A

Dissertation Report on

DESIGN AND DEVELOPMENT OF SOLAR POWERED VENTILATION SYSTEM FOR ONION STORAGE

Submitted in partial fulfilment of the requirements

of the degree of

Bachelor of Technology

by

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CERTIFICATE

This is to certify that the report entitled 'Design and Development of Solar Powered Ventilation System for Onion Preservation' submitted Jaydatt Avinash Jaybhaye (MIS No. 111910047) & Shantanu Shailesh Deshmukh (MIS No. 142010004) in the partial fulfilment of the requirement for the award of Bachelor of Technology (Mechanical Engineering) of College of Engineering Pune, affiliated to the Savitribai Phule Pune University, is a record of his own work.

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This report entitled

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(An autonomous institute of Govt. of Maharashtra)

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ABSTRACT

Onion is one of the important commercial crops grown on a large scale in many countries. The process of harvesting onion crops requires five to ten days for a big farm and for better storage life onions should be gone through field curing and drying. So, daily harvested onions are temporarily stored on the farm. Tarpaulin is used to protect them from direct sunlight and rain.

Fresh onions have a very high amount of water content around 85-90% and at this water content onions have a very high specific heat capacity. Due to this improper ventilation of onions in peculiar time, 40 to 60% of onions get spoiled in the future and its storage life decreases.

To tackle these problems, we have used a VCR system to get the required cooling rate for the air. To induce forced circulation of air, we can use a blower with a duct system. The blower is adjusted such that, the suction side is at the cooling coil. Then this cool air is supplied to the storage facility with the help of duct. Over the main duct small opening are made, so that equal distribution of air in every direction can be achieved. In the evening and night time, atmospheric temperature is low. This cool air is circulated through onions using a blower and duct system.

Study shows that for proper storage of onion bulb the temperature should be 25 to 30 0C and humidity should be 60 to 75 %. This condition reduces the storage losses, which are in the form of physiological loss in weight, rotting and sprouting. If we can achieve these temperature and humidity conditions, we can provide proper ventilation to onion storage and will help to reduce losses as much as possible.

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NOMENCLATURE

T_0	Atmospheric Temperature (0C)
T_i	Temperature inside Tarpaulin (^{0}C)
RH_0	Atmospheric Relative Humidity (%)
RH_i	Relative Humidity inside Tarpaulin (%)
K	Thermal Conductivity (W/mK)
Cp	Specific Heat Capacity (kJ/kgK)
P	Density (kg/m^3)

ABRIVIATION

CFM	Cubic Feet per Minute
VCR	Vapor compression refrigeration
Temp	Temperature

Chapter 1 : Introduction

1.1 Introduction

Onion (Allium cepa L.) is one of the oldest bulb crops, known to mankind and is consumed worldwide. It is one of the most important commercial vegetable crops grown in India and is believed to be originated in Central Asia. It is valued for its distinct pungent flavour and is an essential ingredient for the cuisine of many regions. Onion is the queen of the kitchen.

After harvesting the onion bulbs are kept for curing. This process removes excess moisture from the outer layers of the bulb prior to storage. The dried skin provides a surface barrier to water loss and microbial infection, thereby preserving the main edible tissue in a fresh state. The removal of moisture also reduces shrinkage during its post-harvest handling and storage. Drying also reduces shrinkage during subsequent handling, reduces the occurrence of sprouting, and allows the crop to ripen before fresh consumption or long-term storage. Various experiments have been carried out on the effect of different curing methods on the storage life of onions. Among the different curing methods, field cured bulbs kept under 50 percent shade for 15 days and tops removed 15 days after harvest (T5) were found superior with minimum storage losses.

In India, the farmers practice different storage methods. The onions are bulk stored in special structures with thatched roofs and side walls made up of bamboo sticks or wire mesh for ventilation. Modern structures are also there for their storage. Despite the achievements in production techniques, a significant reduction in post-harvest losses is still a goal to be achieved. Storage losses of rabi harvest onions range from 30 % to 60 %. For onions stored under natural ventilation, the storage period lasted five months with storage losses of 4.18 to 4.71 percent, whereas in forced ventilation, the storage period was extended to eight months with 2.21 to 2.25 percent losses.

1.2 Onion Drying & Curing

Properly drying onions prior to storage is key to their preservation and prevents the development of bacteria, mold, and freezing of the onions. Drying is especially important in wet climates or if the onions have been exposed to extended periods of moisture through the harvesting season. The perishability of onions is directly related to their respiration rate; less moisture present at the time of storage means a longer shelf life.

It is extremely important that the onions are dry before they are lifted from the field and that all excess moisture is gone before they are stored. A dry outer layer of skin protects and maintains onion freshness and quality during storage. Bulbs harvested for storage require a total of 14 to 20 days of drying and curing prior to being stored. An onion is dried correctly if the neck is tight and outer scales are of uniform colour and dry to the touch. The proper technique prevents shrinkage and sloughing off the onion caused by excessive drying.

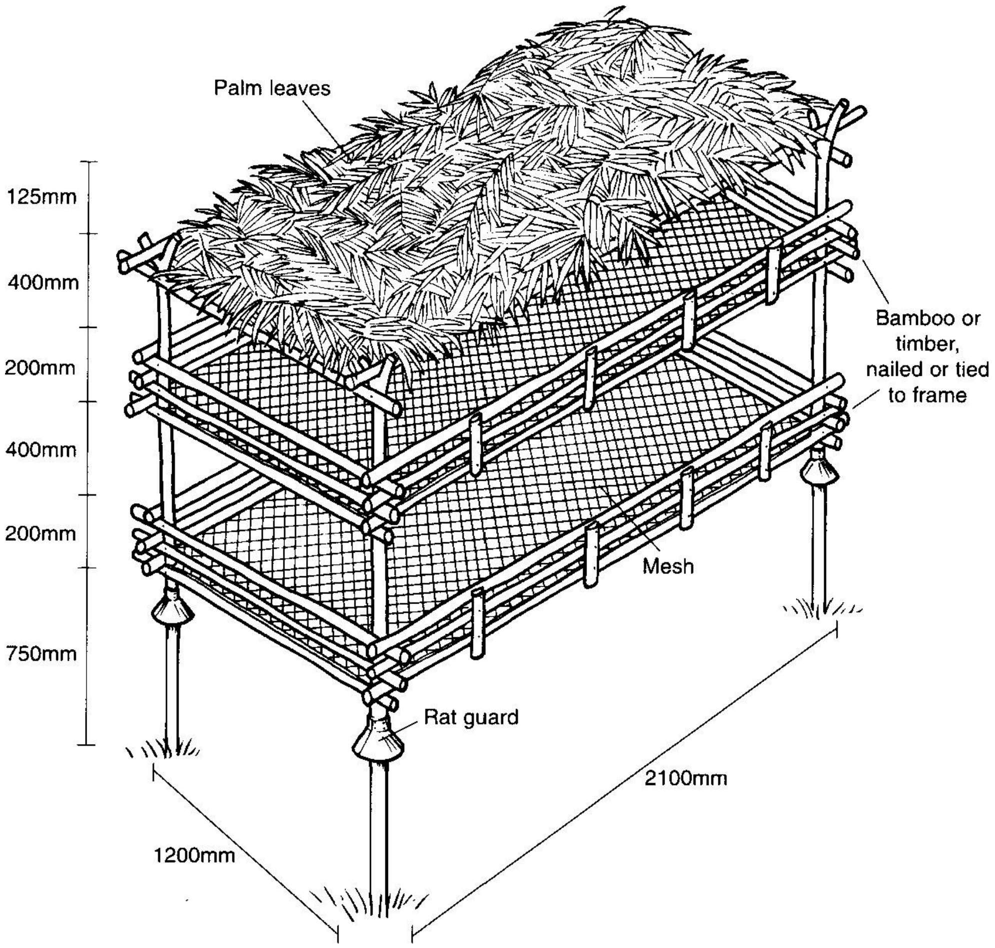

Fig 1: Permanent shed for outdoor drying of onions

Curing, like drying, requires heat application (natural or artificial) before the onions are placed in a storage facility. Proper curing optimizes maximum storage life and quality of onions, protects them from damage and disease, and promotes natural dormancy. Curing processes vary from grower to grower in each geographical growing region. Cost-effectiveness and sustainability are dependent on weather conditions and available resources.

Artificial curing can reduce the incidence of neck-rot and spoilage of the onions and may be necessary if onions are exposed to significant amounts of moisture, humidity, or low temperatures during the harvesting season. Artificial curing methods involve blowing hot air on onions placed on large pallets. The hot air near 66°C must blow at approximately 3-4 feet/second for a period of 16-24 hours. It is important to monitor the onions to avoid cooking or overheating, as temperatures exceeding 52° C for 24 hours or 46°C for 48 hours can severely damage onions in storage.

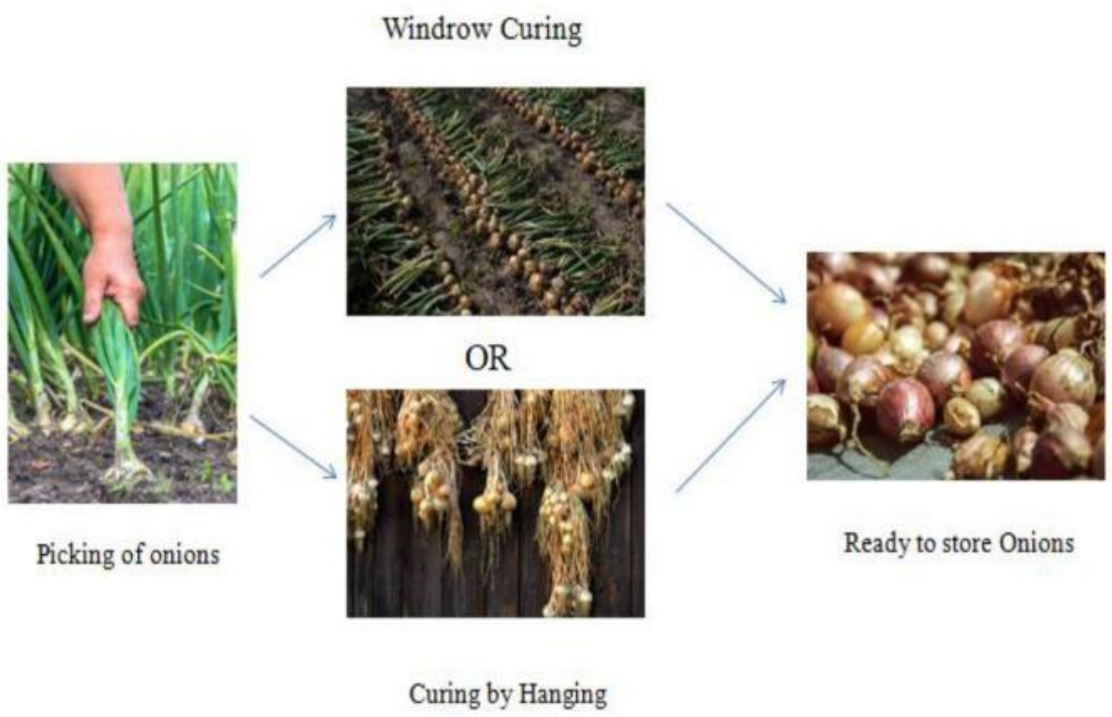

Fig 2 : Process of Curing Onions

Natural curing may be beneficial if onions are grown in a climate hot and dry enough for them to be cured outside. In natural curing, onions are typically windrowed, topped, and left to dry in the field in bags or crates for a period of at least 5 days. During this time, precipitation could disrupt the curing process. If the weather does not permit windrowing, other drying methods may be necessary. It has been noted that for optimal curing, the use of bulk pallets or wooden crates should be considered. It should also be noted that if curing in crates or pallets is not possible, curing onions in burlap bags are suggested. Onion has been correctly cured when the neck is dry and shrunken.

