

Continuous Dryer

Rotary Dryer

The rotary drier is basically a cylinder, inclined slightly to the horizontal, which may be rotated, or the shell may be stationary, and an agitator inside may revolve slowly. In either case, the wet material is fed in at the upper end, and the rotation, or agitation, advances the material progressively to the lower end, where it is discharged. Figure 5.2 shows a direct heat rotary drier. Typical dimensions for a unit like this are 9 ft diameter and 45 ft length. In direct-heat revolving rotary driers, hot air or a mixture of flue gases and air travels through the cylinder. The feed rate, the speed of rotation or agitation, the volume of heated air or gases, and their temperature are so regulated that the solid is dried just before discharge

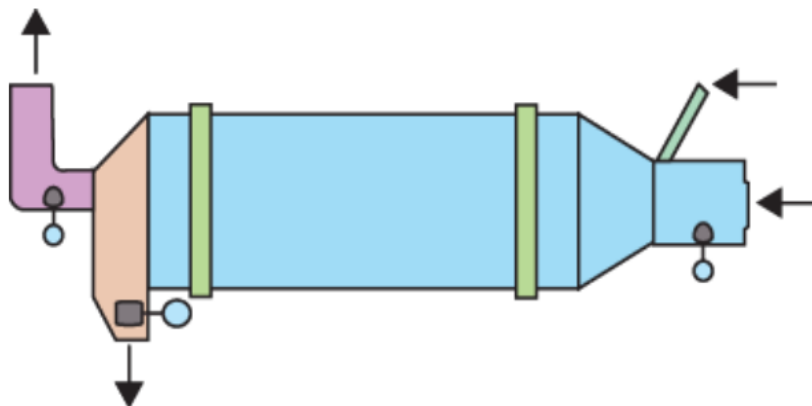


Figure 5.2 Counter current direct heat rotary dryer

LECTURE 9

MASS TRANSFER FOR BIOLOGICAL SYSTEMS

The shell fits loosely into a stationary housing at each end. The material is brought to a chute that runs through the housing; the latter also carries the exhaust pipe. The revolving shell runs on two circular tracks and is turned by a girth gear that meshes with a driven pinion. The inclination is one in sixteen for high capacities and one in thirty for low ones. As the shell revolves, the solid is carried upward one-fourth of the circumference; it then rolls back to a lower level, exposing fresh surfaces to the action of the heat as it does so. Simple rotary driers serve well enough when fuel is cheap. The efficiency is greatly improved by placing longitudinal plates 3 or 4 in. wide on the inside of the cylinder. These are called lifting flights. These carry part of the solid half-way around the circumference and drop it through the whole of a diameter in the central part of the cylinder where the air is hottest and least laden with moisture.

Drum Dryer

In drum dryers (Fig 5.3) a liquid containing dissolved solids or slurry carrying suspended solids forms a thin layer on the outside surface of a large rotating drum. For a single drum unit thickness of the film can be controlled by an adjustable scraping blade. In case of a double drum unit thickness can be controlled by the gap between the drums (figure 5.3). A gas, normally air may be blown over the surface for rapid removal of moisture. The rotation of the drum adjusted so that all of the liquid is fully vaporized and a dried deposit can be scrapped off with the help of flexible or adjustable knife. This type of dryer mainly handles the materials that are too thick for a spray dryer and too thin for a rotary dryer. The solid collects on an apron in front of the knife and rolls to a container or to a screw conveyor. The operation of the drum drier is continuous. The drum is rotated continuously by a gear driven by a pinion that receives its motion through a belt, a chain, or a reduction gear from. The speed of the drum may be regulated by a variable-speed drive to adopt the speed to any slight variation in the feed quality.

The speed of the drum regulated depending upon the nature of materials (i.e wet or dry), if the product material is wet/dry quite a distance before the knife is reached, the speed should be decreased/increased. The design

LECTURE 9
MASS TRANSFER FOR BIOLOGICAL SYSTEMS

of the components is similar to that of drum filter. The knife may be held just against the surface. It may be brought closer by turning the adjusting wheels. The knife supports may be turned through part of a circle so that the angle of the blade of the knife relative to the drum surface may be selected for the greatest shearing effect.

