TFT 211 NOTES

INTRODUCTION TO FOOD PROCESS ENGINEERING

1. The Scope of Food Process Engineering

Process engineering is basically concerned with the design and integration of the series of manufacturing stages which result in the transformation of a raw material to the finished product. Food process engineering is therefore concerned with the design and integration of a series of manufacturing stages which result in the transformation of agricultural materials to food products. There are three major criteria which must be borne in mind when considering the design of a process. First, the process must produce both the product and any by-product at the required specification. Secondly, the process must be reliable and efficient both in its own operation and in continuity with preceding and succeeding process stages. Thirdly, and having allowed for the first two requirements, the overall processing costs should be kept to a minimum.

The study of food process engineering is an attempt to analyse all forms of physical; processing in the food industry into a small number of basic operations which are called unit operations. Though the food process industry is combination of diversified complicated and differing processes, the essential concept is to divide physical food processes into basic unit operations, each of which is unique and dependent on coherent physical principles.

Some common unit operations in the food industry are, for solids, screening, size reduction, weighing, blending, for fluids, sedimentation, leaching, agitation, fluid flow units, drying, evaporation, distillation, crystallization, membrane separation, gas absorption, filtration and general operations such as heat transfer and reaction.

2. Engineering units and dimensions with emphasis on the S.I. units

Most physical properties in engineering which are measured in the laboratory are expressed in one system of units or the other. These measurements are comparison to known standards. The results of which are expressed in terms of multiples of the known quantity. Measurements consists of three parts:

1. The dimension of the quantity
2. The unit which represents a known or standard quantity and
3. A number which is the ratio of the measured quantity to the standard quantity.

Dimension

The fundamental dimensions are length, mass, time and temperature and a derived unit , force. These dimensions are represented symbolically by length [L], mass [M] time [T], expressed in terms of these fundamental dimensions.

Examples: Area= [L]2, Volume= [L]3 , velocity = [L]/ [T], Pressure =[F]/[L]2

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Density =[M]/[L], Energy = [F] x [L]

Units

Dimensions are measured in terms of units. A unit is a term used to designate or indicate the size or amount of a quantity of a certain dimension e.g. inches, feet, meter, centimetre, millimetre, micro meter are all units of length. To facilitate comparison, these units have been defined in terms of physical quantities.

The meter (m) is defined as 1,650,763.73 times the wavelength in vacuum of the radiation corresponding t the undisturbed transition between $2p_{10}$ and $5d_5$ of the atom Krypton 86.

The kilogram (kg) is the weight of a standard lump of platinum-iridium.

The second (s) is the time taken for light of a given wavelength to vibrate a given number of times; 9,192,631.77 times the period of radiation corresponding to the transition between two neighbouring states of the atom Caesium 33.

The degree Celsius (^oC) is a one hundred part of the temperature interval between the freezing point and the boiling point of water at standard pressure.

There are five units system (Table 1)which have been used over the years. These are the Foot-Pound-Second (FPS) system, the Centimetre-Gram-Second (CGS) system, the British engineering system, the American engineering system and lately the Systeme Internationale de Unites (SI)

Table 1: Unit Systems

System	Length	Mass	Time	Force
CGS	Centimeter (cm)	Gram (g)	Seconds (s)	Dyne
FPS	Foot (ft)	Pound (lb)	Seconds (s)	Poundal
British Engineering	Foot (ft)	Slug	Seconds (s)	Pound weight
American Engineering	Foot (ft)	Pound mass (lbm)	Seconds (s)	Pound Force
SI	Meter (m)	Kilogram (kg)	Seconds (s)	Newton

1 pound weight = 32.2 Poundals; 1 slug = 32.2 Pound mass

Mass which is a measure of the quantity of matter in a substrate should be differentiated from weight which is the force exerted on a body by the earth's gravitational attraction. The mass of a body represents the number of molecules and is independent of changes in volume and gravitational attraction. It is the inertia of a body that is, its resistance to change in motion.

Force though a derived unit is also a basic unit is derived by Newton's second law of motion which states that the force acting on a body is proportional to the product of its mass and acceleration. This can be expressed mathematically in terms of basic units as

$F = KMa$

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Where M is the mass of the body and a is the acceleration of the body. Acceleration is defined as the rate of change in velocity (v) which is defined as the rate of change in distance in the direction of the force and K is the proportionality constant.