Other natural curing methods minimize handling by allowing crops to cure in place. In the cure-in-place method, water supply to onions is cut 1 to 2 weeks before lifting, working best in areas with dry, warm harvesting seasons. Once fields have been dried, onions can be undercut (removal of roots) by a machine, then lifted, topped, and loaded in a one-step process for immediate bagging or storing. This minimal handling process maximizes efficiency by reducing costs, energy usage, and the number of harvesting processes.

1.3 Post Harvesting Losses in Onion

I. Physiological loss in weight

Onion bulbs contain 85-90 % water. Being in an active stage, it produces and loose water due to respiration and transpiration. The storage condition influences the rate of water loss. The storage condition is governed by temperature, relative humidity, air movement and atmospheric pressure. The injuries increase the rate of respiration and accelerate weight loss. The weight loss may be 5-6 percent per month of storage in ambient storage conditions in tropical conditions. The storage losses increase with the duration of storage due to an increase in rotting and sprouting. The weight loss in onions increases with an increased storage period and is affected by the time of storage due to variation in temperature, relative humidity and rainfall. The season of storage also influences the weight loss as it is more in Kharif (rainy) season crop as compared to late Kharif (Late rainy) and rabi (winter) crop. The physiological weight loss was 19.29 to 20.87 and 6.14 to 4.97 percent for ambient stored onions and cold-stored onions with Hessian cloth bags and Nylon net bags respectively. The physiological weight loss was much higher in ambient stored onions as compared to cold-stored onions. The total storage losses were reduced to 39.23 percent in ventilated bamboo structures compared to conventional storage structures (53 %) after five months of storage of onion bulbs.

II. Sprouting

Sprouting is one of the principal factors limiting the storage life of onion bulbs. Sprouting is a result of normal physiological changes in stored bulbs, which as biennials; develop reproductive shoots in their second year. The storage condition does not cause sprouting, but only affects its rate. Onion varieties varied significantly in the percentage of sprouted bulbs during storage and sprouting increases with an increase in the storage period. A study on the influence of storage temperature and humidity on the keeping quality of onions shows that sprouting in stored onions was generally influenced little by the humidity, but it increases with an increase in temperature (over the range of 0 to 10° C). An increase in sprouting percentages towards the end of the storage period could be due to the decrease in temperature or due to the loss of dormancy in the bulbs. Many workers indicated that if the duration of storage is extended into the winter season and the temperature drops to intermediate levels, sprouting is rapidly encouraged.

III. Rotting

Improper curing, injuries from the field and thick neck allow the entry of pathogens during curing and transport. These pathogens cause the blackening of scales and rotting of bulbs. Fusarium bulb rot and neck rot are the most prevalent diseases of stored onion in tropical conditions. Bacterial soft rot (Erwinia caratovora), black mold rot (Aspergillus niger), Fusarium bulb rot (Botrytis spp) are common storage diseases. These are the most destructive post-harvest diseases of the onion bulbs. Different parts of the bulbs from the base to the neck may be attacked. The affected tissues are watersoaked and appear shrunken and brownish in the advanced stages of infection. Under dry conditions, decayed tissues are dry and papery. Mycelial growth often accompanies the affected areas. Black mold rot produces black powdery masses on the outside scale, following the veins. Certain fungi may only induce discolorations or blemishes, lowering the market value of onions. The study shows that rotting of the onion bulbs stored during cold storage and post-cold storage with sprout suppressant and packaging materials at ambient conditions. There is no rotting of bulbs in cold-stored onions after four months of storage. Rotting is higher at ambient storage than cold storage even after four months of post-storage at room temperature. The rotting is 4.44 % and 16.04% in cold-stored onions during four months of post-cold storage and ambient stored onions respectively.

Fig 3: a) Sprouting Fig 3: b) Rotting

IV. Root growth and other disorders

High relative humidity and insufficient ventilation is the main reason cause of root growth. Researchers found that under humid and high-temperature conditions, roots grew within a few days. The rooting of bulbs is generally low. The exposure of onions to direct sunlight results in the greening of bulbs. It is more observed, especially in white onions. The outer fleshy scales of the bulb become light to dark green and these may have undesirable flavor.

1.4 Onion Storage Types

In India, the farmers practice different storage methods. The onions are bulk stored in special houses with thatched roofs and side walls are made up of bamboo sticks or wire mesh for good air circulation. In North India, the sides are also covered with gunny cloth. Onions are stored in these sheds by spreading them on the dry and damp-proof floor or racks. Periodical turning of bulbs or removal of rotten, damaged and sprouted bulbs should be done. Well-ventilated improved storage structures with racks or tiers having two or three layers of bulbs would be desirable for proper storage. Storage losses of rabi harvest onions range from 30 % to 60 %. Major loss in storage is physiological loss of weight about 25 – 30 % followed by 10 – 15 % in sprouting of bulbs and finally microbial decay or rotting accounts for 10 – 15 %.

Fig 4: Hang on string method

Tat storage with a brick base is comparatively better than other local methods of onion storage.Storage in crates at room temperature and storage in tat with ground base is not economical. The onion bulbs stored in a shed lost 25.75 percent after 90 days of storage compared to 48.42percent in onion stored in a room without ventilation and also found that with an increase in ventilation by partitioning the ‘tat’ the percent of loss in weight is decreased as compared to the completely filled tat without a gap. Onion storage under natural ventilation, the storage period lasted five months with storage losses of 4.18 to 4.71 percent, whereas in forced ventilation, the storage period is extended to eight months with 2.21 to 2.25 percent losses. Onion bulbs stored in a shed lost 25.75 percent after 90 days of storage compared to 48.42 percent in onions stored in a room without ventilation and also found that with an increase in ventilation by partitioning the 'tat', the percent of loss in weight is decreased as compared to the completely filled tat without a gap.

Fig 5: Roof over Pattarai

Maleic Hydrazide @ 800 ppm sprayed bulbs stored in polyethylene bags recorded lower rotting(15.8%) as compared with the untreated bulbs (17.6%). The same treatment recorded less sprouting and sprout length as compared with the control. The curing method of storage is thebest method of storing onion under ambient conditions followed by the hanging method.

Fig 6: Low cost storage structure

Traditional storage shed known as chawl and model stores in rabi onion and revealed that afterfive months storage period, the storage losses are 70 percent in poorly ventilated chawl compared with 50 percent in better-ventilated model store. Among different storage methods practiced by the farmers, split bamboo storage structure with a central hollow is found better and the extent of losses by way of spoilage, and sprouting was minimum during storage.

Fig 7: Forced air onion storage

The conventional onion storage structure called chawl which has no aeration at the bottom and onion can be stored up to 1.5 to 2.0 m in height resulting in a lot of bruising and decay, and also reported onion stored in a modified improved storage structure with a bottom and central ventilation with the raised floor (60 cm) of structure above ground reduced the storage losses from 99.2 to 70.0 percent during five months storage. The storage temperature of 15°C along with relative humidity of 50 to 70 percent could be helpful to reduce the rotting and desiccation to the desired level to lengthen the storage life of onion bulbs in storage. The total losses in low-cost bottom ventilated structures are much lower (35.17%) than in recommended bottom ventilated structures (44.96%). The sprouting and black mould infection are also lower in low- cost storage structures.

1.5 Thermophysical Properties of Onions

Freshly harvested onions have a water content of more than 80%. Following are the propertiesof onion for 85% water content:

- Density = 1040.3 kg/m^3

- Specific heat = 3.79 kJ/kgK
- Thermal Conductivity = 0.5 W/mK
- Thermal Diffusivity = 1.39 x 107 m^2/s

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Chapter 2: Literature Review

2.1 Introduction

This chapter deals with the literature referred concerning the project work. This chapter consists of the research work referred in order to develop some background knowledge, recent updates as well as the scope of this research in the future.

2.2 Review of Research Paper

1) **C. Karthikeyan et al. [CDDS09]** studied about Pattarai which is constructed in levelled fields by placing equal-sized rectangular stones to act as a load barrier kept at 2 feet in-between each stone. The custom-made neem wooden board is placed over the stones and all three sides are covered with manually woven bamboo sheets. The structure is filled with onions and the fourth side is either covered with jute gunny bags or bamboo sheets as per the convenience of the farmer. The top portion of the pattarai is covered with coconut thatches to prevent from rainfall, and excess sunlight, which also facilitates ventilation to the stored onions.
2) **S. A. Ranpise et al. [SRBS01]** used the conventional onion storage structure called chawl which has no aeration at the bottom and onion can be stored up to 1.5 to 2.0 m in height resulting in a lot of bruising and decay, and also reported onion stored in a modified improved storage structure with bottom and central ventilation with the raised floor (60 cm) of structure above ground reduced the storage losses from 99.2 to 70.0 percent during five months storage. The storage temperature of 15°C along with relative humidity of 50 to 70 percent could be helpful to reduce the rotting and desiccation to the desired level to lengthen the storage life of onion bulbs in storage.
3) **K. C. Krishnamurthy et al. [KACS87]** studied the storage trials at Pimpalgaon in Maharashtra in a traditional storage shed known as chawl and model stores in rabi onion and revealed that after five months storage period, the storage losses were 70 percent in poorly ventilated chawl compared with 50 percent in bitter ventilated model store. In India, different storage methods are practiced by the farmers. Among those, a split bamboo storage structure with a central hallow was found better and the extent of losses by way of spoilage, and sprouting were minimum during storage.
4) **K. Singh et al. [KD73]** found that tat storage with a brick base was comparatively better than other local methods of onion storage. Storage in crates at room temperature and

storage in tat with ground base was not economical. The onion bulbs stored in a shed lost 25.75 percent after 90 days of storage compared to 48.42 percent in onion stored in a room without ventilation and also found that with an increase in ventilation by partitioning the ‘tat’ the percent of loss in weight was decreased as compared to the completely filled tat without gap.

5) **C. S. Iordachescu et al. [CN83]** studied six methods of onion storage with the cv. Staltgart Giant. In the variants under natural ventilation, the storage period lasted five months with storage losses of 4.18 to 4.71 percent, whereas in forced ventilation, the storage period was extended to eight months with 2.21 to 2.25 percent losses.
6) **S. C. Khurana et al.** [SC84] reported that onion bulbs stored in a shed lost 25.75 percent after 90 days of storage compared to 48.42 percent in onions stored in a room without ventilation and also found that with an increase in ventilation by partitioning the ‘tat’, the percent of loss in weight was decreased as compared to the completely filled tat without a gap.
7) **S. B. Maini et al. [SA00]** observed that in Sudan, mud or straw cottage was used for storing onions. Straw cottage was constructed in such a way that, they were ventilated by the prevailing wind passing through them. After five months of storage by this method, 50 to 60 per cent of bulbs were marketable. The higher temperature of 30 and 35°C caused less sprouting but higher rotting and loss in weight was observed compared to lower temperature (20- 25°C).
8) **P. C. Tripathi et al. [PK03]** reported that the total losses in low cost bottom ventilated structure are much lower (35.17%) than recommended bottom ventilated structure (44.96%). The sprouting and black mould infection was also lower in low cost storage structure.
9) **S. K. Arora et al. [SKSA93]** reported that the minimum sprouting (60.5%), rotting (15.0%) and total loss (35.0%) in wire mesh shed storage compared to ordinary room storage of onion bulbs (77.5, 20.5 and 72.7%, respectively).
10) **Subbaram et al. [MT90]** showed that in ventilated bamboo storage structure for onion, the total losses reduced to 39.23 per cent compared to conventional storage structure having 53 per cent after five months storage.
11) **P. C. Tripathi et al. [PK16]** studied seven different onion storage structures. To minimize storage losses and develop an efficient onion storage structure this onion storage structure was designed and constructed at NRC for Onion and Garlic. The findings of the experiment indicate that bottom ventilated structures were found

efficient in reduction of storage losses in onion stored at ambient atmospheric conditions.

