A Practical Manual on

Agricultural Structures And Process Engineering

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Preface

The authors are engaged in research as Ph.D. Scholars at ICAR- IARI, New Delhi. All the authors contributing to the manuscript are engaged in the sub discipline of agricultural processing and Structures. The manuscript contains practical experiments related to field of agricultural processing and agricultural structures. The manuscript will be beneficial to the entire fraternity of students, teachers and researchers engaged in the concerned discipline. The authors have attempted to put the practical experiments in a precise manner. Sample problems have been included after every practical in order to gain a comprehensive understanding of the practical subject. The authors believe gaining a practical knowledge of the subject is the uttermost important pillar for the development of skills and entire upliftment of the discipline.

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Suggestions for the refinement and betterment of manuscript are always welcome.

Content

Practical - 1

A Performance Evaluation of Different Types of Cleaners, Separators and Determination of Separation Efficiency

Objective: To study the different types of cleaning equipment for grains.

Theory: Cleaning and grading are the first and most important post-harvest operations undertaken to remove foreign and undesirable materials from the threshed crops/grains and to separate the grains/products into various fractions. The comparative commercial value of agricultural products is dependent on their grade factors. These grade factors further depend upon.

1) Physical characteristics like size, shape, moisture content, colour, etc.
2) Chemical characteristics like odour, free fatty acid content
3) Biological factors like germination, insect damage

A mixture of seeds can be separated on the basis of difference in length, width/thickness, specific gravity, surface texture, and drag in moving air, colour, shape, electrical conductivity and magnetic properties.

Cleaning in agricultural processing generally means the removal of foreign and undesirable matter from the desirable grains/products. This may be accomplished by washing, screening, hand picking, etc.

Grading refers to the classification of cleaned products into various quality fractions depending upon the various commercial values and other usage.

Sorting refers to the separation of cleaned products into various quality fractions that may be defined on the basis of size, shape, density, texture and colour.

Scalping refers to the removal of few large particles in an initial process.

Screening is a method of separating grain/seed into two or more fractions according to size alone. For cleaning and separation of seeds, the most widely used device is screen. When solid particles are dropped over a screen, the particles smaller than the size of screen openings pass through it, whereas larger particles are retained over the screen or sieve. A single screen can thus make separation into two fractions. When the feed is passed through a set of different sizes of sieves, it is separated into different fractions according to the size of openings of sieve. Screens along with an air blast (air screen) can satisfactorily clean and sort most of the granular materials. The screens are generally suspended by hangers, and when this unit is oscillated by an eccentric unit they have a horizontal oscillating motion and at the same time a smaller vertical motion. These two motions cause grains to travel downward to the screen and at the same time the grains are thoroughly stirred during the passage.

Equipment for cleaning

It is very difficult to clearly differentiate among the processes of cleaning, grading and separation because all of these are carried out simultaneously with the common procedures.

The operation of cleaning, grading and separation of the products are performed by exploiting the difference in engineering properties of the materials. These products may be used either for food or seed purposes. Various types of cleaning, grading and separation equipment have been designed and developed on the basis of properties of product to be handled. Thus, these equipments can be classified based upon the following characteristics of the material.

1) Size
2) Shape
3) Specific gravity or weight
4) Surface roughness
5) Aerodynamic properties
6) Ferro-magnetic properties
7) Colour
8) Electrical properties

Air-screen cleaners: A single screen can make the separation into two fractions. The screening unit may be composed of two or more screens as per the cleaning requirement. This equipment is made of mild steel. The separation takes place due to difference in size of grain and foreign matter. The cleaner is operated by hanging on an elevated point with the help of four ropes. Grain is fed on the screening surface in batches. The screens can be changed as per the grain to be handled. The cleaner is swung to and fro till all the grain is screened. The cleaned grain is retained by the bottom sieve which can be discharged by pulling a spring loaded shutter. Impurities of larger size, stubbles, chaff, etc., are retained on the top sieve and can be removed easily. Downstream from the bottom sieve consists of dust, dirt, broken, shrivelled grain, etc., which drop down during the operation.

The screens used in combination with air blast perform satisfactory cleaning and separation operations for most of the granular materials. The air-screen cleaner uses three cleaning systems; blower or aspirator, upper screens and lower grading screens. The air-screen grain cleaner can be classified in two distinct types:

Vibratory air-screen cleaner: The screening unit is composed of double or multiple (up to 8 number) screens. These screens are tightened together and suspended by hangers in such a manner that these have horizontal oscillating motion and slightly vertical motion. These two motions in combination move the grain down the screen and at the same time toss sufficiently above the screen so that the bed of grain is properly stirred. The slope of the screen is adjustable to control the rate of downward travel of the grain. The screens are available in various shapes like; round, triangular or slotted holes as discussed earlier. Sometimes the holes of the screen are clogged when fine degree of sorting is made by the machine. To avoid the clogging, the screens are generally fitted with a brush which moves under the screen and pushes the clogged material back through the screen. Other such devices can also be used for this purpose.

A simple vibratory type air-screen cleaner is having two screen machine fitted with aspirator to suck the lighter materials. The grain passes from the feed-hopper over baffle plates to the upper screen. Light particles are sucked away by aspirator during the operation. Coarse impurities such as stones, straw particles, etc., are screened off by upper screen and discharged out through an outlet. The grain falls through on to the lower screen, where the sand and the dust particles are screened off. The grains leave the machine through discharge funnel. While passing through the funnel the grains are again cleaned by upward draft of air in the ascending separator. During this process the remaining light impurities and shrivelled grains are sucked away and the light impurities are removed by a cyclone separator to which dust bags are attached for the collection of the impurities.

Such cleaners can also be operated manually either using hand or pedal system. But the capacity of cleaners is lower than the power operated machines. The machine is made up of mild steel and consists of a grain hopper, with feeding mechanism, sieve box on hanging shoes, blower unit, driving and eccentric unit. The machine can be operated either manually (pedal) or electric motor.

Rotary screen cleaner: The rotary screen cleaner has normally circular decks. Their motion is circular in horizontal plane. These have either single or double drum. A single drum rotary screen cleaner is shown below.

The machine consists of a rotary screen, aspirator and hopper and equipped with an electric motor which gives drive to the rotary screen and the aspirator. The mixture is fed into the hopper.

The sound grains pass through the screen perforations into the centre of the screen drum, whereas oversized material is retained above and passed out though an outlet. The sound grains come out at the centre side of the screen drum rotating at low speed and fall onto the vibratory screen which removes the dirt particles. The light particles like straw and dust are sucked away by the aspirator and discharged through the aspirator outlet. The cleaned grains are delivered through the discharge chute.

A double drum rotary screen cleaner has two rotary screens and other components are same as in the case of single drum rotary screen cleaner. The two screens rotate in opposite direction to each other.

Study questions

1. Draw neat labelled diagram of hand operated double screen cleaner, Vibratory air screen cleaner, pedal operated air screen cleaner and single drum and double drum rotary screen cleaner?

