Course No. - ENGG 364

Course title -
Protected Cultivation and
secondary Agriculture.

Credit - 2 (1+1)

-

ENGG 364 **2 (1+1)**

Course Title - Protected Cultivation and Secondary Agriculture

Theory

Lecture	Topic	Weightage (%)
1	Green house technology - Green house technology: Introduction, History of green house, Advantages of green house, Green house effect.	6
2	Types of Green houses -Types of Green houses: Green house type based on Shape, Utility, Construction and Covering materials	7
3	Plant response to green house environment -Plant response to green house environment : Light, Temperature, Relative Humidity, Ventilation and Carbon di-oxide.	6
4	Planning and Design of green house - Planning and Design of green house: Site selection and orientation, structural design and covering materials.	6
5	Materials of construction - Materials of construction for traditional and low cost green house: Wood, G.I., aluminum, steel, R.C.C. and Glass	6
6	Irrigation Systems used in green house - Irrigation Systems used in green house: Rules of watering, Overhead Sprinklers , Drip irrigation system and Foggers (Mist spraying)	6
7	Design criteria of green house for Cooling and Heating purposes - Design criteria of green house for Cooling and Heating purposes: Cooling - Natural ventilation, forced ventilation Heating- Heating system, solar heating system, Water & Rock storage.	6
8	Engineering Properties - Engineering Properties of cereals, pulses and oil seed. Their applications in PHT equipment design and operation: Physical properties: Size and Shape (Roundness and Sphericity) Porosity, Coefficient of friction, and angle of repose, Thermal properties: Definition of Specific heat and Thermal conductivity. Aero & hydrodynamic properties: Definition of Terminal velocity	6
9	Drying and Dehydration - Drying and Dehydration: Definition of drying and dehydration, Utilities/Importance of drying Grain drying Theory- EMC definition, Thin layer drying and deep bed drying.	6
10&11	Moisture Measurements- Moisture measurements: Moisture content and its measurement, Moisture content representation: Dry basis and wet basis Moisture Content determination Methods:- Direct methods- Air oven method, Vacuum oven method and Infra-red method Indirect Methods- Electrical resistance method and Di-electric method .	12
12	Various Drying Methods - Various Drying Methods: Sun drying, Mechanical Drying Mechanical Drying Methods:- Contact drying, Convection drying, Radiation drying	6
13	Numerical on Moisture content and its representation- Conversion of wet basis moisture contents to dry basis moisture contents Conversion of dry basis moisture contents to wet basis moisture contents, Problems on drying Problems on moisture contents Problem No.1 & No.2.	6

14&15	Commercial Grain Dryers - Commercial Grain Dryers: Construction and working principle - Deep bed dryer, Flat bed dryer, Recirculating dryer – (LSU and Baffle dryers) , Tray dryer and Solar dryers	14
16	Material Handling Equipments - Material Handling Equipment’s: Construction and working principle- Conveyor- Belt conveyor and Screw conveyor Elevator- Bucket elevator	8

Lecture No.1

Green house technology - Green house technology: Introduction, History of green house, Advantages of green house, Green house effect.

Greenhouse definition –

A building, room, or area, usually chiefly of glass, in which the temperature is maintained within a desired range, used for cultivating.

Introduction

After the advent of green revolution, more emphasis is laid on the quality of the product along with the quantity of production to meet the ever- growing food requirements. Both these demands can be met when the environment for the plant growth is suitably controlled. The need to protect the crops against unfavourable environmental conditions led to the development of protected agriculture. Greenhouse is the most practical method of achieving the objectives of protected agriculture, where the natural environment is modified by using sound engineering principles to achieve optimum plant growth and yields.

History

A greenhouse is a framed or an inflated structure covered with a transparent or translucent material in which crops could be grown under the conditions of at least partially controlled environment and which is large enough to permit persons to work within it to carry out cultural operations.

The growing of off - season cucumbers under transparent stone for Emperor Tiberius in the 1st century, is the earliest reported protected agriculture. The technology was rarely employed during the next 1500 years. In the 16th century, glass lanterns, bell jars and hot beds covered with glass were used to protect horticultural crops against cold. In the 17th century, low portable wooden frames covered with an oiled translucent paper were used to warm the plant environment.

In Japan, primitive methods using oil -paper and straw mats to protect crops from the severe natural environment were used as long ago the early 1960s. Greenhouses in France and England during the same century were heated by manure and covered with glass panes. The first greenhouse in the 1700s used glass on one side only as a sloping roof. Later in the century, glass was used on both sides. Glasshouses were used for fruit crops such as melons, grapes, peaches and strawberries, and rarely for vegetable production.

Protected agriculture was fully established with the introduction of polyethylene after the World war II. The first use of polyethylene as a greenhouse cover was in 1948, when professor Emery Myers Emmert, at the University of Kentucky, used the less expensive material in place of more expensive glass

The total area of glasshouses in the world (1987) was estimated to be 30,000 ha and most of these were found in North- Western Europe. In contrast to glasshouses, more than half of the world area of plastic green houses is in Asia, in which China has the largest area. According to 1999 estimates, an area of 6, 82,050 ha were under plastic greenhouses (Table 1.1). In most of the countries, green houses are made of plastic and glass; the majority is plastic.

Glasshouses and rigid plastic houses are longer-life structures, and therefore are most located in cold regions where these structures can be used throughout the year. In

Japan, year round use of greenhouses is becoming predominant, but in moderate and warm climate regions, they are still provisional and are only used in winter.

In India, the cultivation in the plastic greenhouses is of recent origin. As per 1994-95 estimates, approximately 100 ha of India are under greenhouse cultivation.

Table 1. Estimated world use of plastic greenhouses (1999)

Region	Area (ha)
Europe	1,80,000
Africa and the Middle East	55,000
America	22,350
Asia China - 3,80,000 Japan – 51,042 Korea – 2,200	4,50,000
World Total	**6,82,050**

Since 1960, the greenhouse has evolved into more than a plant protector. It is now better understood as a system of controlled environment agriculture (CEA), with precise control of air and root temperature, water, humidity, plant nutrition, carbon dioxide and light. The greenhouses of today can be considered as plant or vegetable factories. Almost every aspect of the production system is automated, with the artificial environment and growing system under nearly total computer control.

Greenhouse Effect

- In general, the percentage of carbon dioxide in the atmosphere is 0.035% (345 ppm).
- But, due to the emission of pollutants and exhaust gases into the atmosphere, the percentage of carbon dioxide increases which forms a blanket in the outer atmosphere.
- This causes the entrapping of the reflected solar radiation from the earth surface.
- Due to this, the atmospheric temperature increases, causing global warming, melting of ice caps and rise in the ocean levels which result in the submergence of coastal lines.
- This phenomenon of increase in the ambient temperature, due to the formation of the blanket of carbon dioxide is known as **greenhouse effect**.
- The greenhouse covering material acts in a similar way, as it is transparent to shorter wave radiation and opaque to long wave radiation.
- During the daytime, the shorter wave radiation enters into the greenhouse and gets reflected from the ground surface.
- This reflected radiation becomes long wave radiation and is entrapped inside the greenhouse by the covering material.
- This causes the increase in the greenhouse temperature. It is desirable effect from point of view of crop growth in the cold regions.

Advantages of Greenhouses

- The following are the different advantages of using the green house for growing crops under controlled environment:

- Throughout the year four to five crops can be grown in a green house due to availability of required plant environmental conditions.
- The productivity of the crop is increased considerably.
- Superior quality produce can be obtained as they are grown under suitably controlled environment.
- Gadgets for efficient use of various inputs like water, fertilizers, seeds and plant protection chemicals can be well maintained in a green house.
- Effective control of pests and diseases is possible as the growing area is enclosed.
- Percentage of germination of seeds is high in greenhouses.
- The acclimatization of plantlets of tissue culture technique can be carried out in a green house.
- Agricultural and horticultural crop production schedules can be planned to take advantage of the market needs.
- Different types of growing medium like peat mass, vermiculate, rice hulls and compost that are used in intensive agriculture can be effectively utilized in the greenhouse.
- Export quality produce of international standards can be produced in a green house.
- When the crops are not grown, drying and related operations of the harvested produce can be taken up utilizing the entrapped heat.
- Greenhouses are suitable for automation of irrigation, application of other inputs and environmental controls by using computers and artificial intelligence techniques.
- Self-employment for educated youth on farm can be increased.

Lecture No.2

Types of Green houses - Types of Green houses: Green house type based on Shape, Utility, Construction and Covering materials.

Types of Green houses –

A) Based on shape

a. Lean-to type greenhouse
b. Even span type greenhouse
c. Uneven span type greenhouse
d. Ridge and furrow type greenhouse
e. Saw tooth type Greenhouse
f. Quonset greenhouse

B) Based on Utility

a. Greenhouses for active heating
b. Greenhouses for active cooling

C) Based on Construction

a. Wooden framed structures

  b. Pipe framed structures
  c. Truss framed structures

D) Based on Covering Material

  a. Glass greenhouses
  b. Plastic film greenhouses
  c. Rigid panel greenhouses
  d. Shading nets

A) BASED ON SHAPE

- Greenhouses can be classified based on their shape or style.
- For the purpose of classification, the uniqueness of the cross section of the greenhouses can be considered as a factor.
- As the longitudinal section tend to be approximately the same for all types, the longitudinal section of the greenhouse cannot be used for classification.
- The cross sections depict the width and height of the structure and the length is perpendicular to the plane of cross section.
- Also, the cross section provides information on the overall shape of the structural members, such as truss or hoop, which will be repeated on every day.
- The commonly followed types of greenhouse based on shape are lean-to, even span, uneven span, ridge and furrow, saw tooth and quonset.

a) Lean-to type greenhouse

- A lean-to design is used when a greenhouse is placed against the side of an existing building.
- It is built against a building, using the existing structure for one or more of its sides (Fig.1).
- It is usually attached to a house, but may be attached to other buildings.
- The roof of the building is extended with appropriate greenhouse covering material and the area is properly enclosed.
- It is typically facing south side.
- The lean-to type greenhouse is limited to single or double-row plant benches with a total width of 7 to 12 feet.
- It can be as long as the building it is attached to.
- It should face the best direction for adequate sun exposure.

The advantage of the lean-to type greenhouse

- ✓ It is that, it usually is close to available electricity, water, and heat.
- ✓ It is a least expensive structure.
- ✓ This design makes the best use of sunlight and minimizes the requirement of roof supports.

It has the following disadvantages:

- ✓ limited space, limited light, limited ventilation and temperature control.
- ✓ The height of the supporting wall limits the potential size of the design.
- ✓ Temperature control is more difficult because the wall that the greenhouse is built on, may

  collect the sun's heat while the translucent cover of the greenhouse may lose heat rapidly.

- ✓ It is a half greenhouse, split along the peak of the roof.

b) Even span type greenhouse

- The even-span is the standard type and full-size structure, the two roof slopes are of equal pitch and width (Fig.1).
- This design is used for the greenhouse of small size, and it is constructed on level ground.
- It is attached to a house at one gable end.
- It can accommodate 2 or 3 rows of plant benches.
- The cost of an even-span greenhouse is more than the cost of a lean-to type, but it has greater flexibility in design and provides for more plants.
- Because of its size and greater amount of exposed glass area, the even-span will cost more to heat.
- The design has a better shape than a lean-to type for air circulation to maintain uniform temperatures during the winter heating season.
- A separate heating system is necessary unless the structure is very close to a heated building.
- It will house 2 side benches, 2 walks, and a wide center bench.
- Several single and multiple span types are available for use in various regions of India. For single span type the span in general, varies from 5 to 9 m, whereas the length is around 24 m. The height varies from 2.5 to 4.3 m.

c) Uneven span type greenhouse

- This type of greenhouse is constructed on hilly terrain.
- The roofs are of unequal width; make the structure adaptable to the side slopes of hill (Fig. 2).
- This type of greenhouses is seldom used now-a-days as it is not adaptable for automation.

d) Ridge and furrow type greenhouse

- Designs of this type use two or more A-frame greenhouses connected to one another along the length of the eave (Fig. 2).
- The eave serves as furrow or gutter to carry rain and melted snow away.
- The side wall is eliminated between the greenhouses, which results in a structure with a single large interior, Consolidation of interior space reduces labour, lowers the cost of automation, improves personal management and reduces fuel consumption as there is less exposed wall area through which heat escapes.
- The snow loads must be taken into the frame specification of these green house since the snow cannot slide off the roofs as in case of individual free standing greenhouse, but melts away.
- In spite of snow loads, ridge and furrow greenhouses are effectively used in northern countries of Europe and in Canada and are well suited to the Indian conditions.

e) Saw tooth type Greenhouse

- These are also similar to ridge and furrow type greenhouses except that, there is provision for natural ventilation in this type.

- Specific natural ventilation flow path (Fig. 3) develops in a saw- tooth type greenhouse.

f) Quonset greenhouse

- This is a greenhouse, where the pipe arches or trusses are supported by pipe purling running along the length of the greenhouse (Fig 3).
- In general, the covering material used for this type of greenhouses is polyethylene.
- Such greenhouses are typically less expensive than the gutter connected greenhouses and are useful when a small isolated cultural area is required. These houses are connected either in free, standing style or arranged in an interlocking ridge and furrow.
- In the interlocking type, truss members overlap sufficiently to allow a bed of plants to grow between the overlapping portions of adjacent houses.
- A single large cultural space thus exists for a set of houses in this type, an arrangement that is better adapted to the automation and movement of labour.

