

Lecture No.1

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.

Green House:

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.

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:

1. Throughout the year four to five crops can be grown in a green house due to availability of required plant environmental conditions.
2. The productivity of the crop is increased considerably.
3. Superior quality produce can be obtained as they are grown under suitably controlled environment.
4. Gadgets for efficient use of various inputs like water, fertilizers, seeds and plant protection chemicals can be well maintained in a green house.
5. Effective control of pests and diseases is possible as the growing area is enclosed.

6. Percentage of germination of seeds is high in greenhouses.
7. The acclimatization of plantlets of tissue culture technique can be carried out in a green house.
8. Agricultural and horticultural crop production schedules can be planned to take advantage of the market needs.
9. 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.
10. Export quality produce of international standards can be produced in a green house.
11. When the crops are not grown, drying and related operations of the harvested produce can be taken up utilizing the entrapped heat.
12. Greenhouses are suitable for automation of irrigation, application of other inputs and environmental controls by using computers and artificial intelligence techniques.
13. Self-employment for educated youth

Lecture No.2

Greenhouse structures of various types are used successfully for crop production. Although there are advantages in each type for a particular application, in general there is no single type greenhouse, which can be considered as the best. Different types of greenhouses are designed to meet the specific needs.

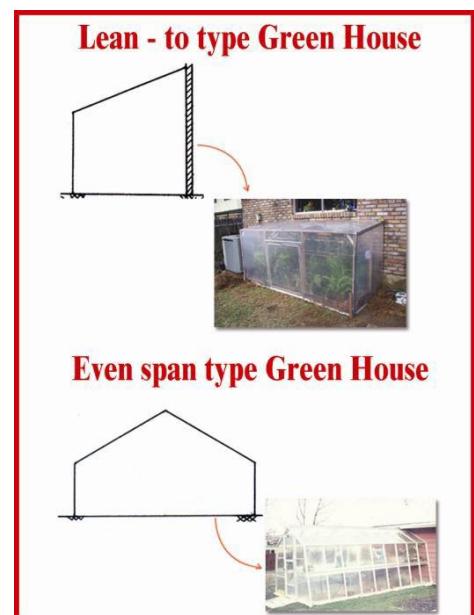
2.1 Greenhouse type based on shape

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 tends 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.

2.1.1 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 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.

2.1.2 Even span type greenhouse

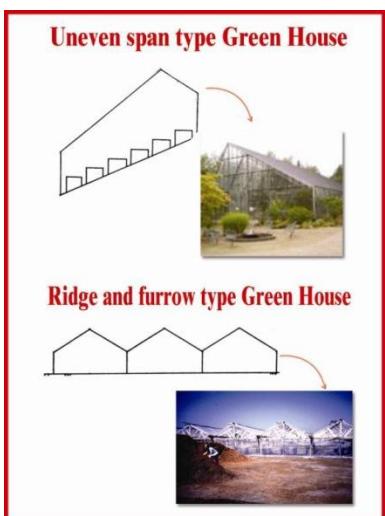
The even-span is the standard type and full-size structure, the two roof slopes are of equal pitch and width (Fig.1). This design is used for the greenhouse of small size, and it is constructed on level ground. It is attached to a house at one gable end. It can accommodate 2 or 3 rows of plant benches. 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.

2.1.3 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.

2.1.4 Ridge and furrow type greenhouse

Designs of this type use two or more A-frame greenhouses connected to one another along the

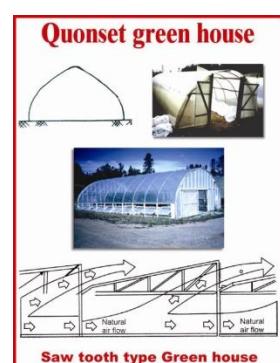


length of the eave (Fig. 2). The eave serves as furrow or gutter to carry rain and melted snow away. The side wall is eliminated between the greenhouses, which results in a structure with a single large interior. Consolidation of interior space reduces labour, lowers the cost of automation, improves 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

specifications of these greenhouses since the snow cannot slide off the roofs as in case of individual free standing greenhouses, 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.

2.1.5 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.



2.1.6 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.

2.2 Greenhouse type based on utility

Classification of greenhouses can be made depending on the functions or utilities. Of 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.

2.2.1 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.

2.2.2 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%.

2.3 Greenhouse type 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 in turn 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.

2.3.1 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

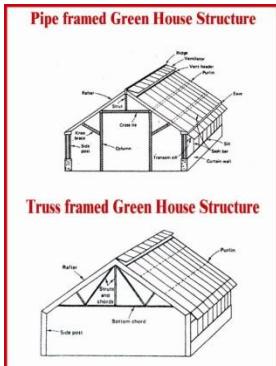
is commonly used as it is inexpensive and possesses the required strength. Timber locally available, with good strength, durability and machinability also can be used for the construction.

2.3.2 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.

2.3.3 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.

2.4 Greenhouse type 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.

2.4.1 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 greenhouses 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.

2.4.2 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.

2.4.3 Rigid 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.

2.5 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

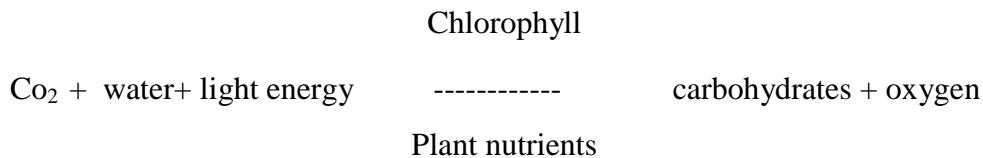
Plant response to greenhouse environments - light, temperature, relative humidity, ventilation and carbon dioxide and environmental requirement of agriculture and horticulture crops inside green houses.

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.

3.1 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



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 700nm. 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 colour. 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.

3.2 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°C , 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°C higher than the night temperature on cloudy days and 8°C higher on clear days. The night temperature of green house crops is generally in the range of 7 to 21°C . Primula, mathiola incana and calceolaria grow best at 7°C , carnation and cineraria at 10°C , rose at 16°C , chrysanthemum and poinsettia at 17 to 18°C and African violet at 21 to 22°C .

3.3 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.

3.4 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°C 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.

3.5 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) exists 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 uneconomical, 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 CO_2 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

Equipment required for controlling green house environment – summer cooling and winter cooling, natural ventilation, forced ventilation and computers.

Precise control of various parameters of green house environment is necessary to optimize energy inputs and thereby maximize the economic returns. Basically, the objective of environmental control is to maximize the plant growth. The control of green house environment means the control of temperature, light, air composition and nature of the root medium. A green house is essentially meant to permit at least partial control of microclimate within it. Obviously green houses with partial environmental control are more common and economical. From the origin of greenhouse to the present there has been a steady evolution of controls. Five stages in this evolution include manual controls, thermostats, step-controllers, dedicated micro processors and computers. This chain of evolution has brought about a reduction in control labour and an improvement in the conformity of green house environments to their set points. The benefits achieved from green house environmental uniformity are better timing and good quality of crops, disease control and conservation of energy.

4.1 Active summer cooling systems

Active summer cooling is achieved by evaporative cooling process .The evaporative cooling systems developed are to reduce the problem of excess heat in green house. In this process cooling takes place when the heat required for moisture evaporation is derived from the surrounding environment causing a depression in its temperature. The two active summer cooling systems in use presently are fan-and pad and fog systems. In the evaporative cooling process the cooling is possible only up to the wet bulb temperature of the incoming air.

4.1.1 Fan-and Pad cooling system

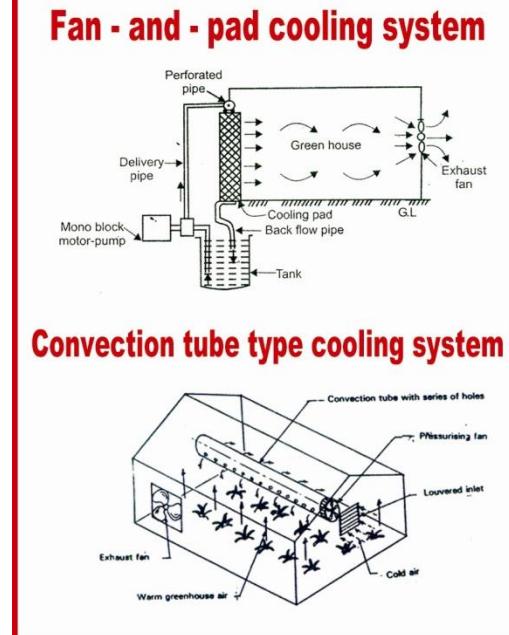
The fan and pad evaporative cooling system has been available since 1954 and is still the most common summer cooling system in green houses (Fig.5). Along one wall of the green house, water is passed through a pad that is usually placed vertically in the wall. Traditionally, the pad was composed of excelsior (**wood shreds**), but today it is commonly made of a **cross-fluted-cellulose material** some what similar in appearance to corrugated card board. Exhaust fans are placed on the opposite wall. Warm outside air is drawn in through the pad. The supplied water in the pad, through the process of evaporation, absorbs heat from the air passing through the pad as well as from surroundings of the pad and frame, thus causing the cooling effect. Khus-khus grass mats can also be used as cooling pads.

4.1.2 Fog cooling system

The fog evaporative cooling system, introduced **in** green houses in 1980, operates on the same cooling principle as the fan and pad cooling system but uses quite different arrangement (Fig.5). A high pressure pumping apparatus generates fog containing water droplets with a mean size of less than 10 microns using suitable nozzles. These droplets are sufficiently small to stay

suspended in air while they are evaporating. Fog is dispersed throughout the green house, cooling the air everywhere. As this system does not wet the foliage, there is less scope for disease and pest attack. The plants stay dry throughout the process.

This system is equally useful for seed germination and propagation since it eliminates the need for a mist system.



Both types of summer evaporative cooling system can reduce the greenhouse air temperature. The fan-and pad system can lower the temperature of incoming air by about 80% of the difference between the dry and wet bulb temperatures while the fog cooling system can lower the temperature by nearly 100% difference. This is, due to the fact that complete evaporation of the water is not taking place because of bigger droplet size in pad and pad, whereas in the fog cooling system, there will be complete evaporation because of the minute size of the water

droplets. Thus lesser the dryness of the air, greater evaporative cooling is possible.

4.2 Active winter cooling systems

Excess heat can be a problem during the winter. In the winter, the ambient temperature will be below the desired temperature inside the green house. Owing to the green house effect the entrapment of solar heat can rise the temperature to an injurious level if the green house is not ventilated. The actual process in winter cooling is tempering the excessively cold ambient air before it reaches the plant zone. Otherwise, hot and cold spots in the green house will lead to uneven crop timing and quality .This mixing of low temperature ambient air with the warm inside air cools the green house in the winter. Two active winter cooling systems commonly employed are convection tube cooling and horizontal air flow (HAF) fan cooling systems.

4.2.1 Convection tube cooling

The general components of convection tube are the louvered air inlet, a polyethylene convection tube with air distribution holes, a pressurizing fan to direct air in to the tube under pressure, and an exhaust fan to create vacuum. When the air temperature inside the green house exceeds the set point, the exhaust fan starts functioning thus creating vacuum inside the green house. The louver of the inlet in the gable is then opened through which cold air enters due to the vacuum. The pressurizing fan at the end of the clear polyethylene convection tube, operates to pick up the cool air entering the louver. A proper gap is available for the air entry, as the end of the convection tube is separated from the louvered inlet by 0.3 to 0.6m and the other end of the tube is sealed. Round holes of 5 to 8 cm in diameter are provided in pairs at opposite sides of the tube spaced at 0.5 to 1m along the length of the tube.

Cold air under pressure in the convection tube shoots out of holes on either side of the tube in turbulent jets. In this system, the cold air mixes with the warm greenhouse air well above the plant height. The cool mixed air, being heavier gently flows down to the floor level, effects the complete cooling of the plant area. The pressurizing fan forcing the incoming cold air in to

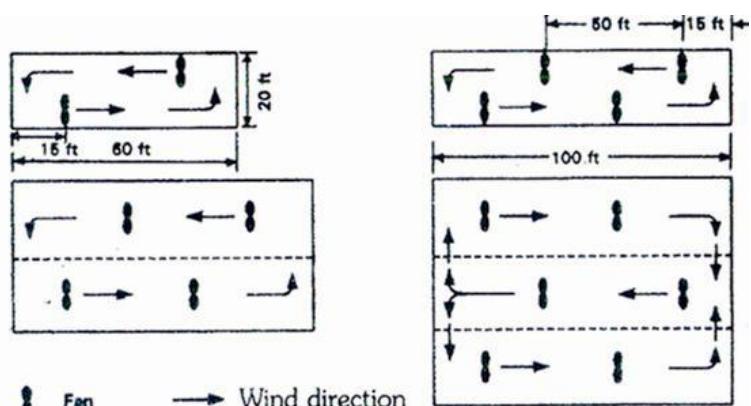
the convection tube must be capable of moving at least the same volume of air as that of the exhaust fan, thereby avoiding the development of cold spots in the house. When cooling is not required, the inlet louver closes and the pressurizing fan continues to circulate the air within the greenhouse. The process minimizes the temperature gradient at difference levels. The circulation of air using convection tube consumes more power than a circulation system.

4.2.2 Horizontal air flow cooling

HAF cooling system uses small horizontal fans for moving the air mass and is considered to be an alternative to convection tube for the air distribution. In this method the green house may be visualized as a large box containing air and the fans located strategically moves the air in a circular pattern. This system should move air at 0.6 to 0.9 m³/min/m² of the green house floor area. Fractional horse power of fans is 31 to 62 W (1/30 to 1/15hp) with a blade diameter of 41cm are sufficient for operation. The fans should be arranged in such a way that air flows are directed along the length of the greenhouse and parallel to the ground. The fans are placed at 0.6 to 0.9m above plant height and at intervals of 15m. They are arranged such that the air flow is directed by one row of the fans along the length of the greenhouse down one side to the opposite end and then back along the other side by another row of fans (Fig. 6). Greenhouses of larger widths may require more number of rows of fans along its length.

Temperatures at plant height are more uniform with HAF system than with convection tube system. The HAF system makes use of the same exhaust fans, inlet louvers and controls as the convection tube system. The only difference is the use of HAF fans in the place of convection tubes for the air distribution. Cold air entering through the louvers located at the higher level in the gables of the green house is drawn by the air circulation created by the network of HAF fans and to complete the cycle, proper quantity of air is let out through the exhaust fans. The combined action of louvered inlet, HAF fans and the exhaust fans distribute the cold air throughout the greenhouse.

Similarly to the convection tubes, the HAF fans can be used to distribute heat in the green house. When neither cooling nor heating is required, the HAF fans or convection tube can be used to bring warm air down from the upper level of the gable and to provide uniform temperature in the plant zone. It is possible to integrate summer and winter cooling systems with heating arrangements inside a green house for the complete temperature control requirements for certain days of the season.



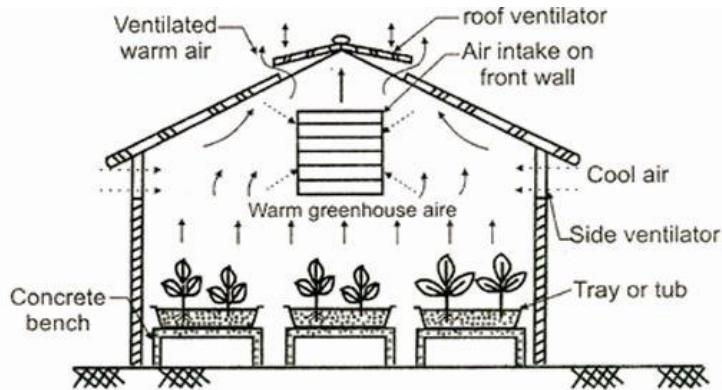
4.3 Green house ventilation

Ventilation is the process of allowing the fresh air to enter in to the enclosed area by driving out the air with undesirable properties. In the green house context, ventilation is essential for reducing temperature, replenishing CO₂ and controlling relative humidity. Ventilation requirements for green houses vary greatly, depending on the crop grown and the season of production. The ventilation system can be either a passive system (natural Ventilation) or an active system (forced ventilation) using fans. Usually green houses that are used seasonally

employ natural ventilation only. The plant response to specific environment factor is related to the physiological processes and hence the latter affects the yield and quality. Hence, controlling of environment is of great importance to realize the complete benefit of CEA. Manual maintenance of uniform environmental condition inside the green house is very difficult and cumbersome. A poor maintenance results in less crop production, low quality and low income. For effective control of automatic control systems like micro processor and computer are used presently to maintain the environment.

4.3.1 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

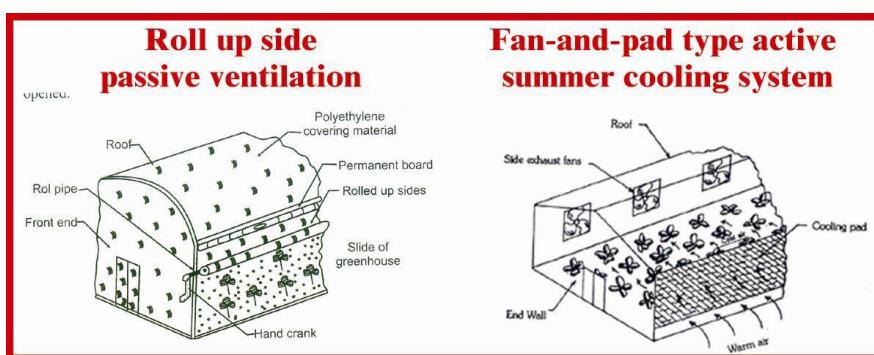


the greenhouse. The ventilators on the roof as well as those on the side wall accounts, each about 10% of the total roof area. During winter cooling phase, the south roof ventilator was opened in stages to meet cooling needs. When greater cooling was required, the north ventilator was opened in addition 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.

4.3.1.1 Roll up side passive ventilation in poly houses

In roll up method of ventilation, allowing the air to flow across the plants. The amount of ventilation on one side, or both sides, may be easily adjusted in response to temperature,



prevailing wind and rain (Fig.8). During the periods of excessive heat, it may be necessary to roll the sides up almost to the top. Passive ventilation can also be accomplished by

manually raising or parting the polyethylene sheet. The open vent areas must be covered with screens to prevent virus diseases. The holes must be large enough to permit free flow of air. Screens with small holes blocks air movement and cause a build up of dust. Rollup side passive ventilation on plastic greenhouses is only effective on free standing greenhouses and not on gutter connected greenhouses.

4.3.2 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 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.

4.3.3 Microprocessors

Dedicated microprocessors can be considered as simple computers. A typical microprocessor will have a keypad and a two or three line liquid crystal display of, sometimes, 80-character length for programming. They generally do not have a floppy disk drive. They have more output connections and can control up to 20 devices. With this number of devices, it is cheaper to use a microprocessor. They can receive signals of several types, such as, temperature, light intensity, rain and wind speed. They permit integration of the diverse range of devices, which is not possible with thermostats. The accuracy of the microprocessor for temperature control is quite good. Unlike a thermostat, which is limited to a bimetallic strip or metallic tube for temperature sensing and its mechanical displacement for activation, the microprocessor often uses a thermistor. The bimetallic strip sensor has less reproducibility and a greater range between the ON and OFF steps. Microprocessors can be made to operate various devices, for instance, a microprocessor can operate the ventilators based on the information from the sensor for the wind direction and speed. Similarly a rain sensor can also activate the ventilators to prevent the moisture sensitive crop from getting wet. A microprocessor can be set to activate the CO₂ generator when the light intensity exceeds a given set point, a minimum level for photosynthesis.

4.3.4 Computers

Now-a-days, computer control systems are common in greenhouse installation throughout Europe, Japan and the United States. Computer systems can provide fully integrated control of temperature, humidity, irrigation and fertilization, CO₂, light and shade levels for virtually any size growing facility. Precise control over a growing operation enables growers to realize saving of 15 to 50% in energy, water, chemical and pesticide applications. Computer controls normally help to achieve greater plant consistency, on-schedule production, higher overall plant quality and environmental purity.

A computer can control hundreds of devices within a green house (vents, heaters, fans, hot water mixing valves, irrigation valves, curtains and lights) by utilizing dozens of input parameters, such as outside and inside temperatures, humidity, outside wind direction and velocity, CO₂ levels and even the time of the day or night. Computer systems receive signals from all sensors, evaluate all conditions and send appropriate commands every minute to each piece of equipment in the greenhouse range thus maintaining ideal conditions in each of the various independent greenhouse zones defined by the grower (Fig.9). Computers collect and record data provided by greenhouse production managers. Such a data acquisition system will enable the grower to gain a comprehensive knowledge of all factors affecting the quality and timeliness of the product. A computer produces graphs of past and current environmental conditions both inside and outside the greenhouse complex. Using a data printout option, growers can produce reports and summaries of environmental conditions such as temperature, humidity and the CO₂ status for the given day, or over a longer period of time for current or later use.

As more environmental factor in the greenhouse is controlled, there comes a stage when individual controls cannot be coordinated to prevent system overlap. An example is the greenhouse thermostat calling for heating while the exhaust fans are still running. With proper software program, which uses the environmental parameters as input from different sensors, can effectively coordinate all the equipment without overlap and precisely control all parameters affecting plant development as desired. Despite the attraction of the computer systems, it should be remembered that the success of any production system is totally dependent on the grower's knowledge of the system and the crop management. Computers can only assist by adding precision to the overall greenhouse production practice, and they are only as effective as the software it runs and the effectiveness of the operator. The advantages and disadvantages of computerized control system are as follows:

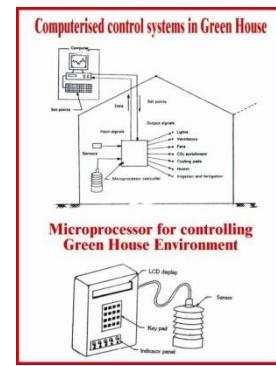
Advantages

1. The computer always knows what all systems are doing and, if programmed properly, can coordinate these systems without overlap to provide the optimum environment.
2. The computer can record the environmental data, which can be displayed to show current conditions or stored and processed ones to provide a history of the cropping period, and if desired it may also be displayed in table or graph form.
3. A high-speed computer with networking facility can control several remotely located greenhouses, by placing the computer in a central area and the results can be monitored frequently by the management.
4. With proper programming and sensing systems, the computer can anticipate weather changes and make adjustments in heating and ventilation systems, thus saving the energy.

5. The computer can be programmed to sound an alarm if conditions become unacceptable to and to detect sensor and equipment failure.

Disadvantages

1. High initial cost investment.
2. Requires qualified operators.
3. High maintenance, care and precautions are required.
4. Not economical for small scale and seasonal production.



Lecture No.5

Planning of green house facility - 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.

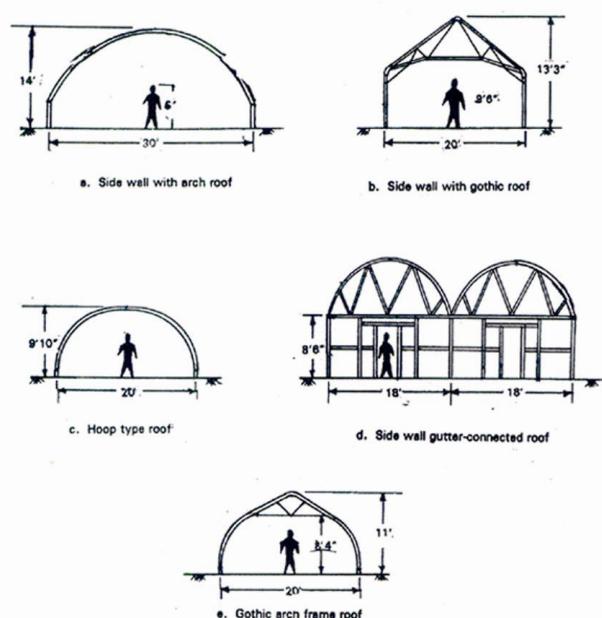
It is an enclosing structure for growing plants, greenhouse must admit the visible light portion of solar radiation for the plant photosynthesis and, there fore, must be transparent. At the same time, to protect the plants, a greenhouse must be ventilated or cooled during the day because of the heat 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.

5.1 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.

5.2 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.

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

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

5.3 Covering materials

The following factors are to be considered while selecting the greenhouse covering material i.e., light, transmission, 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 be taken into consideration: the purpose for which greenhouse facility is intended and service life of material. In temperate 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.