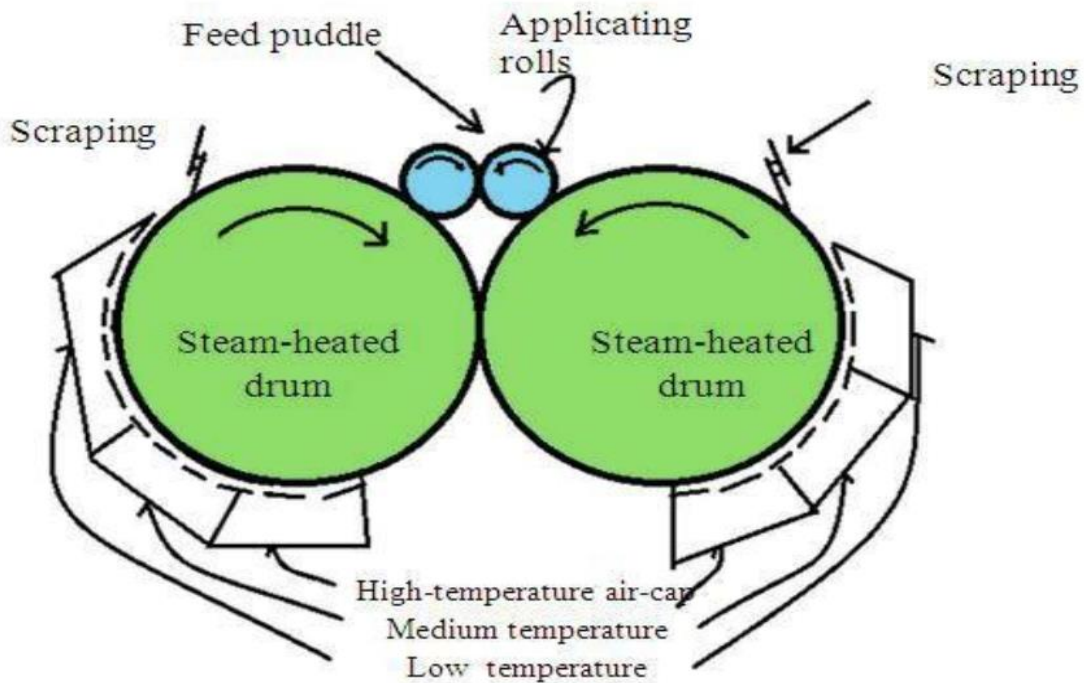
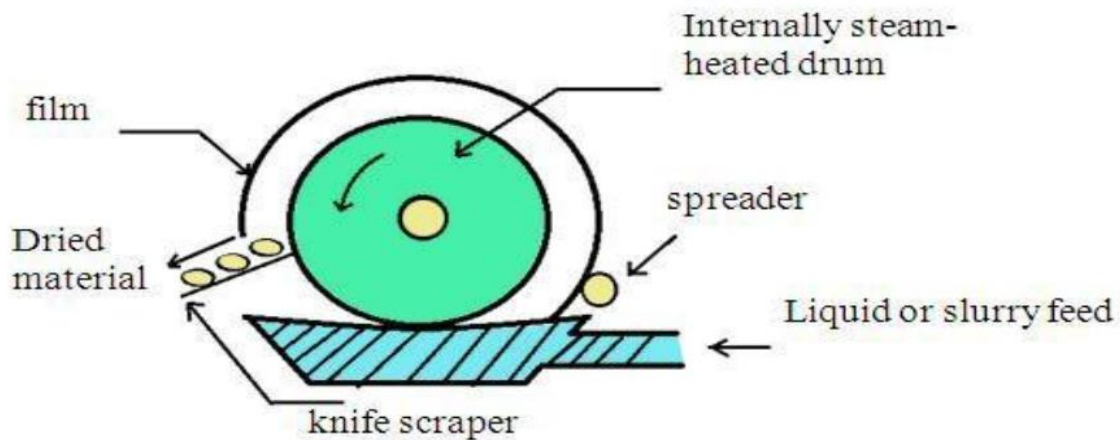