V= [L]/ [T]

a = [L]/ [T] x 1/ [T] = [L]/ [T]

Any free body in the earth's gravitational field will be accelerated according to the law of gravitational attraction. This acceleration due to gravity (g) varies with local position on the earth and with the altitude. By international agreement the standard value is taken as 32.1789ft/ sec^2 or 9.807m/sec^2, 980.665cm/sec^2. In most engineering calculations it is convenient to regard force as one of the basic dimensions.

A force of I dyne is the force necessary to give a mass of one gram an acceleration of one cm/s^2.

A force of I poundal is the force necessary to give a mass of one pound an acceleration of one ft/s^2.

A force of I pound weight is the force necessary to give a mass of one slug an acceleration of one ft/s^2.

A force of I pound force is the force necessary to give a mass of one pound mass an acceleration of one 32.2 ft/s^2.

A force of I Newton is the force necessary to give a mass of one kilogram an acceleration of one m/s^2.

Attachment of units to all numbers which are not fundamentally dimensionless has the following practical benefits in engineering problems:

(a) It reduces the possibility of inadvertent inversion of any portion of the calculation
(b) It reduces the calculation in many cases to simple ratios which can be easily manipulated
(c) It reduces the intermediate calculations and eliminates considerable time in problem solving.
(d) It enables the student to approach the problem logically rather than by remembering a formula and plugging numbers into the formula
(e) It demonstrates the physical meaning of the numbers in the problems.

Dimensional Consistency

In all engineering calculations all equations must be dimensionally consistent. That is each term on both sides of an equation must represent the same kind of quantity and thus reduce to the same dimensions. Dimensions can be handled algebraically and therefore they can be divided and multiplied. In order to ensure dimensional consistency a dimensional conversion

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factor gc which has the same numerical value as g the acceleration due to gravity has been introduced. This means that its value varies with the system of unit.

$F = KMa$

$K = F/ Ma =[F]/ [M][L]/[T]^2 = [F][T]/ [M][L]$

The proportionality factor K has the units of force, time, mass and length and it is the reciprocal of g_c

In the FPS system the unit of force is in poundals, Mass is lb_m, length is ft and time is seconds. Therefore the unit of K is

K= 1 Poundal.s^2/lbm. Ft

1/K = lbm.ft/poundal.s^2= g_c

In the American engineering system F is lb_f, m is lb_m, a is 32.17ft/s^2. Therefore the unit of K

K= lb_f/ lb_m. 32.17ft/s^2

1/K = 32.17lb_m.ft/ lb_f . s^2

Similarly in the CGS system

K=1dyne/ gm.cm/s^2

g_c = 1/K =1gm. cm/dyne.s^2

In the SI system

K= 1 Newton / kg .m/s^2

1/K = g_c =1 kg. m/ N.s^2

In the British Engineering system

K= 1 lb_{wt}/ slug. ft/s^2

G_c =1/K= 1 slug.ft/lbf.s^2

Dimensional ratio

Expressing quantities in ratio gives one a comparative idea between the quantities in question. These ratios are always dimensionless. Dimensionless ratios are often used in process engineering comparing the unknown with some well known material or factor.

Example: Specific gravity which is a ratio of density of any substance A to that of water.

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ρ_A / ρ_{H2O}

Dimensionless ratios are used frequently in the study of fluid flow, mass and heat transfer.

Unit Consistency

Unit consistency implies that the units employed for the dimensions should be chosen from a consistent group. When quantities are reported in different unit system, they must be converted using conversion factors to a common system before calculations are carried out. Conversion factors are given below:

Precision of Measurement, Scientific Notation and Significant figures

All the physical measurements carry some degree of precision. The statement of quantity should either itself imply the tolerance or else the tolerance should be explicitly specified. For example 10.1 ± 0.05 m means the length measured could be between 10.15 and 10.05 m.

The precision of the result from any mathematical manipulation cannotrt be better than that of the initial measurement

Example : The volume of a tank with the following dimensions

Radius	2.550m
Height	10.0 m
Volume	$\pi R^2 H = 3.147 \times (2.550)^2 \times 10.0 = 204.282$ m^3

With a calculator but the correct answer is 204 m^3 since the least precise quantity is the height and it only has three significant numbers.

Expressing numbers in powers of 10 as shown below means expressing numbers in scientific notation

The significant figures of a number are the digits from the first non zero digit on the left to either (a) the last digit (zero or non-zero) on the right if there is a decimal point , or (b) the lastr non-zero digit of the number if there is no decimal point.