Practical - 2

Study of Grain Grading Equipments

Objective: To study the different types of grading equipment for grains

Theory: The grader performs the separation according to size alone. The mixture of grain and foreign matter is dropped on a screening surface which is vibrated either manually or mechanically. A typical seed grader consists of a hopper, feed roller for controlling the feed rate, set of three sieves, pulley, eccentric system, outlets, frame and electric motor. The sieves are detachable and can be replaced by suitable sieves if other round grains are to be graded. The seed is put into the hopper and it is dropped onto the sieve though feed rollers. Sieves are vibrated through an eccentric system. Graded seeds are collected through three different spouts. The machine is suitable for grading of food grains.

The schematic diagram of a groundnut grader consists of a feeding hopper, two oscillating sieves, brushes below the sieves to avoid clogging, frame and an electric motor. There are two oscillating sieves which are oscillated by the eccentric mechanism. At the head end of the sorting sieve, a spreader is provided to create uniform layer for efficiency in grading. The machine grades groundnut pods/kernels into three distinct grades according to size e.g., Grade-I, Grade-II and rejects. Oscillating sieves are replaceable by different grades depending upon the groundnut varieties to be graded.

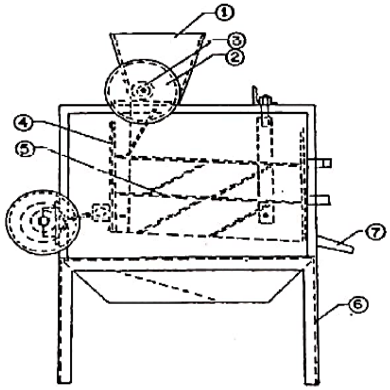


Fig 1: Schematic diagram of a seed grader

1. Hopper
2. Pulley
3. Feed roll
4. Hanger
5. Sieve
6. Frame
7. Seed outlet

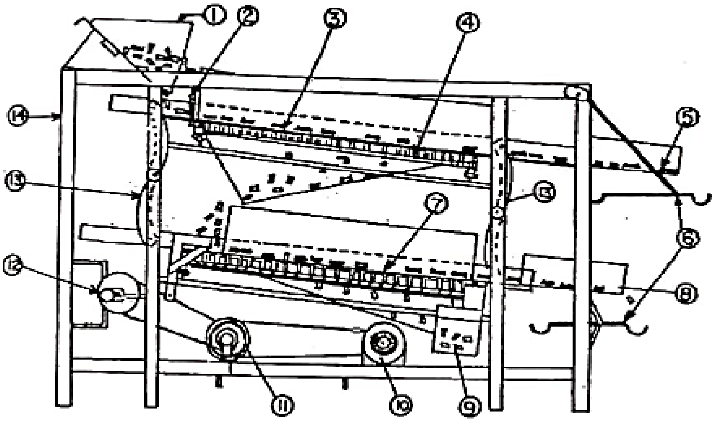


Fig 2: Schematic diagram of a groundnut grader

1. Hopper
2. Damper
3. Top sieve
4. Sliding brush
5. Grade
6. Gunny bag holder
7. Bottom sieve
8. Grade II
9. Rejects
10. Electric motor
11. Stepped cone pulley
12. Eccentric
13. Bell crank lever
14. Frame

Observations and calculation

Weight of the grain taken (W) =

Time taken for cleaning and grading (T) =

Fraction of good grain in feed (X) =

Fraction of good grain in grain outlet (Y) =

Fraction of good grain in impurity outlet (Z) =

Capacity of cleaner = (W)

Effectiveness of cleaning =

$$= \frac{(X-Z)\ Y\ (Y-X)\ (1-Z)\ x\ 100}{(Y-Z)^2 (1-X)\ X}$$

Practical - 3

Performance Evaluation of Indented Cylinder and Screen Precleaner

Objective: To determine the cleaning efficiency of indented cylinder pre-cleaner for grains.

Theory: The cylinder sorter consists of a horizontal cylinder with indents on the inside surface. The indents, which are approximately hemispherical in shape, pick up grains from the mixture in the cylinder. The grains that are wider roll out of the indents before they have been lifted sufficiently to fall past the separating edge, S. The grains of smaller width are elevated a greater distance prior to falling and are deposited in the centre trough for removal or additional treatment. Separation is made on the basis of length of grain. Length is also a separating factor since long grains or foreign material in the form of sticks and stalks are not picked up by the indents. Fineness of separation is controlled by moving the separating edge, S. The higher the edge, the shorter the length of the grain that is removed. The speed of the cylinder which is usually standardized by design is an important performance factor since centrifugal force, which is related to speed, tends to keep the grains in the pockets. The point of discharge is raised as the cylinder speed increases.

This sorting machine is especially useful for cleaning and sorting the grain into grade fractions, particularly the sorting, where large quantities of specific materials are handled. Milling and seed enterprises and terminal grain elevators are examples. Even though each machine is fixed as regards size of indents and speed of operation, wide flexibility of use is possible. For example, a single machine will handle cleaning and grading operations pertaining to barley, wheat, rye, and oats.

The disc separator separates on the basis of grain length. The pockets, which are slightly undercut as shown in the figure, can pick up and retain short grains, but long grains fall out. It is especially adapted for removing dissimilar materials. For example, wheat, rye, cockle, wild peas, mustard, wild buckwheat, pigeon grass, pin oats, and barley can be removed from oats. Similar separations can be made from other grains.

The mix to be separated is moved through the machine by flights on the disc spokes. The material (which may be either desirable or undesirable) not lifted by the discs is tailed from the end of the separator. A number of distinct separations can be made in a single machine by installing banks of discs with different characteristics. The pockets in the first bank of discs are smaller than the second bank so that the smallest material is removed first. The second bank has larger pockets than the first, and the next larger fraction is removed next. The largest grains pass through the centre of the discs and are tailed from the machine.

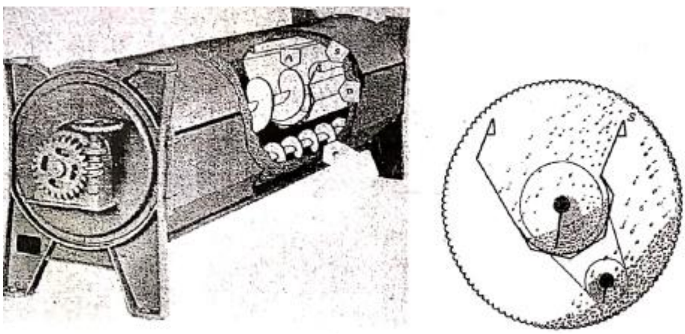


Fig 3: Cross section and phantom view of a cylinder sorter

Disc and cylinder separators have high capacity. Since all the moving parts are rotating rather than reciprocating, long life and moderate power requirements are characteristic. Each machine is fitted with a cylinder or discs having fixed characteristics. Consequently, these separators are not as versatile as certain other sorters. Even so, a single machine can be used for a sufficient number of separations to make it a general utility machine for a milling or seed-processing enterprise.