Figure 5.3 Double drum dryer

Flash Dryer

The flash driers (figure 5.4), also called pneumatic dryers, are similar in their operating principle to spray dryer. The materials that are to be dried (i.e. solid or semisolid) are dispersed in finely divided form in an upward flowing stream of heated air. These types of dryer are mainly used for drying of heat sensitive or easily oxidizable materials. The wet materials that are to be dried can be passed into a high-temperature air stream that carries it to a hammer mill or high-speed agitator where the exposed surface is increased. The drying rate is very high for these dryers (hence the term *flash dryers*), but the solid temperature does not rise much because of the short residence time. A flash dryer is not suitable for particles which are large in size or heavy particles. The special advantage of this type of dryer is that no separate arrangement is required for transporting the dried product. The fine particles leave the mill through a small duct to maintain the carrying velocities (drying gas) and reach a cyclone separator.

A solid particle takes few seconds to pass from the point of entry into the air stream to the collector. The inlet gas temperature is high and varies from 50°C to 315°C , for example, in 2 seconds, or from 650°C to 175°C in 4 seconds. The thermal efficiency of this type of dryer is generally low. A material having an initial moisture content of 80 % may be reduced to 5 or 6 % in the dried product.

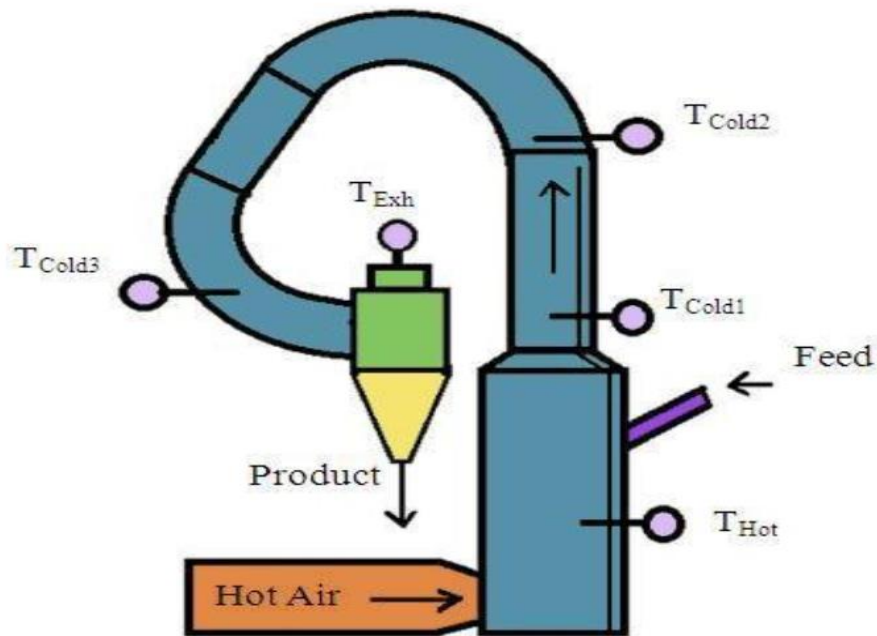


Figure 5.4: Flash dryer

Fluidised Bed Dryer

Fluidized bed dryer consist of a steel shell of cylindrical or rectangular cross section. A grid is provided in the column over which the wet material is rests. In this type of dryer, the drying gas is passed through the bed of solids at a velocity sufficient to keep the bed in a fluidized state. Mixing and heat transfer are very rapid in this type of dryers. The dryer can be operated in batch or continuous mode (figure 5.5). Fluidized bed dryer are suitable for granular and crystalline materials. If fine particles are present, either from the feed or from particle breakage in the fluidized bed, there may be considerable solid carryover with the exit gas and bag filters are needed for fines recovery. The main advantage of this type of dryer are: rapid and uniform heat transfer, short drying time, good control of the drying conditions.

In case of rectangular fluid-bed dryers separate fluidized compartments are provided through which the solids move in sequence from inlet to

LECTURE 9 MASS TRANSFER FOR BIOLOGICAL SYSTEMS

outlet. These are known as *plug flow dryers*; residence time is almost the same for all particles in the compartments. But the drying conditions can be changed from one compartment to another, and often the last compartment is fluidized with cold gas to cool the solid before discharge.