Examples

$2300 = 2.3 \times 10^3$ has two significant figures

$2300.0 = 2.3000 \times 10^3$ has five significant figures

$23040 = 2.304 \times 10^4$ has four significant figures

$0.035 = 3.5 \times 10^{-2}$ has two significant figures

$0.03500 = 3.500 \times 10^{-2}$ has four significant figures

The number of significant figures in a reported value of a measured or calculated quantity provides an indication of the precision with which the quantity is known. The more significant

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figure, the more precise is the value. Generally if a measured quantity is reported with three significant figures, it means that the value of the third digit may be off by as much as one half.

Example: A mass of 8.3g (two significant figures) means that the mass lies somewhere between 8.25 and 8.35, whereas if you give the value as 8.300g (four significant figures) then the mass lies between 8.2995 and 8.3005 g

A rule of thumb is that when two or more quantities are combined by multiplication and or division, the number of significant figures in the result should be equal to the number of significant figures of the least precise multiplicands or divisors. If the initial result of a calculation violates this rule, the result must be rounded off to reduce the number of significant figures to its maximum allowable value. If several calculations are to be performed in sequence it is advisable to keep extra significant figures of the intermediate quantities and to round off only the final result.

The rule of thumb for addition and subtraction concerns the position of the last significant figure in the sum that is, the location of this figure relative to the decimal point when two or more numbers are added or subtracted, the position of the last significant figures of each number should be compared. Of these positions, the one farthest to the left is the position of the last permissible figure of the sum.

Finally, a rule of thumb for rounding off numbers in which the digit to be dropped is a 5 is always to make the last digit of the rounded off numbers even.

UNITS AND CONVERSION FACTORS

Problems / Tutorials

1. What is a conversion factor?
2. What are the conversion factors for the following
   (a) min^2/s^2 (b) ft^2/in^2
3. Using dimensional equation convert the following
   (a) 60ft/s to m/s (b) 100miles/h to km/s
   (c) $3g/cm^3$ to lb/ft^3 (d) 300joules to Hp
   (e) 1 $dyne/cm^2$ to lbf / in^2 (f) $48cm/s^2$ to ft/s^2
   (g) 800ft-lbf/s to Hp

4. If the viscosity of oil is given as 7.5 x 10-2 lbf / ft. s, calculate the viscosity in SI units ($N.s.m^{-2}$), CGS ($dyne.sm^{-2}$).

5. Derive the dimension and units for the following for the following terms: volume, pressure, work, energy and power in SI, CGS and FPS.

6. Show that the following terms are dimensionless ratios

   (a) Reynolds number $DV\rho/\mu$ (b) prandtl number $\mu C/k$ where D is diameter (m), V is velocity (m/s), ρ is density (kg/m3), μ is viscosity (kg/sm), C is heat capacity (J/kg °C) and k is thermal conductivity (J/ms °C).

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7. Show that the following equations are dimensionally and unit consistent:

(a) q= UAT (b) Z= P/ρg (c)P= nRT/V where q is rate of heat flow (W), A is area (m2), T is temperature (K), Z is height (m), P is pressure (Pa), ρ is density (kg/m3), g is acceleration due to gravity (m/s2), n is number of moles (moles), R is the gas constant (m3 Pa/moles K), V is volume (m3) and U is overall heat transfer coefficient (J/s. K m2).

8. Consider the equation D(m) = 3t (s) +4

(a) What are the units of 3 and 4

(b) Derive an equation for distance in ft in terms of time in minutes.

9. Express the following quantities in scientific notation and indicate how many significant figures each has:

(a) 13,400 (b) 13400.0 (c) 0.000025 (d) 0.004040

10. Compute the following taking cognisant of significant figures

(a) (6.24)(48.36)/(0.002560) (b)(2.38 x 104)(0.36x 10-6) (c)2.000+ 20.5

(d) 48.36 - 9.00 (e)8.7500 x 104/120

11. Round off the following number to three significant figures:

(a) 2565 (b) 23.35 (c) 2.765 x 10-7

Process and Process Variables

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A process is any operation or series of operations that cause a physical or chemical change in a material or mixture of materials e.g. concentration of orange juice. The material that enters a process is referred to as the input or feed to the process and that which leaves is called the output or product.

A process unit is an equipment or apparatus in which one of the operations that constitute a process is carried out. Each process unit has associated with it a set of input and output process streams, which consist of materials that enters and leave the unit.

Process variables characterize a process which can either be measured or calculated. Some of these are mass, volume, density, concentration and pressure.