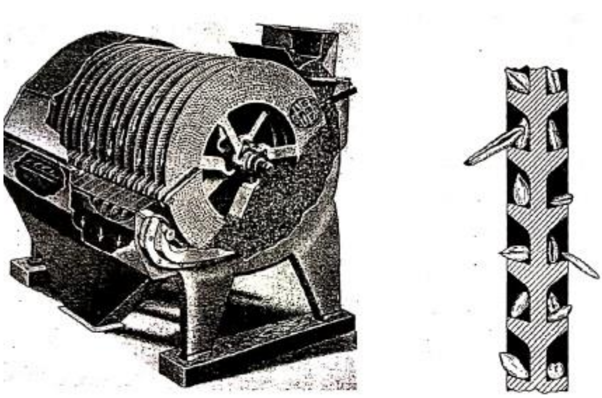


Fig 4: Disc separator and cross section of disc pockets or indents

Observations and calculation

Weight of the grain taken (W) =

Time taken for separation (T) =

Fraction of good grain in feed (X) =

Fraction of good grain in grain outlet (Y) =

Fraction of good grain in impurity outlet (Z) =

Capacity of spiral separator =

Effectiveness of spiral separator = $\frac{(X-Z)\ Y\ (Y-X)\ (1-Z)\ x\ 100}{(Y-Z)^2 (1-X)\ X}$

Results

1) Capacity of spiral separator =
2) Effectiveness of spiral separator =

Practical - 4

Measurement of Colour

Objective: To determine the colour of the fruits & vegetables.

Materials required

1. Sample
2. Balance
3. Colorimeter

Procedure

1. The Colour measurements were made using the colorimeter CR200b (Minolta Chroma Instrument, Osaka, Japan) holding the sensing head directly on the cube
2. It is lightweight, compact tristimulus colour (L*, a*, b*) (red, green and blue) analyzer for measuring reflected light colour
3. It combines advance electronic and optical technology in a hand held unit to provide high accuracy and complete portability
4. Using an 8 mm diameter (measuring area) diffused illumination and a viewing angle, the Chroma meter takes accurate colour measurements instantaneously and the readings displayed
5. A pulse xenon are (PXA) lamp in a mixing chamber provides diffused lighting over the sample surface. Six high sensitivity silicon lightning over the sample surface. Six high sensitivity silicon photocells, filtered to match the CI (Commission international l'Eclairage) standard observer responses, were used by the Chroma meter thus detects any slight variation in the spectral power distribution of the PXA lamp, and compensates automatically
6. Chromaticity may be measured either as YXy (CIE, 1931) or L*, a*, b*) (CIE,1976) coordinate and the colour difference could be in tems of (Yxy)
7. (L*, a*, b*) or (E a b) data can be converted between coordinate system or between chromatically y and colour difference measuring

modes by the meter. The CR-200b also offers a choice of either CIE illuminate C or D65 lighting conditions and in the present experiment, the CIE illuminate was used. After initial calibration of the meter was placed on the plant leaves and samples were measured in terms of Yxy, L* a* b* and AE

8. The fresh and dehydrated leaves from each replicate sample were measured for

L* = ([-] to [+] lightness co-ordinate)

a* = (green [-] to red [+] colour space coordinate)

b* = (blue [-] to yellow [-] colour space coordinate)

Three measurements made on each face of the leaves. The L* a* and b* readings were recorded and later statistically.

Results

Sample number	L	a*	b*	Remarks
1.				
2.				
3.				
4.				
5.				

Practical - 5

Measurement of Hardness of the Food Product

Objective: Determination of hardness of given food material.

Theory

Solid foods are generally characterized in terms of stress – strain relationship. The stress may be of tensile, compressive, tangential (shear) or torsional (acting on a transverse cross section). The classification of solid foods is even more hazy than that of fluid foods. There are two major groups: elastic and non-elastic. Viscoelastic foods, mostly of semi-solid and solid nature, form an important group of non-elastic foods. Hardness is a measure of the resistance to localized plastic deformation induced by either mechanical indentation or abrasion.

Materials required: Sample, Hardness, tester (Texture analyzer) and plates.

Procedure

1. The hardness test of solid food was conducted using standard techniques (AOAC 1980)
2. Keep a sample of 2.5 m^3 of solid food breaks
3. The force applied till the solid food breaks
4. The reading displayed and recorded indicates the force applied to sample
5. The experiment was repeated at different sample
6. The average is directly gives hardness of the material which is expressed in terms of total load applied per unit area (kg/cm^2)

Fig 5: Chatillon MT150 manual food texture tester

Result: Hardness of given sample is as follows:

SL. No.	Sample	Trial number	Hardness (kg/cm^2)
1.		1	
		2	
		3	
2.		1	
		2	
		3	
3.		1	
		2	
		3	
4.		1	
		2	
		3	

Practical - 6

Determination of Specific Gravity

Objective: To determine the volume, density and specific gravity of the fruits and vegetables by platform scale method.

Theory: Density and specific gravity of food material and agricultural product play an important role in Drying, storage, design of silo and bin, separation of undesirable material, determining of purity of seed and texture and softness of fruits. The simple technique platform scale is use for measurement of specific gravity of large object such as fruits and vegetables.

Materials required: Sample, Platform scale, Water, Balance and etc.

Procedure

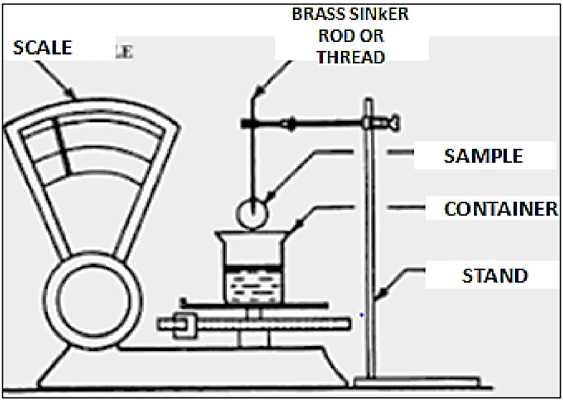


Fig 6: Platform scale for measurement of volume and density and specific gravity

1. The fruit is first weighted on the scale in air
2. The fruit is forced into the water by means of sinker rod because it is necessary to whole mass is entirely should be in the water for correct measurement
3. The volume of liquid is computed by the determining the mass of displaced water and dividing by the known density of water
4. The mass of water the displaced water is the scale's reading with the object submerged minus the mass of the container and water

Formula used for calculate the volume of displaced water:

Volume (m^3) = $\frac{mass of displaced water (kg)}{density of water\ (kg/m^3}$

5. After knowing the weight of fruit in air and the volume, weight of density of fruit is then obtained by the ratio of weight to volume
6. The specific gravity is determined after the getting of all values which is required to find out the specific gravity by the formula

Specific gravity =$\frac{Weight\ in\ fruit\ in\ air \times Specific\ gravity\ of\ water}{Weight\ of\ displaced\ water}$

Practice problem: Determine the volume and specific gravity of an apple, using the platform scale method. Assuming a specific gravity of 1.0 and a weight density of 70.4lb/ft^3 for water.