B) Based On Utility

- Classification of greenhouses can be made depending on the functions or utilities.
- The different utilities, artificial cooling and heating of the greenhouse are more expensive and elaborate.
- Hence based on the artificial cooling and heating, greenhouses are classified as green houses for active heating and active cooling system.

a) Greenhouses for active heating

- During the night time, air temperature inside greenhouse decreases.
- To avoid the cold bite to plants due to freezing, some amount of heat has to be supplied.
- The requirements for heating greenhouse depend on the rate at which the heat is lost to the outside environment.
- Various methods are adopted to reduce the heat losses, viz., using double layer polyethylene, thermo pane glasses (Two layers of factory sealed glass with dead air space) or to use heating systems, such as unit heaters, central heat, radiant heat and solar heating system.

b) Greenhouses for active cooling

- During summer season, it is desirable to reduce the temperatures of greenhouse than the ambient temperatures, for effective crop growth.
- Hence suitable modifications are made in the green house so that large volumes of cooled air is drawn into greenhouse.
- This type of greenhouse either consists of evaporative cooling pad with fan or fog cooling.
- This greenhouse is designed in such a way that it permits a roof opening of 40% and in some cases nearly 100%.

C) Based On Construction

- The type of construction is predominantly influenced by the structural material, though the covering material also influences the type.
- Span of the house inurn dictates the selection of structural members and their construction.
- Higher the span, stronger should be the material and more structural members are used to make sturdy truss type frames.
- For smaller spans, simpler designs like hoops can be followed.
- Therefore based on construction, greenhouses can be broadly classified as wooden framed, pipe framed and truss framed structures.

a) Wooden framed structures

- In general, for the greenhouses with span less than 6 m, only wooden framed structures are used.
- Side posts and columns are constructed of wood without the use of a truss.
- Pine wood is commonly used as it is inexpensive and possesses the required strength.
- Timber locally available, with good strength, durability and machine ability also can be used for the construction**.**

b) Pipe framed structures

- Pipes are used for construction of greenhouses, when the clear span is around 12m (Fig. 4).
- In general, the side posts, columns, cross ties and purlins are constructed using pipes.
- In this type, the trusses are not used.

c) Truss framed structures

- If the greenhouse span is greater than or equal to 15m, truss frames are used.
- Flat steel, tubular steel or angular iron is welded together to form a truss encompassing rafters, chords and struts (Fig. 4).
- Struts are support members under compression and chords are support members under tension.
- Angle iron purlins running throughout the length of greenhouse are bolted to each truss.
- Columns are used only in very wide truss frame houses of 21.3 m or more.
- Most of the glass houses are of truss frame type, as these frames are best suited for pre-fabrication.

D) Based On Covering Materials

- Covering materials are the major and important component of the greenhouse structure.
- Covering materials have direct influence on the greenhouse effect inside the structure and they alter the air temperature inside the house.
- The types of frames and method of fixing also varies with the covering material.
- Based on the type of covering materials, the greenhouses are classified as glass, plastic film and rigid panel greenhouses.

a) Glass greenhouses

- Only glass greenhouses with glass as the covering material existed prior to 1950.
- Glass as covering material has the advantage of greater interior light intensity.
- These green houses have higher air infiltration rate which leads to lower interior humidity and better disease prevention.
- Lean-to type, even span, ridge and furrow type of designs are used for construction of glass greenhouse.

b) Plastic film greenhouses

- Flexible plastic films including polyethylene, polyester and polyvinyl chloride are used as covering material in this type of greenhouses.
- Plastics as covering material for greenhouses have become popular, as they are cheap and the cost of heating is less when compared to glass greenhouses.
- The main disadvantage with plastic films is its short life.
- For example, the best quality ultraviolet (UV) stabilized film can last for four years only. Quonset design as well as gutter-connected design is suitable for using this covering material.

c) panel greenhouses

- Polyvinyl chloride rigid panels, fibre glass-reinforced plastic, acrylic and polycarbonate rigid panels are employed as the covering material in the quonset type frames or ridge and furrow type frame.
- This material is more resistant to breakage and the light intensity is uniform throughout the greenhouse when compared to glass or plastic.
- High grade panels have long life even up to 20 years.
- The main disadvantage is that these panels tend to collect dust as well as to harbor algae, which results in darkening of the panels and subsequent reduction in the light transmission.
- There is significant danger of fire hazard.

d) Shading nets

- There are a great number of types and varieties of plants that grow naturally in the most diverse climate conditions that have been transferred by modern agriculture from their natural habitats to controlled crop conditions.
- Therefore, conditions similar to the natural ones must be created for each type and variety of plant.
- Each type of cultivated plant must be given the specific type of shade required for the diverse phases of its development.
- The shading nets fulfill the task of giving appropriate micro-climate conditions to the plants.
- Shade nettings are designed to protect the crops and plants from UV radiation, but they also provide protection from climate conditions, such as temperature variation, intensive rain and winds.
- Better growth conditions can be achieved for the crop due to the controlled micro-climate conditions “created” in the covered area, with shade netting, which results in higher crop yields. All nettings are UV stabilized to fulfill expected lifetime at the area of exposure.

- They are characterized of high tear resistance, low weight for easy and quick installation with a 30-90% shade value range.
- A wide range of shading nets are available in the market which are defined on the basis of the percentage of shade they deliver to the plant growing under them.

Lecture No. 3

Plant response to green house environment -Plant response to green house environment: Light, Temperature, Relative Humidity, Ventilation and Carbon di-oxide.

The productivity of a crop is influenced not only by its heredity but also by the microclimate around it. The components of crop microclimate are light, temperature, air compositions and the nature of the root medium. In open fields, only manipulation of nature of the root medium by tillage, irrigation and fertilizer application is possible. The closed boundaries in greenhouse permit control of any one or more of the components of the micro climate.

A) Light

- The visible light of the solar radiation is a source of energy for plants.
- Light energy, carbon dioxide (Co_2) and water all enter in to the process of photosynthesis through which carbohydrates are formed.
- The production of carbohydrates from carbon dioxide and water in the presence of chlorophyll, using light energy is responsible for plant growth and reproduction.
- The rate of photosynthesis is governed by available fertilizer elements, water, carbon dioxide, light and temperature.
- The photosynthesis reaction can be represented as follows
  Chlorophyll
  Co_2 + water + light energy → carbohydrates + oxygen Plant
  nutrients
- Considerable energy is required to reduce the carbon that is combined with oxygen in CO_2 gas to the state in which it exists in the carbohydrate.
- The light energy thus utilized is trapped in the carbohydrate.
- If the light intensity is diminished, photosynthesis slows down and hence the growth.
- If higher than optimal light intensities are provided, growth again slows down because of the injury to the chloroplasts.
- The light intensity is measured by the international unit known as Lux.
- It is direct illumination on the surrounding surface that is one meter from a uniform point source of 1 international candle.
- Green house crops are subjected to light intensities varying from 129.6klux on clear summer days to 3.2 Klux on cloudy winter days.
- For most crops, neither condition is ideal.
- Many crops become light saturated, in other words, photosynthesis does not increase at light intensities higher than 32.2klux.
- Rose and carnation plants will grow well under summer light intensities.

- In general, for most other crops foliage is deeper green if the greenhouse is shaded to the extent of about 40% from mid spring (May) to mid fall (August and September).
- Thus, it is apparent that light intensity requirements of photosynthesis are vary considerably from crop to crop.
- Light is classified according to its wave length in nanometers (nm).
- Not all light useful in photosynthesis process.
- UV light is available in the shorter wavelength range, i.e less than 400nm.
- Large of quantities of it is harmful to the plants. Glass screens are opaque to the most UV light and light below the range of 325nm. Visible and white light has wavelength of 400 to 700 nm.Far red light (700 to 750nm) affects plants, besides causing photosynthesis.
- Infrared rays of longer wavelengths are not involved in the plant process.
- It is primarily, the visible spectrum of light that is used in photosynthesis.
- In the blue and red bands, the photosynthesis activity is higher, when the blue light (shorter wavelength) alone is supplied to plants, the growth is retarded, and the plant becomes hard and dark in color.
- When the plants are grown under red light (longer wavelength), growth is soft and internodes are long, resulting in tall plants.
- Visible light of all wavelengths is readily utilized in photosynthesis.

B) Temperature

- Temperature is a measure of level of the heat present.
- All crops have temperature range in which they can grow well.
- Below this range, the plant life process stop due to ice formation within the tissue and cells are possibly punctured by ice crystals.
- At the upper extreme, enzymes become inactive, and again process essential for life cease.
- Enzymes are biological reaction catalyst and are heat sensitive.
- All biochemical reactions in the plant are controlled by the enzymes.
- The rate of reactions controlled by the enzyme often double or triple for each rise of temperature by 10^0C, until optimum temperature is reached.
- Further, increase in temperature begins to suppress the reaction and finally stop it.
- As a general rule, green house crops are grown at a day temperature, which are 3 to 6^0C higher than the night temperature on cloudy days and 8^0C higher on clear days.
- The night temperature of green house crops is generally in the range of 7 to 21^0C. Primula, mathiola incana and calceolaria grow best at 7^0C, carnation and cineraria at 10^0C, rose at 16^0C, chrysanthemum and poinsettia at 17 to 18^0C and African violet at 21 to 22^0C.

C) Relative humidity

- As the green house is a closed space, the relative humidity of the green house air will be more when compared to the ambient air, due to the moisture added by the evapo-transpiration process.
- Some of this moisture is taken away by the air leaving from the green house due to ventilation.
- Sensible heat inputs also lower the relative humidity of the air to some extent.

- In order to maintain the desirable relative humidity levels in the green houses, processes like humidification or dehumidification are carried out.
- For most crops, the acceptable range of relative humidity is between 50 to 80%.
- However for plant propagation work, relative humidity up to 90% may be desirable.
- In summer, due to sensible heat addition in the daytime, and in winters for increasing the night time temperatures of the green house air, more sensible heat is added causing a reduction in the relative humidity of the air.
- For this purpose, evaporative cooling pads and fogging system of humidification are employed.
- When the relative humidity is on the higher side, ventilators, chemical dehumidifiers and cooling coils are used for de- humidification.

D) Ventilation

- A green house is ventilated for either reducing the temperature of the green house air or for replenishing carbon dioxide supply or for moderating the relative humidity of the air.
- Air temperatures above 35^0C are generally not suited for the crops in green house.
- It is quite possible to bring the green house air temperature below this upper limit during spring and autumn seasons simply by providing adequate ventilation to the green house.
- The ventilation in a green house can either be natural or forced.
- In case of small green houses (less than 6m wide) natural ventilation can be quite effective during spring and autumn seasons.
- However, fan ventilation is essential to have precise control over the air temperature, humidity and carbon dioxide levels.

E) Carbon dioxide

- Carbon is an essential plant nutrient and is present in the plant in greater quantity than any other nutrient. About 40% of the dry matter of the plant is composed of carbon.
- Under normal conditions, carbon dioxide (CO_2) exits as a gas in the atmosphere slightly above 0.03% or 345ppm.
- During the day, when photosynthesis occurs under natural light, the plants in a green house draw down the level of Co_2 to below 200ppm. Under these circumstances, infiltration or ventilation increases **carbon dioxide levels,** when the outside air is brought in, to maintain the ambient levels of CO_2.
- If the level of CO_2 is less than ambient levels, CO_2 may retard the plant growth.
- In cold climates, maintaining ambient levels of CO_2 by providing ventilation may be un- economical, due to the necessity of heating the incoming air in order to maintain proper growing temperatures.
- In such regions, enrichment of the green house with CO2 is followed.
- The exact CO_2 level needed for a given crop will vary, since it must be correlated with other variables in greenhouse production such as light, temperature, nutrient levels, cultivar and degree of maturity.
- Most crops will respond favorably to Co_2 at 1000 to 1200 ppm.

Lecture No.4

Planning and Design of green house - Planning and Design of green house: Site selection and orientation, structural design and covering materials.