12) **P. Thompson et al. [PSAM86]** observed that onions can be stored at high temperatures of over 25°C at a range of relative humidity (75-85%) which is necessary for minimizing water loss. However, weight loss, desiccation of bulbs and rots occurred at high temperatures, making the system uneconomic for long periods of storage that is required for successful onion marketing.
13) **L. U. Opara et al. [OL03]** studied that in tropical climates, high-temperature storage of onions can be achieved under both ambient and heated storage conditions. Under these conditions, ventilation must be carefully applied inside the store to achieve the required temperature and humidity levels.
14) **P. C. Tripathi et al. [PK19]** did a review on onion storage in the tropical region which says that storage losses in onions in tropical regions are high and a lot of attempts have been made to reduce the losses. But the storage conditions, climatic conditions, cost of storage, and poor adoption of the research findings are the main impediments. There is still a need to develop cost-effective technologies for onion storage in the tropics.
15) **M. H. Hatem et al. [MSYK14]** studied the effect of storage conditions on the quality of onion bulbs. This study was conducted to investigate the effect of storage conditions on the quality parameters of onion bulbs, with the objective to keep quality, reduce losses, prolong shelf life and keep the price stable and ensure uniform providing of the onion bulbs during the year. Results show that forced ventilated and natural ventilated storage systems recorded maximum marketable product and naturally ventilated with perforated pipes can be recommended for the local community, which assure simplicity and ease to apply.

2.3 Literature summary

The literature review indicates that present storage systems are designed for storing onions after 15 days of field drying and not for immediate storage. But the specific heat capacity of the onion is very high at the initial stage. So, proper ventilation should be provided at the initial stage of storage. So, it is important to provide a ventilation system to minimize losses. By maintaining temperature and humidity from the initial stage, we can improve the quality and storage life of onion bulbs by providing a proper ventilation system.

We also referred to a study did by a M.Tech student Mr. Sushant Mandake of College of Engineering, Pune. The title of the thesis is design and development of solar operated ventilation system to preserve freshly harvested onions with the help of waterproof and breathable tarp material. The aim of the study was to achieve the desired conditions for the on-field storage using different types of fabric sheets and duct system with blower powered by solar.

Results from on field Experimentation:

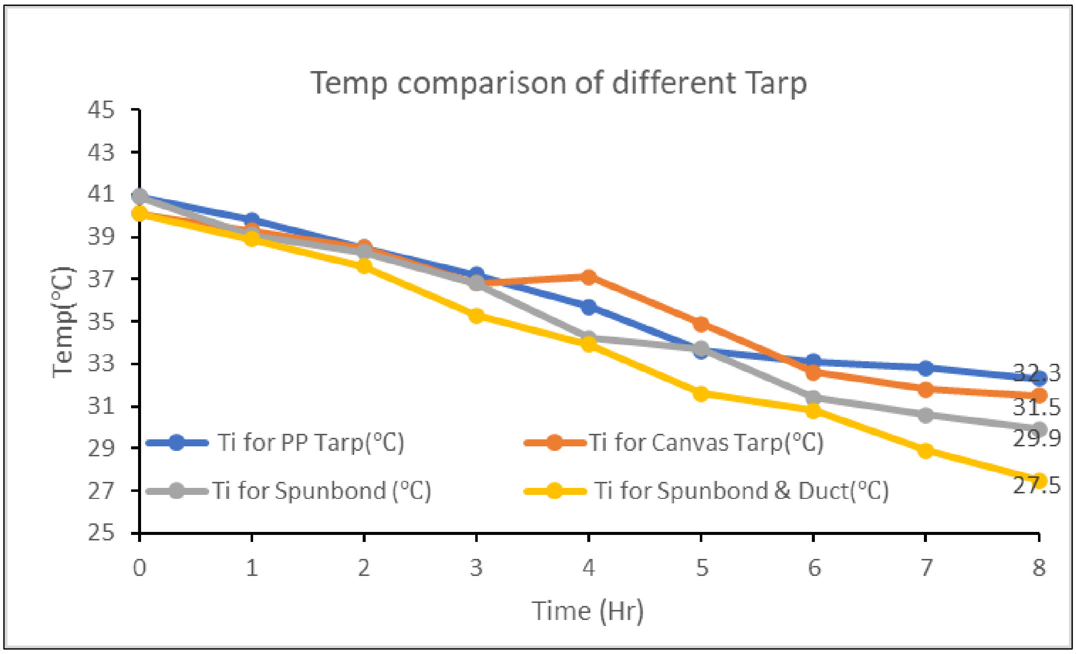

Fig 8: Temperature Comparison of Different Tarpaulin

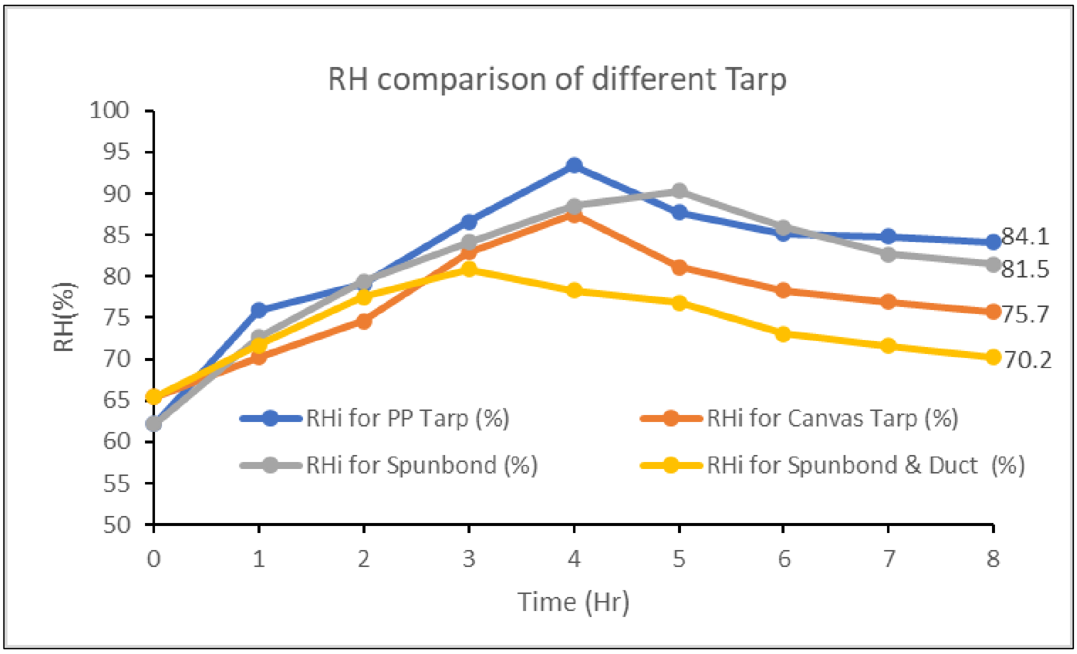

Fig 9: Relative Humidity Comparison of Different Tarpaulin

From the above graphs it can be concluded that for proper ventilation conditions, we can use spun bond fabric with a duct system that can give desired temperature and humidity range.

Chapter 3: Problem Definition

3.1 Problem Statement

Onion is one of the important commercial crops widely used in all households all year round. The process of harvesting onion crops requires five to ten days for a big farm. Onion is a semi perishable vegetable and is harvested during rabi season accounts 65% of onion production, hits the markets from April to May. The same crop must continue to meet the consumer demand till the month of October-November every year before the kharif crop is harvested and brought to the market. It is therefore vital to successfully store onion in order meet the regular supply. It is observed that nearly 30-40% of the crop is lost during storage due to the various reasons in form of physiological weight loss, rotting, sprouting etc. In unexpected situations such as natural calamities, the losses even go beyond 50% creating heavy stress both on demand and supply sides. The losses occurred during storage are in terms of qualitative as well as in quantitative ways. From the graph it can be observed that the prices of onions are relatively higher in the months of August to December. The prime aim is to store onion up to the peak demand period, with minimum losses.

Fig 10: Price Variation of Onions according to month

3.2 Objectives

After studying the problem statement following objectives are finalized for the project:

- To carry out a proper literature survey to find possible solutions for the onion storage problem and the feasibility of the solution.
- To design and develop a ventilation system with the help of using a VCR system powered by solar energy.
- To provide desired conditioned air to the stack of onions at reasonably higher flow rate.
- To reduce the losses as much as possible and maintain the quality of onion.
- To test the ventilation system for onion preservation.
- Compare the obtained results of proposed system & convectional system.

Chapter 4 : Theoretical Background

4.1 Design of Onion Storage Structures

Onion is a semi perishable vegetable and is harvested during rabi season accounts 65% of onion production, hits the markets from April to May. The same crop must continue to meet the consumer demand till the month of October-November every year before the kharif crop is harvested and brought to the market. It is therefore vital to successfully store onion in order meet the regular supply. It is observed that nearly 30-40% of the crop is lost during storage due to the various reasons in form of physiological weight loss, rotting, sprouting etc. In unexpected situations such as natural calamities, the losses even go beyond 50% creating heavy stress both on demand and supply sides. The losses occurred during storage are in terms of qualitative as well as in quantitative ways. Hence, it is imperative to take some crucial steps pertaining to onion storage with minimum losses to ensure the adequate supply to the market there by reducing the price fluctuations.

Table 4.1 : Current Quantitative losses and Expected Targets

	Type of loss	Reported losses	Expected loss with potential solutions
1	Physiological weight loss (PLW)	20-25%	15-20%
2	Rotting/ decay	10-12%	≤ 7-10%
3	Sprouting	8-10%	≤ 6-7%

Qualitative losses:

1. Black mold: 25-30% reduction in market value
2. Outer skin removal: 25-30% reduction in market value

Various abiotic factors like temperature, relative humidity affects the health of onions hence their balance is must needed to store the crop with minimum losses.

- High temperature (Above 32°C) + Low RH (Less than 60%) = Weight loss
- Low temperature (0 - 2°C) + Low RH (Above 70%) = Sprouting
- High Temperature (Above 32°C) + High RH (Above 70%) = Rotting
- Temperature (25-30°C) + RH (60-65%) = Recommended

OR

Temperature (0-5°C) + RH (65-70%) = Recommended

When removing the onions from cold storage, they must be heated up/conditioned to the outside temperature to avoid post-storage sprouting and the decay temp should not increase more than

2°C/day. This process of conditioning requires great energy and a lot of time where the scope of improvement is needed. The irradiation treatment of onion bulbs in which sprouting has not been initiated is recommended during the vernalization process at low temperature before storage, otherwise it makes black colour spot inside the bulb.

Scope of improvement:

- Optimization of various abiotic factors during tempering / conditioning.
- Development of sensor-based detection system of onion weight loss/ rotting/ sprouting/ decaying etc.

4.1.1 Naturally ventilated structures (Kandha Chawl):

Kandha Chawl are the naturally ventilated structure, a scientific onion hut to minimize the losses due to storage. In India, the onions are mostly stored in such structures without any control of temperature and relative humidity. The farmers construct different types of Kandha Chawl based on the capacity required.

- **Low-cost thatched roof bamboo storage structure:**

  This type of storage structure is usually constructed with bamboo framework having the roof made up with sugarcane leaves and is preferred for 'on-farm' storage of onions. This is a single row storage structure that can be made of 5 to 10 tones capacity. The structure is constructed with bamboo rafters. The whole solid bamboos are used for pillars and roof beams. Half split bamboos are used for floor while the sidewalls are made by split bamboos (1/6). The pillars of whole bamboos are erected at five feet distance. The iron angle provide support to all pillars. The bottom ventilation is provided with bricks fixed at the base of all iron angle pillars. The roof is usually made with sugarcane leaves but similar type of grass can be used for this purpose. Inner lining of gunny cloth is provided to check the leakage of rainwater. This type of structure should be made in North to South direction. This type of storage structure is low cost and easy to construct, but leads up to 40-42% losses of onion during four months of storage. The durability of the structure is low due to use of organic material / bamboo. The temperature and humidity cannot be controlled since it works on natural ventilation mechanism.

Fig 11: Low volume structure

- **Bottom and side ventilated storage structure:**

This has provision ventilated floor made of wooden bantams, central ventilated pathway and extended roof. The framework of the structure was constructed with galvanized iron channels. The floor and sides walls were made with wooden bantam of 2.5 cm thickness and gap of 2.5 cm in kept between the bantams. The roof is constructed with asbestos sheets. The roof was extended to 1 meter to avoid splashes of rain. This type of structure has a provision of ventilation from bottom and sides.