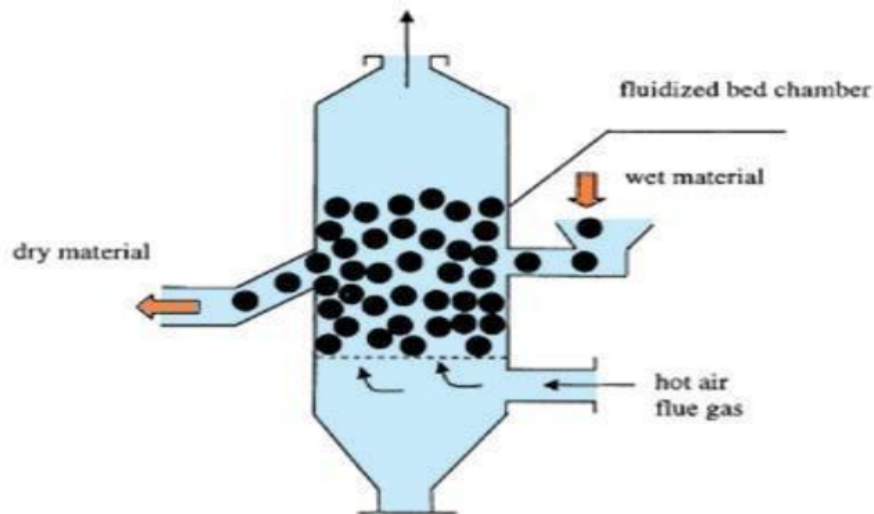


Figure 5.5: Continuous fluidized bed dryer

Screen Conveyor Dryers

Screen conveyor dryer is also called a direct heat continuous type dryer. The solid to be dried are fed on to endless, perforated, conveyor belt through which hot air is forced. The belt is housed in a long rectangular drying chamber or tunnel (figure 2.6). The chamber is divided into series of separate sections, each with its own fan and air heater. Air may be recirculated through, and vented from each section separately or passed from one section to another counter current to the solid movement. The solid is carried through the tunnel and discharged at the opposite end. In order to prevent the higher flow rate of hot air through thinner regions of the bed a uniform feeding rate and distribution of the material over the conveyor is necessary. Coarse granular, flakey, or fibers materials can be dried by through circulation without any pretreatment and without loss of material through the screen. High drying rate can be achieved with good product quality control. Thermal efficiency of this type of dryer is high and with steam heating, the steam consumption for heating the drying gas can be as low as 1.5 kg per kg of water evaporated. Only disadvantage of this type of dryer are high initial cost and high maintenance cost due to the mechanical belt.