- A greenhouse, is basically the purpose of providing and maintaining a growing environment that will result in optimum production at maximum yield.
- The agriculture in the controlled environment is possible in all the regions irrespective of climate and weather.
- It is an enclosing structure for growing plants, greenhouse must admit the visible light portion of solar radiation for the plant photosynthesis and, there for, must be transparent.
- At the same time, to protect the plants, a greenhouse must be ventilated or cooled during the day because of the heat load from the radiation.
- The structure must also be heated or insulated during cold nights.
- A greenhouse acts as a barrier between the plant production areas and the external or the general environment

Site selection and orientation

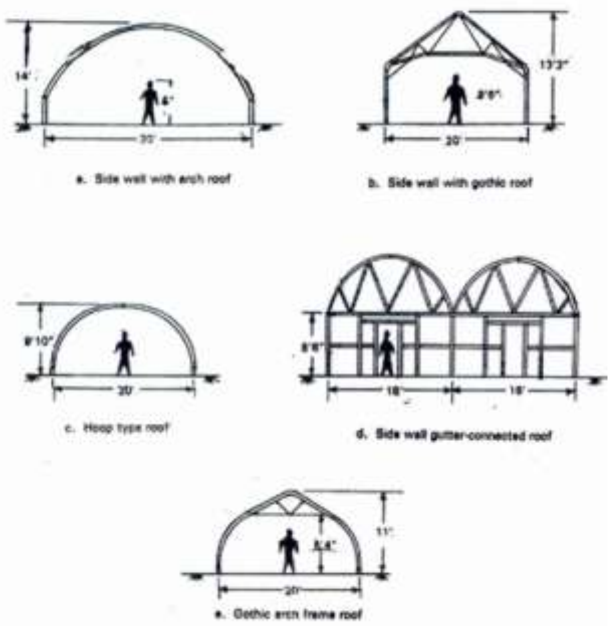
- A greenhouse is designed to withstand local wind, snow and crop loads for a specific cropping activity.
- In this way, the structure becomes location and crop specific.
- The building site should be as level as possible to reduce the cost of grading, and the site should be well aerated and should receive good solar radiation.
- Provision of a drainage system is always possible.
- It is also advisable to select a site with a natural windbreak.
- In regions where snow is expected, trees should be 30.5 m away in order to keep drifts back from the greenhouses.
- To prevent shadows on the crop, trees located on the east, south, or west sides should be at a distance of 2.5 times their height.

Structural design

- The most important function of the greenhouse structure and its covering is the protection of the crop against hostile weather conditions (low and high temperatures, snow, hail, rain and wind), diseases and pests.
- It is important to develop greenhouses with a maximum intensity of natural light inside.
- The structural parts that can cast shadows in the greenhouse should be minimized.
- The different structural designs of greenhouse based on the types of frames are available.
- A straight side wall and an arched roof is possibly the most common shape for a greenhouse, but the gable roof is also widely used.
- Both structures can be free standing or gutter connected with the arch roof greenhouse.
- The arch roof and hoop style greenhouses are most often constructed of galvanized iron pipe. If tall growing crops are to be grown in a greenhouse or when benches are used, it is best to use a straight side wall structure rather than a hoop style house, this ensures the best operational use of the greenhouse.

- A hoop type greenhouse is suitable for low growing crops, such as lettuce, or for nursery stock which are housed throughout the winter in greenhouses located in extremely cold regions.
- A gothic arch frame structure can be designed to provide adequate side wall height without loss of strength to the structure (Fig.10).

- ✓ Loads in designing the greenhouse structures include the weight of the structure itself and, if supported by the structure, loads of the equipment for the heating and ventilation and water lines.
- ✓ Greenhouse structures should be designed to resist a 130 km/h wind velocity.
- ✓ The actual load depends on wind angle, greenhouse shape and size, and the presence or absence of openings and wind breaks.



a. Side wall with arch roof

b. Side wall with gothic roof

c. Hoop type roof

d. Side wall gutter-connected roof

e. Gothic arch frame roof

Fig.10. Structural designs of different greenhouse frameworks

The ultimate design of a greenhouse depends on the following aspects:

- ✓ The overall structural design and the properties of the individual structural components.
- ✓ The specific mechanical and physical properties which determine the structural behaviour of the covering materials.
- ✓ The specific sensitivity of the crop to light and temperature to be grown in the greenhouse.
- ✓ The specific requirements relevant to the physical properties of the covering material.
- ✓ The agronomic requirements of the crop.

Covering Materials

The following factors are to be considered while selecting greenhouse covering material:

i.e. Light, Temperature, Weight, Resistant to impact, and durability to outdoor weathering and thermal stability over wide range of temperatures.

Before selecting the covering material, two important points should bra ken into consideration:

The purpose for which greenhouse facility is intended and service life of material.

In temperature regions where high temperatures are required, the covering material with high light transmission and far IR absorption must be selected. Also the loss of heat by conduction should be minimum.

Sr.no.	Covering material	Life span
1	Glass and acryl sheet	20 years
2	Polycarbonate and fiberglass reinforced polyester sheet	5 – 12 years
3	Polyethylene	2 – 6 months
4	Polyethylene stabilized for UV rays	2 – 3 years

The ideal greenhouse selective covering material should have the following properties:

- It should transmit the visible light portion of the solar radiation which is utilized by plants for photosynthesis.
- It should absorb the small amount of UV in the radiation and convert a portion of it to fluoresce into visible light, useful for plants.
- It should reflect or absorb IR radiation which are not useful to plants and which causes greenhouse interiors to overheat.
- Should be of minimum cost.
- Should have usable life of 10 to 20 years

Lecture no. 5

Materials of construction - Materials of construction for traditional and low cost green house: Wood, G.I., aluminum, steel, R.C.C. and Glass

The following materials commonly used to build frames for greenhouse are:

(i) Wood,
(ii) Bamboo,
(iii) Steel,
(iv) Galvanized iron pipe,
(v) Aluminum and
(vi) Reinforced concrete (RCC).
(vii) Glass

The selection of above materials was based on their Specific physical properties, requirements of design strength, life expectancy and cost of construction materials.

Wood

- Wood and bamboo are generally used for low cost poly-houses.
- In low cost poly-houses, the wood is used for making frames consisting of side posts and columns, over which the polythene sheet is fixed.
- The commonly used woods are pine and casuarina, which are strong and less expensive. In pipe-framed poly-houses, wooden battens can be used as end frames for fixing the covering material.
- In tropical areas, bamboo is often used to form the gable roof of a greenhouse structure. Wood must be painted with white colour paint to improve light conditions

within the green house.

- Care should be taken to select a paint that will prevent the growth of mold.
- Wood must be treated for protection against decay.
- Chromated copper arsenate and ammonical copper arsenate are water based preservatives that are applied to the wood that may come into contact with the soil.
- Red wood or cypress (natural decay resistance woods) can be used in desert or tropical regions, but they are expensive.

Galvanised iron (GI), aluminum, steel and reinforced cement concrete

GI pipes, tubular steel and angle iron are generally used for side posts, columns and purlins in greenhouse structure, as wood is becoming scarce and more expensive. In galvanising operation, the surface of iron or steel is coated with a thin layer of zinc to protect it against corrosion. The commonly followed processes to protect against corrosion are:

Hot dip galvanising (hot process) process: The cleaned member is dipped in molten zinc, which produces a skin of zinc alloy to the steel.

Electro-galvanising (cold process) process: The cleaned member is zinc plated similar to other forms of electro-plating.

- The galvanising process makes the iron rust proof, to eliminate the problem of rusting of structural members.
- Aluminum and hot dipped GI are comparatively maintenance free.
- In tropical areas, double dipping of steel is required, as single dip galvanising process does not give a complete cover of even thickness to the steel.
- Aluminum and steel must be protected by painting with bitumen tar**,** to protect these materials from corrosion, while these materials contact with the ground.
- Now-a-days, the greenhouse construction is of metal type, which is more permanent.
- **RCC** is generally limited to foundations and low walls.
- In permanent bigger greenhouses, floors and benches for growing the crops are made of concrete.

Glass

- Glass has been traditional glazing material all over the world.
- Widely used glass for green house are: (i) Single drawn or float glass and (ii) Hammered and tempered glass.
- Single drawn or float glass has the uniform thickness of 3 to 4 mm.
- Hammered and tempered glass has a thickness of 4 mm.
- Single drawn glass is made in the traditional way by simply pulling the molten glass either by hand or by mechanical equipment.
- Float glass is made in modern way by allowing the molten glass to float on the molten tin. Coating with metal oxide with a low emissivity is used for saving of energy with adequate light transmittance.
- Hammered glass is a cast glass with one face (exterior) smooth and the other one (interior) rough. It is designed to enhance light diffusion.
- This glass is not transparent, but translucent.
- Tempered glass is the glass, which is quickly cooled after manufacture, adopting a procedure similar to that used for steel.

- This kind of processing gives higher impact resistance to the glass, which is generally caused by hail.
- Glass used as a covering material of greenhouses, is expected to be subjected to rather severe wind loading, snow and hail loading conditions.
- The strength mainly depends on the length/width ratio of the panel and on the thickness of the panel, but the most widely used thickness is 4 mm.

Modern material

(i) Polyvinyl chloride film (PVC films)
(ii) Tefzel T^2 film
(iii) Polyvinyl chloride rigid-panel
(iv) Fiberglass-reinforced plastic (FRP) rigid panel
(v) Acrylic and polycarbonate rigid-panel

Lecture no. 6

Irrigation Systems used in green house - Irrigation Systems used in green house: Rules of watering, Overhead Sprinklers , Drip irrigation system and Foggers (Mist spraying)

- ✓ A well-designed irrigation system will supply the precise amount of water needed each day throughout the year.
- ✓ The quantity of water needed would depend on the growing area, the crop, weather conditions, the time of year and whether the heating or ventilation system is operating.
- ✓ Water needs are also dependent on the type of soil or soil mix and the size and type of the container or bed.
- ✓ Watering in the green house most frequently accounts for loss in crop quality.
- ✓ Though the operation appears to be the simple, proper decision should be taken on how, when and what quantity to be given to the plants after continuous inspection and assessment .Since under watering (less frequent) and over watering (more frequent) will be injurious to the crops, the rules of watering should be strictly adhered to.
- ✓ Several irrigation water application systems, such as hand writing, perimeter watering, overhead sprinklers, boom watering and drip irrigation, over sprinklers, boom watering and drip irrigation which are currently in use.

Rules of Watering

The following are the important rules of application of irrigation.

<u>Rule 1:</u> Use a well drained substrate with good structure

If the root substrate is not well drained and aerated, proper watering can not be achieved.

Hence substrates with ample moisture retention along with good aeration are indispensable for proper growth of the plants. The desired combination of coarse texture and highly stable structure can be obtained from the formulated substrates and not from field soil alone.

<u>Rule 2</u>: Water thoroughly each time

Partial watering of the substrates should be avoided; the supplied water should flow from the bottom in case of containers, and the root zone is wetted thoroughly in case of beds. As a rule, 10 to 15% excess of water is supplied. In general, the water requirement for soil based substrates is at a rate of 20 l/m^2 of bench, 0.3 to 0.35 litres per 16.5 cm diameter pot.

<u>Rule 3</u>: Water just before initial moisture stress occurs

Since over watering reduces the aeration and root development, water should be applied just before the plant enters the early symptoms of water stress. The foliar symptoms, such as texture, colour and turbidity can be used to determine the moisture stress, but vary with crops. For crops that do not show any symptoms, colour, feel and weight of the substrates are used for assessment.

Overhead sprinklers

- While the foliage on the majority of crops should be kept dry for **disease control** purposes, a few crops do tolerate wet foliage.
- These few crops can most easily and cheaply be irrigated from overhead.
- Bedding plants, azalea liners, and some green plants are crops commonly watered from overhead.
- A pipe is installed along the middle of a bed.
- Riser pipes are installed periodically to a height well above the final height of the crop (Fig.14).
- A total height of **0.6 m** is sufficient for bedding plants flats and **1.8 m** for fresh flowers.
- A nozzle is installed at the top of each riser.
- **Nozzles** vary from those that throw a 360° pattern continuously to types that rotate around a 360° circle.
- Trays are sometimes placed under pots to collect water that would otherwise fall on the ground between pots and wasted.
- Each tray is square and meets the adjacent tray.
- In this way nearly all water is intercepted.
- Each tray has a depression to accommodate the pot and is then angled upward from the pot toward the tray perimeter.
- The trays also have drain holes, which allow drainage of excess water and store certain quantity, which is subsequently absorbed by the substrate.

Drip Irrigation System

- Drip irrigation, often referred to as trickle irrigation, consists of laying plastic tubes of small diameter on the surface or subsurface of the field or greenhouse beside or beneath the plants. Water is delivered to the plants at frequent intervals through small holes or emitters located along the tube.
- Drip irrigation systems are commonly used in combination with protected agriculture,

as an integral and essential part of the comprehensive design.

- When using plastic mulches, row covers, or greenhouses, drip irrigation is the only means of applying uniform water and fertilizer to the plants.
- Drip irrigation provides maximum control over environment variability; it assures optimum production with minimal use of water, while conserving soil and fertilizer nutrients; and controls water, fertilizer, labour and machinery costs.
- Drip irrigation is the best means of water conservation.
- In general, the application efficiency is 90 to 95%, compared with sprinkler at 70% and furrow irrigation at 60 to 80%, depending on soil type, level of field and how water is applied to the furrows.
- Drip irrigation is not only recommended for protected agriculture but also for open field crop production, especially in arid and semi-arid regions of the world.
- One of the disadvantages of drip irrigation is the initial cost of equipment per acre, which may be higher than other systems of irrigation.
- However, these costs must be evaluated through comparison with the expense of land preparation and maintenance often required by surface irrigation.
- Basic equipment for irrigation consists of a pump, a main line, delivery pipes, manifold, and drip tape laterals or emitters as shown in figure 15:

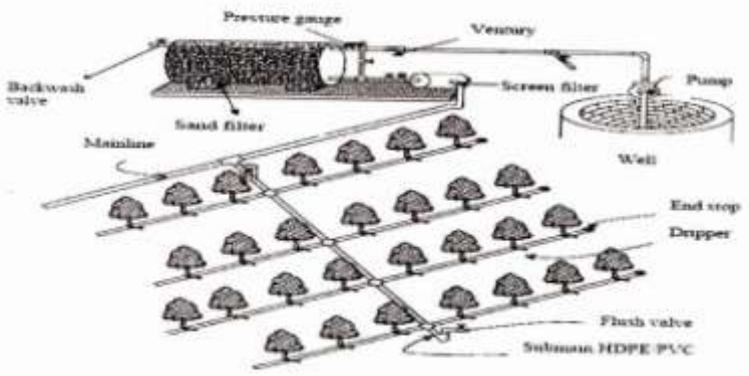


Fig.15. Diagram of drip irrigation system for greenhouse

- The head, between the pump and the pipeline network, usually consists of control valves, couplings, filters, time clocks, fertilizer injectors, pressure regulators, flow meters, and gauges.
- Since the water passes through very small outlets in emitters, it is an absolute necessity that it should be screened, filtered, or both, before it is distributed in the pipe system.
- The initial field positioning and layout of a drip system is influenced by the topography of the land and the cost of various system configurations.