Density

The density of a substance is the mass per unit volume of the substance (kg/ m^3, g/ cm^3, lb/ ft^3).

Density of pure solids and liquids are relatively independent of temperature and pressure and may be found in standard texts such as Chemical engineering handbook,

Chemistry handbook, physics handbook.

Substance	Temperature(° C)	Density (kg/m^3)
Water	20	998.2
Hexane	20	655
Ethanol	20	790
Gycerol	20	1261
Milk	20	1032
20% sucrose solution	20	1081

Density of a mixture of liquids can be estimated by assuming that the component volumes are additive:

$1/\rho_{mix} = \sum x_i / \rho_i$

Where n is the number of components in the mixture, ρ_i is the density of the i^{th} component, and x_i is the mass fraction of this component. This formula works best for mixtures of components with similar molecular structures.

The specific gravity of a substance is the ratio of the density of the substance to the density of water at a specific condition.

$S.G. = \rho / \rho_{ref}$

Where ρ_{ref} is the density of water at 4 °C which is 1000kg/ m3 or 62.43lb/ ft^3

Flow rate

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Continuous processes involve the movement of material from one point to another sometimes between process units, from a production unit to a storage tank or vice versa. The rate at which a material is transported through a process line is the flow rate of that material. The flow rate of a process stream may be expressed as a

Mass flow rate / time ([M]/ [T])

Or as a

Volumetric flow rate / time ([V]/[T]). Suppose a fluid of density ρ kg/m^3 flows in a cylindrical pipe with a cross-sectional area A m^2.

If the mass flow rate of the fluid is F_m (kg/s),

then the volumetric flow rate $F_v = F_m/\rho$

It is easier to measure the volumetric flow rates than mass flow rates. This can be accomplished with a flow meter which can be mounted in the process line to give a continuous reading of the flow rate. Two commonly used flow meters are the rotameter and the orfice meter.

The rotameter is a tapered vertical tube containing a float; the larger the flow rate the higher the float rises in the tube.

Diagrams

Rotameter Orfice meter

The orfice meter is an obstruction in the flow channel with a narrow opening through which the fluid passes. The fluid pressure drops from the upstream side of the orfice to the downstream side: the pressure drop (measured with a differential manometer) varies with the flow rate; the greater the flow rate, the larger the pressure drop.

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Moles and Molecular weight

The atomic weight of an element is the mass of an atom on a scale that assigns ^{12} C a mass of exactly 12.

The molecular weights of atoms that constitute a molecule of the compound e.g. the atomic weight of oxygen O is 16 and molecular weight of O_2 is 32.

A mole or gram mole of a compound is the amount of that compound whose mass in gram is numerically equal to its molecular weight. There is also kg-moles, lb-moles, tonne-moles depending on the unit of mass in question. If the molecular weight of a substance is M, then there M kg/ kg-mole, M g/mole and M lb/ lb-mole of this substance (Note mole means g-mole). The molecular weight is the conversion factor that relates the mass and the number of moles of a quantity of the substance.

One gram-mole of any substance contains 6.02 x 1223 (Avogadros number) molecules of that compound.

The molecular weight of a compound can also be used to relate the mass flow rate of a continuous stream of this compound to the corresponding molar flow rate.

Example:

If CO_2 molecular weight 44.0 flows through a soft drink carbonating system at a rate of 100kg/h, the molar flow rate of CO_2 is

$$\frac{100\text{kg } CO_2 / 1 \text{ kg-mole } CO_2}{h / 44 \text{ kg } CO_2} = 2.27 \text{ kg moles } CO_2 / h$$

Mass, Mole fraction and average molecular weight

Process streams occasionally have only one substance, but more often consist of mixtures of liquids or gases or solutions of one or more solutes in a liquid solvent usually water. The following terms are used to define the composition of a mixture of substances including a component B:

$$\text{Mass fraction } (X_B) = \frac{\text{mass of B}}{\text{Total mass}}$$

$$\text{Mole fraction } (Y_B) = \frac{\text{moles of B}}{\text{Total moles}}$$

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The mass percent of B is $100X_B$ and the mole percent is $100Y_B$. The numerical value of mass or mole fraction does not depend on the mass unit in the numerator and denominator provided these units are the same. If the mass fraction of CO_2 in a mixture of gases is 0.2, then X_{CO2} equals 0.2 kg CO_2 /kg total or 0.2 g CO_2 /g total.