LECTURE 9
MASS TRANSFER FOR BIOLOGICAL SYSTEMS

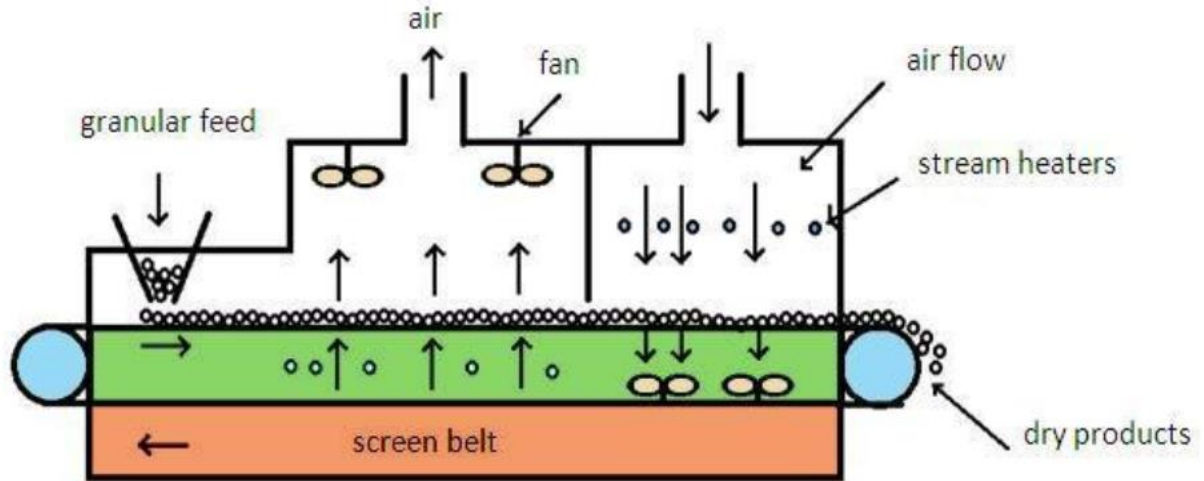
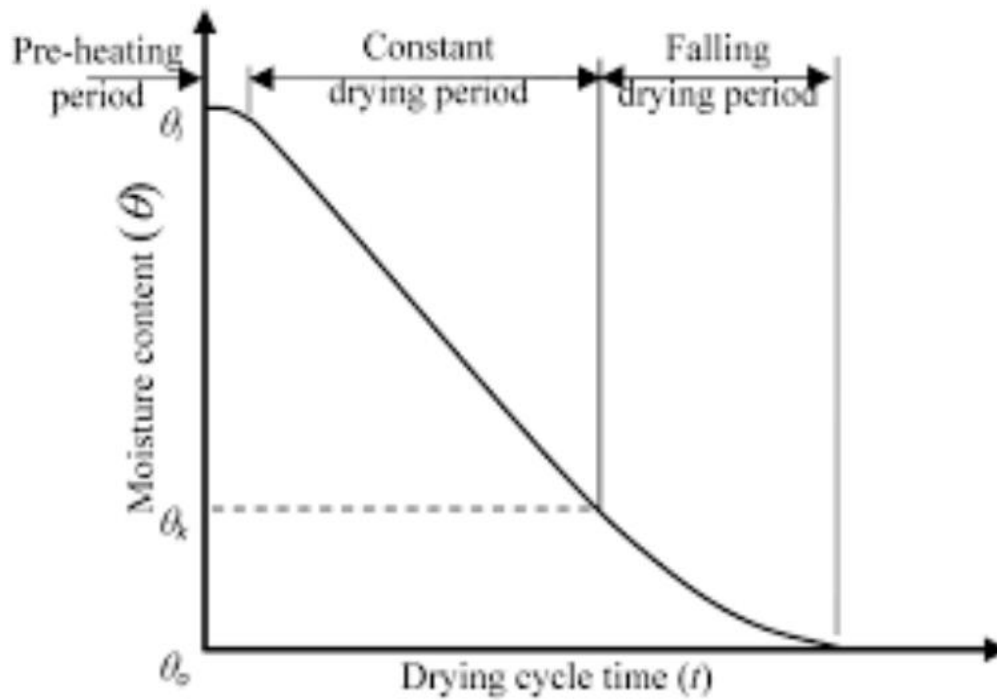