Foggers and Mist Spraying

What is the difference between fog and mist?

- **Fog** particles are generally considered to be less than 50 microns (0.002in) in diameter.
- The particle size typically used in high pressure greenhouse fog systems is about 10 microns. **Mist**, on the other hand, is particles from 50 to 100 microns.
- As a comparison, human hair is about 0.004in diameter that equals 100 microns.
- Breaking one gallon of water into 50 micron droplets will produce about 68 billion droplets of fog.
- Injected into the air, tiny water droplets of fog remain suspended until they are evaporated.
- The smallest particles vaporize almost instantaneously.
- The larger ones are carried by air currents, gradually becoming smaller until they are vaporized. Mist size particles are heavier and take much longer to evaporate.
- These are more likely to fall out and wet the plant surface or saturate the growing medium.
- If they don't evaporate before nighttime, the potential for disease increases.

How fog and mist work for propagation

- The humidity in the air affects the evapotranspiration rate from the leaf surfaces.
- To get good propagation, a balance between humidity and transpiration is needed to allow water and nutrient uptake without excess dehydration.
- In a crop with a dense foliage canopy and without much air movement, a boundary layer of moisture approaching saturation develops around the plants.
- If the growing medium is also saturated, there is a potential for problems from fungi, moss, grey mold and fungus gnats.
- On the other hand, when the air temperature is high and leaf temperature increases, water loss can exceed the ability of the plant to take up moisture and stress can build up within the plant. The use of fog and mist at this time can reduce the air temperature and increase the humidity within the plant canopy without saturating the plant medium.
- With more oxygen in the root zone, faster rooting occurs. Once the root system is established, the relative humidity can be reduced.
- Experience is usually the best approach to determining the proper humidity level.
- Another advantage to the fog system is that foliar feeding, insecticides and fungicides can be applied automatically with a fog system. This saves time and gives a uniform application.

Foggers systems

- Several methods are used to produce fog.
- A typical system uses a high pressure pump, distribution piping and nozzles that break the water stream into very fine droplets.
- Piston pumps are needed to develop the 800 to 1200 psi pressure to get the 10 to 20 micron size droplets.
- Most systems available from irrigation equipment suppliers and labeled as fog systems operate on 50 to 60 psi irrigation water and create a droplet size larger than 50 microns.
- They are really mist systems.
- Copper, stainless steel and re-enforced flexible hose are used for piping.
- Diameter is frequently 1/4in or 3/8in as water supply required is only 1 to 2 gallons/hour/nozzle. For propagation, lines of pipe are evenly spaced above the crop area.
- Plastic, ceramic and stainless steel are used for nozzles.
- Nozzles should have anti-drip check valves to prevent dripping after the system shuts off.
- An integral strainer will keep the nozzle from clogging.
- The greatest problem associated with fogging systems is nozzle clogging from chemical and particulate matter.
- Calcium deposits can coat the inside of the pipe and nozzles reducing flow.
- Water treatment or the use of rain water or bottled water can solve this problem.
- Several levels of filtration of particulate matter should be installed.
- Fog can also be produced by a system using a high-speed fan with water channeled to the tip of the blades.
- The shearing action as the water exits the blades produces a fine fog.
- The fan distributes the fog above the crop canopy.
- This system has the advantage of less clogging as no nozzles are used but some growers have had to remove the system because of the high noise level.

- Water at household pressure, injected through a nozzle into a stream of compressed air will also produce a fine fog.
- Each nozzle requires both a water and air supply.
- Different flow rates and droplet sizes can be achieved by adjusting the water and air pressure. Distribution can be through ducts, HAF fans or nozzles evenly space over the crop.
- For small areas, some growers have used an electrothermal aspirator with good results.
- Fog systems frequently operate with a controller or computer that measures vapor pressure deficit (VPD).
- The difference between saturation water vapor pressure and ambient water vapor pressure is the VPD and represents the evapotranspirational demand of the surrounding atmosphere as well as the proximity to the dew point.
- Due to the fact that relative humidity varies with temperature, it is better to manage propagation with VPD.
- By maintaining the VPD below one, water stress within the plant can be keep at an acceptable level.

Other systems

(i) **Hand watering**
(ii) **Perimeter watering**

Lecture No. 7

Design criteria of green house for Cooling and Heating purposes - Design criteria of green house for Cooling and Heating purposes: Cooling - Natural ventilation, forced ventilation Heating- Heating system, solar heating system, Water & Rock storage.

The term greenhouse refers to a structure covered with a transparent material for the purpose of admitting natural light for plant growth. Two or more greenhouses in one location are referred to as a greenhouse range. A building associated with the greenhouses that is used for storage or for operations in support of growing of plants, is referred to as a service building or head house.

Design criteria of construction

- For locating the greenhouse, a piece of land larger than the grower's immediate need should be acquired.
- The ultimate size of the greenhouse range should be estimated.
- Area should then be added to this estimated figure to accommodate service buildings, storage, access drives and a parking lot.
- The floor area of service buildings required for small firms is about 13% of the greenhouse floor area, and it decreases with the increase in size of the firm.
- On an average, service buildings occupy 10% of the growing area.
- The service building is centrally located in a nearly square design of the firm, which minimizes distance of movement of plants and materials.
- Doors between the service buildings and the greenhouse should be wide enough to facilitate full use of the corridor width.
- Doors at least 3.1 m wide and 2.7 m high are common.
- It is good to have the greenhouse gutter at least 3.7 m above the floor to accommodate

automation and thermal blanket and still leave the room for future innovations.

COOLING

- **Natural Ventilation –**

- In the tropics, the sides of greenhouse structures are often left open for natural ventilation. Tropical greenhouse is primarily a rain shelter, a cover of polyethylene over the crop to prevent rainfall from entering the growing area.
- This mitigates the problem of foliage diseases.
- Ventilators were located on both roof slopes adjacent to the ridge and also on both side walls of the greenhouse.
- The ventilators on the roof as well as those on the side wall accounts, each about 17
- 10% of the total roof area.
- During winter cooling phase, the south roof ventilator was opened in stages to meet cooling needs. When greater cooling was required, the north ventilator was opened in addition to the south ventilator.
- In summer cooling phase, the south ventilator was opened first, followed by the north ventilator.
- As the incoming air moved across the greenhouse, it was warmed by sunlight and by mixing with the warmer greenhouse air.
- With the increase in temperature, the incoming air becomes lighter and rises up and flows out through the roof ventilators.
- This sets up a chimney effect (Fig. 7), which in turn draws in more air from the side ventilators creating a continuous cycle.
- This system did not adequately cool the greenhouse.
- On hot days, the interior walls and floor were frequently injected with water to help cooling.

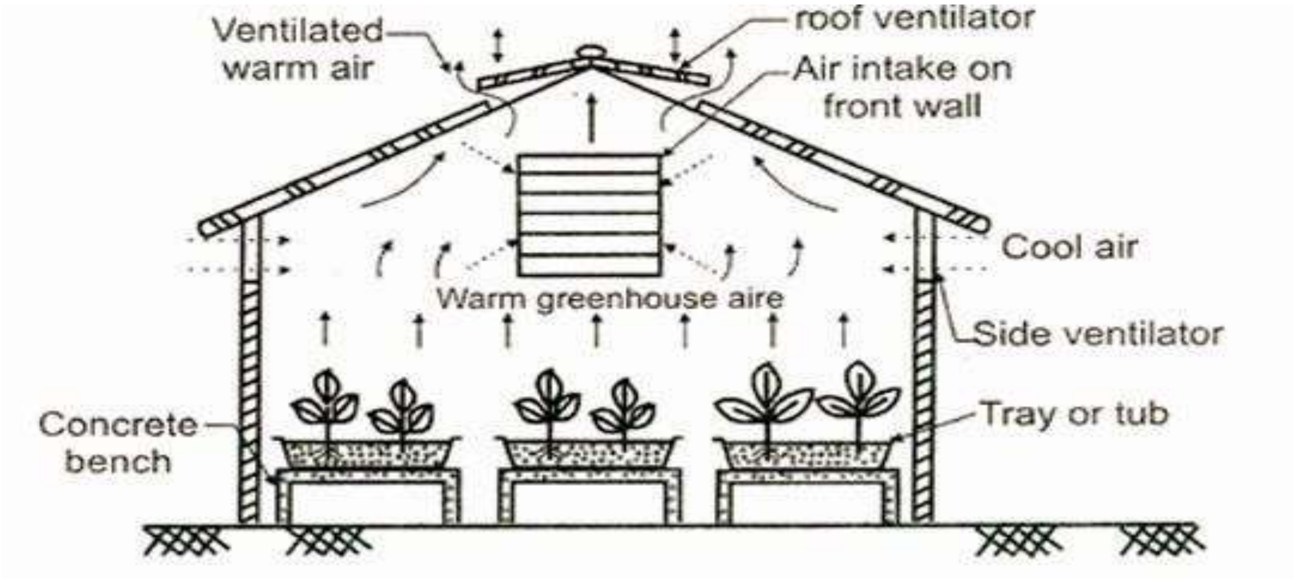


Fig. 7. **Chimney effect in general passive ventilation**

Forced Ventilation

- In forced or active ventilation, mechanical devices such as fans are used to expel the air.
- This type of ventilation can achieve uniform cooling.
- These include summer fan-and-pad and fog cooling systems and the winter convection tube and horizontal airflow systems.
- For mechanical 18 ventilation, low pressure, medium volume propeller blade fans, both directly connected and belt driven are used for greenhouse ventilation.
- They are placed at the end of the green house opposite to the air intake, which is normally covered by gravity or motorized louvers.
- The fans vents, or louvers, should be motorized, with their action controlled by fan operation. Motorized louvers prevent the wind from opening the louvers, especially when heat is being supplied to the green house.
- Wall vents should be placed continuously across the end of the greenhouse to avoid hot areas in the crop zone.
- Evaporative cooling in combination with the fans is called as fan-and-pad cooling system.
- The fans and pads are usually arranged on opposite walls of the greenhouse (Fig.8).
- The common types of cooling pads are made of excelsior (wood fiber), aluminum fiber, glass fiber, plastic fiber and cross-fluted cellulose material.
- Evaporative cooling systems are especially efficient in low humidity environments.
- There is growing interest in building greenhouses combining both passive (natural) and active (forced) systems of ventilation.
- Passive ventilation is utilized as the first stage of cooling, and the fan-pad evaporative cooling takes over when the passive system is not providing the needed cooling.
- At this stage, the vents for natural ventilation are closed.
- When both options for cooling are designed in greenhouse construction, initial costs of installation will be more.
- But the operational costs are minimized in the long run, since natural ventilation will, most often meet the needed ventilation requirements.
- Fogging systems is an alternative to evaporative pad cooling.
- They depend on absolutely clean water, Free of any soluble salts, in order to prevent plugging of the mist nozzles.
- Such cooling systems are not as common as evaporative cooling pads, but when they become more cost competitive, they will be adopted widely.
- Fogging systems are the second stage of cooling when passive systems are inadequate.

HEATING

Heating systems

- The heating system must provide heat to the greenhouse at the same rate at which it is lost by co0nductin, infiltration, and radiation.
- There are three popular types of heating systems for greenhouses.
- The most common and least expensive is the unit heater system.
- In this system, warm air is blown from unit heaters that have self contained fireboxes.
- These heaters consist of three functional parts.
- Fuel is combusted in a firebox to provide heat.

- The heat is initially contained in the exhaust, which rises through the inside of a set of thin walled metal tubes on it way to the exhaust stack.
- The warm exhaust transfers heat to the cooler metal walls of the tubes.
- Much of the heat is removed from the exhaust by the time it reaches the stack through which it leaves the greenhouse.
- A fan in the back of the unit heater draws in greenhouse air, passing it over the exterior side of the tubes and then out from the heater to the greenhouse environment again.
- The cool air passing over hot metal tubes is warmed and the air is circulated.
- A second type of system is central heating system, which consists of a central boiler than produces steam or hot water, plus a radiating mechanism in the greenhouse to dissipate the heat.
- A central heating system can be more efficient than unit heaters, especially in large greenhouse ranges.
- In this system, two or more large boilers are in a single location.
- Heat is transported in the form of hot water or steam through pipe mains to be growing area, and several arrangements of heating pipes in greenhouse is possible (Fig. 12.1).
- The heat is exchanged from the hot water in a pipe coil located across the greenhouse or an in-bed pipe coil located in the plant zone.
- Some greenhouses have a third pipe coil embedded in a concrete floor.
- A set of unit heaters can be used in the place of the overhead pipe coil, obtaining heat from hot water or steam from the central boiler.
- The third type of system is radiation heating system.
- In this system, gas is burned within pipes suspended overhead in the greenhouse.
- The warm pipes supply heat to the plants. Low intensity infrared radiant heaters can save 30% or more, of fuel compared to conventional heaters.
- Several of these heaters are installed in tandem in the greenhouse.
- Lower air temperatures are possible since only the plants and root substrate are heated directly by this mode of heating.
- The fourth possible type of system is the solar heating system, but it is still too expensive to be a viable option.
- Solar heating systems are found in hobby greenhouses and small commercial firms.
- Both water and rock energy storage systems are used in combination with solar energy.
- The high cost of solar heating systems discourages any significant use by the greenhouse industries.