<u>Covering material</u>	<u>Life span</u>
1. Glass and acrylic 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:

- (i) It should transmit the visible light portion of the solar radiation which is utilized by plants for photosynthesis.
- (ii) 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.
- (iii) It should reflect or absorb IR radiation which are not useful to plants and which causes greenhouse interiors to overheat.
- (iv) Should be of minimum cost.
- (v) Should have usable life of 10 to 20 years.

Lecture No.6

Materials for construction of green houses - wood, galvanized iron, glass, polyethylene film, poly vinyl chloride film, Tefzel T² film, fiberglass reinforced plastic rigid panel and acrylic and polycarbonate rigid panel.

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

6.1 Wood

Wood and bamboo are generally used for low cost polyhouses. In low cost polyhouses, 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 polyhouses, 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 greenhouse. 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.

6.2 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:

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

6.3 Glass

Glass has been traditional glazing material all over the world. Widely used glass for greenhouse 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.

6.4 Polyethylene film

Polyethylene is principally used today for two reasons- (i) Plastic film greenhouses with permanent metal frames cost less than glass greenhouses and (ii) Plastic film greenhouses are popular because the cost of heating them is approximately 40% lower compared to single-layer glass or fiberglass-reinforced plastic greenhouses. The disadvantages are : these covering materials are short lived compared to glass and plastic panels. UV light from the sun causes the plastic to darken, thereby lowering transmission of light, also making it brittle, which leads to its breakage due to wind. A thermal screen is installed inside a glass greenhouse that will lower the heat requirement to approximately that of a double-layer plastic film greenhouse, but this increases the cost of the glass greenhouse. Polyethylene film was developed in the late 1930s in England and spread around the middle of this century. Commonly used plastic for greenhouse coverings are thermoplastics. Basic characteristics of thermoplastics are: (i) thermoplastics consists of long chain molecules, soften with heating and harden with cooling and this process is reversible and (ii) thermoplastics constitute a group of material that are attractive to the designer for two main reasons: (a) Thermoplastics have the following specific physical properties- stiffness, robustness and resilience to resist loads and deformations imposed during normal use and (b) It can readily be processed using efficient mass production techniques, result in low labour charge.

The main reason to use polyethylene year round for greenhouse covering is due to presence of UV-inhibitor in it. Otherwise it lasts for only one heating season. UV-inhibited plastic cover may last for a period of 4 to 5 years. UV-grade polyethylene is available in widths up to 15.2 m in flat sheets and up to 7.6 m in tubes. Standard lengths include 30.5, 33.5, 45.7, 61 and 67 m. Some companies provide custom lengths upto a max. of 91.5 m. Condensation on ploythene film is a big problem. Condensation causes disease development, development of water logged condition and oxygen deficient inside the greenhouse. Condensation reduces light intensity

within the greenhouse. To avoid this problem, anti-fog surfactant, which discourages condensation, is built into the film or panel. Warm objects, such as plants, the greenhouse frame and soil radiate IR energy to colder bodies at night, which result in loss of heat in greenhouse. Since polyethylene is a poor barrier to radiant heat, it is formulated with IR-blocking chemicals into it during manufacture, will stop about half of the radiant heat loss. On cold and clear nights, as much as 25% of the total heat loss of a greenhouse can be prevented in this way and on cloudy nights only 15% is prevented. UV-stabilised polyethylene, on an average, transmits about 87% of photosynthetically active radiation (PAR) into the greenhouse. IR absorbing polyethylene, reduces radiant heat loss, transmits about 82% of photosynthetically active radiation (PAR) into the greenhouse. The amount of light passing through two layers of a greenhouse covering is approximately the square of the decimal fraction of the amount passing through one layer. Eg. When 87% passes through one layer of UV-inhibited polyethylene, only 76% (0.87×0.87) passes through two layers. Similarly, when 82% passes through one layer of IR-absorbing polyethylene, only 67% (0.82×0.82) passes through two layers.

6.5 Polyvinyl chloride film (PVC films)

PVC films are UV light resistant vinyl films of 0.2 to 0.3 mm and are guaranteed for 4 to 5 years respectively. The cost of 0.3 mm vinyl film is three times that of 0.15 mm polyethylene. Vinyl film is produced in rolls upto 1.27 m wide. Vinyl films tend to hold a static electrical charge, which attracts and holds dust. This in turn reduces light transmittance unless the dust is washed off. Vinyl films are seldom used in the United States. In Japan, 95% of greenhouses are covered with plastic film, out of which 90% are covered with vinyl film.

6.6 Tefzel T² film

The most recent addition of greenhouse film plastic covering is Tefzel T² film (ethylene tetrafluoroethylene). Earlier, this film was used as covering on solar collectors. Anticipated life expectancy is 20 years. The light transmission is 95% and is greater than that of any other greenhouse covering material. A double layer has a light transmission of 90% (0.95×0.95). Tefzel T² film is more transparent to IR radiation than other film plastics. Hence, less heat is trapped inside the greenhouse during hot weather. As a result, less cooling energy is required. Disadvantage is that, the film is available only in 1.27 m wide rolls. This requires clamping rails on the greenhouse for every 1.2 m. If reasonable width strips become available, the price is not a problem, because a double layer covering will still cost less than a polycarbonate panel covering with its aluminum extrusions, and will last longer, and will have much higher light intensity inside the greenhouse.

6.7 Polyvinyl chloride rigid-panel

Initially, PVC rigid panels showed much promise as an inexpensive covering material (almost 40% of cost of long lasting fiberglass reinforced plastics), has the life of 5 years. After commercial application, these panels indicated that the life expectancy was much shorter, less than 2 years. This is undesirable factor, because the cost of PVC panels was 4 to 5 times that of

Polyethylene film and they required much more time to install. Now-a-days, PVC rigid panels are not in use.

6.8 Fiberglass-reinforced plastic (FRP) rigid panel

FRP was more popular as a greenhouse covering material in the recent past. Advantage of FRP is that it is more resistant to breakage by factors, such as hail or vandals. Sunlight passing through FRP is scattered by the fibers in the panels, as a result the light intensity is rather uniform throughout the greenhouse in comparison with a glass covering. Disadvantages with these are the panels subjected to etching and pitting by dust abrasion and chemical pollution. Based on the grade, the usable life period of FRP panel varies. Some grades give 5 to 10 years, while better grades can last up to 20 years. FRP panels are flexible enough to conform to the shape of quonset greenhouses, which make FRP a very versatile covering material. FRP can be applied to the inexpensive frames of plastic film greenhouses or to the more elaborate frames of glass type greenhouses. The price of FRP greenhouse lies between that of a plastic film greenhouse and that of a glass greenhouse. But the cost is compensated by the elimination of the need for replacement of film plastic in every year or alternate years. Corrugated panels were used because of their greater strength. Flat panels are used occasionally for the end and side walls, where the load is not great. It is available in 1.3 m width, length up to 7.3 m and in a variety of colours. The total quantity of light transmitted through clear FRP is approximately equivalent to that transmitted through glass, but diminishes in relation its colour. For greenhouse crops in general, only clear FRP permits a satisfactory level of light transmission (88 to 90%). Coloured FRP has found a limited use in greenhouses intended for growing houseplants that require low light intensity and in display greenhouses for holding plants during the sales period. FRP has advantage over glass is that, it cools easily. FRP greenhouses require fewer structural members since sash bars are not needed.

6.9 Acrylic and polycarbonate rigid-panel

These panels have been available for about 15 years for greenhouse use. The panels have been used for glazing the side and end walls of plastic film greenhouses and retrofitting old glass greenhouse. Acrylic panels are highly inflammable, whereas polycarbonate panels are non-flammable. Acrylic panels are popular due to their higher light transmission and longer life. Acrylic panels are available in thickness of 16 and 18 mm, and have 83% of PAR light transmission. Acrylic panels cannot be bent, but the thinner panels can be bent to fit curved-proof greenhouses. These panels are also available with a coating to prevent condensation drip. Polycarbonate panels are preferred for commercial greenhouses due to lower price, flame resistance and greater resistance to hail damage. Polycarbonate panels are available in thickness of 4,6, 8, 10 and 16 mm. These panels are also available with a coating to prevent condensation drip and also with an acrylic coating for extra protection from UV light.

Lecture No.7

Design criteria and constructional details of greenhouses - construction of pipe framed greenhouses, material requirement, preparation of materials and procedure of erection.

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.

7.1 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.

7.2 Construction of glass greenhouses

Glass greenhouses have an advantage of greater interior light intensity over plastic panel and film plastic covered greenhouses. Glass greenhouses tend to have a higher air infiltration rate, which leads to lower interior humidity, which is advantageous for disease prevention. On the other hand, glass greenhouses have a higher initial cost than double-layer film plastic greenhouses. While comparing the price of a glass greenhouse to a film plastic greenhouse, one needs to take into account the initial purchase price of each as well as the cost of re-covering the film plastic greenhouse every three to four years.

Several types of glass greenhouses are designed to meet specific needs. A lean-to-type design is used when a greenhouse is placed against the side of an existing building. This design makes the best use of sunlight and minimizes the requirements for roof supports. It is found mostly in the retail industry. An even-span greenhouse is one in which the two roof slopes are of equal pitch and width. By comparison, a un-even-span greenhouse has roofs of unequal width, which makes the structure adaptable to the side of a hill. This style is seldom used today because such greenhouses are not adaptable to automation. Finally, a ridge-and-furrow design uses, two or more A- frame greenhouses connected to one another along the length of the eave. The sidewall is eliminated between greenhouses, which results in a structure with a single large interior. Basically, three frame types are used in glass greenhouses, which are wood frames (6.1 m in width), pipe frames (12.2 m in width) and truss frames (15.2 m in width). Latest glass

greenhouses are primarily of the truss frame type. Truss frame greenhouses are best suited for prefabrication.

All-metal greenhouses proved cheaper to maintain since they required no painting. At present, virtually all glass greenhouse construction is of the metal type. The structural members of the glass greenhouse cast shadows that reduce plant growth during the dark months of the year. Aluminum sash bars are stronger than wooden ones; hence wider panels of glass can be used with aluminum bars. The reduction in materials and the reflectance of aluminum have given these metal greenhouses a great advantage over wooden greenhouses in terms of higher interior light intensity.

Glass greenhouse construction of today can be categorized as high profile or low profile. The low profile greenhouse is most popular in the Netherlands and is known as the Venlo greenhouse. The low profile greenhouses uses single panels of glass extend from eave to ridge. The low profile greenhouse slightly reduces exposed surface area, thereby reducing the heating cost, but more expensive to cool. The high profile greenhouses require more than single panel to cover the eave to ridge. A problem with this design is the unsealed junction between pieces of glass in the inner layer. Moisture and dust may enter between the layers and reduce light transmission.

7.3 Construction of pipe framed greenhouses

The choice of construction of pipe framed greenhouses often favours low initial investment and relatively long life. Galvanized mild steel pipe as a structural member in association with wide width UV- stabilized low density polyethylene (LDPE) film is a common option of greenhouse designers.

7.3.1 Material requirement

The structural members of greenhouse are

- (a) hoops
- (b) foundation
- (c) lateral supports
- (d) polygrip assembly
- (e) end frame

The following materials are required for a greenhouse having 4m × 20 m floor area:

- (i) GI pipe class A (25 mm diameter, 85 cm long, 30 m total length)
- (ii) GI pipe class B (15 mm diameter, 6.0 m long, 21 No.s)
- (iii) GI sheet (20 gauge, size 90 × 24 cm, 4 sheets)
- (iv) MS flat (25 × 3 mm size, 4 m length)
- (v) Lateral support to end frames (10 mm diameter rod, 10 m length)
- (vi) Cement concrete (1: 3: 6 mix, 1.0 m³)
- (vii) UV- stabilized LDPE film (single layer 800 gauge, 5.4 m²/kg, 154 m²)

- (viii) Polygrip (channel 2000 3.5 4 cm, 2 No.s; Angle 2000 2 2 cm, 2 No.s; both made from the procured 20 gauge GI sheet, key 6 mm diameter, 56 mm length)
- (ix) Wooden end frames (5 5 cm wood, 0.15 m³)
- (x) Nuts and bolts 9 6 mm diameter, 35 mm long, 70 sets)
- (xi) Miscellaneous items like nails, hinges and latches as per requirement

7.3.2 Procedure of erection

- (1) A 4m by 20m rectangular area is marked on the site, preferably orienting the longer dimension in east-west direction. This rectangle will act as the floor plan of the greenhouse (Fig.11).
- (2). Mark four points on the four corners of the rectangle.
- (3) Start from one corner point and move along the length of marked rectangle, marking a point every 1.25 m distance until reaching the other corner (16 bays; 17 points). The same procedure is repeated on the other side of the rectangle.
- (4). Dig 10 cm diameter holes upto 70 cm depth on all marked points with the help of bucket auger (or) a crowbar. This way a total of 34 holes on both the parallel sides of the greenhouse floor is obtained.
- (5) Polygrip sections formed according to the drawing into two 20m length.
- (6). Fix the prefabricated polygrip channels to the foundation pipes on 1.25 m spacing with the help of 6 mm diameter bolts.
- (7). Set these assemblies on temporary supports between the holes with the foundation pipes hanging vertically in the holes.
- (8). Pour cement concrete mix of 1: 3 : 6 around foundation pipes in such a way that the lower 15 cm to 20 cm ends are covered in concrete. The concrete is compacted around the foundation pipes with the help of the crowbar and is allowed to cure for 2-3 days.
- (9) After curing, fill the soil around the foundation pipes to the ground level and compact it well.
- (10). Position end frames on the two ends. Mark the position of legs and dug holes for fixing of legs. Now install both the end frames.
- (11). Put the ringside of lateral support members on adjacent foundation pipe to the corner, and other side is hooked to the end frame.
- (12). Put all the hoops in the foundation pipes in such away that straight portion of hoop is inserted into the foundation and rests on the bolt used for fixing of polygrip channel .
- (13). Take a 20 m long ridge line by spacing 15 mm diameter pipes together. Put the 20m long pipe at the ridge line of the hoops.
- (14) Use cross connectors on the ridge line pipe, in such a way that one half of it remains on the one side of the hoop and the other half on the other side.
- (15) Put two bolts of 6 mm diameter in the holes provided in the ends of cross-connector. Tie a few of them with the help of nuts.
- (16) Repeat the same procedure for joining all the hoops with ridge line pipe.

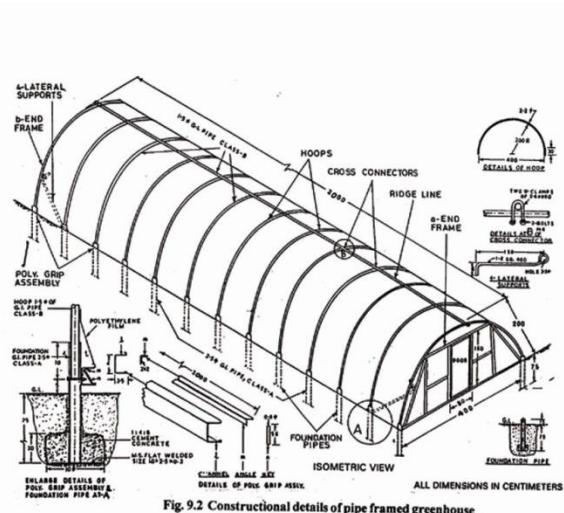


Fig. 9.2 Constructional details of pipe framed greenhouse

(17) While forming cross-connectors, the distance between the cross-connectors or hoops should be maintained 1.25 m center to center. This poly grip mechanism will provide a firm grip of the ridge line pipe and hoops at right angles without allowing for slippage.

(18) Spread polyethylene film over the structure from one end to the other end without wrinkles and keeping the edges together.

(19) Place polyethylene film between the polygrip channel and right angle strip and secure them under pressure with the help of iron rods. The film is stretched gently and fixed on the other parallel side by polygrip. This way the polyethylene is secured on both the longer sides.

(20) On the other two remaining ends, polyethylene is nailed to the end frames using wooden battens and nails.

(21) The remaining portion of the end frames is covered with polyethylene film, which is secured with wooden battens and nails.

(22) Mechanical ventilation, heating and cooling equipment is installed on the frames as per the crop requirement.

Lecture No.8

Greenhouse heating and distribution systems. Greenhouse utilization - off-season drying of agricultural produce. Economic analysis of greenhouse production - capital requirement, economics of production and conditions influencing returns.

The northern parts of our country experience cold winters, where heating system need to be employed in the greenhouses along with cooling systems for summer. Whereas the southern region greenhouses need only cooling systems since the winter cold effect is not that severe. Greenhouse heating is required in cold weather conditions, if the entrapped heat is not sufficient during the nights. The heat is always lost from the greenhouse when the surroundings are relatively cooler. Heat must be supplied to a greenhouse at the same rate with which it is lost in order to maintain a desired temperature: Heat losses can occur in three different modes of heat transfer, namely conduction, convection, and radiation. Maintenance of desired higher temperature, compared with the surroundings needs heating systems and heat distribution systems. For the purpose of greenhouse heating, apart from conventional systems, solar energy can also be used and the heat can be stored using water and rock storage. Different heat conservation practices are available to effectively utilize the heat energy.

8.1 Modes of heat loss

The heating systems, in a continuous process, should supply the heat just enough to compensate which is lost. Most heat is lost by conduction through the covering materials of the greenhouse. Different materials, such as aluminum sash bars, glass polyethylene, and cement partition walls, vary in conduction according to the rate at which each conducts heat from the warm interior to the colder exterior. A good conductor of heat loses more heat in a shorter time than a bad conductor and vice versa. There are only limited ways of insulating the covering material without blocking the light transmission. A dead air space between two coverings appears to be the best system. A saving of 40% of the heat requirement can be achieved when a second covering is applied. For example greenhouse covered with one layer of polyethylene loses, 6.8 W of heat through each square meter of covering every hour when the outside temperature is 1°C lower than the inside. When second layer of polyethylene is added, only 3.97 W/m^2 is lost (40% reduction).

A second mode of heat loss is that of convection (air infiltration). Spaces between panes of glass or FRP and ventilators and doors permit the passage of warm air outward and cold air inward. A general assumption holds that the volume of air held in a greenhouse can be lost as often as once every 60 minutes in a double layer film plastic or polycarbonate panel greenhouse, every 40 minutes in a FROP or a new glass greenhouse every 30 minutes in an old well maintained glass greenhouse, and every 15 minutes in an old poorly maintained glass greenhouse. About 10% of total heat loss from a structurally tight glass greenhouse occurs through infiltration loss.

A third mode of heat loss from a greenhouse is that of radiation. Warm objects emit radiant energy, which passes through air to colder objects without warming the air significantly. The colder objects become warmer. Glass, vinyl plastic, FRP, and water are relatively opaque to

radiant energy, whereas polyethylene is not. Polyethylene, greenhouses can lose considerable amounts of heat through radiation to colder objects outside, unless a film of moisture forms on the polyethylene to provide a barrier.

8.2 Heating systems

The heating system must provide heat to the greenhouse at the same rate at which it is lost by conduction, 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 its 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.

8.2.1 Heat distribution systems

Heat is distributed from the unit heaters by one of two common methods. In the convection tube method, warm air from unit heaters are distributed through a transparent polyethylene tube

running through the length of the greenhouse. Heat escapes from the tube through holes on either side of the tube in small jet streams, which rapidly mix with the surrounding air and set up a circulation pattern to minimize temperature gradients.

The second method of heat distribution is horizontal airflow. In this system, the greenhouse may be visualized as a large box containing air, and it uses small horizontal fans for moving the air mass. The fans are located above plant height and are spaced about 15 m (50 ft) apart in two rows. Their arrangement is that, the heat originating at one corner of the greenhouse is directed from one side of the greenhouse to the opposite end and then back along the other side of the greenhouse. Proper arrangement of fans is necessary for effective distribution in horizontal airflow system for various greenhouse sizes. Both of these distribution systems can also be used for general circulation of air and for introducing cold outside air during winter cooling.

8.2.2 Solar heating system

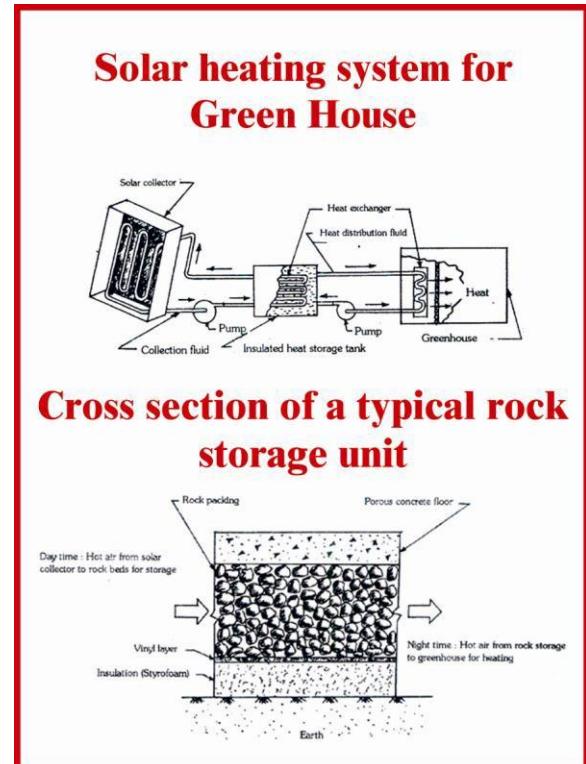
Solar heating is often used as a partial or total alternative to fossil fuel heating systems. Few solar heating systems exist in greenhouses today. The general components of solar heating system (Fig. 12) are collector, heat storage facility, exchange to transfer the solar derived heat to the greenhouse 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.

8.3 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 1°C rise in temperature. Rocks can store about 0.83 kJ for each 1°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 from 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°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 supply 14.2 kJ of heat, as it cools by 17°C .

A rock storage bed can be used with an air-collector and forced air heating system. In this case, heated air from the collector, along with air excessively heated inside the greenhouse during the day, is forced through a bed of rocks (Fig. 12). The rocks absorb much of the heat. The rock bed may be located beneath the floor of the greenhouse or outside the greenhouse, and it should be well insulated against heat loss. During

the night, when heat is required in the greenhouse, cool air from inside the greenhouse is forced through the rocks, where it is warmed and passed back into the greenhouse. A clear polyethylene tube with holes along either side serves well to distribute the warm air uniformly along the length of the greenhouse. Conventional convection tubes can be used for distributing solar heated air. The water or rock storage unit occupies a large amount of space and a considerable amount of insulation is provided if the unit is placed outside. Placing it inside the greenhouse offers an advantage in that escaping heat is beneficial during heating periods, but it is detrimental when heating is not required. Rock beds can pose a problem in that they must remain relatively dry. Water evaporating from these beds will remove considerable heat.

8.4 Economics of greenhouse production

Regardless of the type, protected agricultural systems are extremely expensive. The equipment and production cost may be more than compensated by the significantly higher productivity of protected agricultural systems as compared with open field agriculture. The cost and returns of protected agriculture vary greatly, depending on the system used, the location and the crop grown. By design, all protected agricultural systems of cropping are intensive in use of land, labour, and capital. Greenhouse agriculture is the most intensive system of all. The intensity of land use is greatly dependent upon the system of protected agriculture. Year-round greenhouse crop production is therefore much more intensive than seasonal use of mulches and row covers. Coinciding with intensity are yields, which are normally far greater per ha from year round than from seasonal systems. The normal benefit of higher yields of CEA over the open field agriculture depends on the system used and the region of production.

8.5 Capital requirements

The capital requirements differ greatly among the various systems of protected agriculture. Mulching is least expensive while greenhouses require the most capital per unit of land. Total

cost involved in the production is the sum of fixed cost and operating cost (Fig.13). The fixed capital costs include land, fixed and mobile equipment, and structures like grading, packing and office. Fixed costs also include taxes and maintenance. The fixed capital costs for greenhouses clearly exceed those of other systems of protected agriculture, but vary in expense according to type of structure, and environmental control and growing systems. Operating costs include labour, fuel, utilities, farm chemicals and packaging materials. The operating or variable costs and fixed costs are annual expenditures and these can be substantial. Annual costs may correlate to some extent with capital investment. The flow diagram of capital requirements of production is shown in figure.

In estimating the capital requirements, the farmer must include the cost of the entire system as well as the mulch. While greenhouse production systems may be far more expensive than open field systems of equal land area, open field systems of protected agriculture are normally more expensive in field area than in greenhouse production. Greenhouses are expensive, especially if the environment is controlled by the use of heaters, fan and pad cooling systems and computer controls.

