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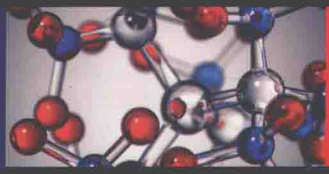
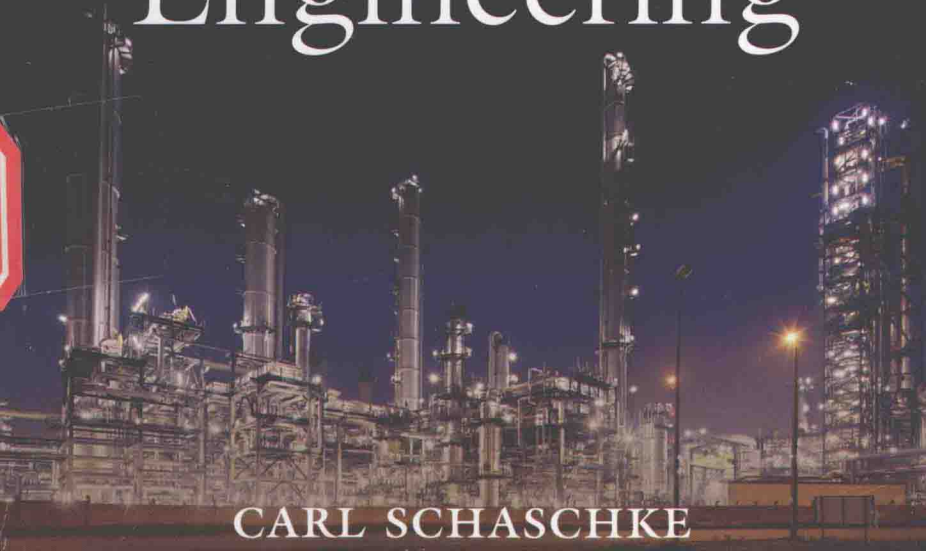


DICTIONARY OF Chemical Engineering



CARL SCHASCHKE

A Dictionary of

Chemical Engineering

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A Dictionary of

Chemical Engineering

Professor Carl Schaschke is a chemical engineer having worked first at BNFL at Sellafield in Cumbria. After then completing a PhD, his academic career began at Napier University. He is currently professor at the University of Strathclyde. He has had several secondments including to the Fawley oil refinery and BBC TV's *Tomorrow's World*. His teaching and research interests include chemical engineering applications under extreme conditions. He is a Fellow of IChemE and UK representative of the EFCE Working Party on High Pressure Technology. He is married with two daughters, Emily and Rebecca.

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Preface

The purpose of this dictionary is to provide a quick, useful, and comprehensive reference to commonly used and, in some case, less commonly used terms from the field of chemical engineering. As with any dictionary, it is intended to provide definitions to words; it is not merely a brief glossary of terms, nor is it intended to be encyclopedic, with lengthy and overly long explanations. It is aimed at students at school and undergraduate students who will encounter, perhaps for the first time, unfamiliar technical terms. It is also aimed at postgraduates engaged in chemical engineering research as well as practitioners of chemical engineering in industry who may require clarification regarding terms. This dictionary is also aimed at the general reader who in the course of their work or daily lives may encounter unfamiliar terms.

The focus of the dictionary is scientific and engineering terms. It includes core and fundamental terms commonly encountered across all degree programmes of chemical engineering worldwide. It includes many scientific and engineering concepts, laws, theories, and hypotheses. It includes significant organizations, international legislation, and biographical notes of influential scientists and engineers who have contributed to the development of the discipline. There are definitions of many types of specialist process equipment encountered in chemical engineering. This dictionary should therefore enable the reader to distinguish between a lute and a dead leg or a Hortonsphere and a holley-mott. Being a diverse discipline, there is an emphasis on established processes across a wide range of industries spanning nuclear, mineral, oil and gas, food, and pharmaceutical processing. Some older or former processes are also included where their usage was pioneering at the time or influenced later processes. Products, raw materials, and feedstocks are included, though to a far lesser extent; only those upon which major industries are based, such as crude oil, natural gas, minerals, and ores, are included. The full details of chemicals and their properties are included in the sister dictionaries such as the *Oxford Dictionary of Chemistry*.

As a branch of engineering in its own right, the roots of chemical engineering extend back to the nineteenth century. While many of the original and familiar terms are still in use today (such as *unit operations* attributed to Arthur D. Little), chemical engineering in the twenty-first century has expanded considerably and diversified into many new technological fields such as renewable energies, nanotechnology, and biomolecular engineering. Many students and professional engineers alike encounter new terms almost daily with which they may not be familiar or entirely clear. This dictionary therefore aims to provide up-to-date, clear, concise terms and definitions, and other useful and valuable information that can be used as a quick reference source.