Fig 12: High volume structure

These current prevailing structures that may vary in their capacity as well as the cost to fulfil the requirements of all income groups of farmers/traders. Though these naturally ventilated storage structures are well adopted, still considerable losses occur as there is no control of temperature, relative humidity and airflow which are very important for successful storage of onion with minimum losses. The construction of the 50 MT double row modified bottom and side ventilated storage structure needs approximately Rs. 7 lakhs. Majority of the farmers in India store the onion in this type of naturally ventilated storage structures but such structures are not suitable in regions with extreme high temperatures, and high relative humidity / high temperatures with low relative humidity or low temperatures with high relative humidity. There is a scope to improve this structure by providing proper ventilation, controlling temperature in extreme summer conditions, reducing relative humidity with suitable materials and other means.

4.1.2 Controlled onion storage structures

Although cold storage systems are used in certain countries for onion, which is rarely adopted in India due to poor economics and lack of cold chain facilities required to maintain the quality in the high ambient temperature prevalent in our country. Onion storage in ventilation condition is quite satisfactory when the temperature is maintained between 25^0 C to 30^0 C with a relative humidity range of 65-70%.

Fig 13: Controlled storage structure

In controlled onion storage structures, the onions are stored at 0-5°C and 60-65% RH that leads to much lesser losses as compared to ventilated storage structure. The cost of construction (approx. 20-25 lakhs/ 20 tons) and running cost (i.e. Rs 0.60-0.65/ Kg/ month) are very high as energy required to maintain the storage facility in the temperature range of 0-5°C is high. The other problems are condensation and require lot of energy and time. The bulbs start sprouting immediately after they are removed from the cold storage.

Several losses have been reported pertaining to PLW, Rotting, scale removal, sprouting and black mould when onions are stored in storage structures like Low cost thatched roof structure, Modified bottom ventilated double row storage structure or structure with structure chain linked side walls etc.

Table 4.2 : Different types of losses (average) are reported in Rabi Onion that are stored in different storage structures and expected outcomes from potential solutions.

Storage Structures	PLW (%)	Rot (%)	Scale removal (%)	Sprouting (%)	Black mould (%)
Low cost Thatched roof structure	17.4	10.8	0.34	1.35	2.11
Modified bottom ventilated double row storage structure	19.4	17.94	0.32	37.69	11.6
Modified Bottom ventilated storage structure chain linked side walls	22.7	14.19	0.38	3.29	5.58

4.2 Pre- and Post-Harvest Management Practices

By following the below mentioned pre- and post-harvest management practices storage losses can be curtailed.

4.2.1 Pre-harvest care/ practices

- Selection of suitable material that prolongs the storage time and capacity.
- Proper irrigation from time to time without any dry spell.
- Application of recommended dose of fertilizers at proper time. Excess application of nitrogen is reported to increases the rotting losses during storage.
- Neck fall is an indicator of maturity stage hence, best time to harvest is at 50% of neck fall maturity.

4.2.2 Post-harvest care/ practices

- Proper field curing after harvest for 2-3 days by covering the bulb with leaves. De-topping the bulb by leaving 1-2 inch at the top of the bulb.
- Shade curing for 10-14 days.
- Sorting and grading before storage and storage according to grades.

- Disinfection of storage structure before loading of onions.

4.3 Curing

Curing is a drying process carried out to remove excess moisture from the outer skins, roots and neck tissues of harvested onion bulbs. It improves the keeping quality of onion bulbs and reduces the chance of infection by disease causing organisms during storage. The term "curing" is preferred because the removal of moisture is only from the outer scale, rather than from throughout the bulb. An onion bulb is a series of concentric swollen leaves attached to a short stem. Curing surface scales provides a dry barrier around the onion bulb and a sealing against water loss. Curing increases hardness of the bulb and helps to develop colour of cured bulb. Onion curing can be done in the field with natural convection of air or with forced circulation of hot air using artificial curing chambers. In traditional small-scale operations, onion drying is carried out in the field by a process called windrowing. It involves harvesting the mature bulbs and laying them on their sides (in windrows) on the surface of the soil to dry. During curing process, cover the bulbs with onion leaves to prevent sun burn. Field curing for 2-3 days in windrow method by covering with leaves, removal of foliage leaving 2-3 cm neck and then shade curing for 10 to 15 days to remove the field heat and excess moisture from the surface of bulbs is recommended for improving the storage quality of bulbs. Extra short necks increase the likelihood of disease infestation.

Field curing has limitations due to unexpected rains during harvesting time, lack of proper security and other socioeconomic reasons. If dry conditions prevail during the harvesting season, the bulbs can be cured well in the field and in the on-farm store. During wet weather, the bulbs can take longer time to dry and may develop higher levels of rots during storage. Artificial curing could be beneficial during wet weather. Through artificial curing, we can have the control on the temperature and time of curing. Onion curing by artificial means may help to reduce post-harvest losses during wet harvesting seasons, but the economics and feasibility of such operations may preclude their application.

Chapter 5 : Methodology & Design

5.1 Introduction

Our project is nothing but modification of existing system, which is a sturdy structure made up of structural steel and covered by bamboos with extended roof. As, the structure is made sturdy, it will strongly handle harsh climatic conditions, which are usually encountered during storage season. It is modification of existing low volume structures. As, previously discussed about the desired condition of air required, if this conditioned is supplied to the storage stack, it would be possible to preserve the onion beyond 3-4 months.

The conditioned air will produce using a Vapor Compression Refrigeration (VCR) system, the working principle will as follow. The VCR system employed carries a cooling capacity of 0.8TR (tones of refrigeration), which will be sufficient for 200 kg of onions. Atmospheric air will be passed over an evaporative coil, with the help of centrifugal blower at a high pressure. A hood system which will act as a coupling for both blower and duct. This cold air will then pass through an 6 inch PVC round duct having one 90 elbow. As the duct employed is round, losses will be minimum and the surface friction will be less with relatively less cost. Small holes drilled onto the duct will ensure uniform distribution of air in the structure. Various temperature and humidity sensors will be installed at various location to monitor the incoming air condition and take appropriate actions.

As we know onion bulb has high amount of moisture content, so it becomes critical to store it. The same crop must continue to meet the consumer demand till the month of October-November every year before the kharif crop is harvested and brought to the market. It is therefore vital to successfully store onion in order meet the regular supply. It is observed that nearly 30-40% of the crop is lost during storage due to the various reasons in form of physiological weight loss, rotting, sprouting etc. In unexpected situations such as natural calamities, the losses even go beyond 50% creating heavy stress both on demand and supply sides. The losses occurred during storage are in terms of qualitative as well as in quantitative ways. Hence, it is imperative to take some crucial steps pertaining to onion storage with minimum losses to ensure the adequate supply to the market there by reducing the price fluctuations.

5.2 Experimentation

Experimentation of this project is done at Department of Mechanical Engineering, COEP Technological University, Pune. The average temperature in the city is above 350C during summer. Most of the farmers from Maharashtra take onion crops every year. But they face problems will storing onions just after harvesting, as the atmospheric temperature is very high during the daytime. The method they use for onion storage is traditional as shown in figure 14

After harvesting of onion, it is dried. In this storage system, the onions are filled in the structure of height 3.5 ft and 3ft in length and width. The roof of the structure is made up of cement with some proportion of asbestos in it. The cement helps in providing strength and bonding whereas, the asbestos having lower thermal conductivity, allows less heat transfer through the walls. The blower suction side is placed near the evaporator coil. When the blower is turned on, it supplies cool air at 1000 CFM. This cool air is then supplied to the facility with the help two PVC pipes which acts as duct. By continues supply of this air the temperature of onion, they can be brought to desired conditions and can be stored for longer period of time with minimum losses.

Fig 14: Conventional method of Onion storage

As a result, the storage life of onions gets reduced drastically. Due to improper ventilation provided to onion storage in peculiar time, 40 to 60 % of onions get spoiled if stored for a long period of time. Study shows that for proper storage of onion bulb in long run the temperature should be 25 to 30 0C and humidity should be 60 to 75 %. If we can achieve these ambient temperature and humidity conditions, we can provide a proper ventilation system for onion piles.

5.3 Experimental Setup

The experimental setup will be stacked with 200 kg of freshly harvested onions. Conditioned air will be circulated through the onions by using a blower and duct system. An electric blower of 2500 rpm and 1000 CFM specification is used for the forced circulation of air in the onion pile. The power requirement for the blower is 180W and an electric supply of 220V and 60 Hz is required. The duct system is having two PVC pipe arms with a diameter of 6-inch and a length of 6 ft. using a 90 elbow. The duct system is having 2 PVC pipe arms having a diameter of 4-inch and a total length of 7 ft. One end of both arms is connected to the blower by using a hood which acts as coupling. While other ends of arm is covered by end cap.The pipe arm acts as duct placed in onions. Small holes of 25 mm diameter are created at a distance of 5 inch.

Fig 15: Experimental Setup

5.4 Experimental Procedure

1. As there is no standard method to calculate the component size and specification, the components used in the experimentation are selected from the market which are easily available to famers.
2. Stack of onion is stored in the setup of 3.5 ft and 3ft in length and width.
3. For forced circulation of air, the duct system is placed at 0.75 feet from ground level.
4. Dry and cold air is circulated through the pile by blower and duct system.
5. The duct system is having 2 PVC pipe arms having a diameter of 4-inch and a total length of 7 ft.
6. The pipe arm acts as duct placed in onions. Small holes of 25 mm diameter are created at a distance of 5 inch.
7. These 2 pipe arms are connected to the blower with 2-inch PVC elbows and a T- section.
8. Finally, the onion pile is covered with Tarp of different materials for testing purposes.

Fig 16: Actual Experimental Setup without onions

Fig 17: Actual Experimental Setup filled with onions

5.5 System Description

1) Storage Structure

a. Nitrile Insulation Sheet

Nitrile rubber or acrylonitrile butadiene rubber is a co-polymer of butadiene and acrylonitrile. It has good general resistance to oil along with good mechanical properties, especially tensile strength, flexing, compression set and impermeability to gases. The nitrile has been used as an insulation, in order to reduce load through roof. Because of the use of asbestos sheet and nitrile it created a Resistance which eventually helped us to reduce the load through roof. The nitrile used is 12 mm thick, with Thermal Conductivity of 0.036 W/mK.

Fig 18: Nitrile Sheet

b. Asbestos Roof Sheet

For decades, asbestos was added to cement sheets for strength, flexibility and heat resistance. In the United States, asbestos cement sheets were commonly used in building construction. The products were often used in roofing and siding. Asbestos cement sheeting was popular because it was easier to handle than heavy cement and more mouldable for different uses. Asbestos also made cement sheets more durable and resistant to heat and weather conditions.

Specification	Features
Thermal Conductivity of Sheet (k): 0.196 kCal/deg.C	Termite proof
	Dimensionally Stable
Thickness: 8 mm	Versatile,Fire Retardant

- **Advantages of Asbestos**
  - Asbestos is a very good thermal insulator and increases the energy efficiency of the building.

- It is highly resistant to fire and does not burn easily.
- It forms a very strong material when mixed with cement and used as an additive to form a
- composite material called asbestos cement.
- It is a very inexpensive and a very cost-effective material, hence widely used.
- It is extensively used as a protective roofing material in corrugated form.
- It is highly durable and weather proof.
- It is resistant to damage from termites.
- Asbestos is very easy to clean and maintain but difficult to repair.