Figure 5.6: Screen conveyor dryer



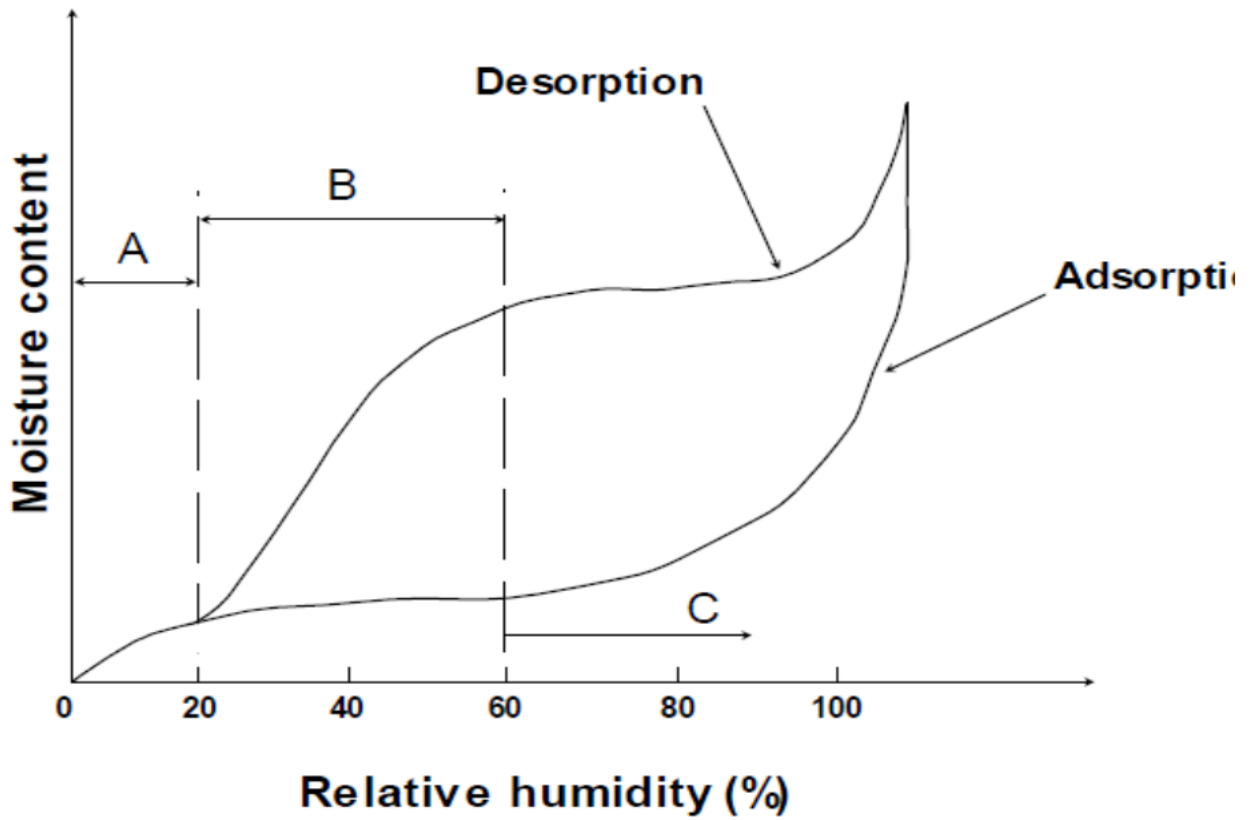


Figure 2 Typical sorption isotherms

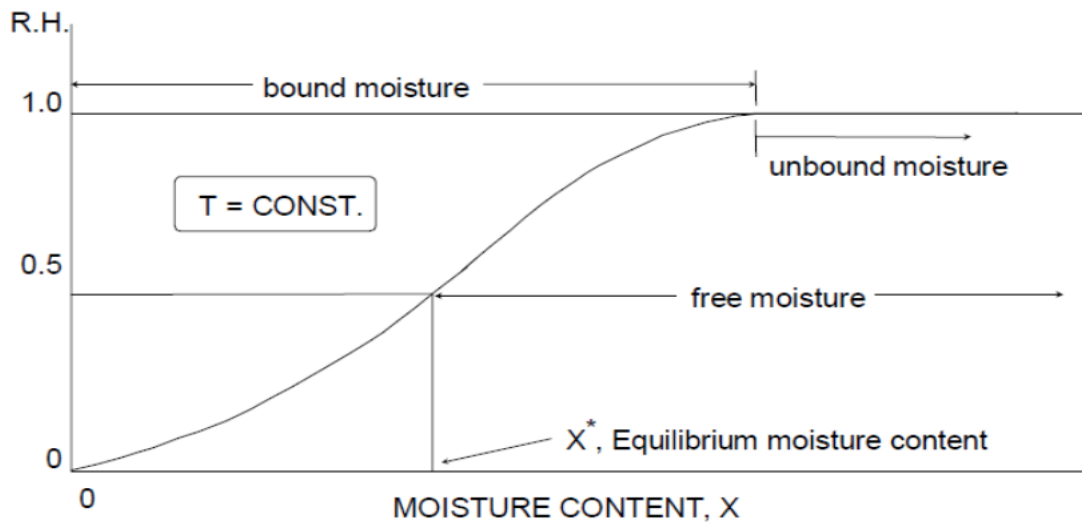


Figure 4 Various types of moisture content

LECTURE 9
MASS TRANSFER FOR BIOLOGICAL SYSTEMS

Table 2 Definitions of commonly encountered terms in psychrometry and drying

Term/symbol	Meaning
Adiabatic saturation temperature, T_{as}	Equilibrium gas temperature reached by unsaturated gas and vaporizing liquid under adiabatic conditions. (Note: For air/water system only, it is equal to the wet bulb temperature (T_{wb}))
Bound moisture	Liquid physically and/or chemically bound to solid matrix so as to exert a vapor pressure lower than that of pure liquid at the same temperature
Constant rate drying period	Under constant drying conditions, drying period when evaporation rate per unit drying area is constant (when surface moisture is removed)
Dew point	Temperature at which a given unsaturated air-vapor mixture becomes saturated
Dry bulb temperature	Temperature measured by a (dry) thermometer immersed in vapor-gas mixture
Equilibrium moisture content, X^*	At a given temperature and pressure, the moisture content of moist solid in equilibrium with the gas-vapor mixture (zero for non-hygroscopic solids)
Critical moisture content, X_c	Moisture content at which the drying rate first begins to drop (under constant drying conditions)