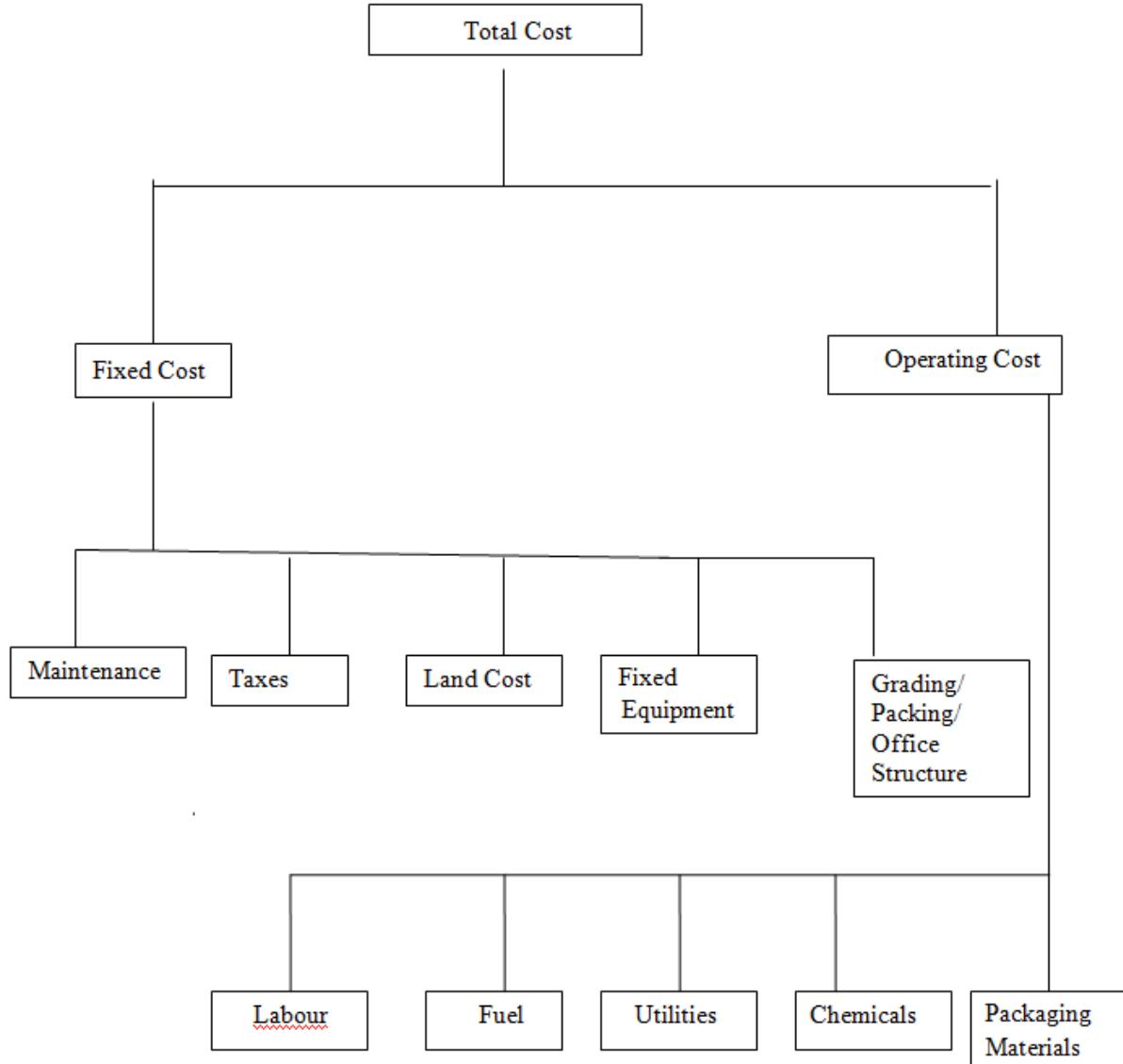
8.6 Economics of production

Production economics considers the various components of fixed and variable costs, compares them with the income and evaluates the net return, on unit area basis. On an average basis, wages account for approximately 85% of the total variable cost. Wages are the greatest expenditure in greenhouse production, followed by amortization costs and then energy costs, and energy expenditure, when heating is necessary. About two-fifths of the expenses are fixed costs and about three-fifths are variable costs. Depreciation and interest on investment accounts for most of the fixed costs.

8.6.1 Conditions Influencing Returns

A number of variables which may not show up in the yearly financial balance sheet influence the returns to green house operators, such as economics of scale, physical facilities, cropping

patterns and government incentives. The size of any system of protected agriculture will depend on the market objectives of the farmer. Most protected agricultural endeavors are family operated. Often the products are retailed directly to the consumer through a road side market at the farm site. In the developed world, greenhouse operations tend to be a size that can be operated by one family (0.4 to 0.8 ha). A unit of 0.4 ha can be operated by two to three labourers, with additional help at periods of peak activity. The labour wages can usually be provided by the owner and his family. Moreover, the owner will pay close attention to management, which is the most important factor. Labour costs may rise significantly if it is necessary to recruit labour from outside the family. Green house owners who hire a highly qualified manager may have to operate a larger greenhouse than family size greenhouses in order to offset the additional salary paid.



The green house system economy can be improved with increased size when:

1. There is a unique opportunity to mechanize certain operations.
2. Labour can be more efficiently utilized.
3. Low cost capital is available.
4. There are economics in the purchase of packaging materials and in marketing.
5. Some special management skills are available.

The physical facilities and location of the green house influence the economics. Another variable that influence the profits from the green house is intensity of production, which is determined by the structures with complete environmental control system facilities year round production and early harvest, thus enabling the grower to realize higher profits. Year-round production offers year round employment to the laborers. It is found that the environmentally controlled green house produced only one-third more revenue than high tunnel structure. With the improved transportation facilities, the new areas of production in combination with the following factors contribute to the lower costs.

1. High sun light intensity undiminished by air pollution.
2. Mild winter temperatures.
3. Infrequent violent weather conditions.
4. Low humidity during the summer for cooling.
5. Availability of water with low salinity levels.

Cropping pattern will have bearing on the green house structure. A high-tunnel structure or any structure not fitted with environmental controlled equipment for heating and cooling will be used only on a seasonal basis. It is common to switch over from green house vegetable production to flower production, especially in structures with more elaborate environmental control systems.

Growers through out the world are currently experimenting with alternative crops, such as herbs. As eating habits change, with times and as the consumers are becoming increasingly conscious of diet and the nutritional value of fruits and vegetables, growers must continually look for alternative to existing cropping patterns. Government policies also influence the financial returns from the crops. Government may provide grants or low interest loans, subsidies towards construction costs, fuels, and use of plastics, such as drip irrigation systems, mulches, row covers and covering materials. Such incentives from the Government encourage the growers and stimulate the green house industry.

8.7 Greenhouse utilization in off-season

Drying is traditional method for preserving the food. It also helps in easy transport since the dried food becomes lighter because of moisture evaporation. Drying of seed prevents germination and growth of fungi and bacteria. The traditional practice of drying agricultural produce in the developing countries is sun drying, which is seasonal, intermittent, slow, and unhygienic. To overcome the problems of sun drying, mechanical drying is introduced with the following advantages: (i) fast drying, (ii) large volumes of produce can be handled (iii) drying parameters can be controlled and quality of the produce can be maintained. The energy demand of conventional mechanical dryers is met by electricity, fossil fuels, and firewood are becoming scarce. Solar energy can be an alternative source for drying of food and solar dryers are employed for the purpose. The use of the greenhouse as a dryer is the latest development. The drying capabilities of the greenhouse can be utilized for curing tobacco leaves, while guarding the harvest from rain damage.

8.7.1 Drying of agricultural produce

In an efficiently managed greenhouse CEA, there will not be any time gap between crops. However, for some other management reasons, if crops are not grown in a particular period, the greenhouse can be utilized as a solar dryer. A small amount of 15 to 30% of the incoming solar radiation is reflected back from the surface of the greenhouse, with the remainder is transmitted into the interior. Most of this transmitted radiation is absorbed by plants, soil and other internal surfaces, the rest being reflected. The usage of greenhouse for the purpose of the drying is of recent origin. Papadikas et al., (1981) investigated the usage of greenhouse type solar dryer for drying grapes. Khollieve et al., (1982) developed a greenhouse type fruit dryer cum hot house used as dryer in summer and as a hot house in winter. They were successful in advocating the year round utilization of the greenhouse facility and thus reducing the operation cost per unit output. In general, the produce is spread as thin layers in trays covering the greenhouse area. The trays can be fabricated with sheet metal and wire mesh. Trays should be arranged horizontally on existing growing benches or frames. For better operation, proper ventilation should be provided by either forced or natural ventilation, to remove the moisture liberating from the produce and to control the air temperature inside the greenhouse. The natural ventilation can be enhanced by using a black LDPE chimney connected to the greenhouse.

8.7.2 Curing of tobacco

Tobacco is an important foreign exchange earning commercial crop of India, which provides employment opportunities to lakhs of people. Curing of tobacco is a delicate and vital process in producing good quality leaves. Tobacco curing essentially refers to drying of the harvested fresh

tobacco leaves under controlled temperature, humidity and ventilation in order to initiate the essential bio-chemical processes. The success of curing also depends on the condition of the harvested leaves and their degree of maturity. The usual curing methods are flue, air, pit, fire and sun curing. The open field sun curing is the cheapest method of curing. The drying capabilities of greenhouse can be successfully utilized for curing the tobacco. Different stages of tobacco curing require specific environmental conditions for the best product, which can be maintained easily in a greenhouse. The harvested tobacco leaves are made into bunches of few leaves by knots and arranged serially to form a string with free ends left for fixing it. Scaffoldings should be erected inside the greenhouse and the string of leaves is tied to them, for the tobacco curing process. To increase the capacity, the strings are tied with judicious gap between them and also put in tiers. As curing progresses, the leaves loose moisture and the string will become lighter and the initial sag in the strings can be corrected. For maintaining uniform product quality, the strings can be cycled among the tiers in a specified sequence. Humidity and temperature control by proper ventilation and frequent inspection is important in tobacco curing operations.

Lecture No.9

Irrigation system used in greenhouses-rules of watering, hand watering, perimeter watering, overhead sprinklers, boom watering and drip irrigation.

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.

9.1 Rules of Watering

The following are the important rules of application of irrigation.

Rule 1: 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.

Rule 2: 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.

Rule 3: 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.

9.2 Hand watering

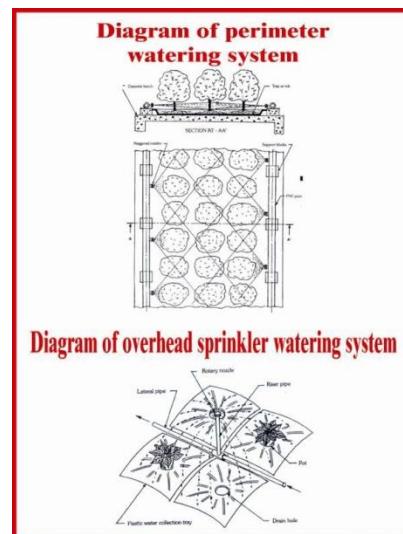
The most traditional method of irrigation is hand watering and in present days is uneconomical. Growers can afford hand watering only where a crop is still at a high density, such as in seed beds, or when they are watered at a few selected pots or areas that have dried sooner than others. In all cases, the labour saved will pay for the automatic system in less than one year. It soon will become apparent that this cost is too high. In addition to this deterrent to hand watering, there is

great risk of applying too little water or of waiting too long between waterings. Hand watering requires considerable time and is very boring. It is usually performed by inexperienced employees, who may be tempted to speed up the job or put it off to another time. Automatic watering is rapid and easy and is performed by the grower it self. Where hand watering is practiced, a water breaker should be used on the end of the hose. Such a device breaks the force of the water, permitting a higher flow rate without washing the root substrate out of the bench or pot. It also lessens the risk of disrupting the structure of the substrate surface.

9.3 Perimeter watering

Perimeter watering system can be used for crop production in benches or beds. A typical system consists of a plastic pipe around the perimeter of a bench with nozzles that spray water over the substrate surface below the foliage (Fig.14).

Either polythene or PVC pipe can be used. While PVC pipe has the advantage of being very stationary, polythene pipe tends to roll if it is not anchored firmly to the side of the bench. This causes nozzles to rise or fall from proper orientation to the substrate surface. Nozzles are made of nylon or a hard plastic and are available to put out a spray are of 180° , 90° or 45° . Regardless of the types of nozzles used, they are staggered across the benches so that each nozzle projects out between two other nozzles on the opposite side. Perimeter watering systems with 180° nozzles require one water valve for benches up to 30.5 m in length.



9.4 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.

9.5 Boom watering

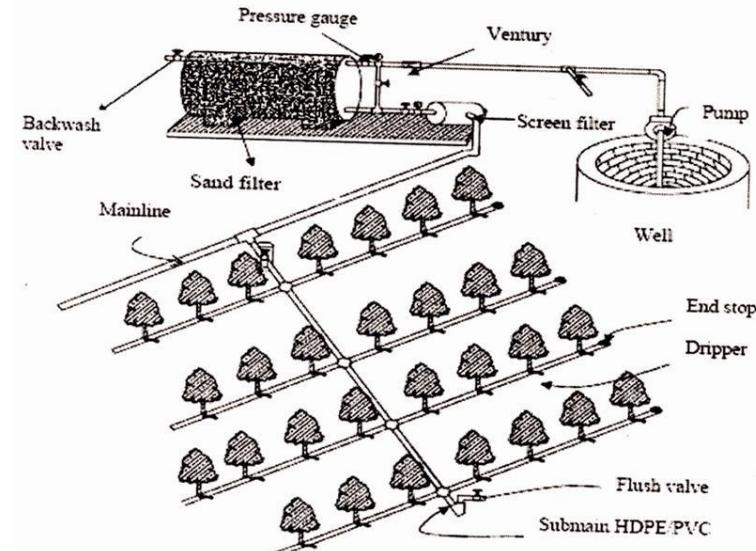
Boom watering can function either as open or a closed system, and is used often for the production of seedlings grown in plug trays. Plug trays are plastic trays that have width and length dimensions of approximately 30×61 cm, a depth of 13 to 38 mm, and contain about 100

to 800 cells. Each seedling grown in its own individual cell. Precision of watering is extremely important during the 2 to 8 week production time of plug seedlings.

A boom watering system generally consists of a water pipe boom that extends from one side of a greenhouse bay to the other. The pipe is fitted with nozzles that can spray either water or fertilizer solution down onto the crop. The boom is attached at its center point to a carriage that rides along rails, often suspended above the centre walk of the greenhouse bay. In this way, the boom can pass from one end of the bay to the other. The boom is propelled by an electric motor. The quantity of water delivered per unit area of plants is adjusted by the speed at which the boom travels.

9.6 Drip Irrigation

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:

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.

Chapter 12: Threshing –threshers for different crops, parts, terminology, care and maintenance

Threshing

- Process of detaching grains from ear heads or from the plants
- Threshing can be achieved by three methods namely rubbing, impact and stripping
- Threshing loosens the grains and separates from the stalk

Principle

- **Bases on the principle that when**
 - Impact is given on crops, the grains are separated
 - The crop mass passes thru a gap between drum and concave, wearing or rubbing action takes place-separates grain from panicle
- **Rupture of the bond between grains and ears is due to**
 - Impact of beaters or spikes over grains
 - Wearing or rubbing action
- **Strength of the bond between grain and panicles depends upon**
 - Type of crop
 - Variety of crop
 - Moisture content of grain
 - Ripening phase of grain

Efficiency and quality of threshing depends upon

- Drum speed
- No. of beaters
- Gap between drum and concave
- Quality & condition of plant mass fed to thresher
- Direction of feeding
- Rate of feeding

Methods

- **Based on power**
 - Manual – capacity varies from 30 to 50 kg/h
 - Power - capacity varies from 300 to 50 0kg/h

- **Based on type of feeding**

- **Throw-in**

- Entire crop is thrown into the cylinder
 - Major portion is threshed by initial impact or spikes of the cylinder

- **Hold-on**

- Holds the panicle end against the wire loop of the rotation

Based on flow of material

- **Through flow**

- Threshed straw and separated grain flow in a direction perpendicular to the axis of the threshing cylinder

- **Axial flow**

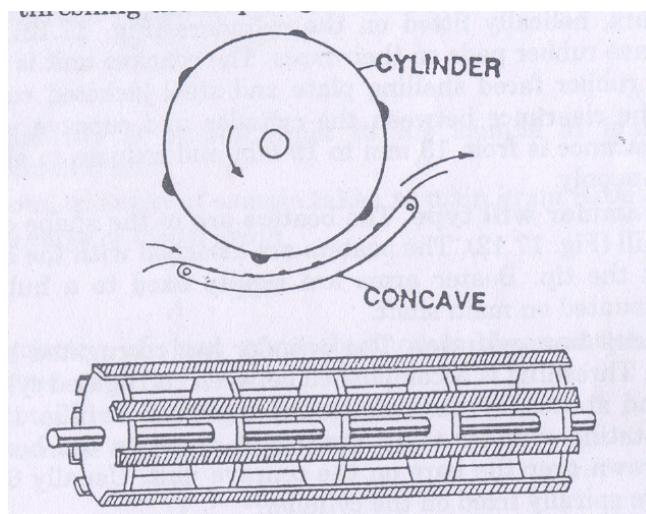
- Threshed straw and separated grain flow in a direction parallel to the axis of the threshing cylinder

Components of thresher

- Concave
- Threshing cylinder
- Cleaning unit

Concave

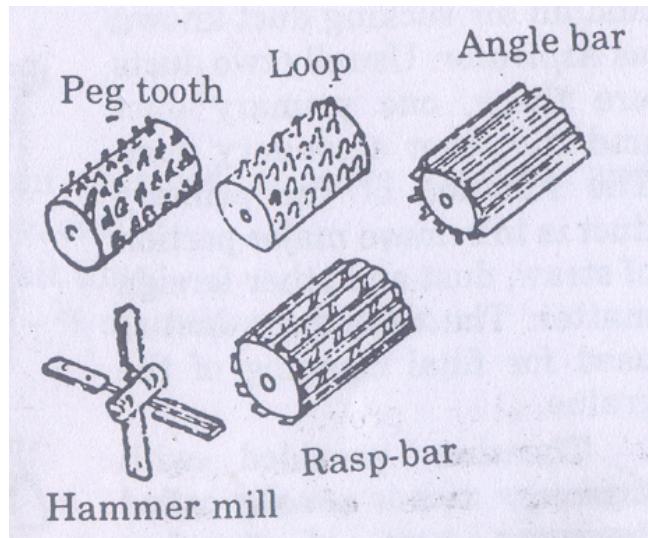
Concave shaped metal grating, partly surrounding the cylinder against which the cylinder rubs the grain from the plant or ear heads & thru which the grains fall on the sieve



Threshing cylinder

- Most important component of thresher
- Balanced rotating assembly comprising rasp beater bar or spikes on its periphery and their support for threshing the crop
- Types
 - Peg tooth
 - Wire loop
 - Rasp bar
 - Angle bar
 - Hammer mill

Types of threshing cylinder



Peg tooth

- The teeth on the concave & cylinder are so arranged that the cylinder teeth pass midway between the staggered teeth on the concave
- The clearance between the cylinder & the concave is adjusted according to the requirement
- As the stalks pass thru the clearance space, the grains get separated from the head due to impact action between the teeth

Wire loop

- Cylinder is studded with number of wire loops through out its outer periphery

- Mostly used on paddy thresher

Angle bar

- Cylinder is equipped with angle iron bars, helically fitted on the cylinder
- The bars have rubber pads on their faces
- The clearance between cylinder and concave unit at the entrance is from 13 mm to 19 mm and reduces to 6 to 9 mm only

Hammer mill type

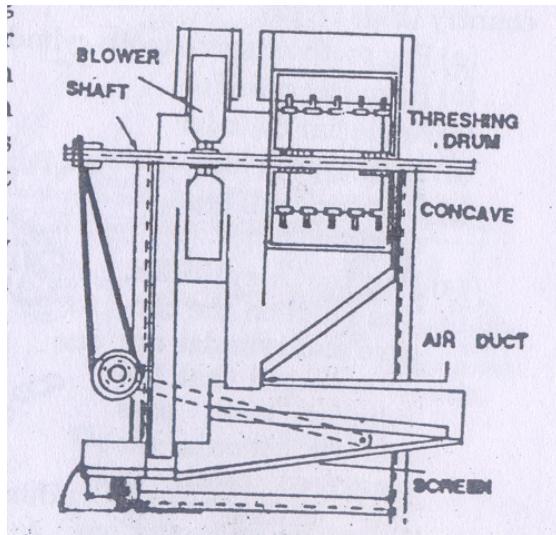
- Beaters are in the shape of hammer mill
- Beaters are attached with the beater arm at the tip
- Beater arms are rigidly fixed to a hub which is mounted on main shaft

Rasp bar cylinder

- Cylinder has corrugated bars round it
- Threshing is accomplished between corrugated cylinder bars and stationary bars of the concave portion
- Rotating cylinder takes the grains out from the head as it is drawn over the bars on the concave unit
- Usually 6 to 8 bars are spirally fixed on the cylinder

Cleaning unit

- Function is to separate & clean the threshed grain
- Mainly consists of two or more oscillating sieves, a fan and air sucking duct known as aspirator
- Usually two ducts viz. primary and secondary duct
- Function of primary duct is to remove major portion of straw, dust and other foreign matter
- Secondary duct is used for final cleaning of the grain



Thresher with aspirator

Threshing efficiency

- The threshed grain received from all outlets with respect to total grain input expressed as percentage by mass
 - Efficiency = $100 - \% \text{ of unthreshed grain}$
- Factors affecting threshing efficiency
 - Peripheral speed of the cylinder
 - Cylinder concave clearance
 - Type of crop
 - Moisture content of crop
 - Feed rate

Cleaning efficiency

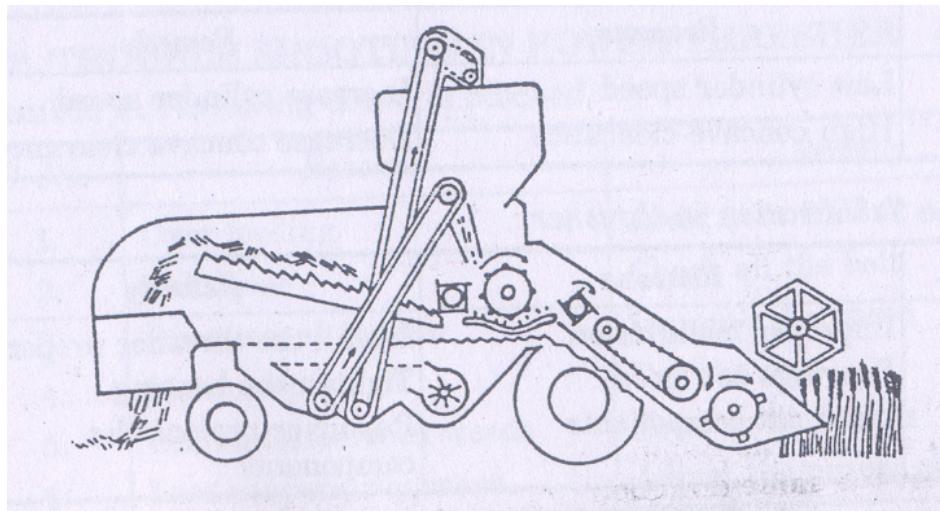
Efficiency = $M/F \times 100$

- M – Quantity of clean grain obtained from the sample taken at main grain outlet
- F – Total quantity of sample taken at main grain outlet

Combine –Harvester-Thresher

- Machine designed for harvesting, threshing, separating, cleaning and collecting grains while moving through the standing crop
- Main functions are
 - Cutting the standing crops

- Feeding the crop to threshing unit
- Threshing the crops
- Cleaning the grains from straw
- Collecting the grains in a container



Combine-Harvester-Thresher

CHAPTER 13: WINNOWING – MANUAL AND POWER OPERATED WINNOWERS, CARE AND MAINTENANCE

Wind winnowing is an agricultural method developed by ancient cultures for separating grain from chaff. It is also used to remove weevils or other pests from stored grain. Threshing, the separation of grain or seeds from the husks and straw, is the step in the chaff-removal process that comes before winnowing. "Winnowing the chaff" is a common expression. In its simplest form it involves throwing the mixture into the air so that the wind blows away the lighter chaff, while the heavier grains fall back down for recovery. Techniques included using a winnowing fan (a shaped basket shaken to raise the chaff) or using a tool (a winnowing fork or shovel) on a pile of harvested grain.