Practical - 7

Single Effect Evaporator

Objective: To determine the overall heat transfer co-efficient, Mass balance and Enthalpy balance of single effect evaporator.

Theory

When one of the components in the solution is non-volatile, the principle of evaporator is used to separate the volatile component from non-volatile component. During evaporation process, concentration of the noon-volatile component increases. The evaporator provides the necessary heat transfer interface to boil off the volatile component. Assuming that the heat losses to the surrounding are negligible compare to the extent heat transfer in the evaporator, the heat transfer coefficient can be established by setting up simple material balance and energy balance equations.

The general equation can be written as,

$Q = UA\Delta T = UA\ (T_s - T_1)$

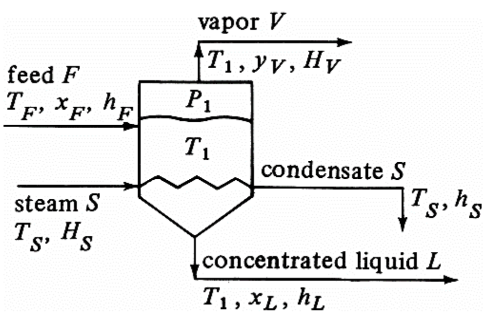
Q = Rate of heat transfer (W)

A = Heat transfer area (m^2)

Ts= Temperature of the condensing steam (K)

T_1 = Boiling point of the liquid (K)

U = Overall heat transfer coefficient (W/m^2K)



F = Feed rate (kg/h)

X_F = Solid fraction in feed (%)

V = Water vapour removed from evaporator (kg/h)

X_L = Solid fraction in product (%)

L = Production rate (kg/h)

S = Steam supplied (kg/h)

T_F = Temperature of feed (K)

T_2 =Boiling point of solution at pressure P (K)

T_S = Saturation temperature (K)

h_F = Enthalpy of feed (J/kg)

H_L = Product enthalpy (J/kg)

H_S = Enthalpy of saturated steam at temperature Ts (J/kg)

Hs = Enthalpy of condensate steam at temperature T_S (J/kg)

H_V = Enthalpy of vapour

Applying the mass balance around the evaporator

Overall mass balance,

$F= V+ L$

Mass balance for the water component

$F (1- X_F) = L (1-X_L) +V$

For solutes, the mass of solid entering the evaporator equals to the mass of solids leaving the evaporator:

$FX_F = LX_L$

Energy balance

Assuming that there is a negligible heat losses from the evaporator, the heat balance state that Total heat entering = Total heat leaving

$Fh_{F} + SH_S = Lh_L+ VH_V + Sh_S$

$S(H_S - h_S) = Lh_L+ VH_V + Fh_F$

$S\lambda s = Lh_L+ VH_V - Fh_F$

Where, λs = latent heat at saturation temperature Ts and it can be obtained from steam table. If heat capacity of feed and product (i.e. C_{PF} and C_{PL}) known, the can be used to calculate enthalpy.

Sample problem: A single effect evaporator is fed with 5000 kg/h of solution containing 1% solute by weight. Feed temperature is 303 k (30 ºC) and is to be concentrated to a solution of 2% solute by weight. The evaporation is at atmosphere pressure (101.325 kPa) and area of evaporator is 69m^2. Saturated steam is supplied at 143.3 kPa as a heating medium. Calculate steam economy and overall heat transfer coefficient.

Available data,

Enthalpy of vapour at 101.325 kPa = 2676.1 kJ/kg

Enthalpy of saturated steam at 143.3 kPa = 2691.5 kJ/kg

Saturation temperature of steam = 383 k (110 ^oC)

Boiling point of saturation = 373 k

Enthalpy of saturated water at 383 k = 461.30kJ/kg

Sample problem

A single effect evaporators to concentrate 20000kg/h of solution shaving a Concentration of 5% salt to a concentration of 20% salt by weight. Steam is fed to the evaporator at a pressure corresponding to the saturation temperature of 399 K (126 ^oC). The evaporator is operating at atmospheric pressure and boiling point rise 7K. Calculate the Heat Load and Steam Economy.

Available data,

Feed temperature = 298 K (25 ^oC)

Latent heat of condensation of steam at 399 K = 2185 kJ/kg

Latent heat of vaporization of water at 373 K = 2257 kJ/kg

Specific heat of feed = 4.0 kJ/kg K

Practical - 8

Study on Drying Characteristics of Grain

Objective: Drying characteristic and determination of drying constant

Materials required: Lab model thin layer dryer, grain, thermometer, oven, weighing balance etc.

Theory: The drying characteristics curve is the plot drawn between the time of drying and the corresponding moisture content and the rate of removal of moisture. The thins layer drying (model) is used to determine the drying constant. This system refers to the drying of grains fully exposed to the ventilating air causing all grain to dry uniformly throughout the drying layer. The moisture carrying capacity of air does not change considerably while passing through the product. The feature of this method of grain drying air:

a) Limited up to 20 cm of grain depth

b) Drying rate is independent of air velocity

c) At a given RH, the drying rate is proportional to the difference between the dry bulb temperature of air in equilibrium with the grain

d) The rate of drying is proportional to the difference between vapour pressure of grain pressure of grain and vapour pressure of drying air

The equation representing the movement of moisture during the falling rate period for the given conditions of drying air is given by the formula

$$\frac{dM}{d\theta} = -k(M - Me)$$

$$\frac{dM}{M-Me} = -k\, d\theta$$

$$\frac{M-Me}{Mo-Me} = e - k\theta$$

Where,

$dM/d\theta$ = Rate of drying h^{-1}

M = Moisture content of grain at any time θ

Mo = Initial moisture content of grain

Me = Equilibrium moisture content

θ = time in h

K = Drying constant, h^{-1}

Model description

The lab model thin layer dryer of a blower heater assembly, plenum chamber and holding bin. The blower used is a built-in type, run by a single phase electric motor and has provision to adjust the air flow rate at the suction side. The delivery end is connected to the heater assembly. The heater assembly is made in the cylindrical shape and 3 No. of heating coils of capacity 1000 W each has been provided and connected in series. The other end of the heater assembly is connected to plenum chamber.

At the inlet of the heater assembly an orifice is provided to measure the airflow rate with the help of a U- tube manometer in term of velocity head. In the plenum chamber a container is provided to hold the grain to be dried. This container can be removed at periodical intervals for weighing the grain along the bin to avoid spilling of grain during handling/transferring.

A stem type thermometer is provided in the plenum chamber' and connected in the circuit to control the temperature of hot air. Timer switch is also provided, in the circuit to put off the complete equipment at the desired time interval of drying.