A set of mass fractions may be converted to an equivalent set of mole fractions by (a) assuming as a basis for c0alculation a mass of the mixture (e.g. 100kg), (b) Using the known mass fractions to calculate the mass of each component in the basis quantity and converting these masses to moles, and (c) Taking the ratio of the moles of each component to the total number of moles. The same procedure is followed to convert mole fractions to mass fraction except that a total number of moles (e.g. 100 moles) is taken as a basis of calculations.

Example: Conversion of a composition by mass to a molar composition

A mixture of gases has the following composition by mass O_2 16%, CO 4%, CO_2 17%, 0.2 kg N_2 63%. What is the molar composition?

Basis: 100kg of mixture

Moles of O_2 (n_o) = <u>100kg total/ 0.16 kg O_2 / 1 mole O_2</u> =0.5moles

Kg total / 32.0 kg O_2

Moles of CO (n_{CO}) = (100) (0.04)/28 = 0.143 moles

Moles of CO_2 (n_{CO2}) = (100) (0.17)/44 = 0.368 moles

Moles of N_2 (n_{N2}) = (100) (0.63)/44.0 = 2.25 moles

Total moles (nT) = (n_O + n_{COo}++n_{CO2} + n_{N2}) =3.279 moles

Y_{O2}	=	0.50/3.279	= 0.15
Y_{CO}	=	0.143/3.279	= 0.04
Y_{CO2}	=	0.386/3.279	= 0.12
Y_{N2}	=	2.25/3.279	=0.69

The average molecular weight or mean molecular weight (M_m) is the ratio of the mass of a sample of the mixture (m_T) to the number of moles (n_T) of all components in the sample. If Y_i is the mole fraction of the ith component of the mixure M_i is the molecular weight of this component, then

$M_m = Y_1M_1 + Y_2M_2 + Y_3M_3 + \ldots\ldots\ldots = \sum Y_iM_i$

Where Y_i is the mole fraction of the ith component of the mixture and M_i is the molecular weight of this component.

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Concentration

The mass concentration of a component in a mixture or solution is the mass of this component per unit volume of the mixture (kg/ m^3, g/ cm^3, lb/ ft^3). The molar concentration of a component is the number of moles of the component per unit volume of the mixture (kg-moles/ m^3, g-moles/cm^3, lb-moles/ ft^3).

The molarity of a solution is the value of the molar concentration of the solute expressed in g-moles solute/ liter solution (e.g. a 2-molar solution of A contains 2 moles of A/ liter of solution).

The concentration of a substrate in a mixture or solution can be used as a conversion factor to relate the mass (or moles) of a component in a sample of the mixture to the sample volume, or to relate the mass (or molar) flow rate of a component in a continuous stream to the total volumetric flow rate of the stream.

Pressure

Fluid Pressure and Hydrostatic head

A pressure is the ratio of a force to the area on which the force acts. Therefore the units of pressure are N/ m^2, dynes/cm^2, lb_f/in^2 or psi. The SI pressure unit N/ m^2 is also called Pascal (Pa).

Let us consider fluid in a closed vessel flowing through a pipe and suppose that a hole of area A is made in the wall of the pipe as shown in the figure below. The fluid pressure may be defined as the ratio F/A, where F is the minimum force that would have to be exerted on a plug in the hole to keep the fluid from emerging

Diagrams

Suppose a vertical column of fluid is h meters in height and has a density of ρ (kg/ cm^3), and that a pressure P_0 (N/m^2) is exerted on the upper surface

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of the column. The pressure P of the fluid at the base of the column is called the hydrostatic pressure of the fluid and is by definition, the force F exerted on the base divided by the base area A. F thus equals the force on the top surface plus the weight of the fluid in the column

$F = P_0A = hA\rho g/ g_c$

$P = F/A = P_0 + h\rho g/ g_c$

This equation is independent of area.

Pressure can also be expressed as head of a particular fluid, that is as the height of a hypothetical column of this fluid that would exert the given pressure at the base if the pressure at the top were zero. 14.7 psi is equivalent to apressure of 33.9 feet of water or 76 centimeters of mercury.

$P = \rho_{fluid}gh$ (head of fluid)/ g_c.