Winnowing, the process of separating quality grains from chaff, is a crucial process in the cultivation of paddy. The traditional way of winnowing is making the dried grains fall from a height using shovels and a sieve. The quality grains which are heavy fall vertically while the weightless chaff and straw get blown away by the wind. Thus, winnowing is effective only when there is a wind. Farmers often have to wait for hours for the wind to blow before they could start the process of winnowing.

Grain winnower

This machine winnows the paddy already threshed by a paddy thresher or other means. It has a feeding hopper at the top to receive the threshed paddy with other impurities. It discharges the threshed paddy over a scalper and removes bigger size impurities. A blower provided at bottom sends a stream of air against the grain falling through the scalper, which separates the straw, chaff and other impurities. The dust, chaff and straw are collected separately and cleaned paddy is taken out through another outlet near the bottom of the unit. The capacity of unit is 625 kg/h and the unit is operated by one hp motor.

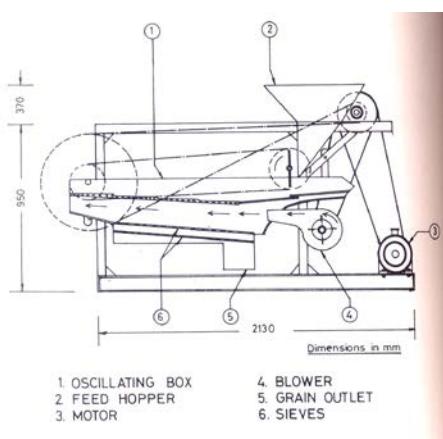
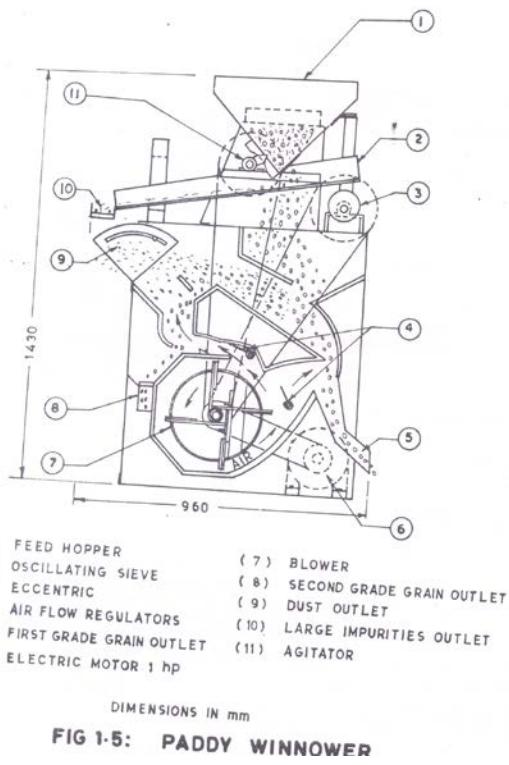


FIG. GRAIN WINNOWER

Paddy winnower

The machine winnows paddy already threshed by the paddy thresher or by other means. It has a feed hopper at the top to receive the threshed paddy, chaff and straw bit. A blower provided at the bottom sends a stream of air which separates straw, chaff and other impurities. The dust, chaff and straw come out through an opening and cleaned paddy is taken out through another spout. The unit is continuous type and operated by one hp electric motor.



Paddy precleaner

Paddy precleaner is used to remove appendages, glumes and foreign matter. The pre-cleaner is provided with an aspirator, a rotating scalping sieve and horizontal reciprocating grading sieve. By suitably changing the sieve, it can also be utilized for other seeds. By using the pre-cleaner, the efficiency of cleaner cum grader is improved. It also removes both smaller and larger size impurities and the dust from the grain. The capacity of the unit is 150 kg/h and it is operated one hp electric motor. The efficiency of the unit is 91%.

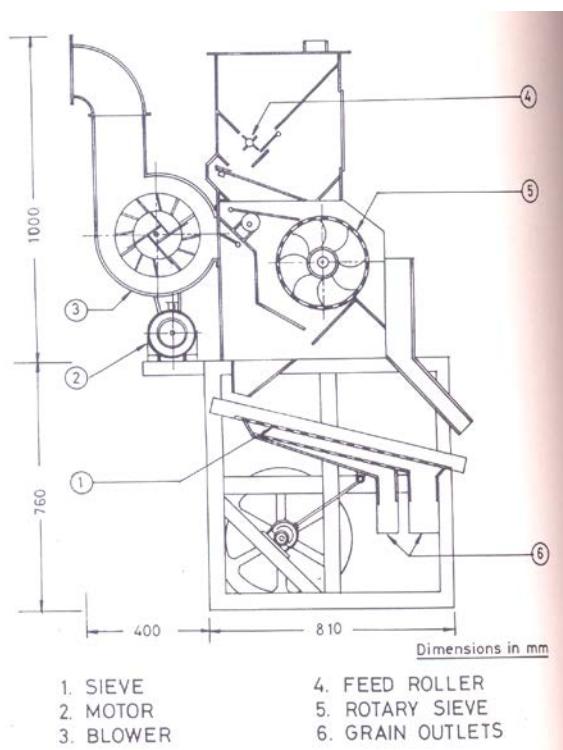
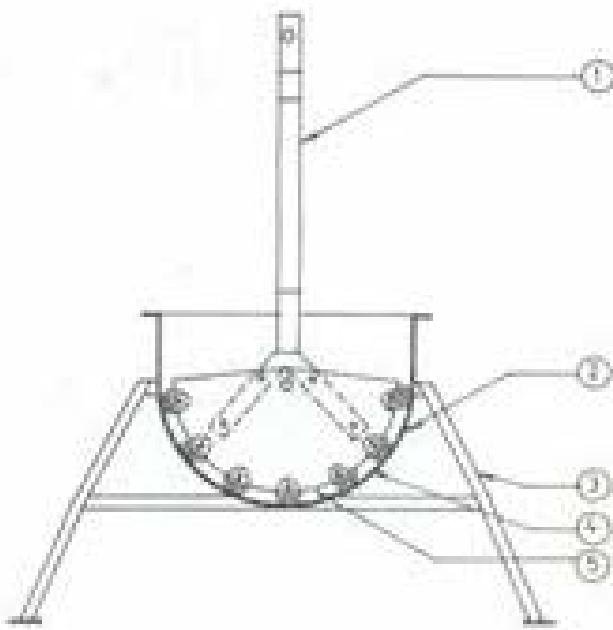


FIG. PADDY PRE-CLEANER

CHAPTER 14: GROUNDNUT DECORTICATOR-HAND OPERATED AND POWER OPERATED DECORTICATORS, PRINCIPLES OF WORKING, CARE AND MAINTENANCE

Groundnut decorticator: Manually operated

Hand operated groundnut decorticator consists of curved 'L' angle frame and four legs. A perforated sieve in a semi circular shape is provided. Seven cast iron peg assemblies are fitted in an oscillating sector. The groundnut pods are shelled between the oscillating sector and the perforated concave sieve. The kernels and husk are collected at the bottom of the unit. The clearance between the concave and oscillating sector is adjustable to decorticate pods of different varieties of groundnut. The sieve is also replaceable according to the variety of groundnut pods.



1. HANDLE
2. CONCAVE SIEVE
3. FRAME
4. SHELLING PAD
5. OSCILLATING SECTOR

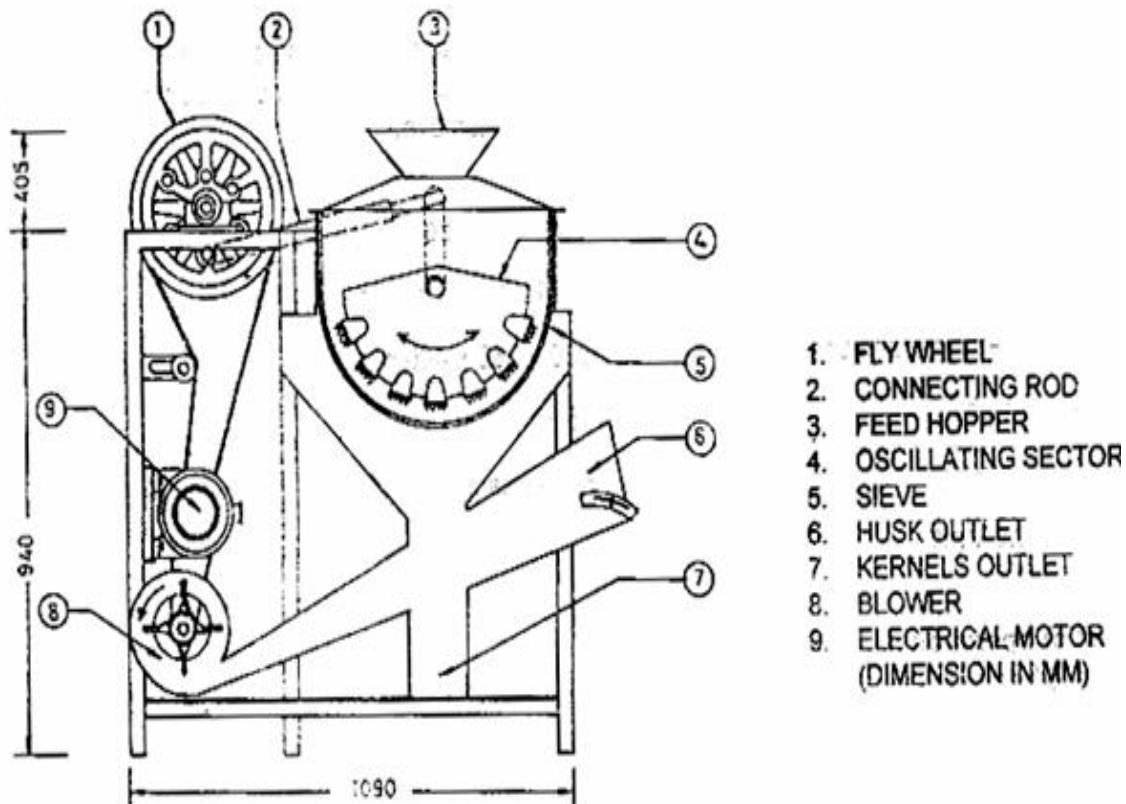
Fig. Groundnut decorticator: Manually operated

Groundnut decorticator: Power operated

The unit consists of a hopper, double crank lever mechanism, an oscillating sector with sieve bottom and blower assembly, all fixed on a frame. A number of cast iron peg assemblies

are fitted ion the oscillating sector unit. The groundnut pods are shelled between an oscillating sector and the fixed perforated concave screen. The decorticated shells and kernels fall down through the perforated concave sieve. The blower helps to separate the kernels from the husk and the kernel are collected through the spout at the bottom. The shells are thrown away from the machine.

Fig.

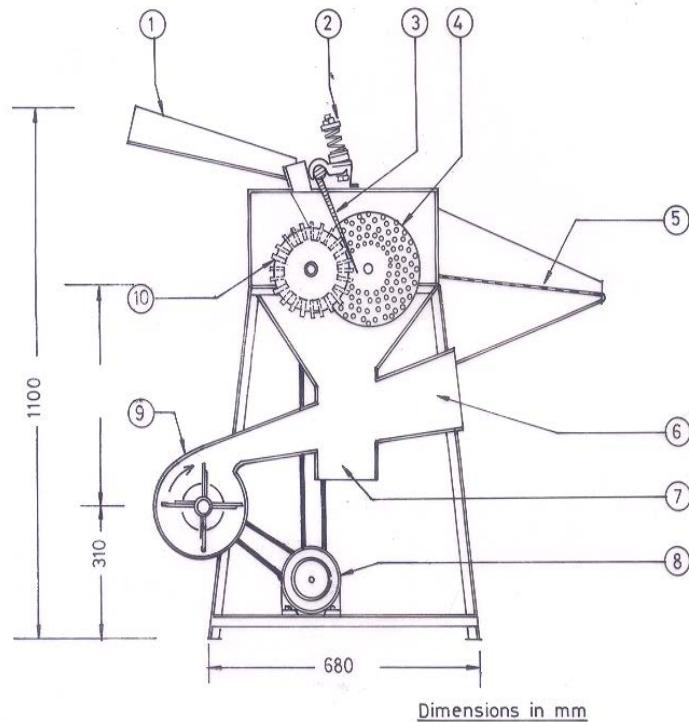


Groundnut decorticator: Power operated

CHAPTER 15: SHELTER – MAIZE AND CASTOR SHELTER

Maize sheller

The maize sheller consists of a bevel gear fixed adjacent to the shelling disc, which pulls the cob inside, while a spring loaded tongue which is provided above the bevel gear holds the cob tight against the shelling disc,. Shelling is accomplished with beating and shearing action of the cast iron projections present in the rotating shelling disc. The shelled kernels with dust are passed through an air stream produced by a blower which separates the kernels. The cleaned kernels are collected at the bottom. The capacity of the unit is 500 kg of cob/h and it is operated by an one hp electric motor.



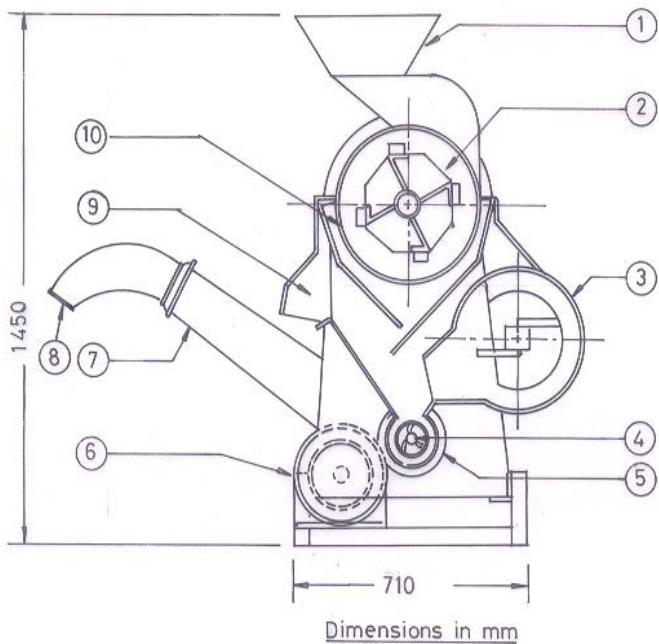
- | | |
|-----------------------|------------------|
| 1. FEED TRAY | 6. HUSK OUTLET |
| 2. COMPRESSION SPRING | 7. GRAINS OUTLET |
| 3. HOLDING TONG | 8. MOTOR |
| 4. THRESHING DISC | 9. BLOWER |
| 5. SIEVE | 10. BEVEL |

FIG. MAIZE SHELTER

Husker sheller for maize

The machine consists of a hopper, rotor, sieve, blower, auger and an elevator. The removal of sheath and shelling of cob take place in the rotor sieve assembly. The shelled kernels are carried by the auger to one end and then elevated to the desired level for direct

collection in bags. The capacity of the unit is 100 quintals per day. It is operated by 7.5 hp electric motor.



- | | |
|-----------------|-------------------------|
| 1. FEED HOPPER | 6. MOTOR |
| 2. ROTOR | 7. GRAIN ELEVATOR |
| 3. BLOWER | 8. MAIZE OUTLET |
| 4. AUGER | 9. HUSK AND DUST OUTLET |
| 5. AUGER CASING | 10. CONCAVE SIEVE |

FIG. HUSKER SHELLER FOR MAIZE

Castor sheller cum winnower

The machine consists of a teakwood cylinder and concave, a feed hopper, blower, sieve assembly and 2 hp electric motor. Unthreshed pods are retained on the top of sieve and come out from chute at the end of the sieve. Partially and completely shelled one pass through the top sieve. The middle sieve retains the partially shelled pods and allows the shelled beans to pass through. The partially shelled pods come out from chute at the end of middle sieve. The lighter hulls are blown out by the blast of air from the blower. The shelled bean comes out from the chute at the middle of the bottom perforated sheet. The perforations allow sand particles; weed seed etc., to be sieved out of the threshed castor bean. Capacity of the unit is 250 kg/h.

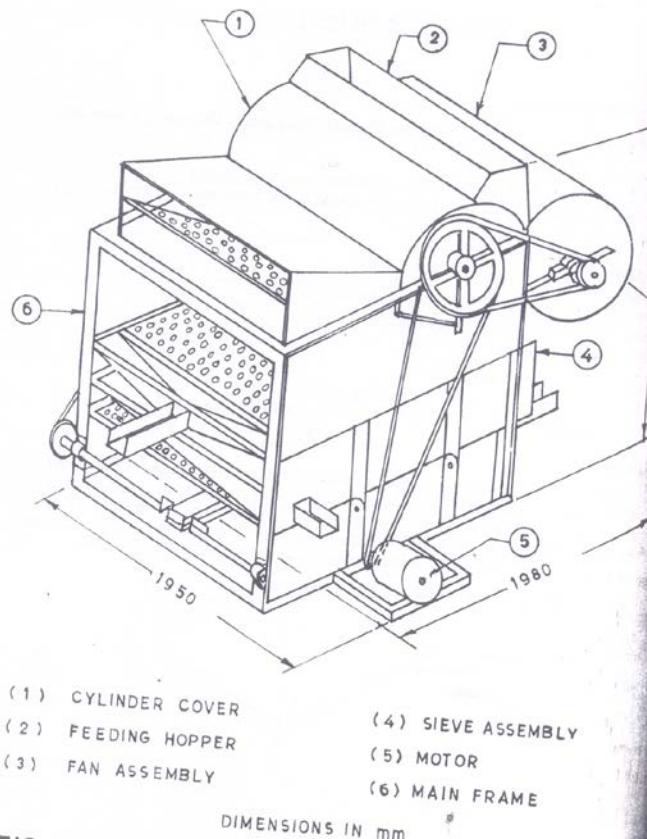


Fig. Castor Sheller cum winnower

Castor Sheller

The sheller consists of a wooden ribbed cylinder of 320 mm length and 380 mm diameter, concave, cylinder cover, feeding chute discharge chute, drive mechanism and crank. The clearance between the concave and cylinder adjustable depending on the size of bean. Shelling drum is operated by crank through a gear unit which shells the castor pods. Manual clearing is done. The unit is operated by two labours. Capacity of the unit is one quintal per day.

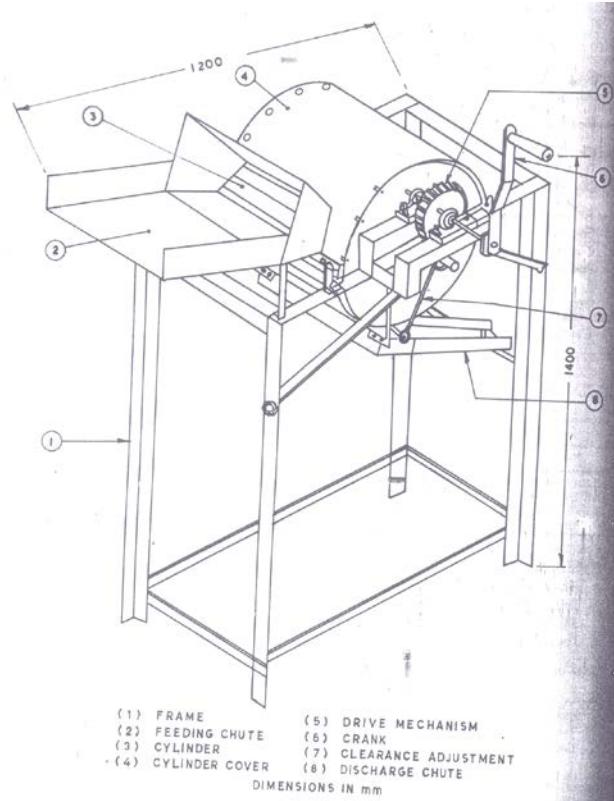


Fig. Castor Sheller

CHAPTER 16: DRYING – GRAIN DRYING, TYPES OF DRYING, TYPES OF DRYERS, IMPORTANCE OF DRYING

- Permits long time storage of grain without deterioration
- Permits continuous supply of product thro' out the year
- Permits early harvest which reduces field damage and shattering loss
- Permits the farmers to have better quality product
- Makes products available during off season

Drying theory

- Convection process in which moisture from a product is removed
- The water content of agricultural product is given in terms of moisture content
- They gain or lose moisture as per the atmospheric conditions
- Moisture migration into or from a product is dependent on the difference of vapour pressure between atmosphere and product
- If the vapour pressure of grain is greater than atmospheric vapour pressure, transfer of moisture from grain to atmosphere takes place
- If the atmospheric vapour pressure is greater than grain vapour pressure, grain absorbs moisture from atmosphere

Drying rate periods

Divided into 3 periods

- Constant rate period
- First Falling rate period
- Second falling rate period

Constant rate period

- Moisture migration rate from inside of product to its surface is equal to the rate of evaporation of water from surface
- This period continues till critical moisture content is reached
- Critical moisture content: Moisture content of a product where constant rate drying ceases and falling rate starts
- This period is very short for agricultural products
- Drying of sand and washed seeds takes place in constant rate period

Falling rate period

- Most of the agricultural products are dried in falling rate drying period
- Movement and diffusion of moisture in interior of grains controls the entire drying process

Controlled by

- Migration of moisture from interior of grains to upper surface due to water vapour diffusion
- Removal of moisture from the surface
- Divided into two periods
- First falling rate period
- Second falling rate period

First falling rate

- Unsaturated surface drying
- Drying rate decreases because of the decrease in wet surface area
- Fraction of wet surface decreases to zero, where first falling rate ends

Second falling rate

- Sub surface evaporation takes place & it continues until the equilibrium moisture content is reached

Mechanism of drying process

- Movement of moisture takes place due to
- Capillary flow – Liquid movement due to surface forces
- Liquid diffusion – Liquid movement due to difference in moisture concentration
- Surface diffusion - Liquid movement due to moisture diffusion of the pore spaces
- Vapour diffusion – vapour movement due to moisture concentration difference
- Thermal diffusion - vapour movement due to temperature difference
- Hydro dynamic flow – water and vapour movement due to total pressure difference

Thin layer drying

- Process in which all grains are fully exposed to the drying air under constant drying conditions i.e. at constant air temp. & humidity.
- Up to 20 cm thickness of grain bed is taken as thin layer
- All commercial dryers are designed based on thin layer drying principles
- Represented by Newton's law by replacing moisture content in place of temperature

$$M-M_e/M_0-M_e = e^{-K\theta}$$

M – Moisture content at any time θ , % db

M_e - EMC, %db

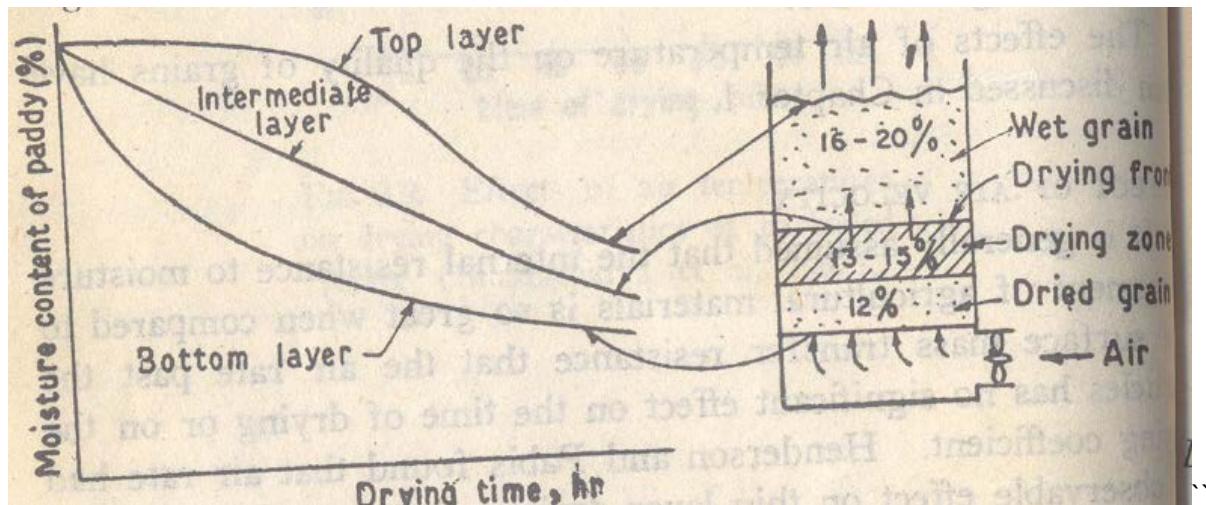
M_0 – Initial moisture content, %db

K – drying constant

θ - time, hour

Deep bed drying

- All grains are not fully exposed to the same condition of drying air
- Condition of drying air changes with time and depth of grain bed
- Rate of airflow per unit mass of grain is small
- Drying of grain in deep bin can be taken as sum of several thin layers
- Humidity & temperature of air entering & leaving each layer vary with time
- Volume of drying zone varies with temp & humidity of entering air, moisture content of grain & velocity of air