Procedure: The empty weight of the grain holding container and weight of sample taken for drying is noted. To determine initial moisture content, minimum three samples of 10 grams each are taken and kept in the oven at 130±2 °C for one hour.

The container with grains is placed in the plenum chamber and drying allowed taking place at desired airflow rate and temperature of hot air by keeping the time switched at desired time interval of 10 minutes. For every 10 minute interval, temperature of air at inlet, hot air and exhaust air from container are recorded. The change in weight at every 10 minutes is also recorded, until a constant value is reached.

Calculations

Sl. No.	Time	Initial wt.	Final wt.	Temp. of air °C (t_0)	Temp. of hot air °C (t_1)	Temp. of exhaust air °C (t_o)
1.						
2.						

3.						
4.						

Initial moisture content if sample = M_i % (db) = W_m/W_d

Weight of grain taken for drying = W kg

Dry matter W kg of grain (W_d) = $\frac{Wd}{Wm+Wd} \times W$ kg

Where,

W_d = Dry weight in the sample (Wd)

W_m = Weight of moisture in the sample (W_m)

Moisture content at a time θ (Mθ) = $\frac{W\theta - Wd}{Wd} \times 100\% \ (db)$

Where,

W θ = Weight of grain at time θ

Drying rate at time θ = ----------------- kg/m^2

A × θ

Where,

A = Area of drying bin (m^2)

Drying constant = ------------------ hr^{-1}

Practical - 9

Determination of Equilibrium Moisture Content and Equilibrium Relative Humidity

Objective: To Determine the equilibrium moisture content and equilibrium relative humidity of grain.

Material requirement: Incubator, hot air oven, desiccator, sulphuric acid, weighing balance, etc.

Theory: When a solid is exposed to a continual supply of air at constant temperature and humidity, having a fixed partial pressure of the vapour, p the solid will either lose moisture from air until the vapour pressure of moisture of the solid equal partial pressure of the vapour. The solid and the gas are then in equilibrium, and the moisture content of the solid in equilibrium with the surrounding condition is known as equilibrium moisture content (EMC).

Methods for determination of EMC

The methods of determination of EMC of food materials can be categorized into two:

1) Static method
2) Dynamic method

In the static method, food is left in the air with known temperature and humidity until it attains equilibrium, while in the dynamic method the conditioned air is agitated or moved by mechanical means and the food attains equilibrium condition further.

Static method

In static methods, to bring the atmospheric air to desired relative humidity levels different concentrations of acids or salt solutions are used. Static methods are generally time consuming, and to bring the food to equilibrium condition, 3-4 weeks are required. Thus in case of high humidity and high temperature conditions, chances of attack of moulds are high. Decomposition and change in food structure is also possible. It is essential to maintain the required humidity and temperature conditions of air throughout the test period. Temperature is normally maintained using an incubator or oven where as relative humidity is maintained using acid/salt solutions in desiccators.

Dynamic method

The following methods are being followed in determination of EMC by dynamic method.

Desorption method

The property of dry air to absorb moisture from moist foods is employed. Most foods are put in an airtight container. When the air comes in equilibrium to food its relative humidity is measured by a hygrometer. Since the container has small quantity of air, it reaches equilibrium with the food within a short period.

Isoteniscope method

This method also employs absorption of moisture by dry air to determine EMC of the food material. But in this method arrangement is available to measure directly the vapour pressure exerted by the moist foods.

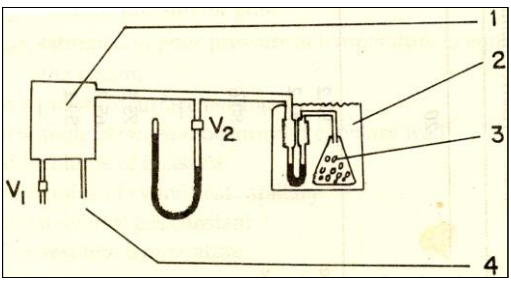


Fig 7: Schematic diagram of an isoteniscope

1) Vacuum storage jar
2) Constant temperature water bath
3) Sample flask
4) Vacuum pump

The food sample is kept in a conical flask. Isoteniscope is a U tube filled with the liquid of negligible vapour pressure. The arms of the tube has an enlarged section above the level of liquid to prevent drawing of liquid out of the tube while evacuating or readmitting air to the flask. The Isoteniscope is connected to a vacuum pump through a vacuum storage jar. Atmospheric pressure can be brought back into this jar by means of a valve 'V1'. The 'V2' is a shut off valve connecting closed while all air is evacuated from the flask, the vacuum storage jar, and from the system. Under this condition, vapour pressure builds up in the flask, which forces the liquid in the two arms of the Isoteniscope to dissimilar level. Bleeding a small amount of air into the vacuum storage jar then equalizes the level of the liquid. This equalization pressure is continued until vapour pressure buildup in the flask has reached the maximum for the temperature of water bath. Valve 'V2' is then closed and the absolute pressure indicated in the manometer is read. The isoteniscope is removed from the flask and a properly weighed stopper closes the flask. The weight of flask with sample is recorded to determine sample moisture content.

Procedure: select various humidities in the range of 10-100. Prepare chemical solution to maintain different relative humidities. The solutions can be prepared from either saturated salt solutions or sulphuric acid solutions of various concentrations. Fill the bottom portion of desiccator with the solution to maintain constant relative humidity above it. Place a non-corrosive wire mesh on a tripod stand in the desiccator with 'grease' lubricating oil and place the desiccator in a constant temperature environment.

Mathematically the equilibrium moisture content is calculated by the Henderson's formula at a particular relative humidity.

Henderson Equation: Henderson developed the following equation to determine the equilibrium moisture content.

$$1 - rh = e{-}CTMe^{n}$$

Where,

Rh = Relative humidity, decimal

T = Absolute temperature, °K

Me = EMC, % (db)

C and n = Constant, dependent on crop type and temperature.

Sample problem: Calculate the EMC of brinjal seed at relative humidity of 10% and temperature of 50 °C using Henderson's equation. Given that constant c is 6.5×10^{-6} and n is 1.8.

Sample problem: Calculate the EMC of the sunflower seed at relative humidity of 50% and temperature of 40 °C using Henderson's equation. Given that constant c = 2.32×10^{-5} and n = 1.68.

Practical - 10

To Study the Milling Quality of Paddy

Objective: To determine the milling efficiency of rice.

Materials required: Paddy sample, Measuring tape, balance, Scale, Huller Electric motor and Tachometer.