Fig 19: Asbestos Sheet for Roof

2) Vapour Compression Refrigeration System

a. Blower

A centrifugal blower is a motor or pump that moves air using centrifugal force created by the rotation of an impeller that pulls air or fluids into the blower and pushes it out through the blower's outlet. The drive design of a centrifugal blower, which can be a belt or direct drive, determines the speed at which the impeller rotates. The speed and efficiency of centrifugal blowers make them adaptable to a wide range of applications, including various types of dryers and HVAC systems. The angle of the blades of a centrifugal blower determines its efficiency and effectiveness or how fast it moves air through the system. The three varieties of blade angles are forward curved, backward curved, and radial. The electric motor is either attached directly to the fan wheel, which is called direct drive, or by a belt or gear mechanism, which can be customized and allows for the ability to change the speed of the fan wheel. Once the air or gas is taken into the inlet of the blower, the motor spins the fan wheel and the air is diverted, typically at about a 900 angle, and sent through the outlet at a specific volume and velocity.

Blower Specification:

Centrifugal type (Induction Motor)

CFM: 1000

Static pressure: 740 Pa

Input: 230V, 1-Ph, 3A

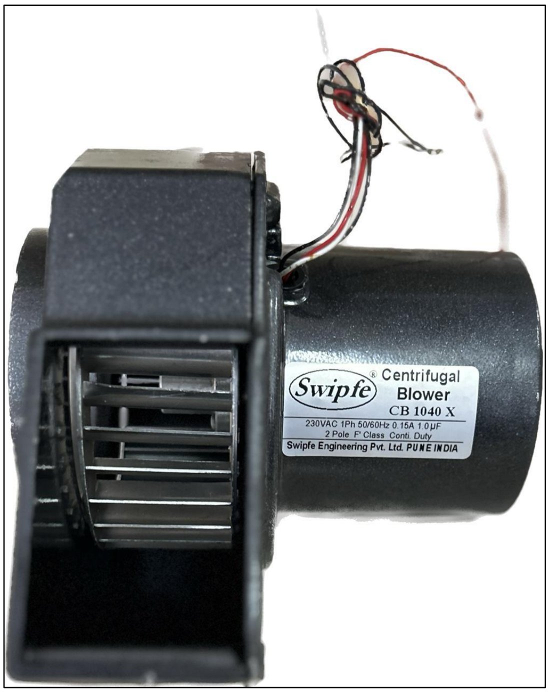

Fig 20: Blower

b. Compressor

Compression is the first step in the refrigeration cycle, and a compressor is the piece of equipment that increases the pressure of the working gas. Refrigerant enters the compressor as low-pressure, low-temperature gas, and leaves the compressor as a high-pressure, high-temperature gas. Compression can be achieved through a number of different mechanical processes, and because of that, several compressor designs are used in HVAC and refrigeration today. Other examples exist, but some popular choices are:

- Reciprocating compressors
- Scroll compressors
- Rotary compressors

We have selected a selected a rotary compressor of 0.8 TR cooling capacity. It works on R22 refrigerant. Rotary compressors, which grew up in the air conditioning industry, are primarily smaller and typically applied in higher evaporator temperatures. Rotary compressors are commonly used on window units, refrigerated appliances, packaged terminal air conditioners, and ductless split systems.

Fig 21: Rotary Type Compressor

c. Condenser

The condenser, or condenser coil, is one of two types of heat exchangers used in a basic refrigeration loop. This component is supplied with high-temperature high-pressure, vaporized refrigerant coming off the compressor. A condenser's function is to allow high pressure and temperature refrigerant vapor to condense and eject heat. There are three main types: air-cooled, evaporative, and water-cooled condensers. The condenser removes heat from the hot refrigerant vapor gas vapor until it condenses into a saturated liquid state, a.k.a. condensation. After condensing, the refrigerant is a high-pressure, low-temperature liquid, at which point it's routed to the loop's expansion device.

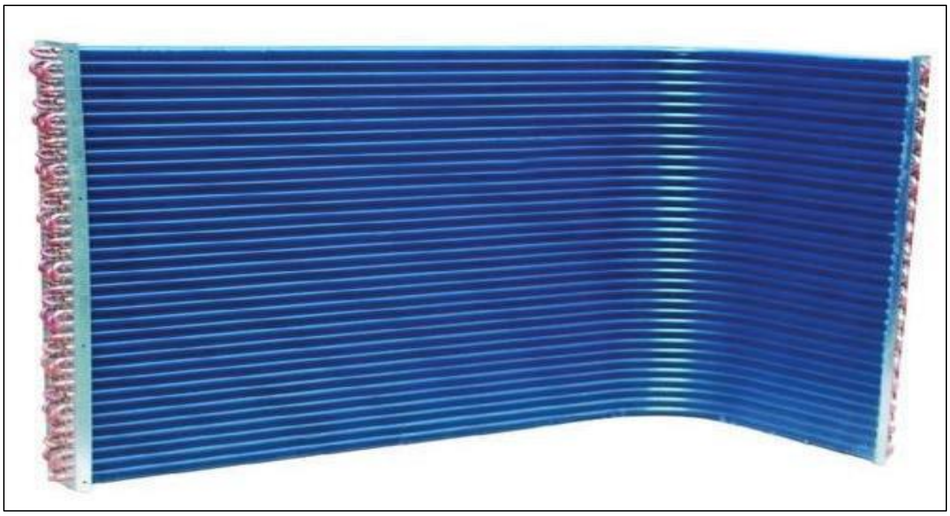

Fig 22: Condenser

d. Evaporator

The evaporator coil is the component in your AC system that absorbs the heat from the air inside your home. It is often either attached to your furnace or located on the inside of your air handler. It works with a condenser coil to complete the heat exchange process that produces cool air. The evaporator coil is full of evaporated refrigerant that the compressor pumps to the metering device as a liquid then into the evaporator. The air that is pushed through the coil from the blower fan will move over the coil where the refrigerant in the evaporator will absorb the heat.

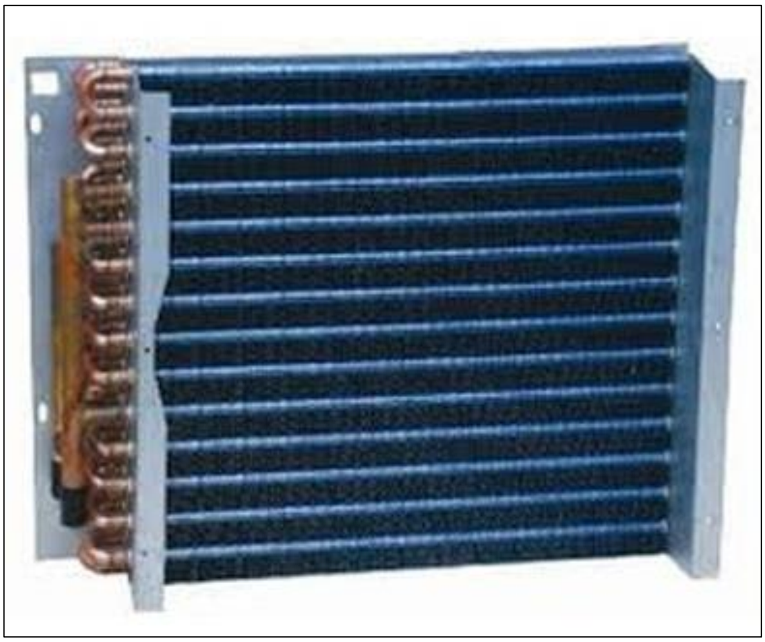

Fig 23: Evaporator

e. Capillary Tube

A tube with a calibrated inside diameter and length used to control the flow of refrigerant. Capillary tubes are the simplest of all refrigerant flow controls, with no moving parts. They normally consist only of a copper pipe, diameter 0.5 to 1.5 mm and length 1.5 to 6 m. The expansion function is caused simply by the pressure drop induced by the long, narrow tube. The capillary tube is vulnerable to clogging, which is why a filter drier and filter are normally mounted before the inlet. The mass flow through the tube depends on the pressure difference between the condensing and evaporating sides It also connects the remote bulb to the thermostatic expansion valve, and/or the remote bulb to the thermostat.

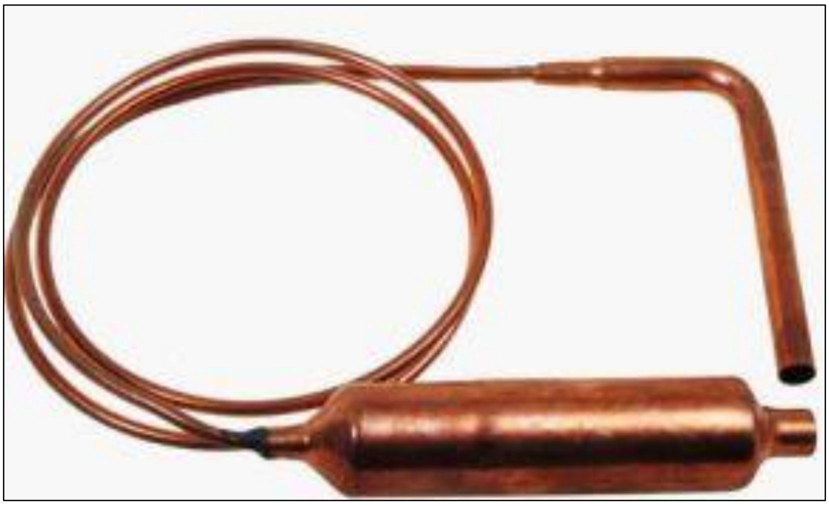

Fig 24: Capillary Tube

f. Blower

A centrifugal blower is a motor or pump that moves air using centrifugal force created by the rotation of an impeller that pulls air or fluids into the blower and pushes it out through the blower's outlet. The drive design of a centrifugal blower, which can be a belt or direct drive, determines the speed at which the impeller rotates. The speed and efficiency of centrifugal blowers make them adaptable to a wide range of applications, including various types of dryers and HVAC systems. The angle of the blades of a centrifugal blower determines its efficiency and effectiveness or how fast it moves air through the system. The three varieties of blade angles are forward curved, backward curved, and radial. The electric motor is either attached directly to the fan wheel, which is called direct drive, or by a belt or gear mechanism, which can be customized and allows for the ability to change the speed of the fan wheel. Once the air or gas is taken into the inlet of the blower, the motor spins the fan wheel and the air is diverted, typically at about a 900 angle, and sent through the outlet at a specific volume and velocity.

Blower Specification:

Centrifugal type (Induction Motor)

CFM: 1000

Static pressure: 740 Pa

Input: 230V, 1-Ph, 3A

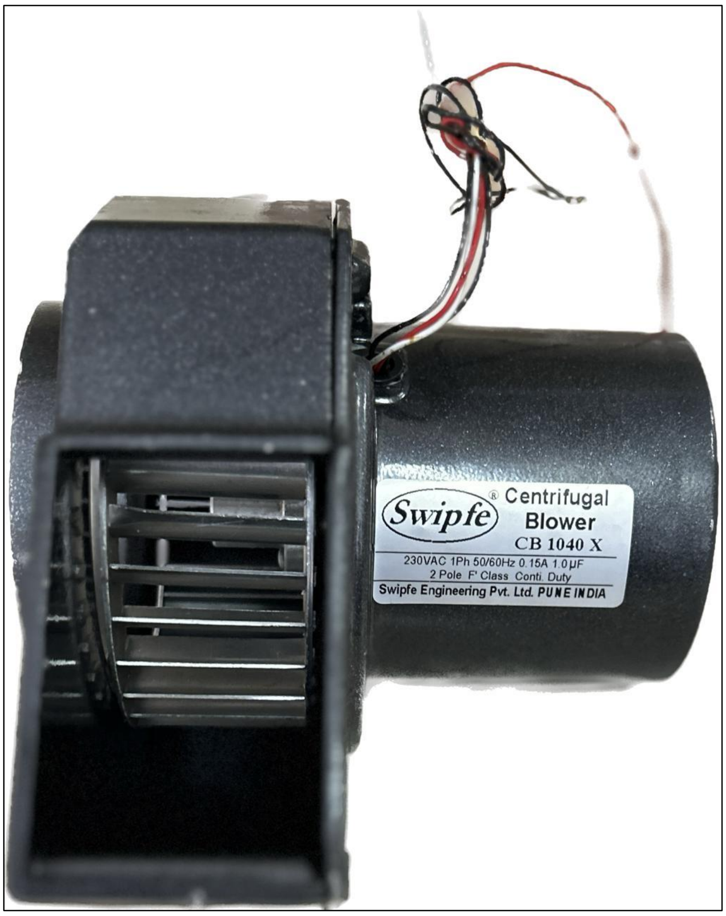

Fig 25: Blower

3) Duct System

To supply air from the blower to every part of the onion pile duct system is used. The Duct system consists of two arms of PVC pipe 4-inch in diameter and 7ft in length. Both arms have holes of 25mm at every 6-inch distance. One end of pipe is connected to the blower by using a coupler and the other end is inserted into the onion stack. While other ends of arms are covered by end caps. Blower supplies air at 1000 CFM and at the small holes we receive air at 500-600 CFM at opening holes of pipe. The small opening in the main pipe helps the conditioned air to distribute evenly in the storage space. Due to this, a proper ventilation is created, which eventually helps onions to stay fresh and maintain quality.