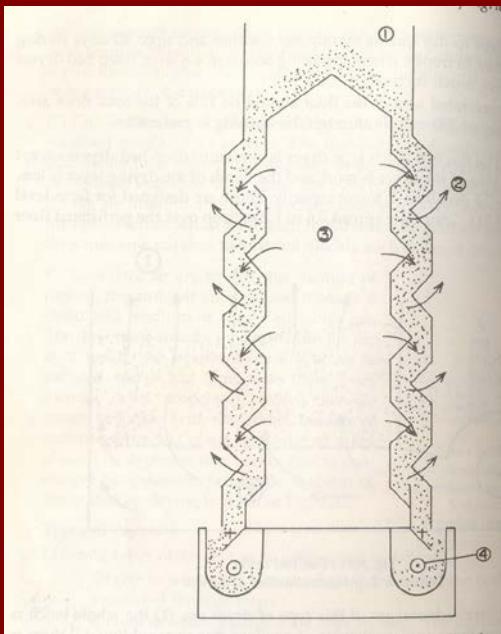
Deep bed drying characteristics at different depths

Continuous flow dryer

- Columnar type dryer in which wet grains flow from top to the bottom of the dryer
- Two types
- Mixing
- Non-mixing

Mixing

- Grains are diverted in the dryer by providing baffles
- Use low air flow rates of 50-95 m³/min/tonne
- Zig-zag columns enclosed by screens are used to achieve mixing
- High drying air temperature of 65°C is used

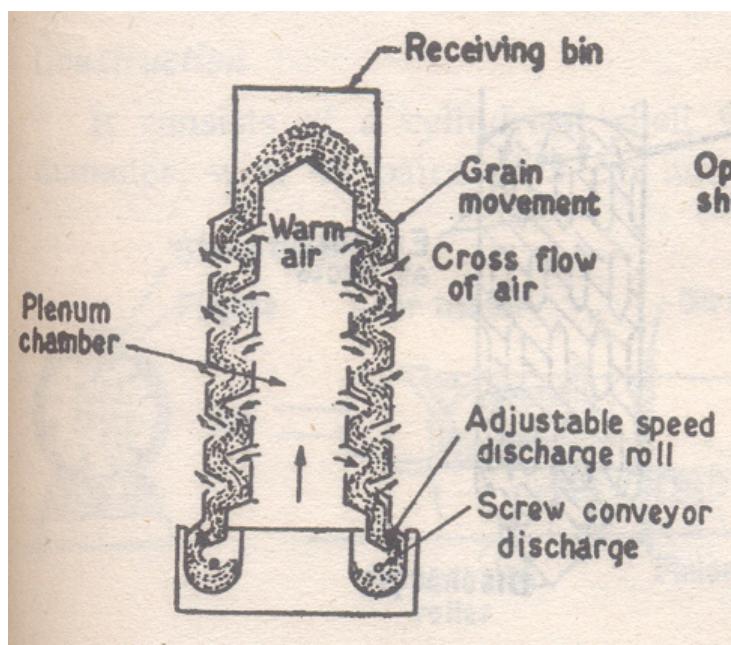


1. Feed hopper
2. Exit air
3. Plenum chamber
4. Dry material outlet

Continuous flow dryer (Mixing type)

Baffle dryer

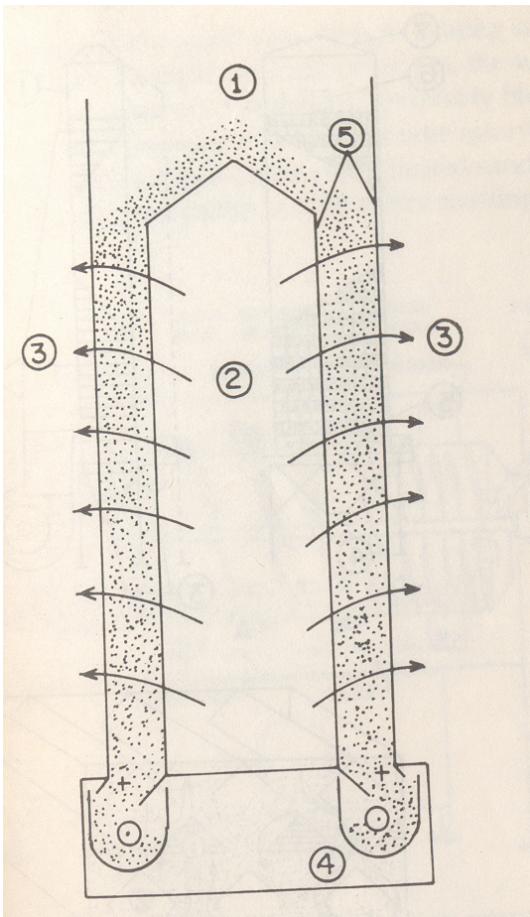
- Continuous flow mixing type dryer
- Consists of receiving bin, drying chamber fitted with baffles, plenum fitted with hot air inlet
- Baffles are fitted to divert the flow & also for mixing
- Grain fed at the top & move downward in a zig-zag path where it encounters a cross flow of hot air
- Bucket elevator is used to recirculate the grain till the grain is dried to desired moisture level
- Uniformly dried product is obtained



Mixing type baffle dryer

Non-mixing

- Grains flow in a straight path
- Baffles are not provided and drying takes place between two parallel screens
- High airflow rates can be used
- Drying air temp. of 54°C is used



1. Feed hopper
2. Plenum chamber
3. Exit air
4. Dry grain outlet
5. Screened grain column

Continuous flow dryer (Non-mixing)

Recirculatory Batch dryer

- Continuous flow non mixing type
- Consists of 2 concentric circular cylinders, set 15-20 cm apart

Bucket elevator is used to feed & recirculated the grain

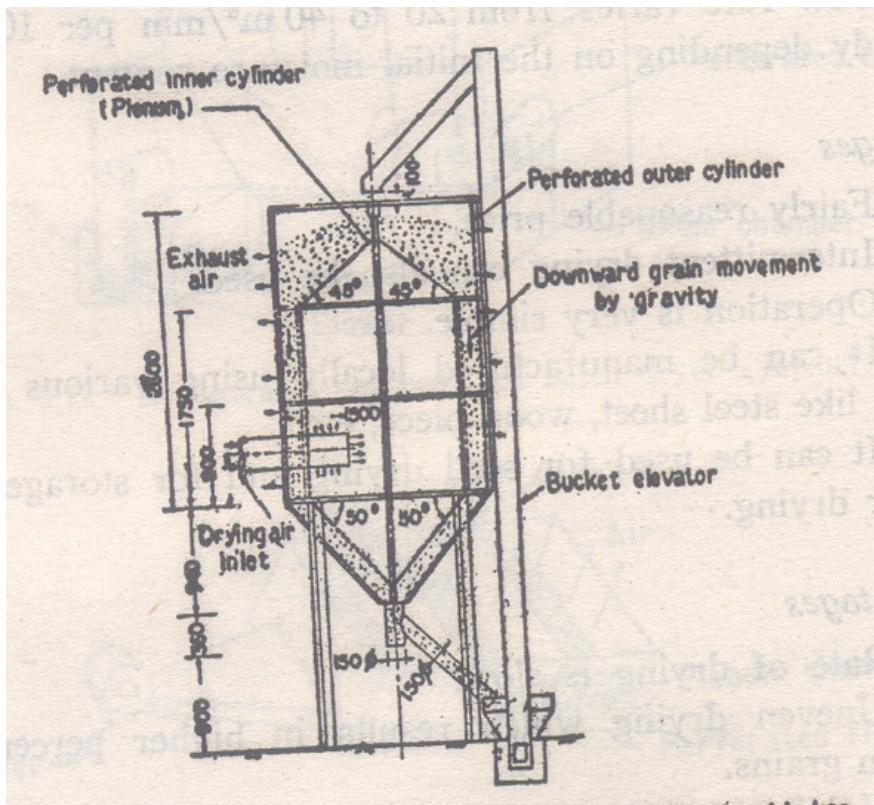
Centrifugal blower blows the hot air into the inner cylinder, acts as a plenum

Grain is fed at the top of the inside cylinder; comes in contact with a cross flow of hot air

The exhaust air comes out through perforations of the outer cylinder

Grain is recirculated till it is dried to desired moisture content

Drying is not uniform as compared to mixing type

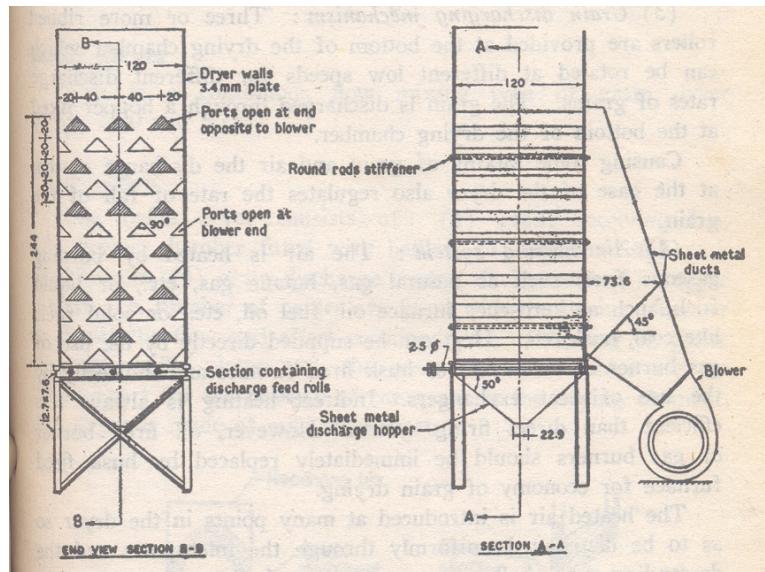


Recirculating batch dryer

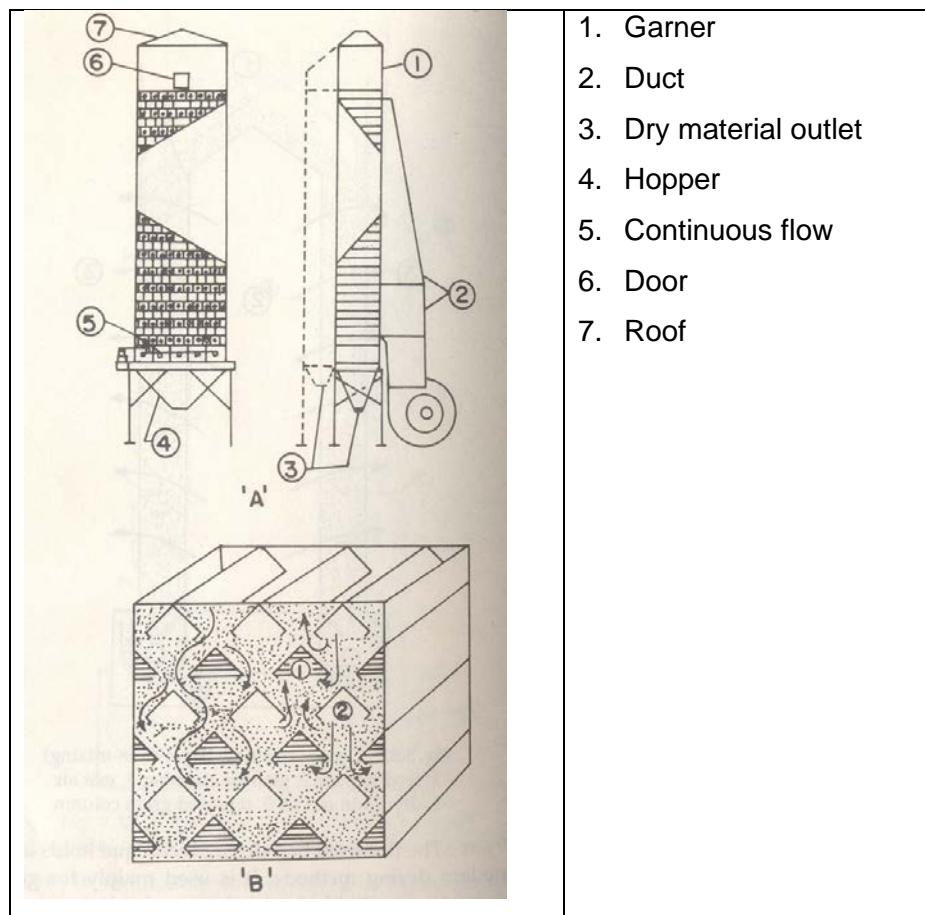
LSU dryer

- Developed at Louisiana state university (LSU)
 - Continuous mixing type dryer
 - Developed specifically for rice to ensure gentle treatment, good mixing & good air to grain contact
 - Consists of rectangular chamber, holding bin, blower with duct, grain discharging mechanism and air heating system
 - Layers of inverted V shaped channels are installed in the drying chamber; heated air is introduced through these channels at many points
 - Alternate layers are air inlet & outlet channels; arranged one below the other in an offset pattern
 - Inlet port consists of few full size ports & two half size ports; all ports are of same size arranged in equal spacing
 - Ribbed rollers are provided at the bottom of drying chamber for the discharge of grain
 - Capacity varies from 2-12 tonnes

- Recommended air flow rate is 60-70 m³/min/tonne
- Air temp. are 60 & 85°C for raw & parboiled paddy
- Uniformly dried product can be obtained
- Can be used for different types of grain
- High capital investment



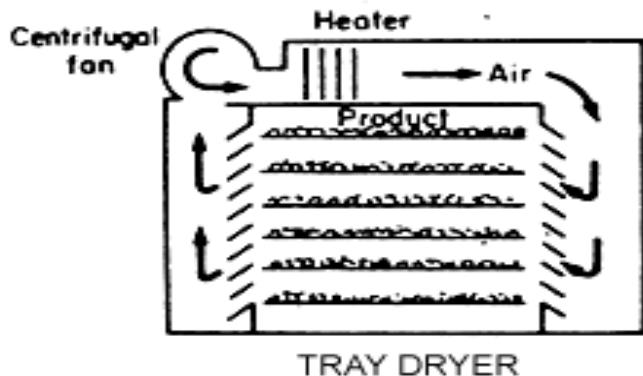
LSU Dryer



LSU Dryer

Tray driers

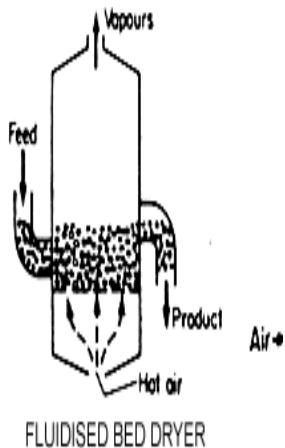
- In tray dryers, the food is spread out, generally quite thinly, on trays in which the drying takes place.
- Heating may be by an air current sweeping across the trays, or heated shelves on which the trays lie, or by radiation from heated surfaces.
- Most tray dryers are heated by air, which also removes the moist vapours.



Fluidized Bed Dryers

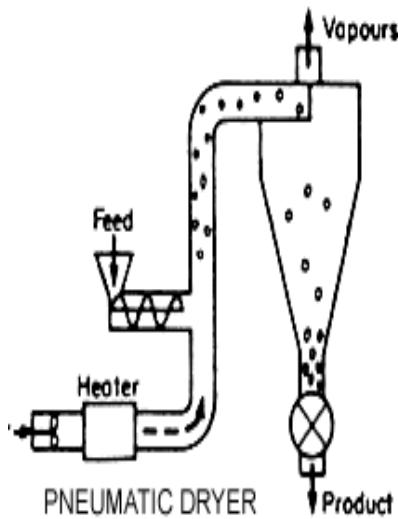
In a fluidized bed dryer, the food material is maintained suspended against gravity in an upward-flowing air stream.

Heat is transferred from the air to the food material, mostly by convection



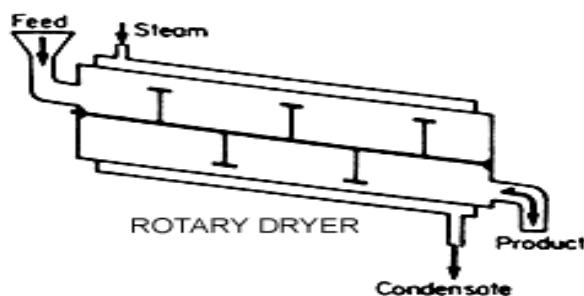
Pneumatic Dryers

- In a pneumatic dryer, the solid food particles are conveyed rapidly in an air stream, the velocity and turbulence of the stream maintaining the particles in suspension.
- Heated air accomplishes the drying and often some form of classifying device is included in the equipment.
- In the classifier, the dried material is separated, the dry material passes out as product and the moist remainder is recirculated for further drying



Rotary Dryers

- The foodstuff is contained in a horizontal inclined cylinder through which it travels, being heated either by air flow through the cylinder, or by conduction of heat from the cylinder walls.
- In some cases, the cylinder rotates and in others the cylinder is stationary and a paddle or screw rotates within the cylinder conveying the material through.



CHAPTER 17: STORAGE- GRAIN STORAGE – TYPES OF STORAGE STRUCTURES

Storage structures

Storage – to maintain the quality of grain after harvest for

- ✓ Maintaining the supply of grain
- ✓ Taking advantage of higher prices

Two methods of grain storage

- ✓ Bag storage
- ✓ Loose in bulk storage

The choice based on the local factors

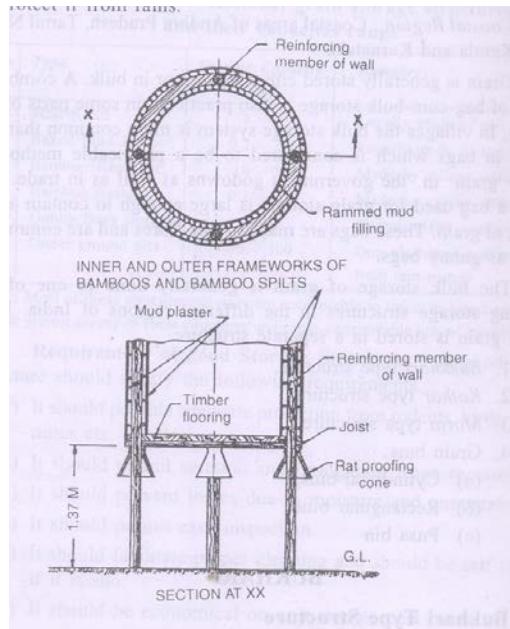
- Type of grain
- Duration of storage
- Value of grain
- Climate
- Transport system
- Cost and availability of labour
- Cost and availability of bags
- Incidents of rodents and certain types of insects

Bag and bulk storages

Bag storage	Bulk storage
Flexibility of storage	Inflexible storage
Partly mechanical	mechanical
slow handling	Rapid handling
Considerable spillage	Little spillage
Low capital cost	High capital cost
High operating cost	Low operating cost
High rodent loss potential	Low rodent loss potential
Reinfestation occurs	Little protection against reinfestation

Traditional storage structures- (Bulk type)

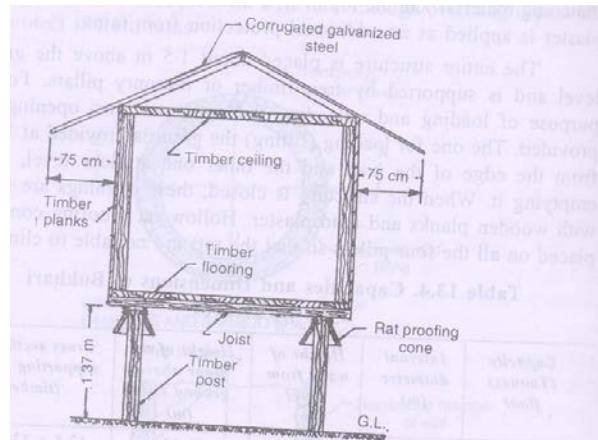
Bukkhari type



- Cylindrical in shape
- Made of mud or combination of mud and split bamboo
- Raised above the ground by wooden or masonry platform
- Floor
- Walls
- Roof
- Improved type – same structure
- Rat proofing cones
- Grains – wheat, gram, paddy, maize and sorghum
- Capacity – 3.5 – 18 t

Kothar type

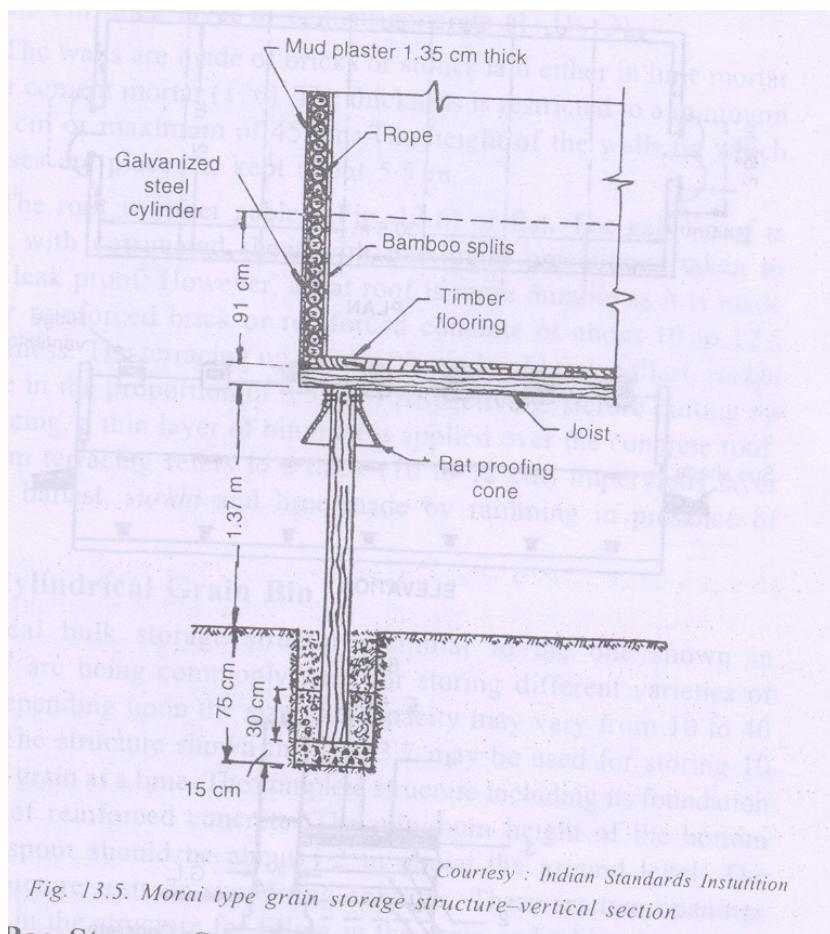
- Store – paddy, maize, sorghum, wheat
- Capacity – 9-35 t
- Structure – box
- Improved Kothar – 5cm thick wooden planks and beams
- No gap between the planks



Courtesy : Indian Standards Institution
Fig. 13.4. Kothar type grain structure-vertical section
Morai Type

Morai type

- Grains – paddy, maize, sorghum
- Capacity – 3.5 – 18 t
- Shape- inverted truncated cone



Courtesy : Indian Standards Institution
Fig. 13.5. Morai type grain storage structure-vertical section
Rat Stomach G.