Procedure

1. Examine the screen, huller blade and belts are in right position
2. Weight a known quantity of paddy and pour into the hopper
3. Keep the huller gate 1/4th open
4. Connect the electric motor to the power source and start the huller
5. Output can be get in two outlets
6. One outlet to collect a mixture of brown rice/ raw rice, broken rice, husk and un-husked paddy
7. Other outlet (a bottom of huller) to collect bran
8. After collecting the output (Mixture), separate them by using different sieves and fans.
9. Weigh them individually
10. The total efficiency of machine can be calculated by using the formula

Efficiency (%) = $\frac{\text{output}}{\text{Input}}$

Efficiency (%) = $\frac{\begin{array}{c}\text{(Mixtute of product (brown rice + husk + broken rice)} \\ + \\ \text{un husked paddy +bran)}\end{array}}{\textit{Weight of paddy}}$

1. The head rice efficiency can be calculated by using the formula

Efficiency (%) = $\frac{\text{output}}{\text{Input}}$

Efficiency (%) = $\frac{\text{Weight of brown rice or raw rice (not even broke rice)}}{\textit{Weight of paddy}}$

Table 1: Per cent of total efficiency and head rice efficiency

SL. No.	Variety of paddy	Brown Rice (%)	Broken Rice (%)	Bran (%)	Husk (%)	Total efficiency (%)	Head Rice efficiency (%)

The experiment is repeated for different varieties, different feed rates, different rpm and different clearance.

Observation

Name the part and write the function of each part

Source of power

Type of power transmission system

Size of hopper

Dimensions of ribbed roller (both ribbed and screw portion)

Total size of sieve

Blade length

Huller capacity

Rice output (%)

Speed (rpm)

Practical - 11

To Determine the Cooking Quality of Rice

Objective

1. Estimation of water uptake ratio for given varieties of rice samples
2. Estimation of Elongation ratio for a given varieties of rice samples

Materials required: Milled rice, Test tube 25ml capacity, Glass cover (To cover the test tube), Petri dish, Wattman No. 1 filter paper and Weighting balance.

Procedure

1. Take 20 ml of water in a test tube cover with a glass cover
2. After about 15 minute weigh about 2gm of rice (Wo) and pour into the tube through a funnel
3. Stir the rice immediately with the wire to dislodge the bubbles
4. Heat the tube in a bath for exactly 15 minutes
5. Then remove the test tube and cool it in the water (Which is taken in beaker) for about 1 minute
6. Pour the cooked rice on a wire mesh and drain well
7. Then spread the rice on a double folded filter paper and then covered with another double fold filter paper and press slightly
8. Transfer the rice into the Petri dish and weight it (W_f)
9. Calculate the apparent water uptake (water absorbed by grain) per gram rice at the respective temperature from the formula. (Repeat the procedure for different varieties)

$$(W) = \frac{(W_{f} - W_0)}{W_0}$$

Where,

W = Water absorbed by grain

W_0= Weight of original grain

W_f= Weight of cooked rice

The water uptake ratio obtained by dividing the apparent water uptake ratio at 80 ^oC by the apparent water uptake at 90 and expressing the value as present water uptake ratio.

$$= \frac{(W_f - W_0)}{W_0}$$

Table 2: Percent of water up take for a given sample

SL. No.	Variety	W_0	W_f	Water uptake ratio (%)
1.				
2.				
3.				
4.				
5.				

Result

Estimation of elongation ratio for given varieties of rice samples

Material required: Milled rice, Test tubes 25 ml capacity, Glass covers (To cover the test tube), Petri dish, Wattman No. 1 filter paper, weighing balance and measuring scale.

Procedure

- Take known quantity of each variety of sample
- Note the initial length of the grain (10 grains) and calculate the mean length of each variety of rice samples
- Cook the rice in a test tube adding water in 1;3 ratio
- After rice has been cooked, take about 10 cooked rice, measure the length and calculate the mean length of each variety of rice samples
- Elongation ratio is calculated by dividing average length of rice sample after cooking with initial grain length

$$\text{Elongation ratio} = \frac{Average\ length\ rice\ after\ cooking}{Initial\ grain\ length}$$

$$\text{Or } \frac{Length\ of\ grain\ before\ cooking}{Length\ of\ grain\ after\ cooking}$$

Table 3: Elongation ratio of the given rice sample

<table>
<tr><th rowspan="3">SL No.</th><th rowspan="3">Variety</th><th colspan="11">Length of grain (mm)</th><th rowspan="2">Elongation ratio (%)</th></tr>
<tr><th colspan="11">Number of samples</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>Mean</th><th></th></tr>
<tr><td>1.</td><td>B.C.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

	A.C.												
2.	B.C.												
	A.C.												
3.	B.C.												
	A.C.												
4.	B.C.												
	A.C.												

B.C. Before cooking and A.C. After cooking

Result

Practical - 12

Design of a Cold Storage System

Objective: To design a cold storage system.

Theory

The cold storage like every other refrigerating systems of the same magnitude employs the vapour compression method of mechanical refrigeration. Heat load factors normally considered in a cold storage design include Wall, floor and ceiling heat gains from solar radiation due to conduction, Load due to ingression of air by frequent door openings and during fresh air charge, Product load from incoming goods and heat of respiration from stored product, Heat from workers working in the room, Cooler fan load, light load, aging of equipment and other Miscellaneous loads.

Methodology

Steps for determination of load of refrigeration:

1. Cold storage for capacity 1000 tons requires room volume approximately 4000 m^3 because nearly 50-60 % of the total volume is utilized for storage purpose. For this purpose one room of size 18m X 15m X 10m (2700 m^3) is considered.
2. Calculate the Structural heat gain: It constitutes the heat transmission into the cold store through wall, ceiling and floor.

The following formula can be used to find out the overall heat transfer coefficient and hence total heat loss.

$$1 / U = 1 / h_{ci} + \Sigma (s_n / k_n) + 1 / h_{co}$$

$$Q = U * A * (T_{ci} - T_{co})$$

3. Calculate the Heat gain, Q = Room volume × air changes per hour × air density × enthalpy change
4. Calculate the Equipment load arising from lighting, evaporators etc.
5. Calculate the energy required in Cooling down to freezing point.
6. Calculate the heat evolved in storage.

7. Calculate the heat of respiration.
8. Calculate the heat arising as a result of human occupancy.

Design of component of cold storage

1. Calculation of COP = refrigerating effect/work done
2. Calculate the horse power required = capacity in TR × 3000 /COP × 630
3. Calculate the Mass flow rate (MFR) = TR × 50 refrigerating effect
4. Assuming volumetric efficiency to be 80%,Actual displacement = theoretical displacement/volumetric efficiency
5. Displacement volume is then calculated using the formula V_d= number of cylinder × πd^2 × length of stroke × RPM of compressor × 60
6. Design of condenser

Condenser design depends on the amount of heat removed by the condenser, thus the following calculation will represent the capacity of Condenser:

Quantity of heat removed (Q_2) = Heat load (Q_1) + work done by compressor in removing Q_1 (W)

7. Design of throttling device
8. Design of evaporator Capacity of evaporator will be equal to the amount of refrigerating effect
9. Cooling towers are used to cool down the temperature of water coming out of the condenser, thus cooling tower of height 5m. For cooling, pump will be required for circulating water.