The dictionary features over 3,000 of the most commonly encountered terms, although the number actually used by chemical engineers is far greater! There are many cases where words are used uniquely within a particular industry, or within a single industrial organization, and are not be found anywhere else. These have not been included. In providing a definition of each of the included words, the aim has been to be inclusive of all aspects of chemical engineering without being too general. If one starts with the very name *chemical engineering*, there are no doubt as many definitions as chemical engineers! Founding member of the Institution of Chemical Engineers Norman Swindin once described chemical engineering as *engineering without wheels*. An amusing definition but it falls a long way short of being helpful or informative.

The SI system of units has been used throughout although it is recognized that British Imperial and American customary units are still widely used in many industries. Reference has been made to commonly encountered units and conversions presented where appropriate.

In the preparation of this dictionary, I am indebted to many people who have assisted in suggesting words, their comments and corrections. Any errors, omissions, misprints, or obscurities are entirely my own. My thanks to the editorial staff of Oxford University Press and in particular Judith Wilson, Jamie Crowther, and Clare Jones, as well as thanks to the copy-editor, Marilyn Inglis, and the proofreader, Sarah Chatwin, for their attentive and invaluable work. Finally, this book could not have been produced without the support of my wife Melodie and my daughters Emily and Rebecca.

Carl Schaschke

Contents

ABE fermentation Another name for the *Weizmann process used for the production of acetone, butanol, and ethanol using the acid-resistant bacterium *Clostridium acetobutylicum.*

ablation The removal of material by *erosion, *evaporation, or *chemical reaction. For short-term protection against high temperatures as a form of fire protection or fireproofing of process equipment, sacrificial materials are used such that during a fire there is resistance and protection to the equipment beneath for a sufficient period of time.

ablimaton *See* SUBLIMATION.

abscissa The horizontal or x-coordinate in a two-dimensional Cartesian coordinate system such as a chart or graph. The *ordinate is the vertical or y-coordinate.

absolute Denoting a number or a measurement that does not rely on a standard reference value.

absolute density The mass per unit volume of a substance. It is the density of the actual substance and does not include any free space that may be between particles. The SI units are $kg\ m^{-3}$.

absolute error The difference between a measured value and its true value.

absolute filter A type of filter used to remove all particles that may be present in the flow of gas into or out of a process. Absolute filters are used for ensuring the sterile flow of air or oxygen to biological reactors as well as for clean rooms and sterile cabinets used for analytical work. Unlike an *air filter, the pore sizes are smaller than the expected particle size. With a typical uniform pore size of 0.2 μm, the pressure drop is greater than that of air filters made from fibrous materials.

absolute humidity The amount of water in air expressed as the mass of water vapour per unit mass of dry air for a particular temperature and pressure condition. The SI units are $kg_{water}\ kg_{air}^{-1}$.

absolute pressure The measurement of gas or air pressure relative to the pressure in a total vacuum. In comparison, the *gauge pressure is measured above atmospheric pressure, which is variable.

absolute roughness (Symbol ε) The roughness of a solid surface expressed as the average height of undulations and imperfections. It is measured using an instrument that draws a stylus over the surface. The roughness of the inner surface of a pipe wall used to transport fluids with turbulent flow has the effect of increasing frictional pressure drop. Expressed

as a ratio with internal pipe diameter, it is used in determining the friction factor of fluids flowing in pipes with turbulent flow. *See* RELATIVE ROUGHNESS.

absolute temperature *See* KELVIN.

absolute viscosity *See* VISCOSITY.

absolute zero The lowest possible thermal energy state of a material. This corresponds to 0 K.

absorbed dose *See* DOSE.

absorber 1. A material that is capable of stopping ionizing radiation. *Alpha particles can be readily stopped by a sheet of paper whereas beta radiation can be resisted by a centimetre of aluminium. Gamma radiation is absorbed by materials with a high density, such as steel and concrete. Neutron absorbers include boron, hafnium, and cadmium and are used in the control rods in nuclear reactors. **2.** A shortened name for an *absorption tower or column.

absorption A mass transfer process in which one or more gases in a gaseous mixture is transferred into a liquid solvent or a solid. It is the most common form of separation of low molecular weight materials. Absorption is often used to remove gases from gas streams that may be harmful downstream or when released from the process. The **absorption factor** is used to determine the ease with which a component will absorb into the liquid phase and is based on liquid and vapour flow rates as well as the vapour liquid equilibrium for the component. For example, ammonia can be absorbed from a gas stream using water as the scrubbing liquid. *Compare* ADSORPTION.