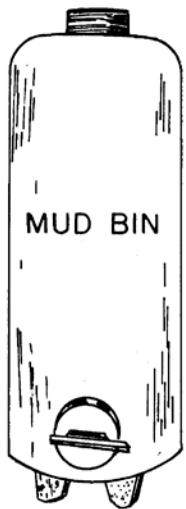
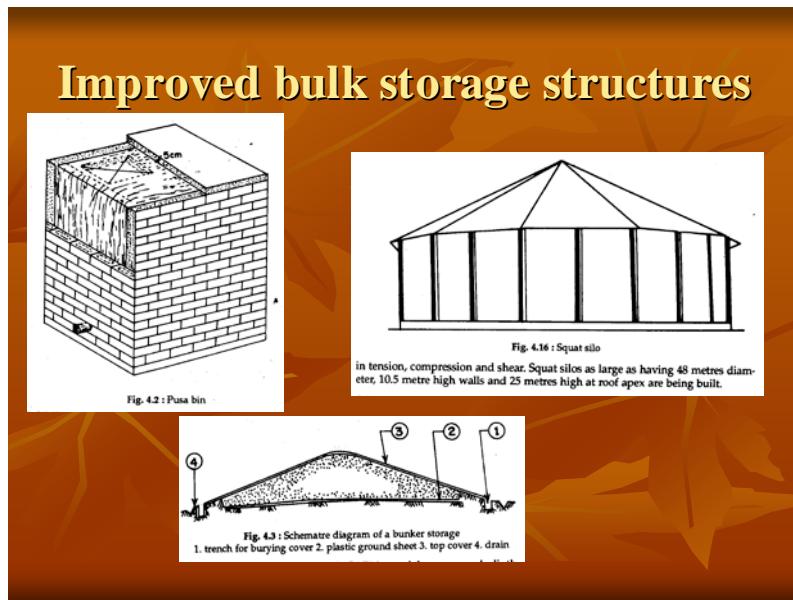


Fig. 4.1 : Mud bin.

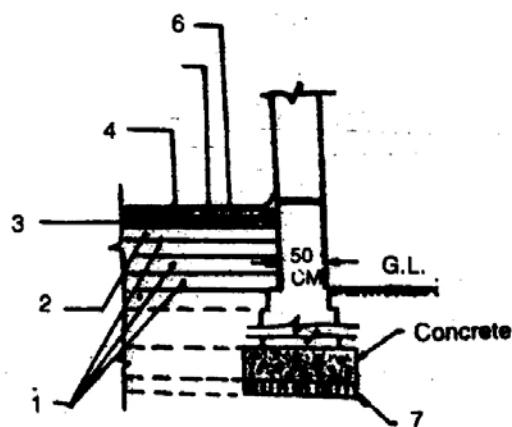
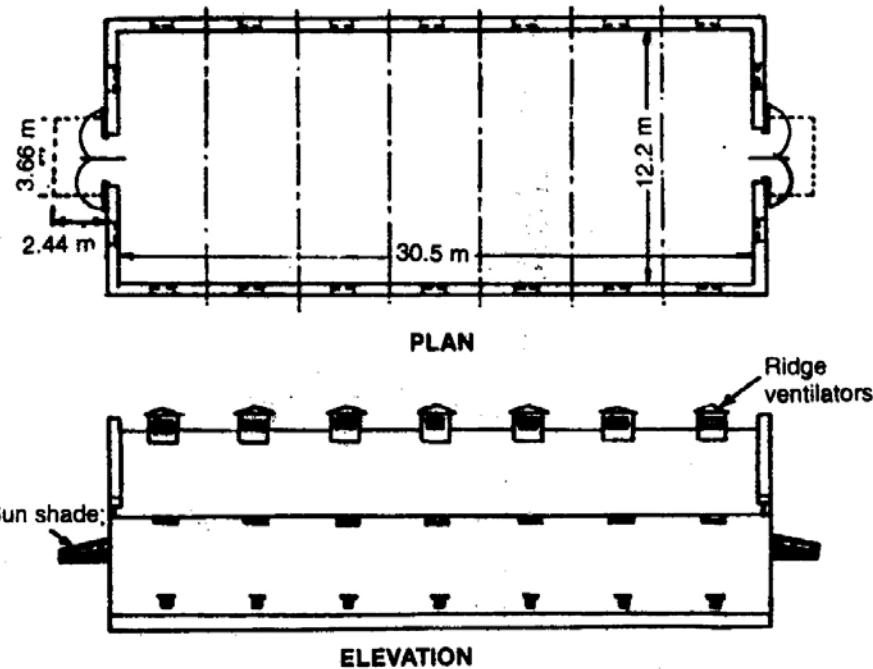


Modern storage structures

- Bagged storage system
- Silo storage system
- Air tight storage system
- Aerated storage system
- Low temperature storage system
- Controlled atmosphere storage system
- Damp grain storage system with chemicals

Bagged storage system

- Storage capacity is from 25 tonnes
- Generally the length is about twice the width or greater
- The entire structure should be moisture proof
- Large size doors of 2.4 x 2.4 m and top ventilators
- Each door is provided with a light overhanging hood
- It should be provide with ventilators – having wire netting and shutter



Courtesy : Indian Standards Institution

Bag Storage structure

Damp proof floor

- 1) 15 cm thick layer of gravel and sand well rammed at the bottom
- 2) 12.5 cm thick layer of stone or brick ballast or double layer of brick
- 3) 10 cm thick layer of cement concrete (1:4:8)
- 4) 1.25 cm thick bitumen mixed with sand
- 5) 4 cm thick layer of cement concrete (1:2:4)
- 6) 2.5 cm thick layer of cement concrete (1: 1 1/2: 3)

The walls are made of bricks or stone laid either in lime mortar (1:2), cement mortar (1:6)

Thickness of the wall is either 37.5 or 45 cm

The height of the walls on which trusses are kept: 5.5 m

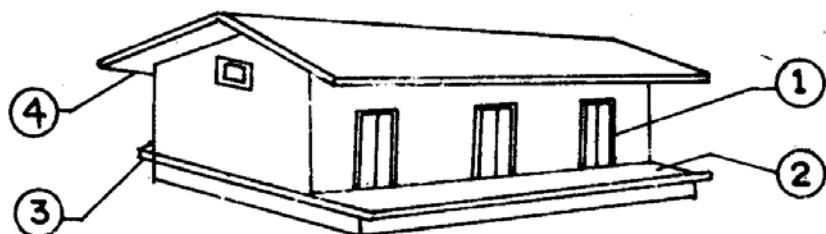
Roof

Either gabled or flat roof

Gabled roof is covered with corrugated sheet

Flat roof is more durable – either reinforced brick or concrete – 10 to 12.5 cm thick

The terracing on the roof is made of brick ballast, surkhi, and lime (3.5: 1:1)



1. Sealed door

2. Floor

3. Rat proof slab

4. Air proof roof

Modern Storage Godown

CHAPTER 18: FRUITS AND VEGETABLES CLEANING – MACHINERY FOR CLEANING FRUITS AND VEGETABLES, CARE AND MAINTENANCE

Impurities in Freshly Harvested Fruits

- Field Soil
- Dust and surface microorganism
- Fungicide / insecticide etc
- Sap
- Black spots

Fruit and Vegetable Cleaning Machine

Specifications

Capacity : 20 kg/batch

Power requirement : 1 person

RPM : 20 – 30 rpm

Fruit and vegetable : Most fruits & vegetable inclusive mango & tomato

Foreign matter removal :

Field Soil, Dust and surface microorganism, Fungicide / insecticide, Sap, Black spots etc



Multifunctional cleaning machine



The machine is a multifunctional fruit and vegetable cleaning equipment with bubbles, spraying and brush available in cleaning with features such as highly cleanliness, energy-saving, water-saving, stable and reliable. This equipment is suitable for cleaning fruits and vegetables. It is easy to operate, convenient in maintenance and wiring.

Fruit cleaning machine



The equipment is suitable for cleaning of ball-shape or oval-shape fruits and vegetables. The fruits and vegetables rotate continuously in all directions randomly. Brushing and spraying is in effect at a same time, with features such as high cleanliness. The machine is easy to operate, convenient in maintenance and wiring.

Brush Type Vegetable & Fruit Cleaning Machine



Production capacity

Apple 30T/h

Watermelon 10T/h

Carrot 8T/h

Orange 35T/h

The fruit and vegetable raw materials are making irregular rotation under the effect of rotary brush roller to carry out spraying and brushing simultaneously. The brush is made of high temperature resistant nylon wire through two kinds of technologies such as hair planting and stainless steel winding.

- a) Brush fruit cleaning machine for apple and fruits
- b) Brush clearing machine for watermelon
- c) Brush cleaning machine for carrot vegetable
- d) Brush cleaning machine for citrus fruit

Surf Type Fruit Cleaning Machine



The equipment is mainly composed of water cabinet, material turning device, fan and lifter etc. It is widely used for soft washing of fruit and vegetable raw materials. The lifter can be made of complete stainless steel and engineering plastic. It can be additionally provided with spray cleaning device.

Roller with Brush Cleaning Machine



The fruit washing equipment consists of a roller with brush washing (cleaning) machine for washing fruits and vegetables. Roller with brush washing machine is made up of stainless steel tube and brush. The brush is made of polyethylene, and will make revolution as the movement of stainless steel chain. Fruits are driven to circumvolve and washed by brush. At the same time, the bad or rejected fruits are picked up by manual and then sent away by scrap conveying device.

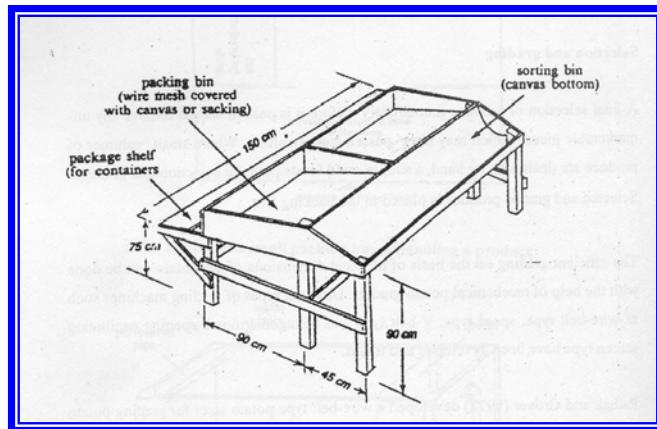
Rolling Drum Brush Washing Machine



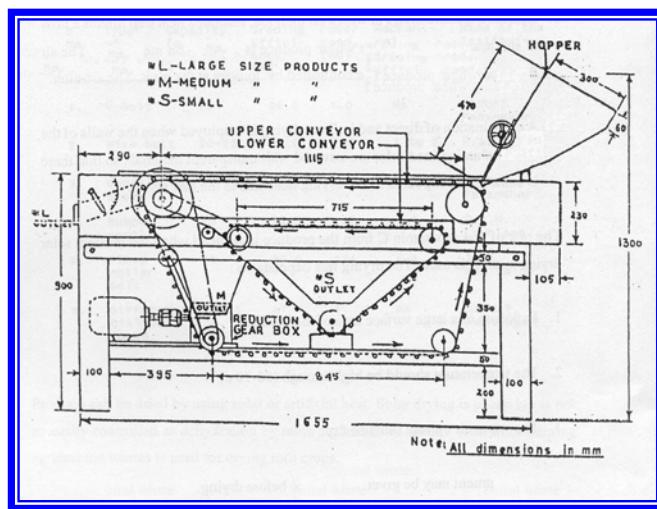
The fruit washing equipment consists of a rolling drum brush washing (cleaning) machine for washing root vegetables. Rolling drum brush washing machine is made up of electric motor, water pump, roller drum, supporter, riding wheel, brush, water spraying tubes, feeding funnel, cover board, water box, transmission shaft, supporter for motor, electric control switches, and other parts.

Roller drum is driven to rotate by chain wheel of electric motor through stainless steel chain. When materials enter into the rotating roller drum, they are washed by spraying water and brush. There are two water boxes in our rolling drum brush washing machine. One is used to hold fresh water, and the other with filtering net in it is to recycle water.

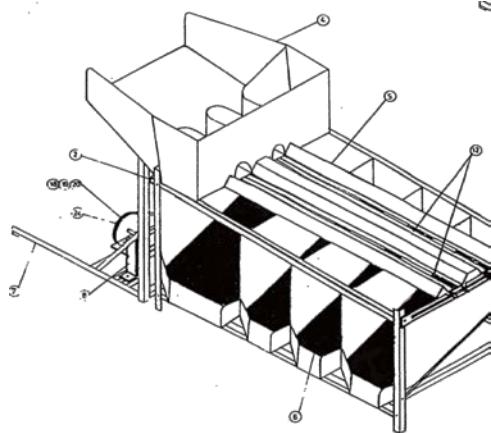
CHAPTER 19: GRADING – METHODS OF GRADING, EQUIPMENTS FOR GRADING OF FRUITS AND VEGETABLES, CARE AND MAINTENANCE



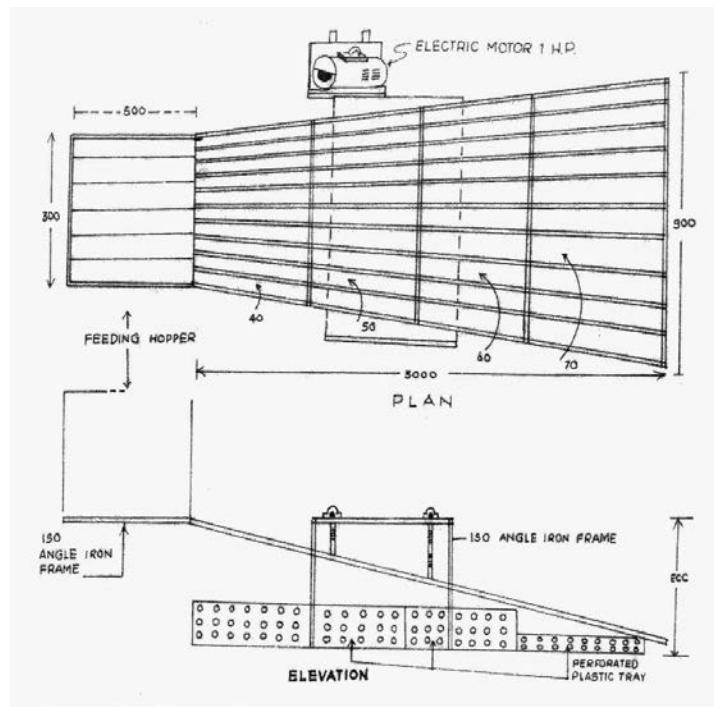
Sorting Bench



IARI Fruit and Vegetable Grader



Divergent roller type fruit sorting machine for lemon and sapota, MPKV, Rahuri



Divergent rails/slit size mango grader.CISH, Lucknow

Fruit and Vegetable Grader for Tomato & Mango

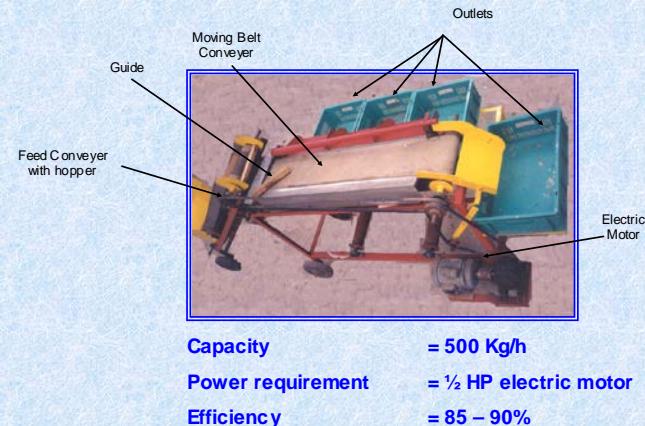


Plate 3.5 Orange grading (weight basis) machine in operation

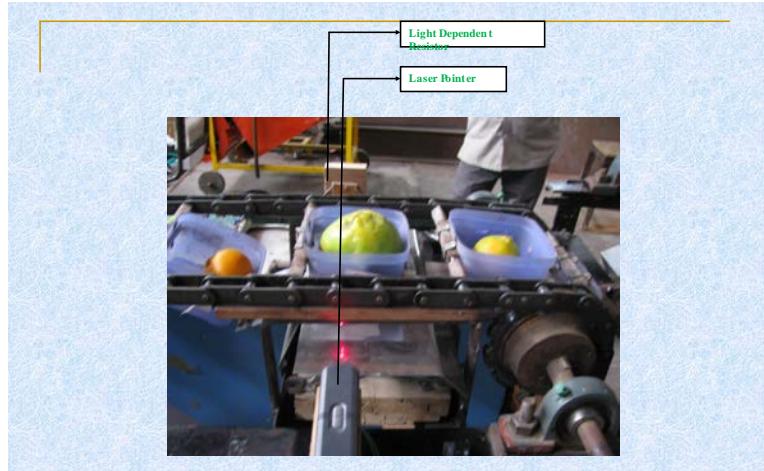


Plate 3.4 Electronic laser sensing assembly of orange grading machine

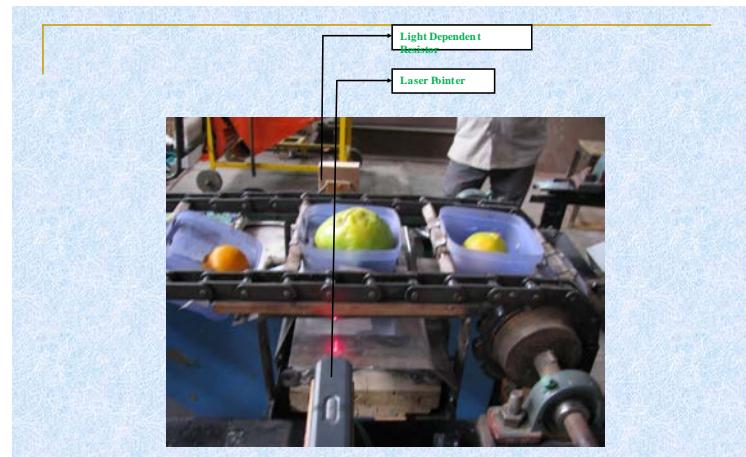
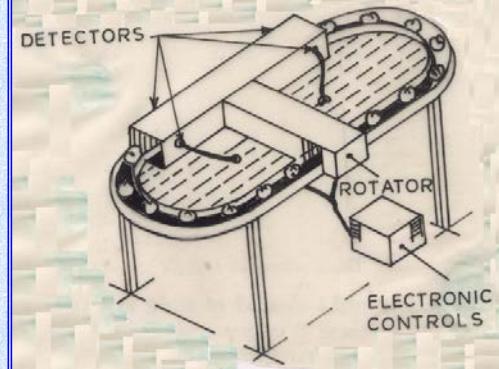


Plate 3.4 Electronic laser sensing assembly of orange grading machine

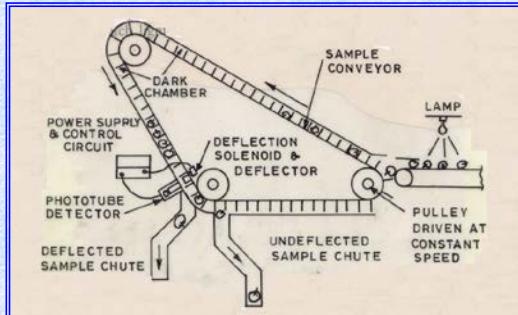
Optical Grader for Apples

(Colour Grading)



Optical Grader for Fruits

(Delayed Light Emission)





Mango grader

Potato grader

Features

- Capacities range from 5 tonne/hr to 30 tonne/hr
- Washing
- Dry brushing lines
- Sizing
- Bagging lines



Onion grader

Features

- Capacities range from 8 tonne/hr to 30 tonne/hr
- Bulk receival
- Top and tailing
- Sizing
- Bagging lines



Sweet Potato Sorter



Electronic sizer for sweet potato



Grader for sweet potato

Belt grader

- Used to separate round from other shaped seeds/parts or weeds in flower, herb, tree, cactus and vegetable seeds.
- For vegetable seeds separation of triangular or sharp shaped seed from round spinach seed



Indented cylinder grader

- Used for separating plant parts and weeds in carrot, onion and lettuce, but also for flower seeds like marigold and impatiens.
- Used for calibrating the seeds based on their length to obtain more uniformity to produce seed pellets



CHAPTER 20: SIZE REDUCTION – EQUIPMENT FOR SIZE REDUCTION, CARE AND MAINTENANCE

Unit operation in which the average size of solid pieces of food is reduced by the application of

- grinding
- compression
- impact forces

Related terms

- **Homogenization or Emulsification**
 - Reduction in size of globules of immiscible liquids
- **Atomization**
 - Size reduction of liquids by droplets
- **Extrusion, Agglomeration or Forming**
 - Size enlargement

Benefits in food processing

- ✓ Increase in the surface area to volume ratio of the food
- ✓ Increases the rate of drying, heating or cooling
- ✓ improves the efficiency and rate of extraction of liquid components
- ✓ Eg. Fruit juice, cooking oil extraction
- ✓ When combined with screening, a predetermined range of particle sizes is produced which is important for the correct functional or processing properties of some products
- ✓ Eg. Icing sugar, spices, corn starch
- ✓ A similar range of particle sizes allows more complete mixing of ingredients
- ✓ Eg. Dried soup and cake mixes

Methods

- ❖ Chopping, cutting, slicing and dicing
- ❖ Large to medium (Cheese and sliced fruit for canning)
- ❖ Medium to small (Diced carrot)
- ❖ Small to granular (minced meat, flaked fish or nuts and shredded vegetables)
- ❖ Milling to powders or pastes
- ❖ Grated products
- ❖ Emulsification and homogenization

Theory

Three types of forces

- Compression
- Impact
- Shearing or Attrition forces

Stress is applied to a food; the resulting internal strains are first absorbed to cause deformation of the tissues. Amount of energy needed to fracture a food is determined by its hardness and tendency to crack – in turn depends on the structure of the food. Fewer the lines of weakness in a food, the higher are the energy input needed to cause fracturing. Harder foods absorb more energy and require a greater energy input to create fractures. Extent of size reduction, the energy expanded and the amount of heat generated in the food depend on both the size of the forces that are applied and the time that food is subjected to the forces. Compression forces are used to fracture friable or crystalline foods. Combined impact and shearing forces are necessary for fibrous foods. Shearing forces are used for fine grinding of softer foods.

Factors influencing the energy input

❖ Moisture content

- Wheat is conditioned to optimum moisture content
- Maize is thoroughly soaked and wet milled for complete disintegration

❖ Heat sensitivity of the food

- Determines the permissible temperature rise and the necessity to cool the mill
- Liquid N₂ or solid CO₂ are mixed with foods before milling to cool the product and to retain volatiles
- ❖ Quantum of the forces that are applied
- ❖ Time that food is subjected to the forces

Equations for energy requirement determination

Kicks law

- Energy required to reduce the size of particles is directly proportional to the ratio of the initial size of a typical dimension to the final size of that dimension

$$E = K_k \ln (D_f/D_p)$$

E – Energy required per mass of feed

K_k – Kick's constant

D_f – Average initial size of feed

D_p – Average size of product

D_f / D_p – Size reduction ratio

- Coarse grinding has RRs below 8:1
- Fine grinding can exceed 100:1
- Grinding of coarse particles in which the increase in surface area per unit mass is relatively small, Kick's Law is a reasonable approximation
- Rittinger's law
 - States that the energy required for size reduction is proportional to the change in surface area of the pieces of food
- $E = K_R \frac{1}{D_p} \frac{1}{D_f}$
- K_R – Rittinger's constant
- For the size reduction of fine powders, in which large areas of new surface are being created, Rittinger's Law fits the experimental data better.

Bond's law

- The work required to form particles of size D_p from very large feed is proportional to the square root of the surface to volume ratio of the product
- $P/f = 0.3162 w_i \frac{1}{\sqrt{D_p}} \frac{1}{\sqrt{D_f}}$

P – Power in kW

f – feed rate, t/hr

D_p – 80% of the product passes through mesh of dia D_p , mm

D_f – 80% of feed passes through mesh of dia, D_f , mm

W_i – Work index

Gross energy requirement in kilowatt-hour per tonne of feed needed to reduce a very large feed to such a size that 80% of the product passes through a 100 micro meter screen

- An ideal size reduction equipment should fulfill the following conditions
 - Large capacity
 - Should yield a pre desired sized product or range of size
 - Small power input requirement per unit of product handled
 - Easy & trouble free operation
- Amount of power required to create smaller particles
- Desired uniformity of size

- Work required to strain the material is temporarily stored in the form of mechanical energy of stress.
- When external force exceeds the amount of stored mechanical energy, the material is disturbed beyond its strength and finally broken into fragments – results in creation of new surface
- Solids have a certain amount of surface energy, thus for creation of new surface, work is required and supplied by the release of stress energy when material breaks.
- Stress energy excess of the new surface energy created is converted into heat energy.