Fig 26: Duct System

to stay fresh and maintain quality.

Fig 26: a) Duct Opening Flow without Onions

Fig 26: b) Duct Flow with Onions

5.6 Losses in Onions

1) **Physiological loss in weight :** The physiological loss in weight (%) was calculated

$$PLW(\%) = \left(\frac{P_i - P_n}{P_n}\right) \times 100$$

using the formula of Kukanoor (2005)

Where, PLW= Physiological Loss in Weight

Pi = Initial Weight

Pn = Weight, days after storage

2) **Sprouting**

To determine sprouting (%) intensity the sprouted bulbs were separated from the experiment and were calculated using the formula of Kukanoor (2005):

$$Sprouting(\%) = \frac{Number\ of\ sprouted\ bulbs}{Total\ number\ of\ bulbs} \times 100$$

3) **Rotting**

Following formula was used to determine the rotting loss (%) (Jamali et al.,2012):

$$Rotting\,(\%) = \frac{Number\ of\ rotted\ bulbs}{Total\ number\ of\ bulbs} \times 100$$

4) Black mold

Following formula was used to determine the black mold loss (%) (Jamali et al.,2012):

$$Black\ mold\,(\%) = \frac{Number\ of\ affected\ bulbs}{Total\ number\ of\ bulbs} \times 100$$

	Type of loss	Reported losses	Expected loss with potential solutions
1	Physiological weight loss (PLW)	20-25%	15-20%
2	Rotting/ decay	10-12%	≤ 7-10%
3	Sprouting	8-10%	≤ 6-7%

5.7 Cooling Load Calculation

Atmospheric Temperature (T_o)= 45°C,

Inside/Required Temperature (T_i)= 25°C,

U = 1.49 W/m2K,

Cp of onion = 3.77 kJ/kg°C,

Area for Calculation(A1) = 1.06×0.9 = 0.954 m^2

Operation time = 6 hr

Atmospheric Temperature (T1) = 45°C

Intermediate Temperature (T2)

Inside/Required Temperature (T3)= 25°C

Asbestos Sheet thickness (L1) = 6 mm

Insulation thickness (L2) = 15 mm

Roof Area (A2) = 1.06 × 1.5 m

Thermal Conductivity of Asbestos (k1) = 0.166 W/mK

Thermal Conductivity of Nitrile (k2) = 0.0.036 W/mK

1) Product load = m x Cp x (T_o-T_i)

$$= \frac{200 \times 3.77 \times 20}{6 \times 3600} = 700\ \text{W}$$

2) Sidewalls = U x A x (T_o-T_i) x 2

= 1.49×0.954× (293) ×2 = 832 W

3) Front wall = U x A x (T_o-T_i) x 2

= 1.49×0.954× (293) ×2 = 832 W

4) Roof :

$$Q = \frac{T1-T2}{R1} = \frac{T2-T3}{R2} = \frac{T1-T3}{R1+R2}$$

$$R1 = \frac{L1}{K1 \times A2} = \frac{0.006}{0.166 \times (1.59)} = 0.022 \text{ K/W}$$

$$R1 = \frac{L2}{K2 \times A2} = \frac{0.015}{0.036 \times (1.59)} = 0.26 \text{ K/W}$$

$$Q = \frac{318-298}{0.022+0.26} = 70.92 \text{ W}$$

Roof = 2 × 70.92 =141.84 W

Total Cooling Load = Product + Sidewalls +Front walls +Roof

= 700+832+832+141.84

= **2505 W**

5.8 Duct Calculations

Cooling load = 2.5 kW

We know,

3412 BTU/hr = 1 kW

1.08 = density of air x Sp. Heat of air x 60

= 0.075lb/ft3 x 0.24 BTU/Ibf X 60

Rated Blower CFM: 720 can go upto 1000CFM

Flow required at the end desired location

CFM = $\frac{\text{BTU/hr}}{1.08 \times \Delta T}$ = 6824/(1.08×20)= **315 CFM** = 8.9 cmm

Mass flow rate at Inlet:

Data Required:
Pipe Diameter (D): 100 mm
Flow rate: 700 CFM

We know that,
1 CFM = 4.71×10^-4 m^3/s
Flow rate = 0.3297 m^3/s
Q = A.V

$0.3297 = \frac{\pi}{4} \times (100)^2 \times V$

V= 42 m/s

Where,
Q = Air Flow rate (m^3/s)
A = Area of Pipe (m^2)
V= Velocity of air (m/s)

$\dot{m} = \rho.V.A$

$= 1.2 \times 42 \times \frac{\pi}{4} \times (100)^2$

=0.3956 kg/s

Where,
ṁ = mass flow of air (kg/s)
A = Area of Pipe (m^2)
V= Velocity of air (m/s)
ρ = density of air (kg/m^3)

Mass flow rate of air entering through inlet duct: **0.3956 kg/s**

5.9 Motivation behind Storage Structure Design

We reviewed a experiment conducted by S. A. Soomro, K. A. Ibupoto1, N. M. Soomro and L. A. Jamali of Sindh Agriculture University. They conducted the experiment over 90 kg of onions stored using three different methods over period of 90 days. The onions were stored under three different storage methods including (i) wooden packed structure on raised platform fully ventilated having bottom and sides covered with rice straw, (ii) Nylon net bag and (iii) open ground fully ventilated from all sides. These methods were performed in a well-ventilated store.

Interval (Days)	Wooden packed Structure (%)	Nylon net bags (%)	Open ground (%)
15	1.24	02.78	04.98
30	2.19	04.94	06.10
45	3.14	06.01	07.99
60	5.05	08.16	09.86
75	6.28	12.36	14.10
90	7.24	17.01	19.38
Mean	4.19	08.54	10.40

Following table shows results of experimentation.

Table 5.1 : Physiological loss in weight under different storage methods

Table 5.2 : Black Mold% under different storage methods

It is concluded from the study that the wooden packed structure ventilated from all sides on raised platform provided better results during 90 days of storage period with minimum losses as compared to those of nylon net bags and open ground. The study suggest that the growers should adopt wooden packed structure method ventilated from all sides on raised platform to store onion bulbs to minimize losses. Therefore, we decided to go for wooden packed structure ventilated from all sides' storage type of structure for experimentation, to achieve maximum shelf life with minimum losses.

5.10 Solar Calculation

1) Solar PV modules and MPPT Charge Controller

A PV module is a packaged interconnected assembly of PV cells, also known as solar cells. An installation of PV modules or panels is known as Photovoltaic array or solar panel. PV cells typically require protection from the environment.

For cost and practically reasons a number of cells are connected electrically and packaged in a photovoltaic module, while a collection of these modules that are mechanically fastened together, wired and designed to be a field-installable unit, sometimes with a glass covering and a frame and backing made of metal, plastic or fiberglass are known as a photovoltaic panel or simply a solar panel. A photovoltaic installation typically includes an array of photovoltaic modules or panels, an inverter, batteries and wiring.

Panels are rated in peak watts (Wp), namely the power produced in an optimally

Days	Wooden packed structure	Nylon net bags	Open ground
15	00.00	01.98	05.32
30	00.00	05.80	10.17
45	00.00	12.00	15.36
60	00.00	15.88	19.36
75	08.19	20.06	24.34
90	11.18	24.27	30.45
Mean	03.23	13.33	17.50

matched load with incident solar radiation 1000 W/m2. A typical panel rating is 40Wp. In a tropical climate, a 40 Wp may produce an average of 150 Wh of electricity per day, and it may fluctuate b/w 100 and 200 Wh depending on the fluctuations in the weather.

A Maximum Power Point Tracker (or MPPT) is a high-efficiency DC-to-DC converter, which functions as an optimal electrical load for a photovoltaic (PV) cell, most commonly for a solar panel or array, and converts the power to a voltage or current level, which is more suitable to whatever load the system is designed to drive. PV cells have a single operating point where the values of the Current (I) and Voltage (V) of the cell result in a maximum power output. These values correspond to a particular resistance, which is equal to V/I as specified by Ohm’s Law. A PV cell has an exponential relationship between current and voltage, and the maximum power point (MPP) occurs at the knee of the curve, where the resistance is equal to the negative of the differential resistance.

A MPPT solar charge controller is the charge controller embedded with MPPT algorithm to maximize the amount of current going into the battery from PV module. MPPT is DC to DC converter which operates by taking DC input from PV module, changing it to AC and converting it back to a different DC voltage and current to exactly match the PV module to the battery.

Fig 27: a) Solar PV Module

Fig 27: b) Charge Controller

Basics of Maximum Power Point Tracking (MPPT) Solar Charge Controller: Examples of DC-to-DC converter are:

- Boost converter is power converter which DC input voltage is less than DC output voltage. That means PV input voltage is less than the battery voltage in system.
- Buck converter is power converter which DC input voltage is greater than DC output voltage. That means PV input voltage is greater than the battery voltage in system.

MPPT algorithm can be applied to both of them depending on system design. Normally, for battery system voltage is equal or less than 48 V, buck converter is useful. On the other hand, if battery system voltage is greater than 48 V, boost converter should be chosen. MPPT solar charge controllers are useful for off-grid solar power systems such as stand-alone solar power system, solar home system and solar water pump system, etc.

Maximum power point trackers utilize some type of control circuit or logic to search for this point and thus to allow the converter circuit to extract the maximum power available from cell. MPPT is not a mechanical tracking system that 'physically moves' the modules to make them point more directly at the Sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Additional power harvested from the modules is then made available as increased battery charge current. MPPT can be used in conjunction with a mechanical tracking system, but the two systems are completely different.

2) Solar PV Module Sizing

a. Power consumption demands

The first step in designing a solar PV system is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system as follows:

- Total Watt-hours per day for each appliance used.

  Total appliance use = (800+180 W x 6 hours)

  = 5880 Wh/day

- Total Watt-hours per day needed from the PV modules. Multiply the total appliances Watt-hours per day times 1.3 (the energy lost in the system) to get the total Watt-hours per day which must be provided by the panels.

  Total PV panels energy needed = 5880 x 1.3

  = 7644 Wh/day

b. Size the PV modules

Different sizes of PV modules will produce different amounts of power. To find out the sizing of PV module, the total peak watt produced needs. The peak watt (Wp) produced depends on size of the PV module and the climate the of site location. We have to consider panel generation factor which is different in each site location.

Panel generation factor:

- The annual average solar direct irradiance of the project site is 6.2 $kWh/m^2/day$, whichconsidered for sizing analysis solar PV panels
- The Wp of the panel is rated using a value of 1000 W/m^2.
- That is equivalent to 6.2 hours of 1000 W/m^2 sunlight every day.

- Each Wp of the panel would therefore deliver 6.2 Wh/Wp/day if all other conditions wereperfect.

The conditions are not perfect, then Correction includes

- 15% for temperature above 25oC.
- 5% for losses due to sunlight not striking the panel straight on (caused by glass having increasing reflectance at lower angles of incidence).
- 10% for losses due to not receiving energy at the maximum power point.
- 5% allowance for dirt.
- 10% allowance for the panel being below specification and for ageing.