Falling rate period	Drying period (under constant drying conditions) during which the rate falls continuously in time
Free moisture, X_f $X_f = X - X^*$	Moisture content in excess of the equilibrium moisture content (hence free to be removed) at given air humidity and temperature
Humid heat	Heat required to raise the temperature of unit mass of dry air and its associated vapor through one degree ($J\ kg^{-1}\ K^{-1}$ or $Btu\ lb^{-1}\ ^\circ F^{-1}$)
Humidity, absolute	Mass of water vapor per unit mass of dry gas ($kg\ kg^{-1}$ or $lb\ lb^{-1}$)
Humidity, relative	Ratio of partial pressure of water vapor in gas-vapor mixture to equilibrium vapor pressure at the same temperature
Unbound moisture	Moisture in solid which exerts vapor pressure equal to that

of pure liquid at the same temperature

Table 2 Definitions of commonly encountered terms in psychrometry and drying (cont'd)

Term/symbol	Meaning
Water activity, a_w	Ratio of vapor pressure exerted by water in solid to that of pure water at the same temperature
Wet bulb temperature, T_{wb}	Liquid temperature attained when large amounts of air-vapor mixture is contacted with the surface. In purely convective drying, drying surface reaches T_{wb} during the constant rate period

LECTURE 9
MASS TRANSFER FOR BIOLOGICAL SYSTEMS

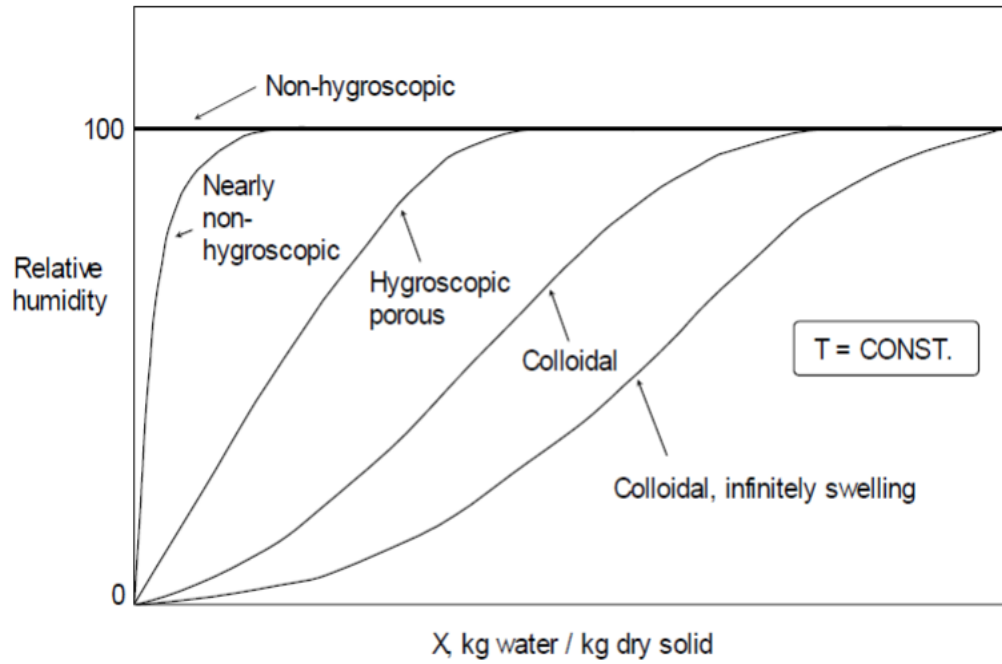


Figure 3 Equilibrium moisture content curves for various types of solids