Hp of pump = ρ*g*Q*H

Sample problem: Design a cold storage for 1000 kg of potato. Assume the necessary details.

Practical - 13

Design of Stacking Arrangement in Bag Storage

Objective: To design stacking arrangement for a bag storage

Theory

Jute bags should not be stacked higher than 4 m and plastic bags 3 m. Plastic bags are more slippery and the stacks will be less stable. Bags should be stacked under cover e.g. under a roof, in a shed or granary or under water proof tarpaulins. A one meter gap should be left between and around stacks and 1.5 m clearance between the top of the stack and the roof. Bags should be stacked on pallets or on an above ground structure to avoid the possibility of absorbing moisture from the floor. Bags should not be stacked on a bed of rice husks or bags filled with rice husks, as these are difficult to keep free from insect infestation. Bags should be stacked so that fumigation can be undertaken easily. The dimensions of the stacks should be set to facilitate sealing with a single fumigation sheet.

Sample problem 1: Design a bag storage structure for storing 250 tonnes of paddy. Assume reasonable data where necessary.

Solution: Design capacity of the storage structure = 250 T = 250,000kg

Capacity of a bag of 100 *60*30 cm (75 kg of paddy)

Hence, Number of bags = $\frac{250,000}{75}$ = 3340

Size of stack: Let there be 10 bags in length and 10 bags in width in a stack.

No of bags/layer = 10*10= 100 If there are 12 layers in a stack, total number of bags/stack.

=100*12 = 1200

Hence, the no of stack required = $\frac{3340}{1200}$ = 2.78 =3 (approx…)

Space required by each stack: Length = (10*1.0) = 10 m, width = (10*0.6) = 6 m and Height = (12*0.3) = 3.6 m

The clear distance between the walls and ends of the stack = 0.8 m

The clear distance between the stack = 2.0 m

Hence, the length of the floor = (3*6.0) + (2*2.0) + (2*0.8) = 23.6 m

And the width of the floor = (10*1.0) + (2*0.8) = 11.6 m

Therefore,

The overall dimension of the godowns may be taken as 24.0 m * 12.0 m. The height of the walls may be kept as 3.0 m above the floor level.

Sample problem 2: Design a bag storage structure for storing 300 T of paddy grain. Assume the necessary details

Practical - 14

Design of a Biogas Plant

Objective: To design a community biogas plant

Theory

A number of factors are taken into consideration before coming on to the optimum size of a biogas plant.

1. Volume of waste generated and to be digested daily
2. Type and amount of waste generated
3. Period of digestion
4. Method of stirring
5. Method of adding the raw material and removing the slurry
6. Climatic condition of the region
7. Subsoil conditions, and the type of cover

Methodology

Step 1: Calculate the capacity of digestion tank using the formula

$$\left(\frac{V1 + V2}{2}\right) * T$$

V1 = Volume of raw material added daily

V2 = Volume of waste after digestion

T= period of retention

Step 2: Calculate the overall production requirement using the details provided in table.

Uses	**Biogas consumed**
Cooking	0.24 m^3/day/person
Gas lighting	0.13m^3/h
Dual fuel engine	0.50 m^3/bhp/hour.
Electricity	0.75 m^3/kwh

Step 3: Selection of suitable raw materials for feeding the digester

Step 4: Calculation of volume of digester for bio gas production (considering 1kg of dry dung gives 0.186 m3 of gas). The head space of 10% is provided in the digester. The concentration of slurry in can be taken 7-9%.

Step 5: Calculations of size of digester required.

Energy available from the biogas digester is given by

$E = ŋ * H_b * V_b$

Ŋ is combustion efficiency of burner, boiler etc.

H_b is the heat of combustion per unit volume (calorific value) of biogas and V_b is the volume of biogas.

$V_b = C * M_o$, C is the biogas per unit dry mass of whole input and Mo is mass of dry input.

Volume of fluid in digester = $V_f = M_o/Þ_o$, $Þ_o$ is dry material in the fluid

Volume of digester = $V_d = V_f * t_r$; V_f flow rate of the digester fluid, t_r is the retention time.

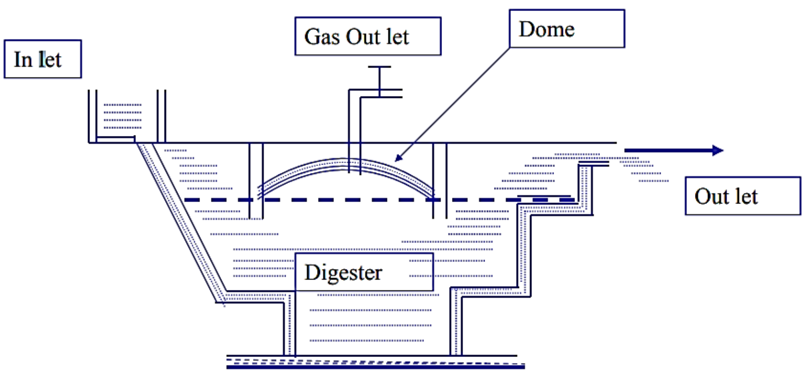


Fig 8: Fixed Dome Biogas plant

Sample problem 1: A village consists of 98 families, each comprising of 5 adults, two children equivalent to one adult person.

Village survey states the report that there are

Animals	Number
Cows	102
Oxes	124
Buffalo	52
Pig	3
Total	281

Design a community biogas only for cooking and house lightning.

Solution

Gas required for cooking/per/day = 0.227 m3

Gas required for lightning 100 lamps per hour = 0.126 m3

Each family is allotted 2 lamps, which would burn 2 hours daily

Calculation of total dung available

Cow = 10 kg/day/cow; Total cow dung = 10 * 102 =1020 kg/day

Ox = 12kg/day; Total dung from oxes = 12* 124 = 1488 kg/day

Buffalo = 15 kg/day/buffalo; Total dung from buffalo = 15*52 = 780 kg/day

Pig = 2 kg/day/pig; Total dung = 2 *3 = 6 kg/day

Total quantity of dung available/day = 2795 kg (Assume 2800 kg)

Gas produced from 1 kg of go bar in winters = 42 litres (November to February)

Gas produced from 1 kg dung in summers = 55 litres (March to October)

Calorific value of biogas = 4713 kcal; (Burning efficiency of 60%)

Density of slurry = 1090kg/m^3

Total gas produced in winter = 42* 2800 = 117.6 m^3/day

Total gas produced in summer = 55* 2800 = 154 m^3/day

It is generally advisable to design the biogas based on the minimum gas generation capacity

Total gas required in village (490 people) for cooking = 0.227 * 490 = 111.23 m^3

Gas required for lightning/day (100 C P lamp two hours daily burning per connection)

= 2 * 0.126 m^3

Total gas requirement for 98 families /day for lightning = 2* 0.126* 98 = 24.69 m^3