Total power = 0.85 ∗ 0.95 ∗ 0.90 ∗ 0.95 ∗ 0.90 = 0.62 of the original Wp rating

Panel Generation Factor (Wh/day per Wp capacity) =

= 6.2*0.62

= $\mathbf{3.84\ Wh/Wp/day}$

To determine the sizing of PV modules, we calculate as follows:

Total Watt-peak rating needed for PV modules

Divide the total Watt-hours per day needed from the PV modules (from item 1.2) by 3.8 to get the total Watt-peak rating needed for the PV panels needed to operate the appliances.

Total Wp of PV panel capacity needed = 7644/ 3.8 = 2011 Wp

Number of PV panels for the system

Divide the answer obtained in item 2.1 by the rated output Watt-peak of the PV modules available. Increase any fractional part of result to the next highest full number and that will be the number of PV modules required.

Number of PV panels needed = 2011 / 250 = 8

Actual requirement = 8 modules

So, this system should be powered by at least 8 modules of 250 Wp PV module.

c. Inverter Sizing

An inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total watt of appliances. The inverter must have the same nominal voltage as your battery.

For stand-alone systems, the inverter must be large enough to handle the total amount of Watts you will be using at one time. The inverter size should be 25-30% bigger than total Watts of appliances. For grid tie systems or grid connected systems, the input rating of the inverter should be same as PV array rating to allow for safe and efficient operation.

Total Watt of all appliances = 980W

For safety, the inverter should be considered 25-30 % bigger size. The inverter size should be about **1200 W** or greater.

d. Battery Sizing

The battery type recommended for using in solar PV system is deep cycle battery. Deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years. The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days. To find out the size of battery, calculate as follows:

- Total Watt-hours per day used by appliances.
- Divide the total Watt-hours per day used by 0.85 for battery loss.
- Divide the answer obtained in item 4.2 by 0.6 for depth of discharge.
- Divide the answer obtained in item 4.3 by the nominal battery voltage.
- Multiply the answer obtained in item 4.4 with days of autonomy (the number of days that you need the system to operate when there is no power produced by PV panels) to get the required Ampere-hour capacity of deep-cycle battery.

Total appliances use = (980 W x 6 hours) = 5880 Wh/day

Nominal battery voltage = 24 V

Days of autonomy = 1 days

$$\textbf{Battery Capacity (Ah)} = \frac{\text{Total Watt-hours per day used by appliances x Days of autonomy}}{\text{(0.85 x 0.6 x Nominal battery voltage)}}$$

$$\text{Battery Capacity (Ah)} = \frac{5880 \times 1}{(0.85 \times 0.6 \times 24)}$$

Total Ampere-hours required 480.39 Ah

So, two batteries of rating **24 V, 270 Ah** is required for 1 day autonomy

5.11 Solar System Summary

	Component	Specification
1	Solar PV Panels	250 W (24V) 8 Nos
2	Solar Inverter	1200 W (24V)
3	Solar Battery	270 Ah (24V) 2 Nos

4	Solar Charge Controller	60 A (24V)

Chapter 6: Results And Discussion

Onion storage in ventilation conditions is quite satisfactory when the temperature is maintained between 250C to 300C with a relative humidity range of 65% to 70%. This environment reduces the storage losses, which are in the form of physiological loss in weight, rotting and sprouting. We conducted the experimentation on 11 of May 2023 for a time span of 5 hrs, over 200 kgs of onions. We used 4-5 temperature and humidity sensors placed at different locations in onions to monitor the changes in temperature and humidity. Also, the ambient conditions were recorded too. Following graph shows the recorded parameters throughout the testing.

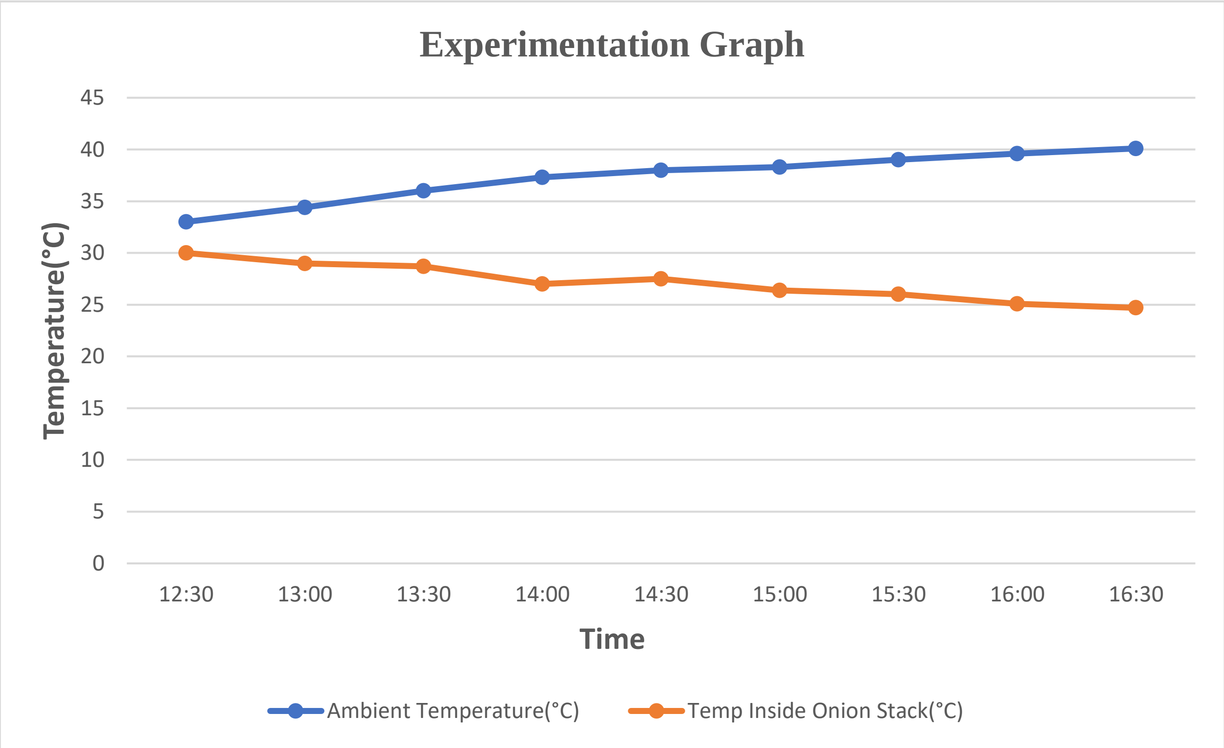

Fig 28: Experimentation Reading Graph

After, observing the graph it can be concluded that, we were able to achieve the desired condition of temperature (25-30 °C) in the onion stack. The results are satisfactory as expected. Though the results of single day test cannot validate the future results from the setup. But, if the same condition is provided daily, it will be able to achieve maximum shelf life and minimum losses.

Chapter 7: Conclusion

7.1 Introduction

The project work consisted of experimental work. The prime objective of the project was to design an adequate ventilation system for onions, which can increase the shelf life up to 6-7 months. Based on the work carried out during the project, the following things can be concluded:

7.2 Conclusions

- Conventional kanda chawls fails to remove heat from central pile of onions, which eventually causes losses and decrease in shelf life.
- Using wooden sheets as walls for the structure rather than chain link has helped in reduction in weight as well as cost.
- Onion storage in ventilated conditions is quite satisfactory when the temperature is maintained between 25 0C to 30 0C with a relative humidity range of 65 to 75 % which reduces the storage losses, which are in the form of physiological loss in weight, rotting, and sprouting.
- The existing storage techniques are designed for onions that have been field dried for 15 days, rather than for immediate storage.
- A ventilation system is essential to achieve on-field onion storage as well as soon after harvestmen storage.
- The calculation and selection solar PV module and auxiliary components is been done. After the installation it would be possible to run the system using solar power.
- To maintain the desired temperature and relative humidity range freshly harvested onion pile we can use a VCR system along a blower and duct system. Also, the blower and duct system will provide forced air circulation to the onion pile.
- Proper ventilation provided to onion storage will result in fewer storage losses and better storage life.
- Material used in structure is mostly available at farm site, which also makes it easy to maintain.

- Employing the suggested system would definitely help in increasing the storage life, which eventually will help farmers to make relatively higher profits by supplying onions at peak demand.

Chapter 8: Future scope

The major goal of this project is to maintain the recommended storage ventilation conditions for onions, which call for a temperature between 25 and 30 °C and relative humidity between 65 and 75 %. The next task for the project may be to assess onion losses after six months of storage, including physiological weight loss, rotting losses, and sprouting losses. If onion storage losses decrease and onion storage life rises, the findings can be validated. Also, as of now humidity control is a missing criterion. Some duct system can be created to reuse the conditioned air, which further can be mixed with fresh air in right proportion. This will definitely help in system power consumption. Design of an efficient, low power consuming VCR system, which would make it possible to make solar powered.

CFD Analysis of the whole system can be performed to get primary idea about possible results. Since it is open system it very difficult to provide boundary conditions, as the temperature, velocity and other governing factors keeps on varying. If some fabric or covering like spun bond fabric is used covering all the sides, and making it a semi closed system. Spun bond fabric is fabric that allows flow of air in one direction only. It also helps in maintaining temperature and tries to maintain required relative humidity. We tried performing CFD analysis of airflow through duct and small openings. This simulation helped in getting basic idea about the static, flow rate during blower selection. Following are the results for future research work.

CFD Results:

1. **Model and boundary conditions**

   Following figure () shows the inlet outlet conditions considered for the analysis. And the other walls are considered adiabatic. Inlet mass flow rate of 0.395 kg/sec is applied at the inlet at temperature of 298.15 K3.Understand and correlate the temperature distribution in the channels experimentally and compare the CFD results validate the stack controller temperature control logic.