Solar heating system

- Solar heating is often used as a partial or total alternative to fossil fuel heating systems.
- Few solar heating systems exist in greenhouses today.
- The general components of solar heating system (Fig. 12) are collector, heat storage facility, exchange to transfer the solar derived heat to the greenhouse air, backup heater to take over when solar heating does not suffice and set of controls.
- Various solar heat collectors are in existence, but the flat plate collector has received greatest attention.
- This consists of a flat black plate (rigid plastic, film plastic, sheet metal, or board) for absorbing solar energy.

- The plate is covered on the sun side by two or more transparent glass or plastic layers and on the backside by insulation.
- The enclosing layers serve to hold the collected heat within the collector.
- Water or air is passed through the copper tubes placed over the black plate and absorb the entrapped heat and carry it to the storage facility.
- A greenhouse itself can be considered as a solar collector.
- Some of its collected heat is stored in the soil, plants, greenhouse frame, floor, and so on.
- The remaining heat is excessive for plant growth and is therefore vented to the outside.
- The excess vented heat could just as well be directed to a rock bed for storage and subsequent use during a period of heating.
- Collection of heat by flat-plate collection is most efficient when the collector is positioned perpendicular to the sun at solar noon.
- Based on the locations, the heat derived can provide 20 to 50% of the heat requirement.

Water and rock storage

- Water and rocks are the two most common materials for the storage of heat in the greenhouse. One kg of water can hold 4.23 kJ of heat for each 1oC rise in temperature.
- Rocks can store about 0.83 kJ for each 1^{o}C. To store equivalent amounts of heat, a rock bed would have to be three times as large as a water tank.
- A water storage system is well adapted to a water collector and a greenhouse heating system which consists of a pipe coil or a unit heater which contains a water coil.
- Heated water from the collector is pumped to the storage tank during the day.
- As and when heat is required, warm water is pumped form the storage tank to a hot water or steam boiler or into the hot water coil within a unit heater.
- Although the solar heated water will be cooler than the thermostat setting on the boiler, heat can be saved, since the temperature of this water need be raised as high as to reach the output temperature of water or steam from the boiler.
- A temperature rise of 17^{o}C above the ambient condition is expected during the daytime in solar storage units.
- Each kilogram of water can supply 71.1 kJ of heat, and each kilogram of rock can supply14.2 kJ of heat, as it cools by 17^{o}C.

Lecture no.8

Engineering Properties - Engineering Properties of cereals, pulses and oil seed. Their applications in PHT equipment design and operation: Physical properties: Size and Shape (Roundness and Sphericity) Porosity, Coefficient of friction, and angle of repose, Thermal properties: Definition of Specific heat and Thermal conductivity. Aero & hydrodynamic properties: Definition of Terminal velocity.

PHT equipment's design and operation

All machines should incorporate certain qualities:

1. It should perform the function for which it is designed.
2. Its work should be done cleanly, and the machine should be easily cleaned.

3. The machine should be as simply designed as possible and of such sturdy construction that few repairs are needed.

4. It should be economical in operation

Food plant equipment design

1. All machine parts must be designed for quick dismantling and reassembling – some merely by removing and replacing a nut or wing screw by hand. It is also best to construct these parts of lightweight material so that they can be easily handled for cleaning.
2. All food contact surfaces should be inert, smooth, nonporous, and non-absorbing; they must withstand the application of chemical cleaners, sanitizers, and pesticides; they must be easily cleaned and readily accessible for inspection
3. Open seams in cooking kettles, mixers, blenders, storage vats, and filling machines must be eliminated.
4. Surfaces of equipment in contact with food must be smooth and continuous; rough spots and crevices must be avoided.
5. All junctions, particularly pipelines and ducts, must be curved or rounded. Cooking kettles, storage tanks, holding vats, and similar units must have long curves at the juncture of the bottom and sidewalls instead of sharp corners.
6. All machine parts in contact with food must be accessible for hand-brush cleaning and/or inspection.
7. Dead-end areas in all machines must be eliminated.
8. Metals like lead, antimony, and cadmium must not be used in fabricating equipment. Copper or copper-containing alloys are not recommended.
9. Stuffing boxes or glands in which food might accumulate and decompose should not be used.
10. Pipe fittings must have a sanitary thread and threaded parts must be accessible for cleaning.
11. Sanitary-type valves, such as plug type, should be used.
12. Runoff valves should be installed as close as possible to mixers, kettles, vats, and tanks.
13. Coupling nuts on piping and valves must have sufficient clearance and must be easily taken apart.
14. Food products should be protected from lubricants and condensates as moisture condensing on ceilings may pick up dirt and peeled paint, later to drop into open cooking kettles or holding vats. PHT equipment's design and operation 40
15. Mixing blades should be welded to the drive shaft or both should be in one piece. Shaft and blades should be removable from the mixer at a point above the surface of the product.
16. Machine parts in contact with food should be constructed of noncorrosive metal.
17. Equipment like kettles, certain mixers, and holding vats and storage bins should have sectional covers, which are free from seams, hinges, crevices, and heads in which dirt might collect.
18. Drive shafts must be sealed so that lubricating grease does not work its way into the food.
19. Any horizontal parts of machines or supports should be at a minimum of 15 cm (6 in) above the floor. Tubular supports are preferred, but if squared tubing is placed horizontally, it should be rotated 45° to eliminate flat surfaces. Equipment occupying large floor areas should have a clearance of 46 cm (18 in) or more to facilitate cleaning.

Physical Properties

Shape and size

- Shape of the grain is connected with the geometrical form of the grain.
- Size of the grain refers to the characteristics of an object which in term determine how much space it occupies and, within limits, can be described in terms of length, width, and thickness.
- The Shape and size together with other characteristics of the grains is important in the design of the seed grader.
- These factors determine the free flowing or bridging tendencies of the seed mass, and therefore, determine the suitable handling and feeding equipment.
- Sphericity and equivalent diameters are also used to describe the shape and size, respectively for the grains.

The **sphericity** (φ) defined as the ratio of the surface area of sphere having the same volume as that of the grain to the surface area of the grain, can be calculated from the axial dimensions of the grain as follows:

$$\emptyset = \frac{(\square\square\square)^{1/3}}{\square}$$

The sphericity (φ) of the fruits can be calculated using the following formula.

$$\emptyset = \frac{\square\square\square^{1/3}}{\square}$$

where,
(a) = major diameter ; (b) = intermediate diameter; (c) = minor diameter The geometrical mean diameter (GMD) can be calculated as follows:

$$GMD = (\square\square\square)^{1/3}$$

Porosity

Properties such as bulk density, true density and porosity of grains are useful in design of various separating, handling, storing and drying systems. Resistance of bulk grain to airflow is a function of the porosity and the kernel size. The porosity (ε) defined as the percentage of void space in the bulk grain which is not occupied by the grain can be calculated from the following relationship:

$$\square = \frac{\square_{\square}\square_{\square}}{\square_{\square}} \times \square\square\square$$

Coefficient of friction

The frictional properties of granular materials are important in designing of storage bins, hoppers, chutes, pneumatic conveying system, screw threshers and conveyors, forage harvesters, etc,. The ratio between the force of friction (F), and the force normal to the surface of contact (N), 35 is known as the coefficient of friction (μ).

Mathematically,

coefficient of friction, $\square = \frac{\square}{\square}$

where, F = Frictional force (Amount of total Weights added + Suspended Pan) N = Normal Load (Weight of the material + Circular Ring).

Angle of Repose

The flowing capacities of different grains are different. It is characterized by the angle of natural slope. The angle of repose is the angle between the base and the slope of the cone formed on a free vertical fall of the grain mass to a horizontal plane.

Thermal Properties

The raw foods are subjected to various types of thermal treatment namely heating, cooling, drying, freezing etc., for processing. The change of temperature depends on the thermal properties of the product. Therefore knowledge of thermal properties namely, specific heat, thermal conductivity, thermal diffusivity is essential for the design of different thermal equipments and for solving various problems on heat transfer operation.

Specific Heat:

Specific heat of a substance is defined as the amount of heat required to raise the temperature of unit mass through 1oC. In mathematical form, specific heat Cp, is written as Cp = Q/m. dT where Q is the amount of heat, m is the mass of material, and dT is the change in temperature.

Thermal Conductivity:

The thermal conductivity is defined as the amount of heat flow through unit thickness of material over an unit area per unit time for unit temperature difference.

Aero and Hydrodynamic Properties

- In handling and processing of agricultural products often air or water is used as a carrier for transport or for separating the desirable product from the unwanted materials.
- The pneumatic separation and conveying has been in use in agricultural machinery and food processing equipment for many years.
- Use of water however, as a carrier for more economical transport or less injury to such products as fruits and vegetables, is a relatively new idea in the agricultural industry.
- In either case, fluid flow occurs around the solids and the problem involves the action of the forces exerted by the fluid on these solids.
- As the principles of this subject, known as fluid mechanics, find increasingly wide applications in handling and processing of agricultural products, it becomes necessary to have a knowledge of those physical properties which affect the aero and hydrodynamic behaviour of agricultural products

Terminal velocity

The terminal velocity of a particle may be defined as equal to the air velocity at which a particle remains in suspended state in a vertical pipe. In the condition of free fall, the particle attains a constant terminal velocity, Vt, the net gravitational accelerating force, Fg, equals the resisting upward drag force, Fr.

Lecture no. 9

Drying and Dehydration - Drying and Dehydration: Definition of drying and dehydration, Utilities/Importance of drying Grain drying Theory- EMC definition, Thin layer drying and deep bed drying.

Definitions

A) Drying-

"Drying is the universal method of conditioning grain by removing moisture to a moisture content level that is in equilibrium with normal atmospheric air in order to preserve its quality and nutritive value for food and feed and its viability for seed."

B) Dehydration-

"**Dehydration** means removal of moisture to very low levels usually to bone dry condition."

Utilities/ Importance

- Draying of grains to about 12% moisture improve the storage period.
- If moisture is not available they can't respire quickly.
- After drying to such a low moisture levels the free water availability will become low or almost negligible which prevent the growth of any microbes which have the potential to cause considerable quantitative and qualitative loses.
- Drying also prevent insect attack.
- It could also helps in preventing germination for a period of time till they get enough moisture,which is an added advantage for grain storage purpose:
- Drying of grains is important because grains with high amount of moisture deteriorate both in terms of quality and quantity quickly.
- They may germinate if not dried as they would have enough moisture in them and other conditions if available.
- Drying is important to prevent free water availability for microbial growth.
- Drying is important to prevent respiration.

Theory of Grain Drying

- Generally the term drying refers to the removal of relatively small amount of moisture from a solid or nearly solid material by evaporation.
- Therefore, drying involves both heat and mass transfer operations simultaneously.
- In convective drying the heat required for evaporating moisture from the drying product is supplied by the external drying medium, usually air.
- Because of the basic differences in drying characteristics of grains in thin layer and deep bed, the whole grain drying process is divided into thin layer drying and deep bed drying.

Methods of drying grains

- Drying of grains can be done in different ways depending upon the source of heat utilized for the purpose.
- The most common methods are based on the **mode of heat transfer:** Conduction drying: (i) conduction drying, (ii) convection drying, and (iii) radiation drying.
- The other methods of drying are: dielectric drying, chemical drying, vacuum drying and freeze drying.

- Convection drying is commonly used for drying of all types of grain and conduction drying can be employed for drying of parboiled grain.

EMC – Equilibrium Moisture Content

Definition - The air passes through the dried zone and picks up moisture in the drying zone until it reaches equilibrium moisture content (EMC) in the case of very wet grain.

- Henderson (1952) developed the following equation to express the equilibrium moisture curve mathematically: 1- RH = exp $-\square\square\square^{\square}_{\square}$

Where,
RH = equilibrium relative humidity, decimal
Me = E.M.C dry basis, per cent
T = temperature, ^{o}K and c and
n = product constants, varying with material

Classification of grain drying

Grain drying is classified based on two principles: (i) Thin layer drying and (ii) deep bed drying.

1. Thin layer drying

Thin layer drying refers to the grain drying process in which all grains are fully exposed to the drying air under constant drying conditions, i.e., at constant temperature, and humidity. Generally, up to 20 cm thickness of grain bed is taken as thin layer.

All commercial flow dryers are designed on thin layer drying principle.

