Information Sheet for
Damage Management Technicians

THE PROCESS OF DRYING – Energy (Part 1 of 3)

Subsequent information sheets in this series will consider permeance and humidity in relation to drying

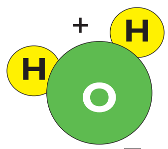
TO ENHANCE UNDERSTANDING of how the drying process works, it is necessary to have a basic knowledge of what is actually happening while drying is taking place, and some background information on the chemistry and physics around the 'science' of drying.

This series of three articles, addressing energy, permeance and humidity, will add to your understanding of some of the complexities associated with the process of drying.

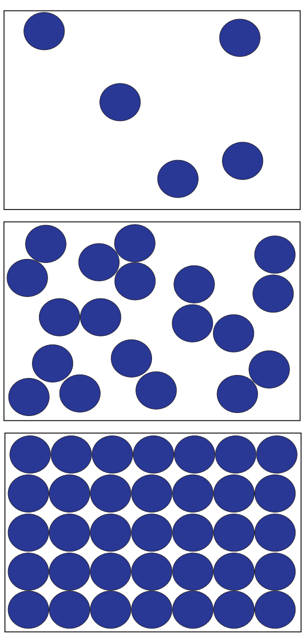
THE CHANGING 'STATE' OF WATER

Water exists in three states of matter: solid (ice) liquid (water) and gas (steam/vapour). The primary factor that ultimately determines what state water will take is the amount of energy each of its molecules contains.

Each water molecule contains one atom of oxygen and two atoms of hydrogen. The side nearest the hydrogen is positively charged and the side nearest the oxygen is negatively charged. This polarity creates a strong chemical attraction between molecules.



The more energy each water molecule possesses the more rapidly it can move, so when molecules are moving quickly enough the chemical attraction they have to each other is no longer sufficient to hold them together. As water molecules lose or gain enough energy to create or break the bonds with one another, then a change of state occurs. This is called a 'phase change'.



GAS
High temperature
= more energy
= less chemical
attraction, allowing
molecules to escape
and evaporate

LIQUID
Variable temperature
= variable energy
= sufficient chemical
attraction to maintain
liquid state

ICE
Low temperature
= low energy
= strong chemical
attraction, allowing
molecules to combine
to form a solid state

Molecular movement in matter

There are several phase changes that can occur depending upon whether energy is being added or removed. The amount of energy required to change the state of water is substantial. In fact it requires more energy to change water from one state to another, during the phase changes, than is required for almost any other molecule.

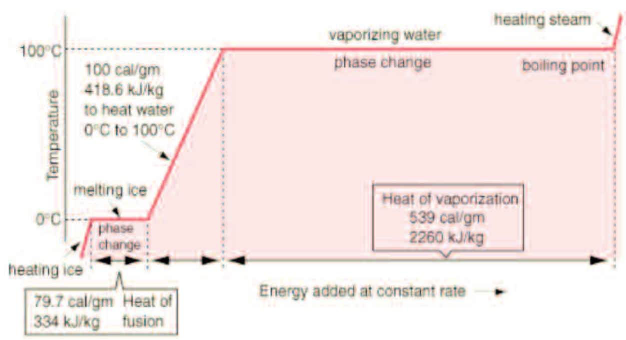
Energy in the damage management restorative drying industry is measured by using dry bulb temperature, or more simply by degrees (Celsius or Fahrenheit). Where temperature is higher there is more energy present and it is important to understand that temperature measurements are vitally important in restorative drying processes

But temperature is not a specific measurement of heat, which is most commonly measured in Calories (British Thermal Units)

A Calorie is defined as the amount of energy required to raise one gram of water by one degree Celsius at a pressure of one atmosphere, which equals 4.184 joules.

PHASE CHANGES

Transitions between solid, liquid, and gaseous states typically involve large amounts of energy. If heat were added at a constant rate to a mass of ice to take it through its phase changes to liquid water and then to steam, the energies required to accomplish the phase changes (called the latent heat of fusion and the latent heat of vaporisation) would lead to a plateau in the temperature versus time graph.



Energy used in a phase change

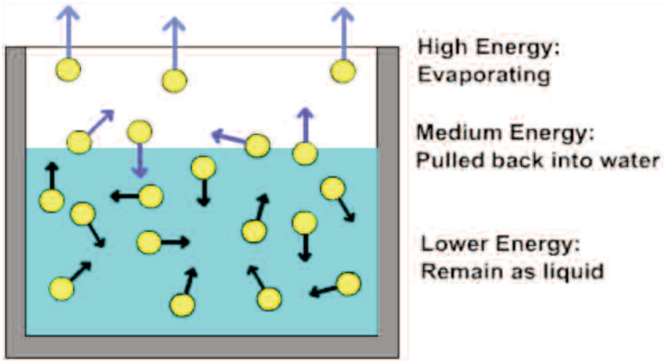
EVAPORATION

Evaporation is a type of vaporisation that occurs only on the surface of a liquid. The other type of vaporisation is boiling, which occurs through the entire mass of the liquid.