P (mm Hg) = P_0 (mm Hg) + h (mm Hg)

Atmospheric pressure, Absolute pressure and gauge pressure

The pressure of the atmosphere can be thought of as the pressure at the base of a column of fluid (air) located at the point of measurement (at sea level). The pressure P_0 at the top of the column equals 0, and ρ and g are average values of the density of air and the acceleration of gravity between the top of the column and the measurement point. The atmospheric pressure at sea level is 760.0 mm Hg and designated as a standard pressure of 1 atmosphere. The fluid pressure refered to so far are all absolute pressures since a pressure of zero corresponds to aperdect vacuum. Many pressure measuring devices give the gauge pressure of fluid or pressure relative to atmospheric pressure. A gauge pressure is equal to atmospheric pressure

$P_{absolute}$ (Psia) = P_{gauge} (Psig) + $P_{atmospheric}$

Fluid pressure measurement

Temperature

The temperature of substance in particular state of aggregation (solid, liquid or gas) is a measure of the average kinetic energy possessed by the substance molecules. Since this energy cannot be measured directly, the temperature must be determined indirectly by measuring some physical

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property of the substance whose value depends on the temperature in a known manner. Such properties and the te,mperature measuring devices based on them include electrical resistance of a conductor (resistance thermometer), voltage at the junction of two dissimilar metals (thermocouple), spectra of emmited radiation (pyrometer and volume of affixed mass of a fluid (Mercury thermometer).

Temperature scales can be defined in terms of any of these properties, or in terms of physical phenomenon like freezing and boiling which take place at fixed temperatures and pressures. The two most common temperature scales are defined using the freezing point Tf and boiling point T_b of water at a pressure of one atmosphere.

For the Celsius or centigrade scale T_f is assigned a value of 0°C and T_b is assigned a value of 100°C. Absolute zero (thermotrically the lowest temperature attainable in nature) on this scale falls at -273.15°C.

For the Farenheit scale T_f is assigned a value of 32°C and T_b is assigned a value of 212°F. Absolute zero falls at -459.67°F.

The Kelvin and Rankine scales are defined such that absolute zero has a value of 0 and the size of a degree is the same as a Celsius and farenheit degree scale respectively. The relationship between these temperature are given below :

$T(K) = T(^{o}C) + 273.15$

$T(^{o}R) = T(^{o}F) + 459.67$

$T(^{o}R) = 1.8\ T(K)$

$T(^{o}F) = 1.8\ T(^{o}C) + 32$

A degree is both a temperature as well as temperature interval. The conversion factors between these scales are :

$1.8\ ^{o}F/ 1^{o}C$; $1.8\ ^{o}R /1K$; $1\ ^{o}F/1\ ^{o}R$; $1\ ^{o}C/1\ K$

TUTORIALS

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Moisture Content

Moisture content expresses the amount of water present in a moist sample.

Two bases are widely used to express moisture content, namely moisture content wet basis and moisture content dry basis.

Moisture content wet basis (MC_{wb}), is the amount of water per unit mass of moist (or wet) sample.

Thus $$MC_{wb} = \frac{\text{mass of water}}{\text{mass of moist sample}}$$ (For commercial purpose)

Moisture content dry basis (MC_{db}), is the amount of water per unit mass of dry solids (or bone dry) sample.

Thus $$MC_{db} = \frac{\text{mass of water}}{\text{mass of dry solids}}$$ (For scientific purpose)

A relationship between MC_{wb} and MC_{db} may be developed.

$$MC_{db} = \frac{MC_{wb}}{1- MC_{wb}} \times 100$$

$$MC_{wb} = \frac{MC_{db}}{1- MC_{db}} \times 100$$

Note: MC_{db} can be greater than 100%.

Mass Balance

Many food processes involve separating or combining constituents in order to achieve desired product characteristics, such processes may be

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accompanied by chemical changes. Most processed foods represent some blending of ingredients.

Laws of Consevation of Mass

The basis for calculating the relative quantities of materials in such processes is the law of conservation of mass. This state that the quantity of material put into an operation must equal the quantity that comes out

Input – Output = accumulation

This relation must apply to the total, to individual constituents and to chemical elements.

In a continuous process there is no accumulation or depletion of constituents within the operation until processing is completed. For example, If a material Making a Mass balance

A mass balance involves equating the input and output of materials in a system, defining a system to which the balance will be applied and Choosing a basis for calculation

The steps in making mass balances can be summarised as follow:

- Draw a sketch or diagram representing the process, including all pertinent information on stream rates and compositions
- Show the appropriate boundaries of the system with a dashed line and select an appropriate basis for calculation.
- Designate letters or other symbols to represent unknown quantities that are to be determined.
- Write the mass balance relationships for the various constituents in terms of the known and known quantities.
- Solve the resulting algebraic equations for the unknown quantities. Sometimes a solution of several simultaneous equations may be necessary.

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