The features of thin layer method of grain drying are:

a) Limited to 20 cm of grain depth.
b) Drying rate is independent of air velocity.
c) At a given RH and moisture content, the drying rate is proportional to the difference between the dry bulb temperatures of air in equilibrium with the grain.
d) The rate of drying is proportional to the difference between the vapour pressure of moisture in the grain and vapour pressure of moisture in the drying air.

2. Deep bed drying

- Deep bed drying process refers to the heterogeneous drying of grain in deep layer (more than 20 cm deep) where drying is faster at the inlet end of drying chamber than at the exhaust end. The drying of grain in a deep bin (Fig 30.) can be taken as the sum of several thin layers of grain arranged one above another.
- The rate of moisture removal is maximum for the bottom layer and decreased exponentially for subsequent layers.
- Dry air becomes cooler and moister as it moves up in the grain bed.
- Actually, all grains in the drying chamber may be considered to be in 3 zones: (a) dried zone; (b) the drying zone; (c) the wet zone.
- The dried zone will gradually move upward as drying proceeds in the direction of air movement.
- The air passes through the dried zone and picks up moisture in the drying zone until it reaches equilibrium moisture content (EMC) in the case of very wet grain.
- In this way, as the air moves, its drying capacity goes on decreasing.
- Drying will cease as soon as the product comes in equilibrium with the air.

- The upper edge of the drying zone at the interface with the wet zone is called the drying front. The drying front indicates the level of grains in the bin at which, the grain have just started loosing moisture to the drying air.
- The volume of drying zone varies with the temperature and humidity of entering air, the moisture content of the grain and velocity of air movement.
- The drying rate in a bin varies from layer to layer from time to time and depends upon the characters of grains and the air used for drying.

Lecture no. 10 & 11

Moisture Measurements- Moisture measurements: Moisture content and its measurement, Moisture content representation: Dry basis and wet basis Moisture Content determination Methods:- Direct methods- Air oven method, Vacuum oven method and Infra-red method Indirect Methods- Electrical resistance method and

Moisture content

All agricultural products are hygroscopic in nature and contain some percent of moisture.
This moisture content of substance is usually expressed in percentage by weight.
Two methods are used to express this moisture content.
These methods are wet basis (*m*) and dry basis (*M*).

Moisture content, wet basis

Moisture content is usually expressed is percentage by weight on wet basis as

$$m=\frac{\square_{\square}}{\square_{\square}+\square_{\square}} \times 100 \ldots\ldots . . \ldots (1)$$

W_m = Weight of moisture
W_d = Weight of bone dry material

Moisture content, dry basis

$$M = \frac{\square_{\square}}{\square_{\square}} \times 100 = \frac{\square}{\square\square\square-\square} = 100\ldots\ldots.. (2)$$

- The moisture content on dry basis is more simple to use in calculation as the quantity of moisture present at any time is directly proportional to the moisture content on dry basis. Use of the wet basis measurement is common in the grain industry.
- However, use of the wet basis has one clear disadvantage is that, the total mass changes as moisture is removed.
- Since the total mass is the reference base for the moisture content, the reference condition is changing as the moisture content changes.
- On the other hand, the amount of dry matter does not change.
- For a given product, the moisture content dry basis is always higher than the wet basis moisture content.

Problem: The moisture content of grain is 25% on w.b. and is equal to ----- % on d.b.
M= 25/75= 33.3 % d.b.)

Moisture measurement

Moisture content can be determined by direct and indirect methods.

Direct method includes air-oven drying method (13020C) and distillation method.

Direct methods are simple and accurate but time consuming, where as indirect methods are convenient and quick but less accurate.

Direct method: Grind the sample (2 to3 g), keep the sample in oven for about 1 hour at 13020C and place the sample in desiccator and then weigh.

Distillation method: 100 g grain + 150 ml mineral oil is heated in a flask at 200˚C for 30-40 minutes. Moisture condenses in a measuring cylinder

Air Oven Method

The **grain** moisture **air-oven** reference **methods** are procedures used to determine the percent moisture content in **grain**.

Basically, a small sample of **grain** (ground or unground) that represents a larger sample set of that **grain** is placed in a small metal dish and the weight of the sample is recorded.

Vacuum Oven Method

Vacuum drying is the mass transfer operation in which the moisture present in a substance.

The **oven** door is locked air tight and is connected to **vacuum** pump to reduce the pressure. The materials to be dried are kept on the trays inside the vacuum dryer and pressure is reduced by means of vacuum pump.

Infra-Red Method

Infrared radiation is used in many **moisture** analyzers, such as halogen moisture analyzers which are used to produce **infrared** radiation from a halogen lamp.

The weight of the sample is measured and recorded continuously and once it becomes constant the drying is stopped

Indirect methods

Indirect methods are based on the measurement of a property of the grain that depends upon moisture content. **Two indirect methods are described as follows**:

Electrical resistance method

- Resistance type moisture meter measures the electrical resistance of a measured amount of grain sample at a given compaction (bulk density) and temperature.
- The electrical resistance varies with moisture, temperature and degree of compaction.
- The universal moisture meter (U.S.A), Tag-Happenstall moisture meter (U.S.A) and Kett moisture meter (Japan) are some of the resistance type moisture meters.
- They take only 30 seconds for the moisture measurement.

Dielectric method

- The dielectric properties of grain depend on its moisture content.
- In this type of moisture meter, 200gm grain sample is placed between the condenser plates and the capacitance is measured.
- The measured capacitance varies with moisture, temperature and degree of compaction. The Motomco moisture meter (USA) and Burrows moisture recorder (USA) are some of the capacitance type moisture meters.

- They take about 1 minute for the 55 e measurement of moisture. These are also known as safe crop moisture testers as they do not damage the grain sample.

Lecture No. 12

Various Drying Methods - Various Drying Methods: Sun drying, Mechanical Drying Mechanical Drying Methods:- Contact drying, Convection drying, Radiation drying

Sun drying

This is a traditional method of drying of crops and grains.
Sun drying involves using the energy of the sun to remove moisture from the product.
Major portion of crops is left in the field and threshing yard for drying under sun.
A major quantity of grain is still dried by the sun in most of the developing countries.

The advantages of sun drying are:

1. No fuel or mechanical energy is required.
2. Operation is very simple
3. Viability, germination, baking qualities are fully preserved.
4. Microbial activity and insect/pest infestation are reduced.
5. No pollution
6. Low capital requirement
7. Operating costs are considerable.

The disadvantages of the sun drying are:

1. Uncontrolled and non-uniform drying, results in sun checks or cracks in kernels.
2. Completely dependent on weather.
3. Not possible round the clock and round the year.
4. Excessive losses occur due to shattering, birds, rodents etc. It is usually 0.1 to 0.4%.
5. Require specially constructed large drying floor.
6. The entire process is unhygienic.
7. Unsuitable for handling large quantity of grain within a short period of time.
8. Require large number of unskilled labour.

Mechanical drying

This process utilizes mechanical means to circulate heated air at constant temperature and humidity, through the grain mass to accomplish the removal of excess moisture from the grain.

Its features are:

(a) the rate of drying can be controlled by adjusting the temperature of hot air circulating through the grain mass. Therefore, increase in milling quality with possible reduction in development of cracks in the grain.

(b) Grains can be dried irrespective of weather condition, day or night; the process does not depend on any natural sources like sun energy.

(c) The process is automatic and requires unskilled labour, except a trained person to operate the dryer.

(d) There are practically no losses due to birds, rodents and insects.

(e) The entire process is hygienic.

(f) Possible round the clock and round the year and
(g) Suitable for handling of large quantity of grain within a short period of harvest.
Mechanical drying requires very little space for operation.
Mechanical drying, in conjunction with early harvest, improves the milling quality of paddy considerably.

The disadvantages of mechanical drying are: the process requires fuel and electrical or mechanical power to drive the blower, elevators etc.
Therefore, cost of drying is relatively higher compared to sun-drying for commercial drying. 1

Mechanical dryers The mechanical dryers are classified as: (a) Contact drying
(b) Convection drying (c) Radiation drying.

1. Contact drying

When the heat for drying is transferred to the wet solid mainly by conduction through a solid surface (usually metallic), the phenomenon is known as conduction or contact drying.

2. Convection drying

The drying agent (hot gases) in contact with the wet solid, is used to supply heat and carry away the vapourized moisture. The heat is transferred to the wet solid mainly by convection. Convection drying is most popular in grain drying. Fuel consumption per kg of moisture evaporated is always higher than that of conduction drying.

3. Radiation drying

It is based on the absorption of radiant energy of the sun and its transformation into heat energy by the grain. Sun drying is an example of radiation drying.

Lecture No. 13

Numerical on Moisture content and its representation- Conversion of wet basis moisture contents to dry basis moisture contents Conversion of dry basis moisture contents to wet basis moisture contents, Problems on drying Problems on moisture contents Problem No.1 & No.2

PROBLEMS ON MOISTURE CONTENT

1) Two tones of paddy with 22% moisture content on wet basis are to be dried to 13% moisture content on dry basis. Calculate the weight of bone dry products and water evaporated.

2) Determine the quantity of parboiled paddy with 40 per cent moisture content on wet basis required to produce 1 tonne of product with 12 per cent moisture content on wet basis. Work out the problem on wet basis and check the answer using dry basis.

Lecture no. 14 & 15

Commercial Grain Dryers - Commercial Grain Dryers: Construction and working principle - Deep bed dryer, Flat bed dryer, Recirculating dryer – (LSU and Baffle dryers) , Tray dryer and Solar dryers.

Commercial Grain Dryers -

Deep bed drying

Construction

- Deep bed drying process refers to the heterogeneous drying of grain in deep layer (more than 20 cm deep) where drying is faster at the inlet end of drying chamber than at the exhaust end. The drying of grain in a deep bin (Fig 30.) can be taken as the sum of several thin layers of grain arranged one above another.
- The rate of moisture removal is maximum for the bottom layer and decreased exponentially for subsequent layers.
- Dry air becomes cooler and moister as it moves up in the grain bed.

Working Principle

- Actually, all grains in the drying chamber may be considered to be in 3 zones: (a) dried zone; (b) the drying zone; (c) the wet zone.
- The dried zone will gradually move upward as drying proceeds in the direction of air movement.
- The air passes through the dried zone and picks up moisture in the drying zone until it reaches equilibrium moisture content (EMC) in the case of very wet grain.
- In this way, as the air moves, its drying capacity goes on decreasing.
- Drying will cease as soon as the product comes in equilibrium with the air.
- The upper edge of the drying zone at the interface with the wet zone is called the drying front. The drying front indicates the level of grains in the bin at which, the grain have just started loosing moisture to the drying air.
- The volume of drying zone varies with the temperature and humidity of entering air, the moisture content of the grain and velocity of air movement.
- The drying rate in a bin varies from layer to layer from time to time and depends upon the characters of grains and the air used for drying.

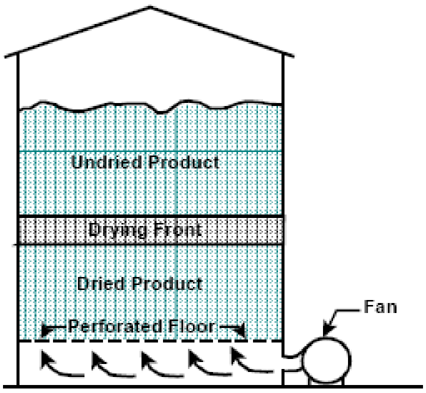


Fig.30. Drying process in deep bin

Recirculatory batch dryer (RPEC dryer)

- This is continuous flow **non-mixing** type of dryer**.**
- This dryer was developed at Rice Processing Engineering Centre (RPEC), IIT, Khargpur.
- It consists of two concentric circular cylinders made of perforated sheets of 20 gauge (Fig.34). The cylinders are set about 20 cm apart, to move the grain downward.
- These two cylinders are supported on four channel sections.
- A bucket elevator of suitable capacity is provided to feed and recirculate the grain into the dryer.
- A centrifugal blower blows the hot air into the inner cylinder which acts as a plenum.
- The hot air from the plenum passing the grain moving downward by gravity and comes out of the perforated cylinder.
- A torch burner is employed to supply the necessary heat with kerosene oil as fuel.
- RPEC dryers are made for half, one and two tones holding capacities.

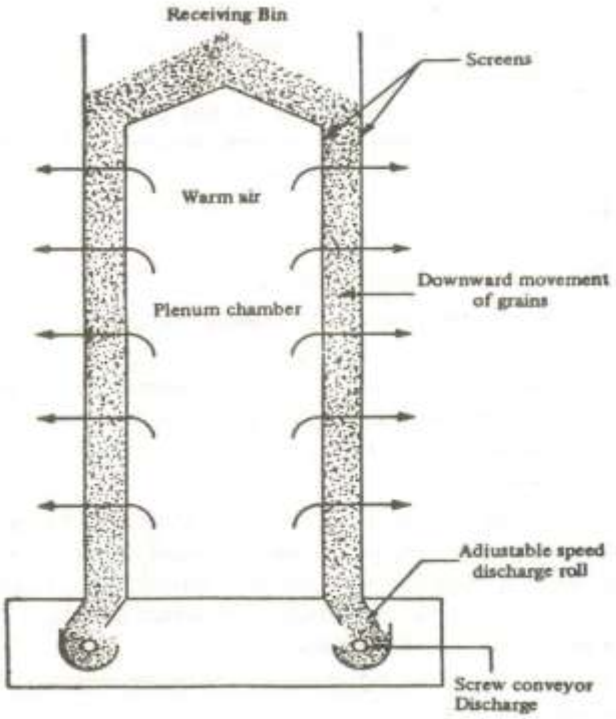


Fig. 34. Longitudinal section of a RPEC dryer (Non-mixing type dryer)

Louisiana state university (LSU) dryer

This is a continuous flow-mixing type of grain dryer which is popular in India and the U.S.A. It was developed at Louisiana State University Baton Rouge, USA in 1949.