absorption tower A tall vertical column containing a packing material in which a gas is absorbed by intimate contact with a liquid flowing downwards under the influence of gravity. The gas can be admitted either countercurrent or cocurrent to the flow of liquid in which one or more of the gaseous components are absorbed into the liquid. The minimum flow rate of scrubbing liquid required to achieve an absorption duty requires an infinite height of packing. In practice, a higher liquid rate is used to achieve a compromise between capital cost (i.e. height of column) and the operating cost (i.e. liquid flow rate). It is also known as a *scrubber.

absorptivity The portion of radiant thermal energy falling on a surface which is converted to heat with the remainder being either reflected or transmitted. The absorptivity is dependent on the wavelength of the energy and the properties of the surface including colour. *Compare* REFLECTIVITY; TRANSMISSIVITY.

accelerant A substance used to initiate and develop a fire. Flammable liquids are the most common form of accelerants.

acceleration (Symbol a) The rate of change of speed or velocity with respect to time. If the acceleration is constant then the final velocity, v, of a body that is initially moving with a velocity u after time t, is $v = u + at$. If the acceleration is not constant, then the acceleration can be found from:

$$a = \frac{dv}{dt} = \frac{d^2s}{dt^2}$$

where s is the distance moved by the body. In the case of motion in a circle, the acceleration is v^2 / r and directed to the centre of the circle of radius r.

acceleration due to gravity (Symbol g) The acceleration experienced by a body due to the Earth's gravitational field. The acceleration is normally taken as 9.806 65 m s^{-2} although it does vary by small amounts over the Earth's surface and with altitude.

acceleration phase The rapid growth of the culture of microorganisms in a bioreactor prior to the *log phase. After the medium within a bioreactor has been inoculated with a small population of microorganisms, there is an initial *lag phase of no growth in which they adjust to their new environment. Cell division then occurs at an increasing rate until the maximum growth rate is reached. The log or exponential phase corresponds to the rapid cell division such that the logarithm of the population increase with time is constant. As the substrate eventually becomes exhausted, this is then followed by a deceleration phase prior to the *stationary phase.

accelerator A substance that alters the rate of a chemical reaction such as a *catalyst.

accumulator A device used to smooth the rate of flow from a reciprocating pump and prevent the destructive effects of *water hammer from occurring. It consists of a vessel located on the pipe close to the pump with a *non-return valve preventing return flow back to the pump. The vessel contains a gas or a bladder bag although some use springs. As the pump discharges, some of the fluid enters the accumulator compressing the gas or spring. At the point of valve closure, the gas or spring expands allowing the accumulated volume to discharge through the pipe.

accuracy A measure of the closeness or agreement of a numerical value to a true value. It is expressed as either *significant figures or decimal places depending on whether proportional or absolute accuracy is important. For example, a number written as 5.425 normally assumes that the four figures are meaningful. It would be incorrect to write the number to a precision of five significant figures unless the *error in the estimate is indicated such as 5.4250 ± 0.0005. *Compare* PRECISION.

acentric factor A parameter used in *equations of state to estimate physical and thermodynamic properties. It is used to characterize the acentricity of molecules in reduced-state correlations along with reduced pressure and reduced temperature.

acetate process A process for the production of cellulose fibres used for textiles. There are two methods: **1.** The cellulose is obtained from wood pulp and dissolved in carbon disulphide and sodium hydroxide. The thick brown liquid that contains cellulose xanthate is forced through orifices into acid. The xanthate decomposes to leave a cellulose fibre known as viscose rayon. **2.** The cellulose obtained from wood pulp and cellulose acetate is formed by dissolving in acetone. The solution is forced through orifices and the solvent is allowed to evaporate leaving a cellulose fibre of acetate rayon.

ACHEMA (Ausstellungstagung für chemisches Apparatewesen) A triennial trade fair for chemical technology and biotechnology held in Frankfurt, Germany.

SEE WEB LINKS

- Official website of ACHEMA.