Evaporation is a type of phase transition; it is the process by which molecules in a liquid state (e.g. water) spontaneously become gaseous (e.g. water vapour). Generally, evaporation can be seen by the gradual disappearance of a liquid from a substance when exposed to a significant volume of gas (air).

On average, the molecules in a glass of water do not have enough heat energy to escape from the liquid. With sufficient heat, the liquid would quickly turn into vapour (boiling).

When the molecules collide, they transfer energy to each other in varying degrees, based on how they collide. Sometimes the transfer is so one-sided for a molecule near the surface that it ends up with enough energy to escape.



Molecular movement during evaporation

For molecules of a liquid to evaporate, they must be located near the surface, be moving in the proper direction, and have sufficient kinetic energy to overcome liquid-phase intermolecular attraction. Only a small proportion of the molecules meet these criteria, so the rate of evaporation is limited. Since the kinetic energy of a molecule is proportional to its temperature, evaporation proceeds more quickly at higher temperatures.

As the faster-moving molecules escape, the remaining molecules have lower average kinetic energy, and the temperature of the liquid thus decreases. This phenomenon is also called evaporative cooling. It is why evaporating sweat cools the human body.

Evaporation also tends to proceed more quickly with higher flow rates between the gaseous and liquid phase in liquids with higher vapour pressure.

For example, laundry on a clothes line will dry (by evaporation) more rapidly on a windy day than on a still day. Three key parts to evaporation are heat, humidity and air movement.

If evaporation takes place in a closed vessel, the escaping molecules accumulate as a vapour above the liquid. Many of the molecules return to the liquid, with returning molecules becoming more frequent as the density and pressure of the vapour increases. When the process of escape and return reaches an equilibrium, the vapour is said to be "saturated," and no further change in either vapour pressure and density or liquid temperature will occur.

Factors influencing the rate of evaporation

Concentration of the substance evaporating in the air

If the air already has a high concentration of the substance evaporating the given substance will evaporate more slowly.

Concentration of other substances in the air

If the air is already saturated with other substances, it can have a lower capacity to absorb the evaporating substance.

Concentration of other substances in the liquid (impurities)

If the liquid contains other substances, it will have a lower capacity for evaporation.

Flow rate of air

This is in part related to the concentration points above. If fresh air is moving over the substance all the time, then the concentration of the substance in the air is less likely to increase with time, thus encouraging faster evaporation. This is the result of the boundary layer at the evaporation surface decreasing with flow velocity, reducing the diffusion distance in the stagnant layer.

Inter-molecular forces

The stronger the forces keeping the molecules together in the liquid state, the more energy they require to escape.

Pressure

Evaporation happens faster if there is less exertion on the surface which would otherwise keep the molecules from escaping.

Surface area

A substance which has a larger surface area will evaporate faster as more surface molecules are able to escape.

Temperature of the substance

If the substance is hotter, then its molecules have a higher average kinetic energy, and evaporation will be faster.

Density

The higher the density, the slower a liquid evaporates

THE REVERSE OF EVAPORATION IS CONDENSATION

When warm moist air comes into contact with cold surfaces a phase change can take place and the water vapour can become a liquid this process is known as condensation.


Condensation forming on a cold bottle

Condensation is the change in the phase of matter from the gaseous phase of an element/ chemical into liquid droplets or solid grains. Upon the slowing-down of the atoms/molecules the chemical attraction between them prevails and brings them together at distances comparable to their sizes.

Condensation commonly occurs when a vapour is cooled and/or compressed to its saturation limit, when the molecular density in the gas phase reaches its maximal threshold. Vapour cooling and compressing equipment that collects condensed liquids is called a 'condenser'.

In the UK, air moisture condensation is most likely to take place in the colder months from September to May, known as the 'condensation season'. Given that moisture travels around a building through either diffusion or thermal currents, it is important to be aware that a room in which condensation is occurring may be far removed from the original source of the moisture.


Condensation forming on the cold internal side pane of glass to an external window

CONCLUSION

Temperature, in the form of heat energy, is often overlooked in the drying process but is one of the key factors in 'drying science', and the amount of energy required for the phase change of liquid to gas is significant.

Hence the high level of energy required to dry concrete is better targeted onto the concrete surface and not the surrounding air, so that the focus of the phase transition is concentrated in a smaller air space over a wider surface. This is why tenting of concrete floors can be a much more efficient way of drying them than using free standing dehumidifiers.

Also the combined effects of heat and air movement on dense wet materials, particularly in cold environments, are best achieved by the use of 'speed drying' techniques which utilise specialist equipment capable of reaching high energy output in a shorter time frame, thus decreasing the drying time.

Understanding how water molecules 'perform' in various conditions and therefore how to create the phase changes needed to remove unwanted moisture, enables us to identify the most appropriate drying techniques and keep drying times to a minimum in any given scenario.