Type of formulation	Young's modulus (MPa)	Tensile strength (MPa)	Elongation at break (%)
LDPE	F0	207.26±0.60	29.66±1.06	56.06±1.21
LDPE/ATCF	F10	226.80±4.88	26.78±0.64	28.18±0.77
	F30	264.93±2.58	24.65±0.41	18.82±0.54
	F50	293.10±3.00	21.57±0.69	14.18±0.61

This table gives information regarding LDPE and its types.

How would we store plants:

The plants aligning area which has been thought is in the rows accordingly on the slant height of the POD the rows are again made up of PTFE the plants will have their own slots in each which the plants will be grown the size of the plants also depends the big plants[greeny leaves] and other similar to that can be grown at the bottom as these rows are very wide and offer a large space the plants have to be placed with maintaining some distance so that there wont be a crowd and it would be easy for the astronauts to pick the plants. The size of the plants decide that where can this plants be grown medium size occupying plants such as oranges, apples can be grown on the middle rows from bottom, the top layers are appointed for less space taking plants. Suppose lets consider that the vertical height from the base of the POD is 5 meter and 20 cm have been given to the storage unit in the remaining 4.8 meters 4 rows can be made with 1.2m gap the rows also wont be congested and plants will have large area to grow and the process of taking grown plants from the POD would also be easy. The roots of the plants are fixed towards the POD exposed to the sprinklers and they would be acquiring nutrient water the shoot would be outwards exposed to lights and the essential gases. The rotating of the POD would also try to shoot away the plant from the pod but with adjustable system the plants can be easily fixed to there places.

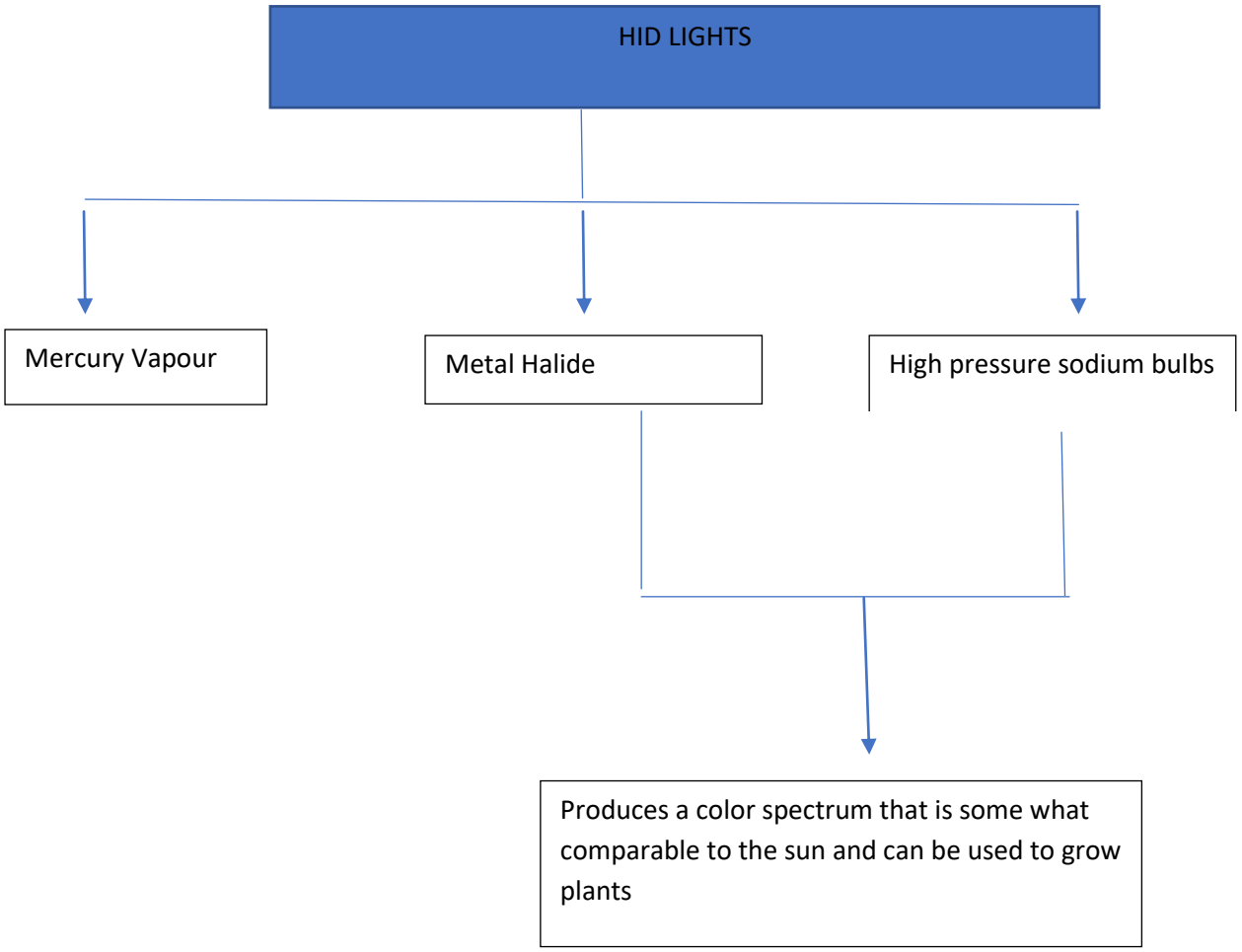
Gases:

When and how gas would be released:

The essential gases required by the plants to carry out photosynthesis are carbon di oxide , fortunately there is no lack of this gases on the space station the carbon di oxide can be taken from the astronauts breath and some part of it can be preserved , this preserved CO2 is going to be entering the POD through the input shaft located on the cylindrical cases. The gas would be release into the chamber when the POD doesnot rotate and small amount of gas would be released at intervals of time so that the effect of gravity remains and the small amount can be quickly consumed by the plants. The releasing of gases would be after the nutrient water reaches the plant in that 1 minute time interval and the lights would also be functioning then providing the required environment for the plants to carry out photosynthesis. As the process of releasing is also quite difficult for manual functioning the process is automated.

Lightning system:

Last but certainly the most important thing in the structure is providing the plants with right spectrum of light which is equal to that of the sunlight to get the produce up to its highest productive level, there are lights which offer this service which are subsets of **HID lights which are and high pressure sodium bulbs metal halide lamps.**



It has been found that this light sources have spectrum to that of sunlight and we know that sunlight is best for plants to carry out photosynthesis as these lights have similar spectrum all kinds of -plants can be grown and the frequency need not has to be checked and this would help in growth. The lights are placed in series together on the interior of POD in vertical columns in hexagonal shape [when viewed from top] there is a perpendicular angle of lights reaching to the leaf surface and this alignment is perfect for the growth of plants.

3. CONCLUSIONS

At the end this project of aeroponics is infused with very high level of technology and engineering which would literally take the basic working principal of aeroponics to whole new level, with the appropriate technology and proper usage and proper functioning of this project the chances that humans could grow their own food miles away from earth up in the skies with just a tap of their fingers, the POD would be the gadget which would wave flag for further space food production. Now the astronauts have to no longer wait for the frozen food supplies to arrive nor do the people have to spend lots of money to send food packages to the space and the POD would be the beginning for human space food production.

REFERENCES

[1] **Ammonium chloride as nitrogen source in sugarcane harvested without burning** .https://doi.org/10.1590/S0100-06832010000400016