Total gas required for cooking and lighting = 136.92 m^3

The gas produced is 138.6 m^3/day

Surplus gas = 136.92-117.6 = 19.32 m^3

We distribute the dung into four digesters

Quantity of dung for each digester = 2800/4 = 700 kg

When unit weight of dung is mixed with unit weight of water to make the slurry

Volume of the daily charge = weight of (dung + water)/density of the slurry = 1.28 m^3

Digester volume = volume of daily charge + retention time = 1.28 * 30 = 38.4 m^3

Allowing 10%head space, actually digester volume = 1.1* 38.4 m^3 = 42.24 m^3

Assuming cylindrical shape, Volume = $\frac{\pi}{4} D^2 H$

H^3= volume/0.785 = 53.88; H = 3.5 m

Height of digester = 3.5 m (say 4m) and Diameter of digester = 4m

Gas holder design since the gas will be stored for only 4 hours in a day and volume of gas holder must be at least 70% of the daily gas production. Production of gas /kg of fresh dung = 0.06 $m^3$for retention period of 30 days

Volume of gas to be retained by the gas holder = 700 * 0.06/2 = 21 m^3

Assuming a diameter of 4m, Volume = 0.785 d^2 h, h = 1.970m

Total slurry = volume fed in = total dung + water = 2800 + 2800 = 5600 kg

Sample problem 2: Design a community biogas plant for a village with 100 adults and 45 children. The village also has a cattle population of 400 cows, 300 buffaloes, 50 goats and 40 pigs. Also find out the cooking and lightning facilities we could generate using the plant.

Practical - 15

Ventilation of Farm Buildings

Objective: To design ventilation system for farm structures

Theory

Purpose of ventilation

To remove the excess heat, remove excess moisture, remove bad odour and supply fresh air to the conditioned space. Ventilation is one of the principal methods employed in farm services. It is important to note that outside air at higher temperature and higher moisture content cannot reduce the humidity inside the building at lower temperature and moisture content.

Procedure

Determining rate of air flow for moisture removal

Design of ventilation to remove moisture is based on a moisture balance. The rate of moisture removal by ventilating air must be equal to the rate of moisture production by animals within the structure. The minimum amount necessary for moisture removal during winter at outside design temperature is used for design considerations.

Air flow can be computed using $Q = \frac{Wa}{Gi - Go}$ … (1)

Q = Necessary rate of flow for moisture removal (cu.ft./h)

Wa = TOTAL moisture production of animals (grains/h)

Gi, Go = Absolute humidity of inside and outside air respectively (grains/cu.ft.)

Removal of heat by ventilation

The rate of heat removal from a building can be computed by the same formula as for heat removal by infiltration.

Gi= 0.018 q (Ti- To) … (2)

Step 1: Draw a plan showing the important features of the structures essential to the problem.

Step 2: Determination of design conditions for the problem

a. Inside air conditions (Temperature and relative humidity and hence the amount of water from psychometric chart)

b. Outside air conditions

c. Sensible heat production

Step 3: Compute total exposed area for heat transmission loss and area of individual sections.

Step 4: Compute the minimum ventilation air flow for moisture removal

Step 5: Determine the heat removed by ventilation using the formula (2)

Step 6: Determination of allowable heat transmission loss that is the difference of total heat production and heat removed by ventilation.

Step 7: Calculate the average U values for the total exposed area based on the total difference from inside to outside.

Step 8: After assigning an assumed value to net wall area, compute the total transmission loss from all areas exclusive of the ceiling

Step 9: Determine the allowable heat transmission loss through the ceiling and compute the U value of the ceiling. Allowable heat loss through ceiling is computed thereafter.

Step 10: The type of construction wall gives the desired U values for the ceiling and walls.

Sample Problem 1: Determine the air flow rate of ventilation to remove 75 percent of moisture from a dairy cattle farm having 20 cows. The average body weight of each cow is 400kg. The inside temperature and relative humidity is 35 C and 60% respectively. The outside air temperature and relative humidity is 20 C and 80 percent respectively. Calculate the sensible heat removed by ventilation.

Solution

Considering normal temperature as 27 C and moisture removal per hour at this temperature as 1.82/hr. total heat /h= 6.7 kJ/h

Total moisture/h = 400 * 20* 1.82 = 14.56 kJ/h

Now since, At 35C RH inside = 60%

RH absolute = 1/0.902

At 20 C

Rh outside = 80%, Rh absolute = 1/0.846

Rate of flow = $Q = \frac{Ma}{Wi-We} = \frac{14.56}{\left(\frac{1}{0.902}\right)-\left(\frac{1}{0.846}\right)}$ = 196.757 m^3/h

Sensible heat = q × C_p× (To- Ti)

= 196.757 ×10.01 × 1.293 × (35-20)

= 2854.78 kcal/kg

Sample question 2: Design the ventilation system for a dairy barn to house 20 cows. Assume the necessary dimensions. Note, window area is 1 square feet per 20 square feet of the floor area.

Assumptions: Inside conditions: temperature 50 F, Rh 75%, hence air contains 3 grains moisture per cubic foot from psychometric chart.

Outside conditions: RH 100% contains 0.45 grain of moisture per cubic foot.

Sensible heat production: 3000 Btu per hour from each animal. Moisture production 3000 grains per hour from each animal.

Total area

Ceiling area: 50×36 = 1800 sq. ft.

Gross wall: (50 + 50 + 36) ×7.5 = 1190 ft^2

Total exposed area = 3090 sq. ft.

Window area = 1000/10 = 90 sq.ft.

Doors: 2(8 ×7) + (3×7) = 133 sq. ft.

Net wall area: 1290 – (133+ 90) = 1067 sq. ft.

Total moisture production = 3000× 20 = 60000 grains/h

P = 60,000/(3-0.45) = 23, 500 cu.ft/h

Heat removed from ventilation = 0.18 × 23500 = 21, 100 Btu/h

Allowable heat transmission loss (3000×20) - 21100 = 38900 Btu/h

Allowable average U value = $\frac{38900}{3090\times50}$= 0.25 Btu/h. Sq.ft (F)

Windows are assumed with single thickness and U =1.13

T_w= 1.13 × 90 (50-0) = 5080 Btu/h

Doors: assume single thickness with U = 0.57

Q_d = 0.57 × 33× (50-0) = 3790 Btu/h

Net walls

Q_w= 0.28 × 1067 × (50-0) = 13,300 Btu/h

Total heat transmission = 13,300 + 5080+ 3790 = 22170 Btu/h

U value for ceiling = $\frac{16370}{1800(50-0)} = 0.186$ Btu/h (Sq. ft) (F)

Assuming the ventilation rate to hold a 60 F stable temperature and 30 F outsides.

$T_i - T_o$ = 30 F

Heat production = assuming animals produce 2600 Btu/h at 60 F

2800 ×20 = 256000 Btu/h

Heat production equal heat transmission plus heat removed by ventilation

Practice problem: Calculate the ventilation requirements of a dairy barn for housing 300 cows in summer season. Assume necessary details.

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