Construction:

It consists of :(1) a rectangular drying chamber fitted with air ports and the holding bin,
(2) an air blower with duct,
(3) grain discharging mechanism with a hopper bottom, and
(4) an air heating system (Fig.36).

(1) **Rectangular bin**:

Usually the following top square sections of the bin are used for the design of LSU dryers:

(i) 1.2m x 1.2 m, (ii) 1.5 m x 1.5 m,
(ii) (iii) 1.8 m x 1.8 m and (iv) 2.1 m x 2.1 m. 74

The rectangular bin can be divided into two sections, namely, top holding bin and bottom drying chamber

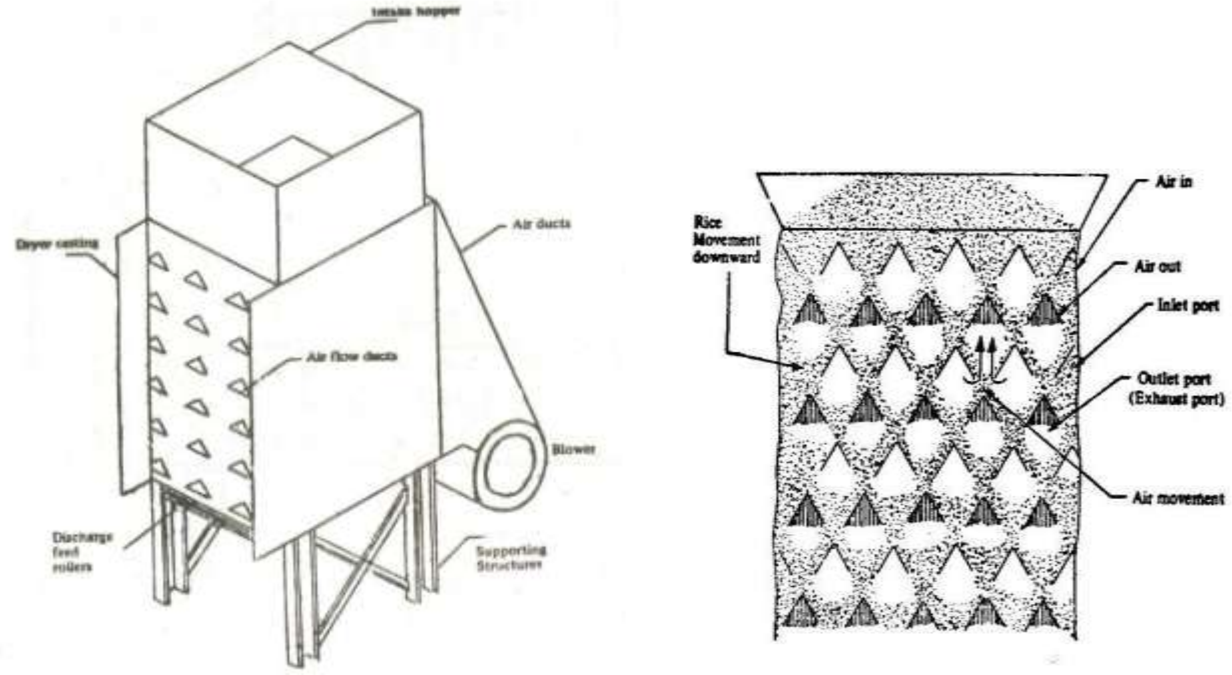
(2) **Air Distribution system**:

- Layers of inverted trough or V- shaped channels (called inverted V-ports) are installed in the drying chamber.
- Alternate rows of these ports are opened on the blower and closed on the exhaust end. These are called inlet ports Hot air enters the drying chamber through these ports.
- The other alternative rows of ports are closed on the blower end and are opened on the exhaust end.
- These are called outlet or exhaust ports as the drying air goes out through these ports.
- The inlet and outlet ports are of uniform sizes and equal in number with equal spacing in between them.
- Usually the inlet ports are given in 3 columns and outlet ports in 4 columns (2 column of full size ports and 2 columns of half-size ports).
- The number of ports containing a dryer varies widely depending on the size of the dryer.
- The inlet and outlet ports are arranged one below the other in a zig-zag path, so that when paddy flows down between these ports, it takes a zig-zag path.
- Hot air enters the inlet ports from the blower end.
- Since these ports are closed on exhaust end, the hot air from these channels or ports flows down through the paddy and enter the outlet ports and leave the drying chamber through exhaust side.
- Some degree of mixing of hot air and paddy occurs in this chamber while air is flowing across it in zig-zag path and paddy flowing downwards.
- Three fluted rolls are attached at the bottom, which are rotated at a slow speed.
- The discharge of the paddy is regulated with these fluted rolls.
- To provide hot air for drying, fuel is burnt to raise the ambient air temperature.
- Heat may be supplied by the direct fired burners or direct or indirect heat exchangers.
- In general, the capacity of the dryer varies from 2 to 12 tonnes of grain, but sometimes dryers of higher capacities are also installed.
- Accordingly power requirement varies widely.
- Recommended air flow rate is 70 m3/min/tonne of dry paddy and optimum air temperatures are 60-70^{O} C and 85^{O} C for raw and parboiled paddy respectively.
- A series of dryers can also be installed.
- In continuous flow dryers, drying air temperature may be as high as 70^{0}C, where as for batch dryers, this temperature seldom exceeds 45^{0}C.

- **Following are some recommendations for the drying operation with particular reference to the operation of an LSU Dryer:**

a) A drying cycle chart in the control room will be a great help and to guide the operator.
b) The dryer should not be operated until it is filled completely with grain.

c) The recommended drying air temperature is 60O C and the air flow rate is 70 cu m/min./ ton of holding capacity of dryer.
d) Tempering in between drying process is recommended to reduce the total drying time. Normally, this tempering period is of 8 hour duration.
e) Feed roll clearance should be the same for all the fluted rolls for uniform drying.
f) The grain temperature during drying should not exceed 40O C.
g) The burner should be started only after the blower has been started.
h) There should be appropriate controls to put the flame off in case of blower failure due to either power or mechanical failure. An automatic fuel cut-off valve is recommended for this purpose.



(a) **(b)**

Fig. 36. (a) LSU type dryer and (b) flow pattern in LSU dryer

Baffle dryer

This is a continuous flow **mixing type** of grain dryer. The main advantage with the dryer is uniformly dried product is obtained.

Construction

The baffle dryer consists of; (1) grain receiving bin, (2) drying chamber fitted with baffles, (3) plenum fitted with hot air inlet, (4) grain discharge control devices and (5) hopper bottom. A number of baffles are fitted with the drying chamber to divert the flow and affect certain degree of mixing of grain. The dryer is made of mild steel sheets.

Operation

Grain is fed at the top receiving bin and allowed to move downward in a zigzag path through the drying chamber where it encounters a cross flow of hot air. A bucket elevator can recirculate the grain till it is dried to the desired moisture level. This design helps in mixing of dried and undried grains.

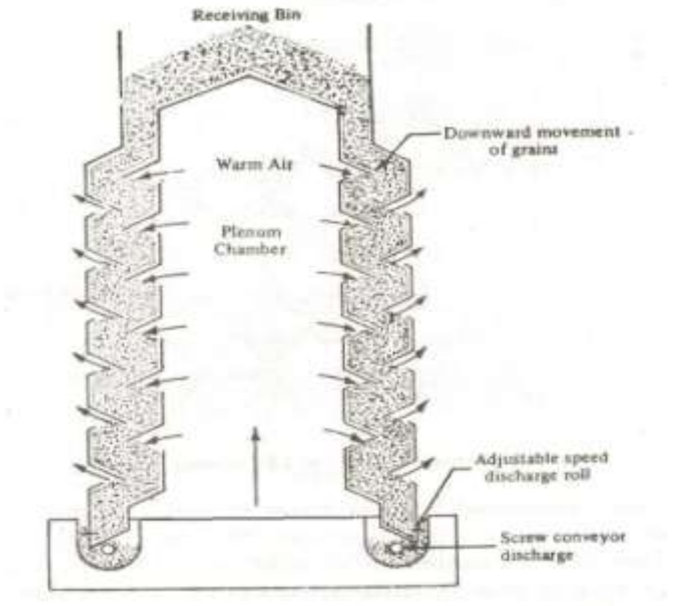


Fig. 35. Baffle dryer

Tray Dryer

- Schematic of a typical batch dryer is shown in fig.
- Tray dryers usually operate in batch mode, use racks to hold product and circulate air over the material.
- It consists of a rectangular chamber of sheet metal containing trucks that support racks. Each rack carries a number of trays that are loaded with the material to be dried.
- Hot air flows through the tunnel over the racks. Sometimes fans are used to on the tunnel wall to blow hot air across the trays.
- Even baffles are used to distribute the air uniformly over the stack of trays.
- Some moist air is continuously vented through exhaust duct; makeup fresh air enters through the inlet.
- The racks with the dried product are taken to a tray-dumping station
- These types of dryers are useful when the production rate is small.
- They are used to dry wide range of materials, but have high labor requirement for loading and unloading the materials, and are expensive to operate.
- They find most frequent application for drying valuable products.
- Drying operation in case of such dryers is slow and requires several hours to complete drying of one batch.
- With indirect heating often the dryers may be operated under vaccum.
- The trays may rest on hollow plates supplied with steam or hot water or may themselves contain spaces for a heating fluid.
- Vapour from the solid may be removed by an ejector or vacuum pump.

Solar Dryer

1. Function Drying of fruits, vegetables and agricultural commodities
2. Specification
   (i) Collector area 2.4 x 1.8 m

(ii) Type and Model Step type,
(iii) Number of trays 10 in five steps
(iv) Insulation (Bottom) Glass wool, 10 cm. thick
(v) Motive power Natural convection

3. General Information

- Step type solar dryer has a collector area of about 4.32 m 2 .
- This multi track step type dryer can hold 10 aluminum trays at a time.
- The absorber is 20 gauge GI sheet, black painted at the top with bottom insulation.
- The drier is covered at the top with 2 layers of 3 mm thick plain glass kept at an air gap of 2.5 cm. At the rear side of the collector, two chimneys of 120 cm height are provided. Chimneys are provided with butterfly valves to control the movement of air.
- Holes provided at the bottom of the collector just below the first step allow the entry of atmospheric air into the dryer

Lecture No. 16

Material Handling Equipments - Material Handling Equipment's: Construction and working principle- Conveyor- Belt conveyor and Screw conveyor Elevator- Bucket elevator

Material handling Equipment

Material handling includes a number of operations that can be executed either by hand (manual) or by mechanical means or devices to convey material and to reduce the human drudgery. The most common types of mechanical devices for grain handling are;

Conveyor- 1. Belt conveyor
2. Screw conveyor
Elevator - Bucket elevator

Selection of material Handling machines and Conveyors

The selection of proper conveying system is important for ease in operation and getting desired capacity for a particular product. Principles based on which the material handling equipment is selected:

- Based on the characteristics of the products being conveyed
- Working and climatic conditions.
- The capacity of conveying
- In a conveying system possibility of use of gravity.
- The capacity of handling / conveying equipment should match with the capacity of processing unit or units.
- Spillage of conveyed products should be avoided.
- Pollution of the environment due to noise or dust by the conveying system should also be avoided.

1. Belt conveyors

- A belt conveyor is an endless belt operating between two pulleys with its load supported on idlers.
- The belt may be flat for transporting bagged material or V-shaped.
- The belt conveyor consists of a belt, drive mechanism and end pulleys, idlers and loading

and discharge devices.

- On the belt conveyor baggage/ product lie still on the surface of belt and there is no relative motion between the product and belt.
- This results in generally no damage to material.
- Belt can be run at higher speeds, so, large carrying capacities are possible.
- Horizontally the material can be transported to longer distance.
- The initial cost of belt conveyor is high for short distances, but for longer distances the initial cost of belt conveying system is low.
- The first step in the design of a belt conveyor with a specified conveying capacity is to determine the speed and width of the belt.
- The belt speed should be selected to minimize product spillage or removal of fines due to velocity of the belt.
- For transportation of grains, the belt speed should not increase 3.5 m/s.
- Generally, for grain conveying, belt speed of 2.5 to 2.8 m/s is recommended.
- The selection of belt width will depend upon the capacity requirement, speed of operation, angle of inclination of belt conveyor, trough angle and depth.