Grinding

- Classified into two
 - Milled to a free flowing meal consisting of sufficiently uniform particle size
- Selective grinding
 - Grinding operation is carried out in various stages depending upon the differences in structural and mechanical properties of components of grain

Degree of grinding

- Ratio of the overall surface area of the ground product to the overall surface area of the feed

$$Dg = Sp/Sf$$

Dg – degree of grinding

Sp – Overall surface area of product

Sf – Overall surface area of feed

Milling efficiency

- Product of coefficient of hulling (E_hulling) and coefficient of wholeness of kernel (E_wk)
- Coefficient of hulling
 - Percentage of the hulled grains obtained from the total amount of grain input
- Coefficient of Wholeness of kernel
 - Ratio of the amount of kernel, crushed grains and mealy waste obtained by any milling system

Size reduction machinery

- Crushers
- Grinders
- Fine grinders
- Cutting machines

Crushers

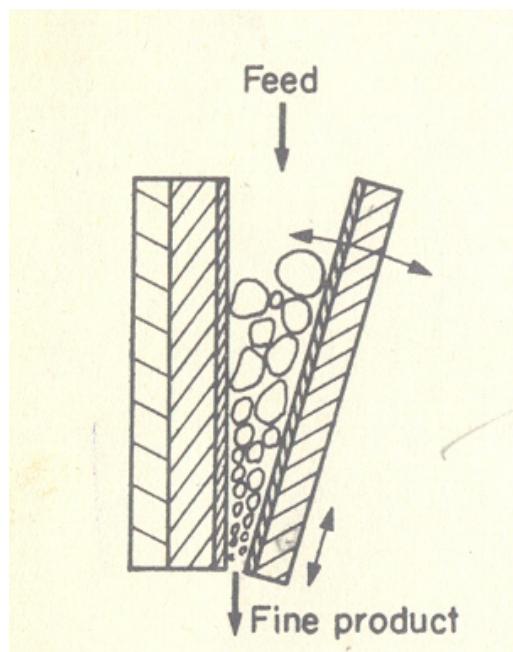
- Squeeze or press the material until it breaks
- Mostly used to break large pieces of solid materials into small lumps
- Use of crushers in agricultural operations is limited

Types

- Jaw crushers
- Gyratory crushers

Jaw crusher

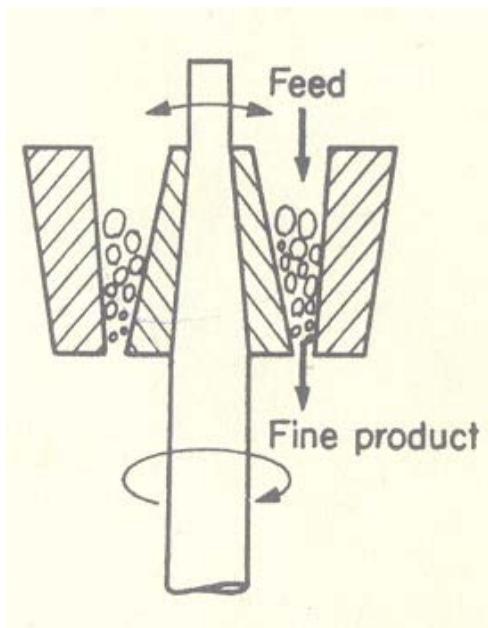
- Feed is admitted between two jaws, which are open at the top like V
- One of the jaws is fixed and vertical, while the other is the swinging jaw
- This jaw reciprocates in a horizontal plane and makes the angle of 20-30° with the fixed jaw
- Movable jaw is operated by an eccentric unit so as to impart great compressive force
- Solids which has to be broken is caught between the two jaws
- Large lumps of solid materials are caught between the upper parts of the jaws
- Subsequently broken and dropped into the narrower space below
- Broken pieces are further reduced next time when jaws come closer.
- No. of strokes given to the movable jaw ranges between 250 to 400 times per minute



Gyratory crusher

- Jaws between which the solid materials fed are circular
- Material is being crushed at all times at some point

- Solids are caught between V shaped space between the head and casing
- Material is repeatedly broken in sufficiently small pieces to pass out from the bottom.
- Speed of crushing ranges between 125 to 425 gyrations per minute
- Discharge from the gyratory crusher is continuous
- Less maintenance is required as compared to jaw crusher
- Power requirement is low



Crushing rolls

- Mainly used for extraction of juice from sugarcane
- Two types
 - Smooth roll crusher
 - Serrated or toothed roll crusher

Smooth roll crusher

- Two heavy smooth faced roll rotating towards each other at same speed on parallel horizontal axes
- Size of the material caught by the rolls depends upon the coefficient of friction between the material and the roll surface
- $D_p = 0.04R + g$

D_p – maximum size of particle

R – roll radius

g – half of the width of gap between the rolls

- Used to make grits or meal from food grains

- One of the rolls should be spring loaded to avoid any damage to roll surface
- Extensively used for making food grains flakes

Serrated or toothed roll crusher

- Rolls are serrated as per need
- Much more versatile than smooth roll crusher
- Best example – Break and reduction rolls of wheat milling
- Disintegrators are toothed roll crushers in which the corrugated rolls are rotating at different speeds
- Size reduction is by compression, impact and shear and not by compression alone, as in the case of smooth roll crushers
- Can accommodate larger particles than smooth roll crushers

Crushing efficiency

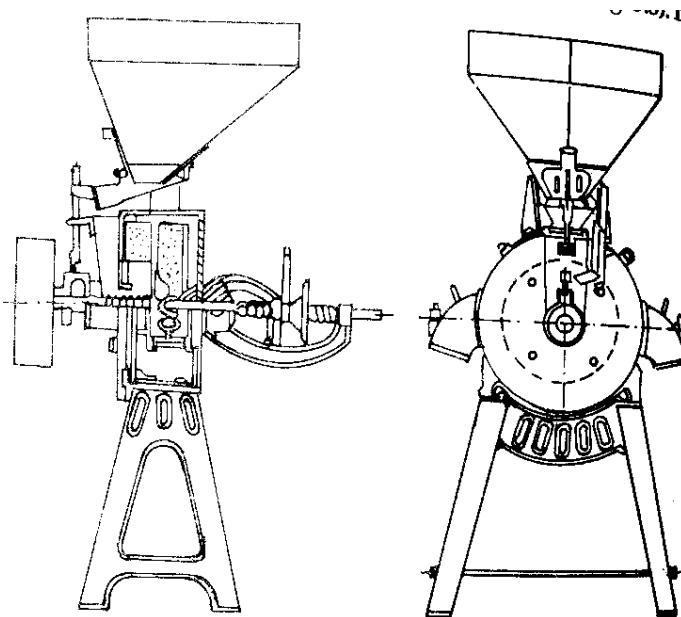
- Ratio of the surface energy created by crushing to the energy absorbed by the solid

Grinders

- Used to mill the grains into powder
- Types
 - Attrition mill
 - Hammer mill
 - Impactors
 - Rolling compression mill

Attrition mill

- Also known as burr mill
- Grains are rubbed between the grooved flat faces of rotating circular disks
- Axis of the roughened disks may be horizontal or vertical
- One plate is stationary and fixed with the body of the mill while the other one is rotating disk
- Material is fed between the plates and is reduced by crushing and shear
- Mills with different patterns of grooves, corrugations on the plates perform a variety of operations
- Overfeeding
 - lowers grinders performance
 - Increases heat generation during milling
- Disks are 20-137 cm in dia and operated at 350 to 700 rpm



- Used for making whole grain and dehusked grain flour
- Use in spice grinding is limited
- Double runner disks type attrition mills are also available
- Used for grinding of soft materials
- Both disks are driven at high speed in opposite direction
- Operated between 1200 to 7000 rpm
- Capacity is large

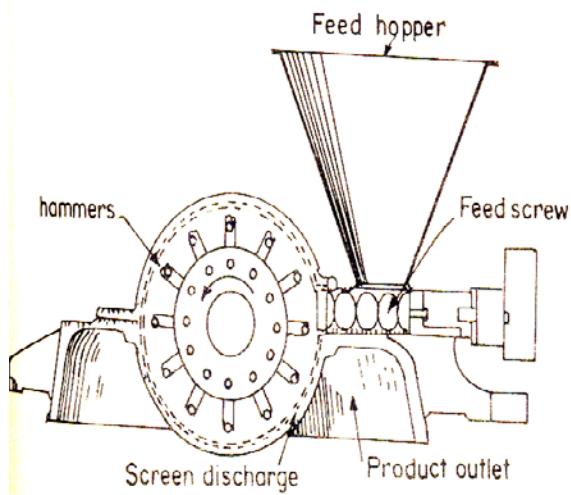
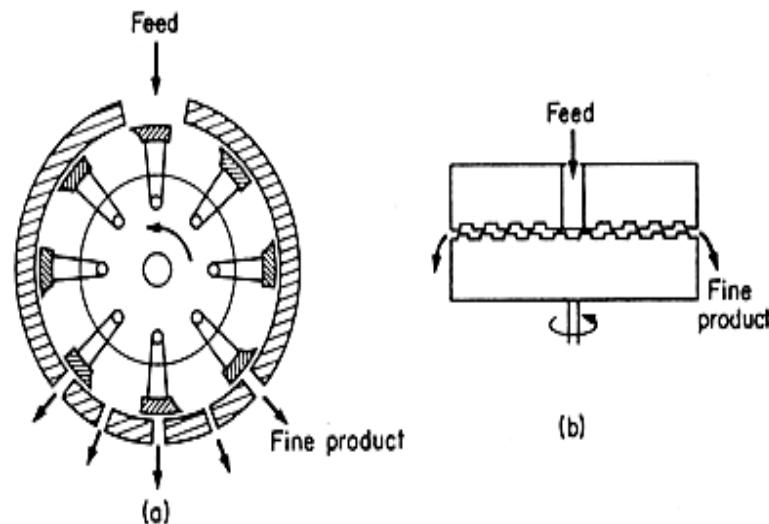
Salient features

- Fineness of grinding is controlled by the type of plates and the gap between them
- Spacing between the plates is adjustable
- Arrangement is spring loaded
 - to avoid damage to plates in case of overloading
 - to overcome the damage to plates by foreign material coming along with the feed
- Lower initial cost
- Lower power requirements

Hammer mill

- Used for various types of size grinding jobs
- Size reduction takes place by impact force
- Consists of high speed rotor rotating inside a cylindrical casing
- Shaft is usually kept horizontal

- Materials are fed into the mill from the top of the casing and is broken by the rotating hammers and fall out through a screen at the bottom
- Feed is broken by the fixed or swinging hammers, pinned to a rotor
- Hammers are rotated between 1550 to 4000 rpm, strike and grind the material until it becomes small enough to pass through the bottom screen



- Fineness of grinding is controlled by the screen size
- There is less chances of damage of hammer in swinging hammer mill
- Can grind tough fibrous solids, steel chips, food grains, hard rock etc.
- Assumed to reduce size by impact of hammers

Salient features

- Simplicity and versatility in design
- Less chances of damage due to foreign objects
- High power requirement
- Capacity and power requirement depend on the nature of feed to be ground
- Used for poultry feed grinding, spices grinding
- Suitable for grinding of wet sorghum and millets
- Also used for potato, tapioca, banana flour making

Ball mill

- ❖ Cylindrical or conical shell slowly rotating about a horizontal axis.
- Half of its volume is filled with solid grinding balls
- Shell is made of steel lined with high carbon steel plate, porcelain or silica rock.
- Size reduction is achieved by impact of the balls when they drop from near the top of the shell
- Energy consumed in lifting the balls is utilized for grinding job
- When the ball mill is rotated , the balls are carried by the mill wall nearly to the top
- Balls are released by the gravitational pull and drop to the bottom and picked up again
- Centrifugal force keeps the ball in contact with the mill wall.
- Due to centrifugal force, if the speed of rotation of mill is faster, the balls are carried to more distance.
- Centrifuging: In case of too high speed, balls stick to mill wall and are not released

Critical speed: Rotational speed at which centrifuging occurs

- At this speed, no impact occurs hence little or no grinding results
- Operating speed must be kept less than the critical speed
- Speed at which the outermost ball released from the mill wall depends on the interaction of gravitational and centrifugal forces
- Critical speed can be determined by
- $n_c = 1/2 \pi \sqrt{g/R-r}$

n_c = critical speed, revolution/sec

g = acceleration due to gravity, 9.8 m/s²

R - radius of the mill, m

r = radius of the ball, m

Roller mills

- Roller mills are similar to roller crushers
- They have smooth or finely fluted rolls, and rotate at differential speeds.
- They are used very widely to grind flour.
- Because of their simple geometry, the maximum size of the particle that can pass between the rolls can be regulated.
- If the friction coefficient between the rolls and the feed material is known, the largest particle that will be nipped between the rolls can be calculated, knowing the geometry of the particles.

CHAPTER 21: EVAPORATION – PRINCIPLES, TYPES OF EVAPORATORS

Evaporation is an operation used to remove a liquid from a solution, suspension, or emulsion by boiling off some of the liquid. It is thus a thermal separation, or thermal concentration, process. We define the evaporation process as one that starts with a liquid product and ends up with a more concentrated, but still liquid and still pumpable concentrate as the main product from the process. There are actually a few instances where the evaporated, volatile component is the main product, but we will not discuss that here.

In most cases it is essential that the product be subject to minimal thermal degradation during the evaporation process, requiring that temperature and time exposure must be minimized. This and other requirements brought on by the physical characteristics of the processed product have resulted in the development of a large range of different evaporator types. Additional demands for energy efficiency and minimized environmental impact have driven development toward very innovative plant configurations and equipment design.

In the field of thermal separation / concentration technology, evaporation plants are widely used for concentration of liquids in the form of solutions, suspensions, and emulsions. The major requirement in the field of evaporation technology is to maintain the quality of the liquid during evaporation and to avoid damage to the product. This may require the liquid to be exposed to the lowest possible boiling temperature for the shortest period of time. This and numerous other requirements and limitations have resulted in a wide variation of designs available today. In almost all evaporators the heating medium is steam, which heats a product on the other side of a heat transfer surface. The following list contains the descriptions of the most common types of evaporators.

1. Falling Film Evaporators
2. Rising Film Evaporators
3. Forced Circulation Evaporators
4. Plate Evaporators
5. Thermal and Mechanical Vapor Recompression (TVR & MVR)

Typical evaporator applications:

- Product concentration
- Dryer feed pre-concentration
- Volume reduction
- Water / solvent recovery
- Crystallization

Falling Film Evaporators

In falling film evaporators, liquid and vapors flow downwards in parallel flow. The liquid to be concentrated is preheated to boiling temperature. An even thin film enters the heating tubes via a distribution device in the head of the evaporator, flows downward at boiling temperature, and is partially evaporated. This gravity-induced downward movement is increasingly augmented by the co-current vapor flow.

Falling film evaporators can be operated with very low temperature differences between the heating media and the boiling liquid, and they also have very short product contact times, typically just a few seconds per pass. These characteristics make the falling film evaporator particularly suitable for heat-sensitive products, and it is today the most frequently used type of evaporator.

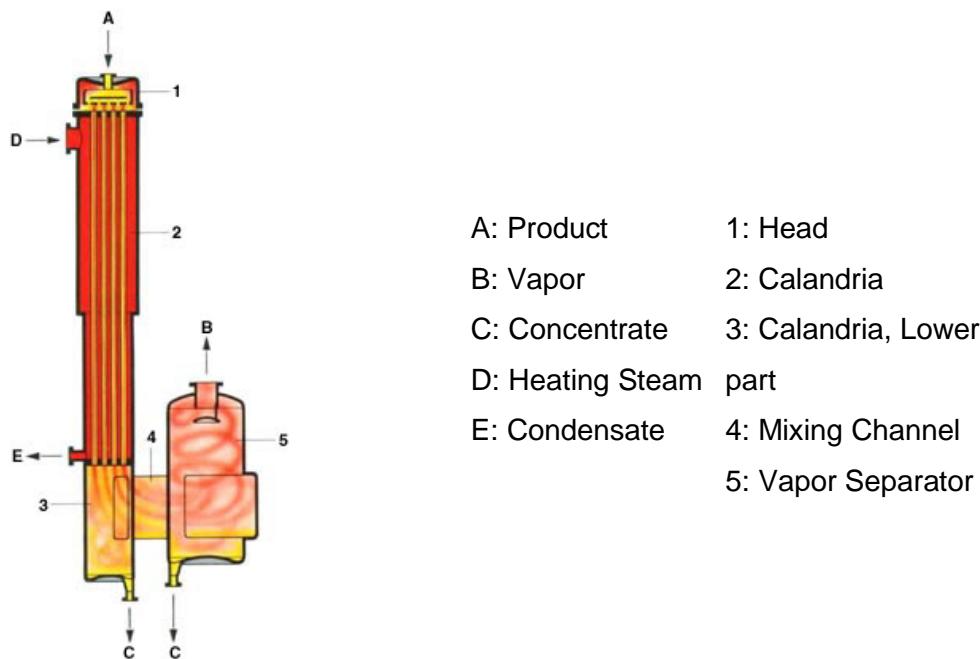


Fig. 1. Falling Film Evaporator

However, falling film evaporators must be designed very carefully for each operating condition; sufficient wetting of the heating surface by liquid is extremely important for trouble-free operation of the plant. If the heating surfaces are not wetted sufficiently, dry patches and incrustations will occur; at worst, the heating tubes will be completely clogged. In critical cases extending or dividing the evaporator effects, keeping the advantages of single pass operation, can increase the wetting rate. The proper design of the liquid distribution system is critical to achieve full and even product wetting of the tubes. Because of the low liquid holding volume in this type of unit, the falling film evaporator can be started up quickly and changed to cleaning

mode or another product easily. Falling film evaporators are highly responsive to alterations of parameters such as energy supply; vacuum, feed rate, concentrations, etc. When equipped with a well-designed automatic control system they can produce a very consistent concentrated product. The fact that falling film evaporators can be operated with small temperature differences makes it possible to use them in multiple effect configurations or with mechanical vapor compression systems in modern plants with very low energy consumption.

Rising Film Evaporators

These operate on a "thermo-siphon" principle. Feed enters the bottom of the heating tubes and as it heats, steam begins to form. The ascending force of this steam produced during the boiling causes liquid and vapors to flow upwards in parallel flow. At the same time the production of vapor increases and the product is pressed as a thin film on the walls of the tubes, and the liquid rises upwards.

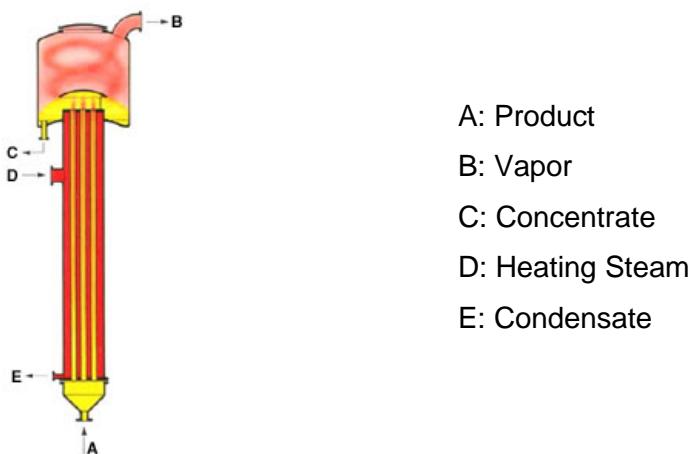


Fig.2. Rising Film Evaporator

This co-current upward movement has the beneficial effect of creating a high degree of turbulence in the liquid. This is advantageous during evaporation of highly viscous products and products that have a tendency to foul the heating surfaces. Usually there must be a rather high temperature difference between the heating and boiling sides of this type of evaporator. Otherwise the energy of the vapor flow is not sufficient to convey the liquid and to produce the rising film. The length of the boiling tubes will typically not exceed 23 ft. This type of evaporator is often used with product recirculation, where some of the formed concentrate is reintroduced back to the feed inlet in order to produce sufficient liquid loading inside the boiling tubes.

Forced Circulation Evaporator

Forced circulation evaporators are used if boiling of the product on the heating surfaces is to be avoided due to the fouling characteristics of the product, or to avoid crystallization. The

flow velocity in the tubes must be high, and high-capacity pumps are required. The circulating liquid is heated when it flows through the heat exchanger and then partially evaporated when the pressure is reduced in the separator, cooling the liquid to the boiling temperature corresponding to this pressure.

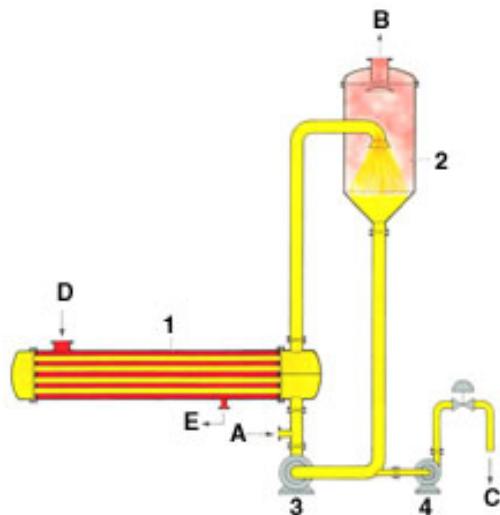


Fig. 3. D: Heating Forced System Circulation

A: Product	1: Calandria
B: Vapor	2: Separator (Flash Cooler)
C: Concentrate	3: Circulation Pump
E: Condensate	4: Concentrate Pump

on Evaporator

The liquid is typically heated only a few degrees for each pass through the heat exchanger, which means the recirculation flow

rate has to be high. This type of evaporator is also used in crystallizing applications because no evaporation, and therefore no concentration increase, takes place on the heat transfer surface. Evaporation occurs as the liquid is flash evaporated in the separator/flash vessel. In crystallizer applications this is then where the crystals form, and special separator designs are used to separate crystals from the recirculated crystal slurry. The heat exchanger (in evaporator parlance sometimes called the "calandria") can be arranged either horizontally or vertically depending on the specific requirements in each case.

Methods of Operation of Evaporators

1. Single-effect evaporators

A simplified diagram of a single-stage or single-effect evaporator is given in Fig.1. The feed enters at T_F K and saturated steam at T_s enters the heat-exchange section. Condensed steam leaves as condensate or drips. Since the solution in the evaporator is assumed to be completely mixed, the concentrated product and the solution in the evaporator have the same composition and temperature T_t , which is the boiling point of the solution. The temperature of the vapor is also T_t , since it is in equilibrium with the boiling solution. The pressure is P_1 , which is the vapor pressure of the solution at T_t .

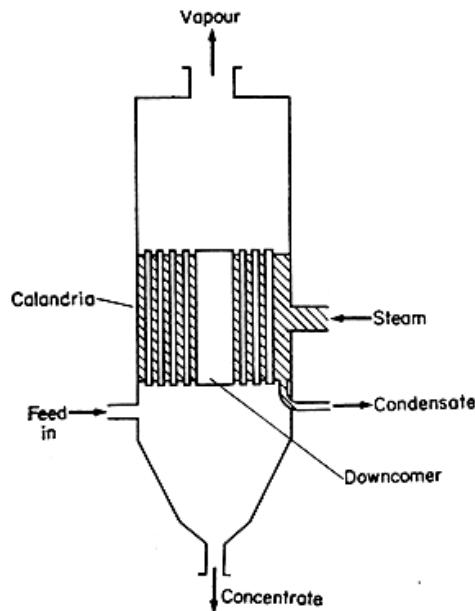
If the solution to be evaporated is assumed to be dilute and like water, then 1 kg of

steam condensing will evaporate approximately 1 kg of vapor. This will hold if the feed entering has a temperature T_F near the boiling point.

The concept of an overall heat-transfer coefficient is used in the calculation of the rate of heat transfer in an evaporator. The general equation can be written

$$q = UA\Delta T = UA(T_s - T_l) \quad (1)$$

where q is the rate of heat transfer in W, U is the overall heat-transfer coefficient in $\text{W}/\text{m}^2 \cdot \text{K}$, A is the heat-transfer area in m^2 , T_s is the temperature of the condensing steam in K, and T_l is the boiling point of the liquid in K.



Single-effect evaporators are often used when the required capacity of operation is relatively small and/or the cost of steam is relatively cheap compared to the evaporator cost. However, for large-capacity operation, using more than one effect will markedly reduce steam costs.

2. Forward-feed multiple-effect evaporators

A single-effect evaporator as shown in Fig.1 is wasteful of energy since the latent heat of the vapor leaving is not used but is discarded. However, much of this latent heat can be recovered and reused by employing multiple-effect evaporators. A simplified diagram of a forward-feed triple-effect evaporation system is shown in Fig.2. If the feed to the first effect is near the boiling point at the pressure in the first effect 1 kg of steam will evaporate almost 1 kg

of water. The first effect operates at a high-enough temperature so that the evaporated water serves as the heating medium to the second effect. Here, again, almost another kg of water is evaporated, which can be used as the heating medium to the third effect. As a very rough approximation, almost 3 kg of water will be evaporated for 1 kg of steam for a three-effect evaporator. Hence, the steam economy, which is kg vapor evaporated/kg steam used, is increased. This also approximately holds for a number of effects over three. However, this increased steam economy of a multiple-effect evaporator is gained at the expense of the original first cost of these evaporators.