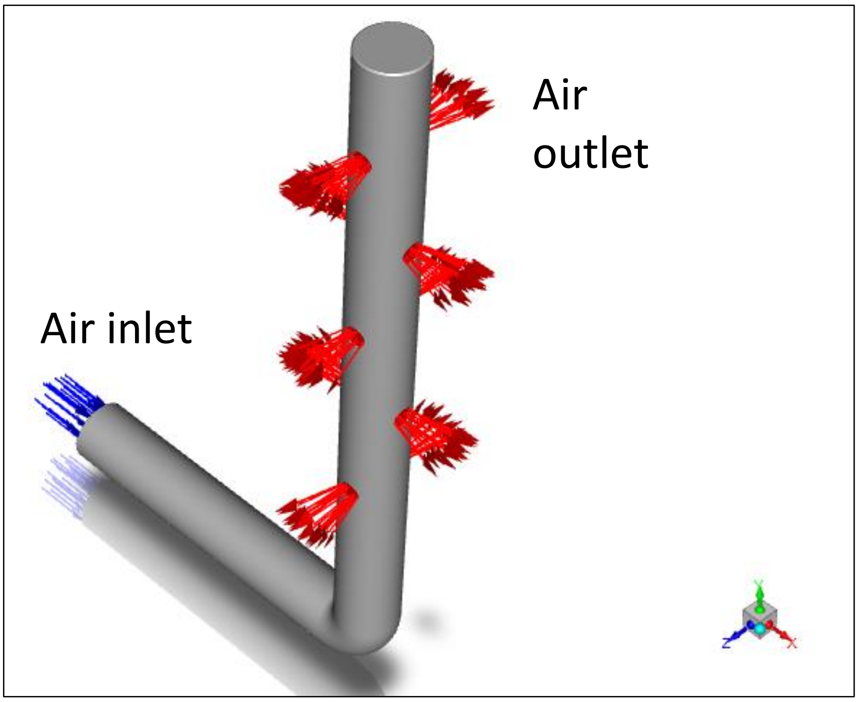

Fig 29: Boundary Conditions

2. Mesh

Type -Tetra mesh

No of Nodes-710007

No of elements-3812286

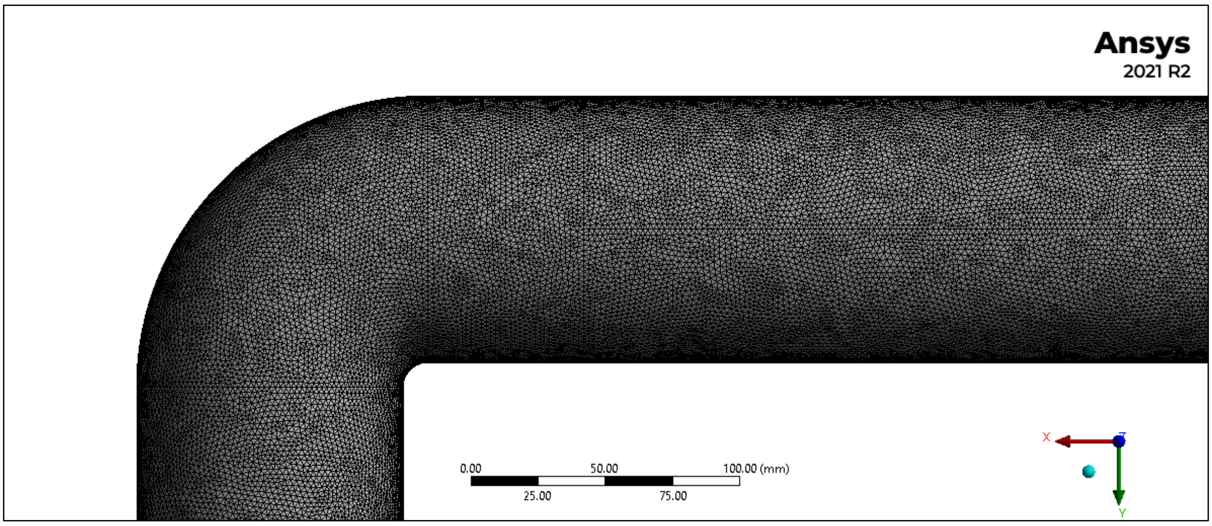

Fig 30: Mesh -element size-2mm

3. Results

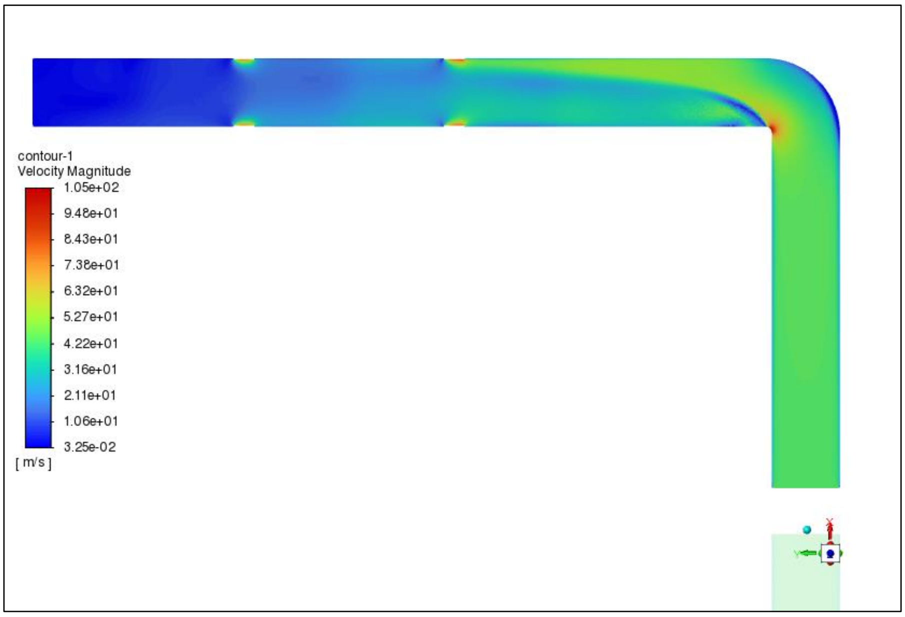

Fig 31: Velocity Magnitude contour (X-Y Plane)

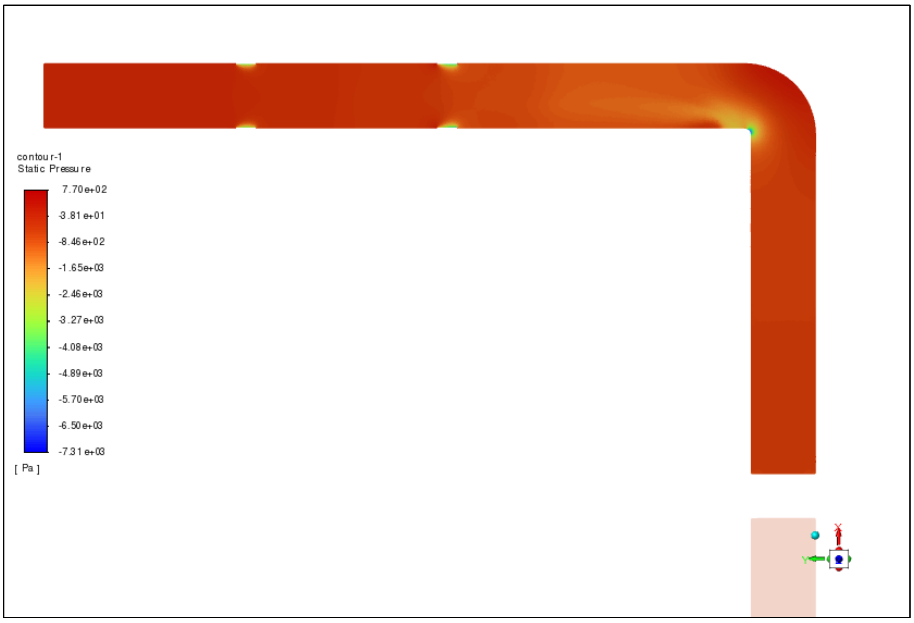

Fig 32: Static Pressure contour (X-Y Plane)

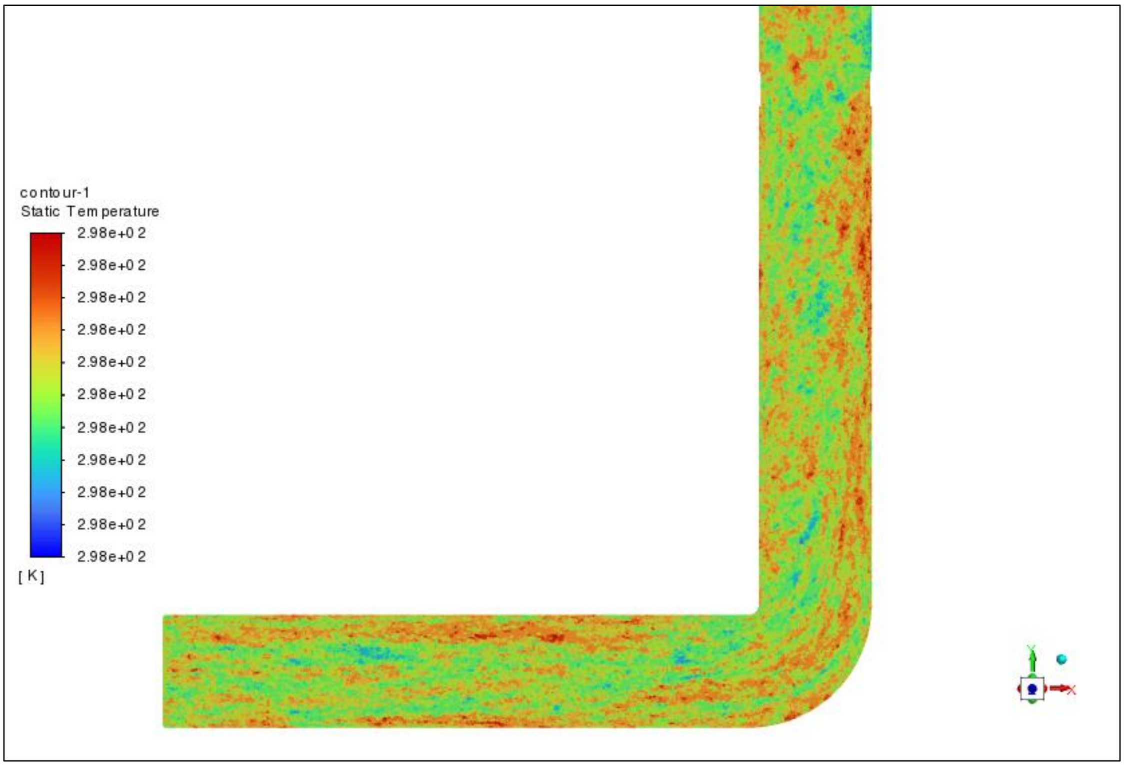

Fig 33: Static temperature contour (X-Y Plane)

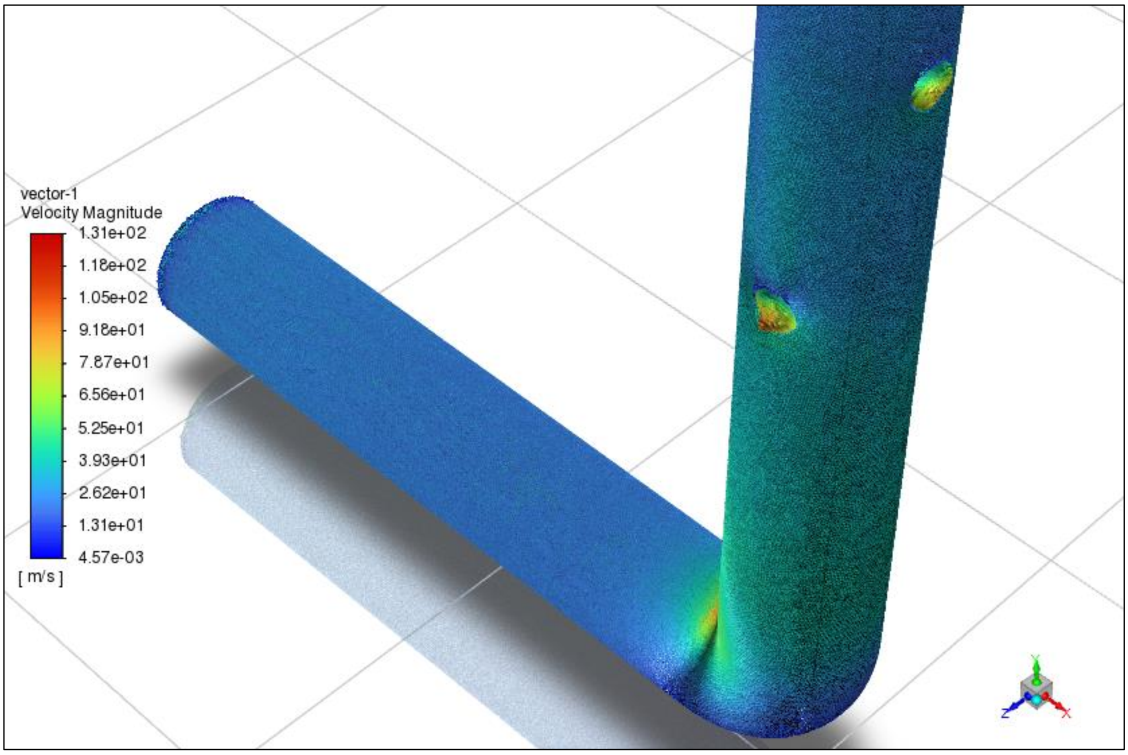

Fig 34: Velocity vector (X-Y Plane)

Table 8 : Duct Mass flow rates & Velocity at different outlets

Location	Mass flow rate([kg/s])	Velocity([m/s])
Inlet	0.39559931	44.258921
Outlet 1	-0.039559918	59.115498
Outlet 2	-0.039559911	62.262306
Outlet 3	-0.039559918	66.991671
Outlet 4	-0.039559932	60.328745
Outlet 5	-0.03955991	59.308877
Outlet 6	-0.039559911	71.465316
Outlet 7	-0.039559916	67.599226
Outlet 8	-0.03955992	58.995604
Outlet 9	-0.039559932	73.714085
Outlet 10	-0.039559923	63.217958

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