Screw Conveyor

- The screw conveyor consists of a tubular or U-shaped trough in which a shaft with spiral screw revolves.
- The screw shaft is supported hanger bearings at ends.
- The rotation of screw pushes the grain along the trough.
- A typical screw conveyor is shown in the following Figure.
- The screw conveyor is used in grain handling facilities, animal feed industries and other installations for conveying of products generally for short distances.
- Screw conveyor requires relatively high power and is more susceptible to wear than other types of conveyors.
- The pitch of a standard screw which is the distance from the centre of one thread to the centre of the next thread is equal to its diameter.
- For example a 10 cm diameter screw has a pitch of 10 cm. Fig.13.2.
- Screw conveyor Fig.13.3. Screw conveyor details As the screw conveyor's driving mechanism is simpler, and no tensioning device is required, the initial cost of the conveyor is lower than any other conveyor with the same length and capacity.
- The main parts of a screw conveyor are, screw blade, screw shaft, coupling, trough, cover, inlet and outlet gates, bearings and drive mechanism.
- The screw conveyor is generally used to move grains horizontally.
- However, it can also be used at any angle up to 90° from the horizontal, but the capacity correspondingly reduced as per the inclination of conveyance.
- The screw basically consists of a shaft and the screw blade or flight.
- The flight is a continuous one piece helix shaped from a flat strip of steel welded onto the shaft. The screw shaft is usually a joint less tube with thick sides and a high tensile strength to reduce the weight.
- The thickness of the steel strip helix decreases from the inner edge to the outer edge.
- Troughs of screw conveyor have different shapes.
- Most common is U shaped trough. In an enlarged or flared trough the side walls become wider at the top (Figure).
- This type of trough is usually used for conveying non-easy flowing materials which may

have lumps.

- The tubular trough is completely closed with circular cross-section and mostly used for conveying materials at inclination or for vertical lift.

Bucket Elevator

A bucket elevator consists of buckets attached to a chain or belt that revolves around two pulleys one at top and the other at bottom.

The vertical lift of the elevator may range between few metres to more than 50 m.

Capacities of bucket elevators may vary from 2 to 1000 t/hr.

Bucket elevators are broadly classified into two general types,

(1) spaced bucket elevators and
(2) continuous bucket elevators.

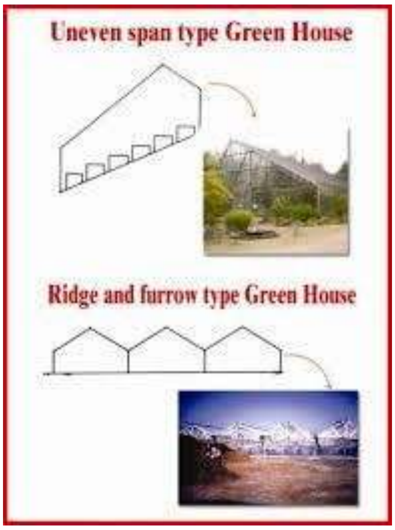
The spaced bucket elevators are further classified as,

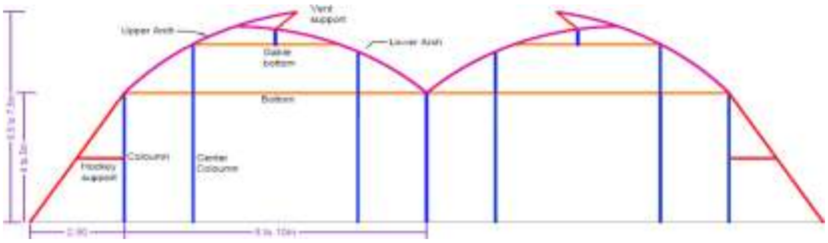
(1) centrifugal discharge elevators,
(2) positive-discharge elevators,
(3) marine leg elevators and
(4) high-speed elevators.

The continuous bucket elevators are classified as

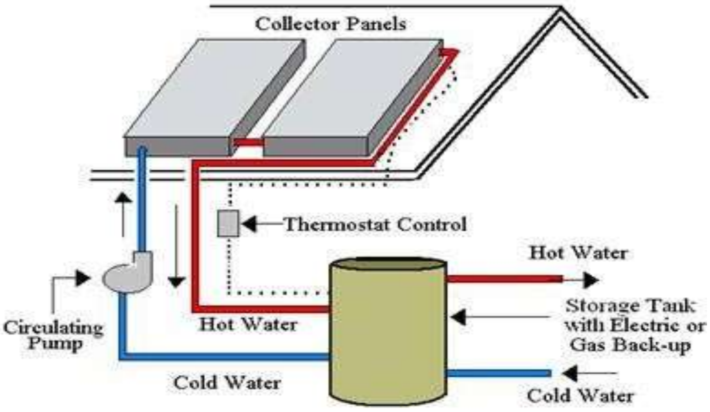
(1) super capacity bucket elevators and
(2) internal-discharge bucket elevators.

- The spaced bucket centrifugal discharge type is most commonly used for elevating the grains. The bucket elevator is a very efficient device for the vertical conveyance of bulk grains.
- Bucket elevators with belts are employed in food industries for vertical conveyance of grains, derivatives and flours.
- Bucket elevators are usually mounted at a fixed location, but 67 they can also be mounted in a mobile frame.
- Bucket elevators have high capacities and it is a fairly cheap means of vertical conveyance.It requires limited horizontal space and the operation of conveying is enclosed in housing, thus it is dust free and fairly quite.
- The bucket elevator has limited wear problem since the product is enclosed in buckets.
- The buckets are enclosed in a single housing called leg, or two legs may be used.
- The return leg may be located at some distance from the elevator leg.
- The boot can be loaded from the front or back or both.

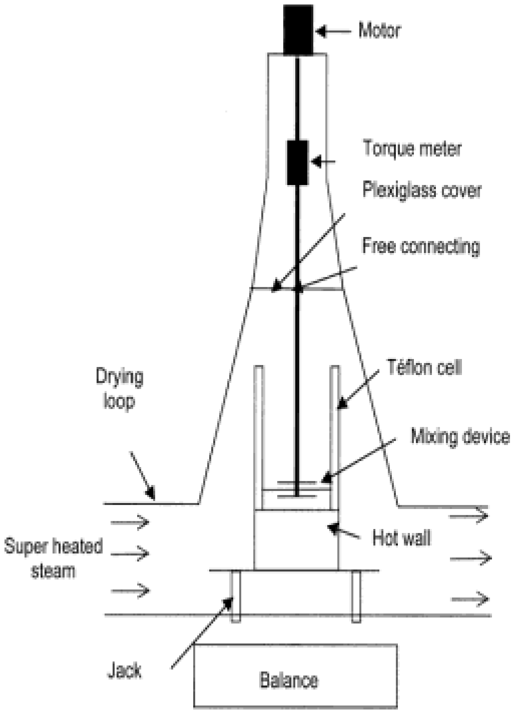


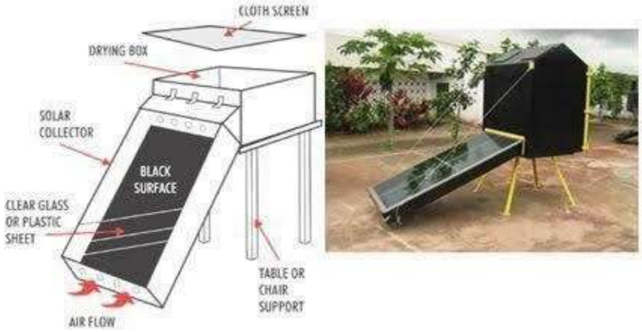


Natural Ventilation



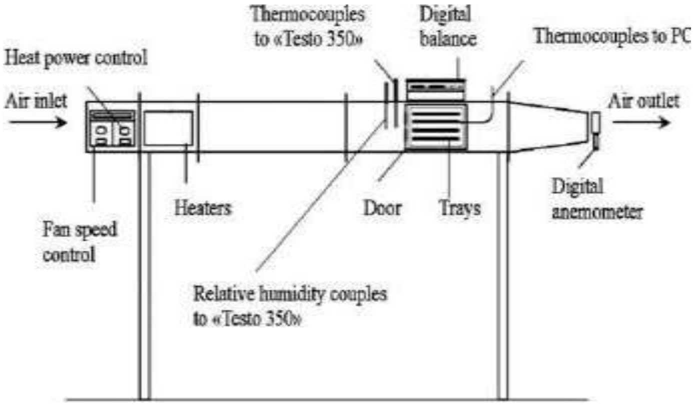
Active Solar Water Heating System



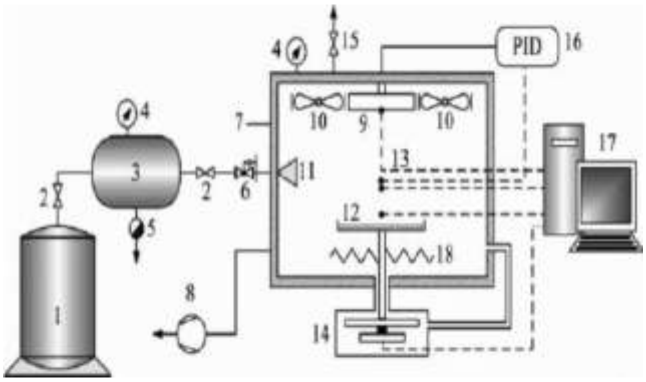


Solar Dryer

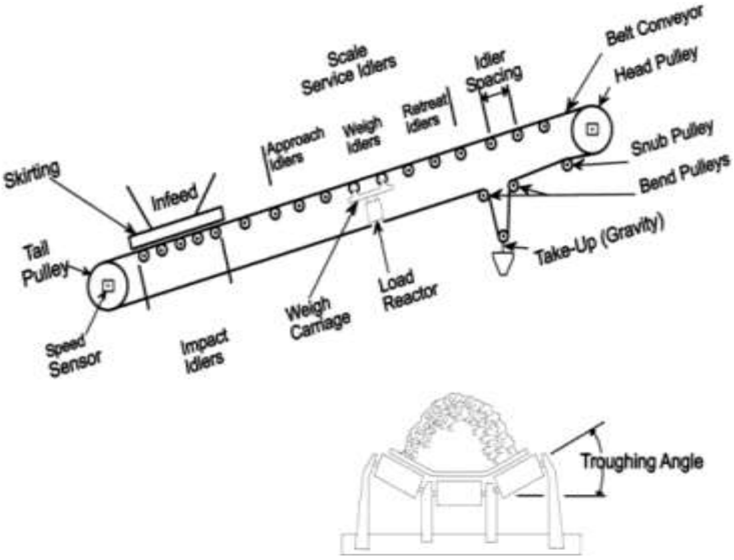
Contact dryer

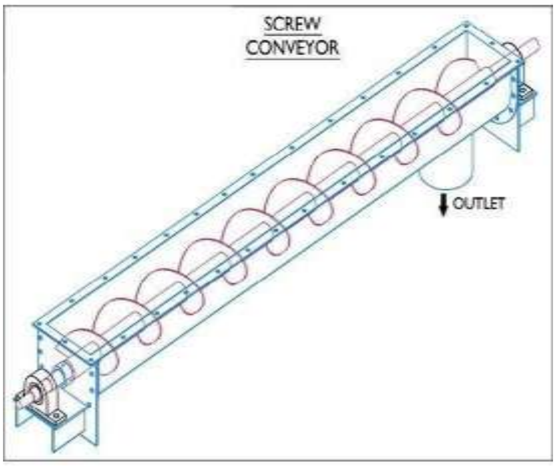


Convection Dryer

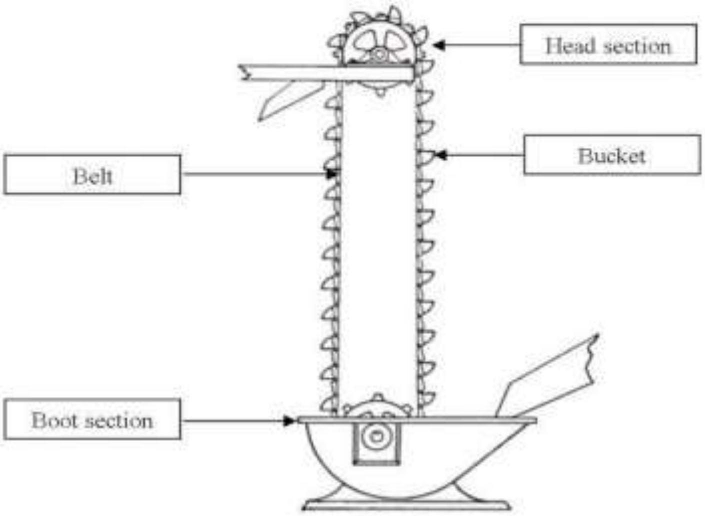


Radiation Dryer

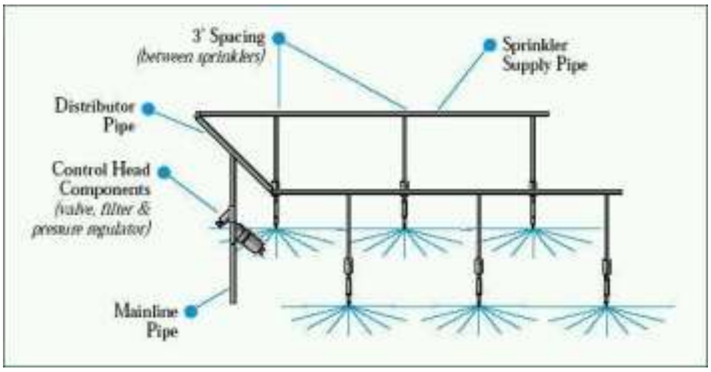




Belt Conveyor



Bucket Elevator



Overhead Sprinkler