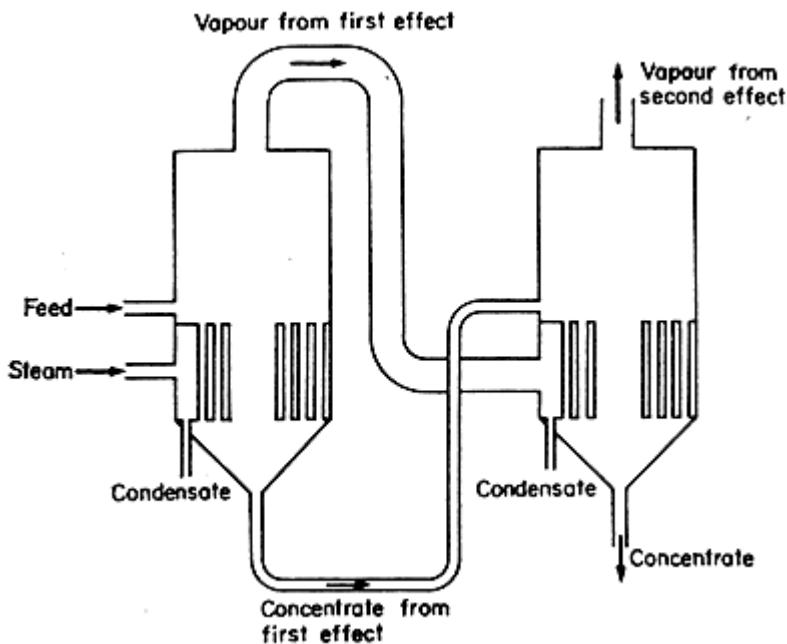


Fig 2. Double effect evaporator – forward feed

In forward-feed operation as shown in Fig.2, the fresh feed is added to the first effect and flows to the next in the same direction as the vapor flow. This method of operation is used when the feed is hot or when the final concentrated product might be damaged at high temperatures. The boiling temperatures decrease from effect to effect. This means that if the first effect is at $P_1 = 1$ atm abs pressure, the last effect will be under vacuum at a pressure P_3 .

3. Backward-feed multiple-effect evaporators

In the backward-feed operation shown in Fig.3 for a triple-effect evaporator, the fresh feed enters the last and coldest effect and continues on until the concentrated product leaves the first effect. This method of reverse feed is advantageous when the fresh feed is cold, since a smaller amount of liquid must be heated to the higher temperatures in the second and first effects. However, liquid pumps are used in each effect, since the flow is from low to high

pressure. This method is also used when the concentrated product is highly viscous. The high temperatures in the early effects reduce the viscosity and give reasonable heat-transfer coefficients.

4. Parallel-feed multiple-effect evaporators

Parallel feed in multiple-effect evaporators involves the adding of fresh feed and the withdrawal of concentrated product from each effect. The vapor from each effect is still used to heat the next effect. This method of operation is mainly used when the feed is almost saturated and solid crystals are the product, as in the evaporation of brine to make salt.

Chapter 22: FOOD STANDARDS AND REGULATIONS

U.S. FOOD SAFETY SYSTEM

The Food and Drug Administration (FDA) is charged with protecting consumers against food that is impure, unsafe, produced under unsanitary conditions, or fraudulently labeled. Through its Center for Food Safety and Applied Nutrition (CFSAN) and the Office of Regulatory Affairs (ORA), the FDA regulates both domestic and imported foods, except meat and poultry and processed eggs and has primary responsibility for enforcing food safety laws including food import and export regulations. (FDA. 2001) Some of the activities of the FDA with particular impact on imported produce include

- Inspecting food production establishments and food warehouses and collecting and analyzing samples for physical, chemical, and microbial contamination.
- Establishing good agricultural practices and good manufacturing practices and other production standards, such as plant sanitation, packaging requirements, and Hazard Analysis and Critical Control Point programs.
- Sampling and inspection of imported foods.
- Working with foreign governments (and with FDA counterparts in these countries, if they exist) to ensure safety of imported foods.
- Taking appropriate enforcement actions.
- Educating industry and consumers on safe food handling practices.

The Centers for Disease Control and Prevention (CDC) work closely with state and local public health epidemiologists and laboratories to identify illnesses and clusters of illnesses that may be food borne. CDC surveys and studies various environmental and chronic health problems and administers national programs for prevention and control of vector-borne diseases (diseases transmitted by a host organism) and other preventable conditions.(CDC. 1999)

The U.S. Department of Agriculture (USDA) has several agencies that may play a role in assuring food safety by establishing the safety of imported fruits and vegetables.

- The Agricultural Marketing Service (AMS) carries out a wide range of programs aimed at facilitating the marketing of agricultural products, assuring consumers a quality food supply, and ensuring fair trading practices. Certain agricultural commodities (including fresh tomatoes, avocados, mangoes, limes, oranges, grapefruit, green peppers, Irish potatoes, cucumbers, eggplants, dry onions, walnuts and filberts, processed dates, prunes, raisins, and olives in tins) must meet United States import requirements relating to grade, size,

quality, and maturity. These commodities are inspected and the AMS must issue an inspection certificate to indicate import compliance.

- The Foreign Agricultural Service (FAS) has primary responsibility for the USDA's overseas programs, including market development, international trade agreements and negotiations, and the collection of statistics and market information.
- The Food Safety and Inspection Service (FSIS) regulates meat, poultry and egg products and maintains a comprehensive system of import inspection and controls.
- The Economic Research Service (ERS) provides estimates of costs of food borne disease and conducts benefit/cost analyses of alternative regulatory options.
- USDA's Animal and Plant Health Inspection Service (APHIS) inspects imported agricultural products for disease and pests which might infect plants and animals. Through monitoring activities at airport terminals, seaports, and border stations, it guards U.S. borders against the entry of foreign agricultural pests and diseases.

U.S. Environmental Protection Agency (EPA) includes regulating pesticides and assuring that drinking water meets standards for health. Through the Office of Pesticide Programs (OPP), EPA determines the safety of new pesticide products, sets tolerance levels for pesticide residues in foods.

INTERNATIONAL FOOD LAWS AND REGULATIONS

Sanitary (human and animal health) and phytosanitary (plant health) standards are necessary to ensure that food is safe for consumers, to prevent the spread of pests and diseases among animals and plants and to ensure fair practices in trade. In recent years, world food trade has been profoundly altered by the adoption of agreements that provide a more precise framework for trade, and define the rights and the obligations of all partners. These agreements served to strengthen the status of institutions like the Codex Alimentarius Commission and the International Plant Protection Convention since these were used as a basis for harmonization.

THE URUGUAY ROUND AGREEMENTS

The Uruguay Round of Multilateral Trade Negotiations, which concluded in 1994, established the World Trade Organization (WTO) to replace the General Agreement on Tariffs and Trade (GATT). The Uruguay Round negotiations were the first to deal with the liberalization of trade in agricultural products, an area excluded from previous rounds of negotiations. They also included negotiations on reducing non-tariff barriers to international trade in agricultural products and concluded with two binding agreements: the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) and the Agreement on Technical

Barriers to Trade (TBT Agreement). The Agreement on the Application of Sanitary and Phytosanitary Measures confirms the right of WTO member countries to apply measures necessary to protect the life and health of humans, animals and plants (FAO, 2000).

The Agreement on Technical Barriers to Trade was established with the objective of preventing the use of national or regional technical requirements, or standards in general, as unjustified barriers to trade (FAO, 2000). The agreement covers standards relating to all types of products including industrial and agricultural products. Not covered are food standards related to sanitary and phyto sanitary measures. It includes numerous measures designed to protect consumers against deception and economic fraud. Examples of food standards covered by the TBT Agreement are those related to quality and labeling. The TBT Agreement basically provides that all technical standards and regulations must have a legitimate purpose and that the impact or cost of implementing a standard must be proportional to the purpose of the standard. It also says that if there are two or more ways of achieving the same objective, the least trade-restrictive alternative should be followed. The agreement also places emphasis on international standards and WTO members are obliged to use international standards or parts of them except where the international standard would be ineffective or inappropriate in the national situation. The TBT Agreement does not include a program for harmonizing national standards.

CODEX ALIMENTARIUS

The adoption of the SPS and TBT Agreements resulted in new emphasis and importance being placed on the work of Codex in establishing international food quality and safety standards.

Codex Alimentarius

The purpose of Codex is

- to guide and promote the elaboration of definitions and requirements for foods and assist in their harmonization
- to facilitate world trade
- to promote consumer protection

The name Codex Alimentarius is taken from Latin and translates literally as “food code” or “food law”. The Codex Alimentarius is a series of food standards, codes and other regulations adopted by the Codex Alimentarius Commission (CAC) that countries can use as models in their domestic food legislation and regulations, and which can be applied to international trade. Codex provides the assurance that any foods produced according to its codes of hygienic practices and complying with its standards are safe and nutritious and offer adequate health

protection. The CAC was created in 1962 by two United Nations organizations, the Food and Agriculture Organization (FAO) and the World Health Organization (WHO). Its main purpose is to promote consumer protection and to facilitate world trade in foods through the development of food standards, codes of practice and other guidelines (FAO/WHO, 1999). Since its inception, the CAC has been responsible for implementing the Joint FAO/WHO Food Standards Program (FAO, 2000).

The CAC is an intergovernmental body with a current membership of 165 Member governments. Membership is open to all Member Nations and Associate Members of FAO and WHO. In addition, observers from international scientific, food industry, food trade and consumer associations may attend sessions of the Commission and of its subsidiary bodies. While observer organizations can fully participate in the proceedings of the meeting, by statute, only Member governments can participate in any decision process. To facilitate international trade, it has been necessary for efforts to be made to harmonize food standards. Those involved in harmonization efforts recognized that countries have the right to adopt standards they feel are appropriate to protect human, animal and plant health and the environment. They also have the right to take the steps necessary to assure these standards are met. However, preventing these standards from becoming barriers to trade is important to promote trade between countries (FAO, 1998).

The Codex Alimentarius is a series of food standards, codes and other regulations adopted by the Codex Alimentarius Commission (CAC) that countries can use as models in their domestic food legislation and regulations, and which can be applied to international trade. Codex provides the assurance that any foods produced according to its codes of hygienic practices and complying with its standards are safe and nutritious and offer adequate health protection. The Codex Committee on Food Hygiene is currently developing a code of hygienic practice for fresh fruits and vegetables entitled "*Draft Code of Hygienic Practice for Fresh Fruits and Vegetables*". This draft code addresses GAPs and GMPs that will help control microbial, chemical, and physical hazards associated with all stages of the production of fresh fruits and vegetables from primary production to packaging. To facilitate international trade, harmonization of food standards is necessary to prevent these standards from becoming barriers to trade between countries.

INDIAN STANDARDS

There are a number of food laws being implemented by various Ministries/Departments. These are primarily meant for two purposes namely (1) Regulation of Specifications of food and (2) Regulation of Hygienic condition of Processing/Manufacturing. Some of these food laws are

mandatory and some are voluntary. The details of various food laws in operation in India are as under:-

A. Food Laws

The main Acts/Regulations/Control orders to regulate trade

- Prevention of Food Adulteration Act 1954
- Plant Quarantine (Regulation of Import into India) Order, 2003
- Meat Food Product Order 1973
- Milk And Milk Product Order 1992
- Bureau Of Indian Standards Act, 1986
- Standards On Weight And Measurement Act, 1976
- Livestock Importation Act, 1898
- AGMARK Act ,1937
- The Infant Milk Substitutes, Feeding Bottles and Infant Foods Act ,1992
- Export (Quality Control and Inspection) Act, 1963
- Essential commodities Act,1955
- Indian Explosives Act,1884
- Energy Conservation Act, 2001

1. Prevention of Food Adulteration Act (Ministry of Health)

The Act lays down specifications for various food products and is mandatory. The Ministry of Health in 1995 had constituted a Task Force. This Task Force recommended that there should be emphasis on good manufacturing practices instead of detection of adulteration and prosecution. It also expresses concern about lack of laboratory equipments and quantified persons. In addition it also suggested that the name of PFA Act be changed to Food Safety Act.

2. Agriculture Produce (Grading & Marking) Act (Ministry of Rural development)

This Act is commonly known as AGMARK and is voluntary. The Act lays down the specifications for various agricultural commodities including some processed foods.

3. Laws being operated by Bureau of Indian Standards (BIS)

BIS is the largest body for formulating standards for various food items. These standards are also voluntary.

4. Essential Commodities Act

A number of quality control orders have been issued under Essential Commodities Act such as FPO, MMPO, Meat Product Order and Vegetable Oils Control Order. These orders are mandatory and primarily meant for regulating the hygienic conditions. They need to be clubbed under one order which may called Food Products Order.

B. Harmonization of Food Laws

The review of multiple laws is necessary to have a uniform and logical approach for regulating the quality of food. The following action is being taken by various Ministries:-

1. The Ministry of Civil Supplies & Consumer Affairs has brought out a paper for consideration of Committee of Secretaries (COS). The paper recommends that BIS should formulate standards for all food items in the country. This will be a major step towards harmonization of food laws and is still under consideration of COS for finalization.
2. The Task Force had advocated promotion of food safety and quality. The Task Force has further made following suggestions
 - o Food Regulation Authority (FRA) be set up to formulate and update food standards for domestic and export market.
 - o FRA should replace the PFA to conform to international standards. The Task Force has given ten specific recommendations such as provision of storage, simplification of sampling procedure, simplification of procedure for nominee, time limit for prosecution, standard methods of analysis to be prescribed, penalty should be graded according to the gravity of offences and provision of adequate/infrastructure and laboratories.
 - o Harmonization of Indian standard with quality norms of Codex and WTO.
 - o The Central Committee of food Standard (CCFS) should be replaced by FRA Governing Body for expeditious decisions.

THE FOOD SAFETY AND STANDARDS BILL, 2005

A Bill to consolidate the laws relating to food and to establish the Food Safety and Standards Authority of India for laying down science based standards for articles of food and to regulate their manufacture, storage, distribution, sale and import, to ensure availability of safe and wholesome food for human consumption and for matters connected therewith or incidental thereto. The Central Government shall, by notification, establish a body to be known as the Food Safety and Standards Authority of India to exercise the powers conferred on, and to perform the functions assigned to, it under this Act. The Food Authority shall consist of a Chairperson and the following twenty-two members out of which one third shall be women, namely

1. Seven Members, not below the rank of a Joint Secretary to the Government of India, to be appointed by the Central Government, to respectively represent the Ministries or Departments of the Central Government dealing with
 - (i) Agriculture
 - (ii) Commerce
 - (iii) Consumer Affairs

- (iv) Food Processing
 - (v) Health
 - (vi) Legislative Affairs
 - (vii) Small Scale Industries who shall be Members ex officio
2. Two representatives from food industry of which one shall be from small scale industries;
 3. Two representatives from consumer organizations
 4. Three eminent food technologists or scientists
 5. Five members to be appointed by rotation every three years, on each in seriatim from the Zones as specified in the First Schedule to represent the States and the Union territories.
 6. Two persons to represent farmers' organization.
 7. One person to represent retailers' organizations.

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FRUIT PRODUCTS ORDER (FPO) REGULATIONS IN FOOD SAFETY

INTRODCUTION

The Food Safety and Standards Act, 2006

"An Act to consolidate the laws relating to food and to establish the food Safety and Standards Authority of India for laying down science based standards for articles of food and to

regulate their manufacture, storage, distribution, sale and import, to ensure availability of safe and wholesome food for human consumption and for matters connected therewith or incidental thereto."

The following laws were consolidated:

1. The Prevention of Food Adulteration Act, 1954 (37 of 1954)
2. The Fruit Products Order, 1955
3. The Meat products Order, 1973
4. The Vegetable Oil Products (Control) Order, 1947
5. The Edible Oils Packaging (Regulation) order, 1998
6. The Solvent Extracted Oil, De oiled Meal, and Edible Flour (Control) Order, 1967
7. The Milk and Milk Products Order, 1992
8. Any other order issued under the Essential Commodities Act, 1955 (10 of 1955) relating to food

"Food Safety" means assurance that food is acceptable for human consumption according to its intended use.

"Food Safety Management System" means the adoption of Good Manufacturing Practices, Good Hygienic Practices, Hazard Analysis and Critical Control Point and such other practices as may be specified by regulation, for the food business"

THE FOOD SAFETY AND STANDARDS AUTHORITY OF INDIA

As per the Gazette notification of India under S.O.2127 dated 28.08.2008, the activities of FPO have been transferred to the Food Safety and Standards Authority of India from 01.12.2008 onwards.

Duties and Functions of Food Authority

1. To regulate and monitor the manufacture, processing, distribution, sale and import of food so as to ensure safe and whole some food
2. To specify the standards and guidelines in relation to articles of food and specifying an appropriate system for enforcing various standards notified under this Act
3. Accreditation of certification bodies in certification of food safety management system for food businesses
4. Enforcement of quality control in relation to any article of food imported into India
5. To provide scientific advice and technical support to the Central Government and the State Governments in matters of framing the policy and rules in areas which have a direct or indirect bearing on food safety and nutrition.

ABSTRACTS OF FRUIT PRODUCTS ORDER, 1955.

CLAUSE 4(1): No person shall carry on the business of manufacture of Fruit & Vegetable Products except and in accordance with the terms of an effective licence granted to him under this order.

CLAUSE 5(2): The following fee being appropriate fees shall be payable for one term or part thereof to be paid ONLY WHEN INSTRUCTED BY THIS OFFICE.

Categories	Minimum manufacturing area, m²	Raw materials stores, m²	Finished goods area, m²	Total area, m²	Minimum height, feet	Licence fee, Rs.
HOME SCALE B: Annual Production of fruit products Except Canned vegetables Not exceeding 10 M.T.	25	10	15	50	10	100
COTTAGE SCALE: Annual Production of fruit products Exceeding 10 MT & upto 50 MT	60	20	40	120	10	250
SMALL SCALE-A: Installed Capacity of not exceeding 1 MT per day or Annual production ranging over 50 MT and upto 100 MT	100	40	60	200	14	400
SMALL SCALE-B: Installed Capacity upto 2 MT per day	150	50	100	300	14	600

And total annual production of more than 100 MT & upto 250 MT						
LARGE SCALE: Installed Capacity of more than 2MT fruit Products per day or total Annual production of 250 MT And above	300	100	200	600	14	1500

NOTE:

1. Area occupied by Machinery shall not be more than 50% of manufacturing area.
2. WATER: Every licensee shall arrange for atleast 1 Kilo litre per day of potable water and its availability. Water shall be adequately increased as per production. Free flowing pipe water supply shall be made available to the processing hall.
3. The workers engaged in Fruit & Vegetable processing shall be got medically examined for their fitness to ensure that they are not suffering from any contagious diseases.
4. For Large/Small Scale B category units, a qualified CHEMIST shall be appointed as QUALITY CONTROL INCHARGE.
5. All the workers engaged in the production of Fruit & Vegetable products shall be provided with clean APRONS AND HEADWEARS.

FRUIT PRODUCTS ORDER (FPO) 1955

- Constituted under Section3 of Essential Commodities Act
- Aims at regulating Sanitary & Hygienic conditions in the manufacture of Fruit Products.
- Mandatory for all Manufacturers of Fruit and Vegetable Products to obtain a licence under FPO.
- Implemented by the Food Safety and Standards Authority of India through Directorate of Fruit & Veg. Processing at its Regional Offices.

Products covered under FPO 1955

- All types of Processed Fruit and Vegetable products (eg:- Pickles,Jams,juices etc..)
- Sweetened aerated water
- Non- Fruit Vinegar & Non- Fruit Syrup.

Important Clauses under FPO-1955

- Clause-4:- No person shall carry on the business of a manufacturer except under and in accordance with the items of an effective licence granted to him under this order in Form-B.
- Clause-5:- Every application for grant of licence under Cl.4 shall be made in duplicates to the licensing officer in Form-A and shall be accompanied by a fee of such amount as is appropriate to the each of the clause of licence.
- Clause-7:-Every manufacturer shall manufacture fruit products in conformity with the sanitary requirements and the appropriate standard of quality and composition specified.
- Clause-9:- Every Manufacturer shall submit by the 31st of January of every year to the licensing officer a return in duplicate in Form-C in respect of each class of Fruit products manufactured, sold and exported by him during the previous term.
- Clause-12:- every manufacturer to whom any directions or order is issued in pursuance of any provision of this order shall be bound to comply with such directions or order any failure shall be deemed to be a contravention of the provisions of this order.

Documents to be submitted for grant of FPO license

- 1) Application in Form A (Copy enclosed)
- 2) Plan of the factory showing the dimensions in metres /sq.metres duly ear-marking the area for Processing, raw-materials store & finished goods Store.
- 3) List of Machinery and Equipments showing the Capacity, Horse-power Used, Number and Source of supply of each Machine.
- 4) Proof of possession of factory premises – Rental/Lease Agreement and Property Tax receipt indicating Name of Owner & address of unit .
- 5) N.O.C. from the Local Government Authority.
- 6) Water Analysis Report –Chemical & Bacteriological, from Public Health Laboratory /GOVT. APPROVED LABORATORY and the report should indicate that the water has been drawn from the factory premises either by The representative of the laboratory or by the Public Health Authority. Under remarks column, it shall clearly indicate that the water is fit for drinking purpose /Potable.

CLAUSE 7

Every manufacturer shall manufacture fruit products in conformity with the sanitary requirements and appropriate standards of quality and composition specified in the Second Schedule of this Order.

THE SECOND SCHEDULE (see Clause 7)

PART 1 (A): SANITARY REQUIREMENTS OF A FACTORY OF FRUIT PRODUCTS

1. The premises shall be adequately lighted, ventilated & cleaned by white washing/ colour washing or oil painting.
2. Windows and doors shall be fly proofed, doors fitted with automatic closing springs. Roof shall be permanent. Floor cemented.
3. The equipment and the factory shall not be used for manufacture of repugnant products like fish, meat, eggs etc., However, permission may be granted a special case if arrangements are made for disinfection of premises after changing from meat products to fruit products (One month idle gap will be required for change over).
4. The premises shall be located in a sanitary place with open surroundings, preferably in industrial area/estates. The premises shall not be used as or communicated directly with Residence.
5. Adequate arrangements for cleaning equipments, machinery, Containers, tables and raw materials shall be provided.
6. Copper, brass or iron equipments, containers or vessels are not permitted , in the preparation, packing or storage of fruit Products.
7. The water used shall be potable and shall be got examined Chemically and bacteriologically by a Public Health Laboratory (if no municipal water is available at the premises). The water sample should be drawn for such examination by the Public Health Authority of the area where the premises is located or should be drawn in the presence of the above authority. Free flowing tap water of 1 kilo litre per day shall be made available.
8. Adequate drainage system and provisions for disposal of refuse shall be made.
9. Sufficient number of laterine & urinals shall be provided for workers.
10. Wherever cooking is done on open fire, proper outlets for the smoke/steam etc., like chimney, exhaust fan etc., shall be provided.
11. The workers engaged in the factory shall be healthy and shall be medically examined, inoculated and vaccinated, whenever required.
12. The workers shall be provided with aprons, head-wears, gloves etc., and shall be personally neat and tidy.

Grant-in-aid: For setting up or up gradation of food processing units, Ministry of Food Processing Industries is giving grants. More details can be obtained from the Ministry's web site – www/mofpi.nic.in

Office Details:

The enforcement of FPO 1955, is being carried out from four regional offices located at

1. New Delhi
2. Mumbai
3. Kolkatta
4. Chennai
5. Guwahatti

The jurisdiction of our office covers Southern States of India *i.e.* Tamil Nadu, Kerala, Karnataka, Andhra Pradesh, Pondicherry and Lakshadweep.

Southern Regional Office is located at

Office of the Deputy Director(F&VP)
Food Safety And Standards Authority Of India,
C-1-D, Rajaji Bhawan, Besant Nagar,
Chennai-600 090
Tel:- 044-24912421, Fax:- 044-24463569

Address of the Food Safety and Standards Authority of India

Food Safety and Standards Authority of India
Ministry of Health and Family Welfare, Government of India,
FDA Bhawan,Kotla Road, New Delhi-110002
Website: www.fssai.gov.in; Tel: 011-23220992