Acheson process A process used for the production of graphite. It involves heating coke mixed with clay to a very high temperature. At a temperature in excess of 4,000°C,

silicon carbide is formed leaving graphite. It is named after the American inventor Edward Goodrich Acheson (1856–1931) who patented the process in 1896.

acid A chemical compound or material containing hydrogen that has the tendency to lose protons and form hydrogen ions in solution. Solutions of acids have *pH values less than 7.

acid egg An egg-shaped vessel used to transport highly corrosive acids. The container has inlet and outlet pipes and is filled with a charge of liquid to be transported. Another pipe is used to admit compressed air or another gas. The pressure of the gas on the liquid surface forces the liquid through the discharge pipe that extends down into the liquid. The acid egg is not very efficient as the compressed air or gas is usually blown off when the operation is completed. *See* MONTEJUS.

acid gas Natural gas, which consists mainly of methane, but also contains significant amounts of carbon dioxide, hydrogen sulphide, and other acidic contaminants. Natural gas from offshore reservoirs that contain these corrosive and toxic contaminants are required to be removed or reduced at the platform before export using an *amine gas treating process. *Compare* SOUR GAS.

acid number A measure of the acidity of oils such as crude oil, mineral oils, and biodiesels. It is expressed as the mass in milligrams of potassium hydroxide titrated in one gram of the oil required to neutralize it.

acid rain A precipitation of rain that has a pH below that of typical rain, which is around pH 5.6. Rainwater is naturally acidic due to the absorption of carbon dioxide from the air to form carbonic acid. However, rainwater will also absorb other gases such as sulphur dioxide and various oxides of nitrogen that have been released into the atmosphere as pollutant gases through processes such as the combustion of fossil fuels and from car exhausts. The dissolved gases form sulphuric and nitric acids with pH values of less than 5.0 and have an adverse effect on trees and plants. Acid rain causes damage to leaves and increases the acidity of the soil preventing further growth. The water run-off into rivers and lakes also prevents freshwater fish from thriving, leaving the water sterile, and has a major impact on the ecosystem.

activated carbon A compound of powdered or granular amorphous carbon mainly made from coconut shells. It has a very high specific surface area used to adsorb vapours and gases. With a surface area typically of around 1,000 m^2 per gram, it is widely used to adsorb vapours and gases. The amount of substance that can be adsorbed is proportional to the absolute temperature and pressure. The activated carbon can be reactivated for reuse using steam to strip the adsorbents and recover the carbon. Activated carbon is used in water and air purification, and used in gas masks for the removal of harmful gases. It is also known as **activated charcoal** and **active carbon**.

activated sludge process A process used in the treatment of sewage and wastewater. *Sludge is formed when air is bubbled through the sewage resulting in the aggregation of flocs. These contain denitrifying bacteria that are capable of decomposing organic substances. Aeration ensures a high level of dissolved oxygen and helps to reduce the *biological oxygen demand. Stirring of the sludge can also aid the process.

activation energy (Symbol E_a) The minimum energy required to activate one mole of a substance to cause a *chemical reaction to take place. For a chemical reaction to proceed,

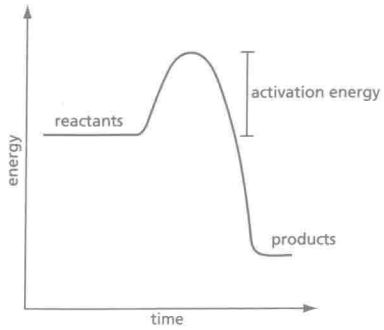

Fig. 1

the reactants are converted to products in which the energy increases to a maximum and falls to the energy of the products (see Fig. 1). The activation energy is the difference between the maximum energy and the energy of the reactants and is therefore the energy than needs to be overcome. *See* ARRHENIUS EQUATION.

active site 1. An available location on the surface of a *catalyst available for reactants to bind and result in a *chemical reaction taking place. The active site can be blocked by a chemical agent or *poison thereby reducing the effectiveness of the catalyst. **2.** On the surface of an enzyme, the active site is the location to which a substrate binds. The binding of the substrate to the enzyme is dependent on the conformation or 3-D shape of the protein. Inhibition prevents the binding from taking place by altering the conformation thereby preventing the substrate from binding, or by blocking the site.

activity 1. The change in one condition to another expressed as a ratio. Examples include *water activity, and chemical activity. The activity of a chemical reaction is used in place of concentration in equilibrium constants for reactions involving non-ideal gases and solutions. **2.** A quantitative term used to characterize the number of atomic nuclei that disintegrate in a radioactive substance per unit time. It is measured in *becquerel (Bq) where one Bq is equal to one disintegration per second. The unit of activity replaces the former unit of the curie (Ci) where one Ci is equal to 37×10^{10} Bq. The specific activity is the activity per unit mass of a pure radioisotope. **3.** (Symbol U) The amount of an enzyme present in a biologically catalyzed reaction. It is usually expressed in terms of units of activity based on the rate of the reaction that the enzyme catalyzes. The international unit of activity is the amount of enzyme that will convert one μmol of substrate to a product in one minute under defined conditions. These are usually 25°C and the optimum pH. **4.** A thermodynamic parameter that measures the so-called active concentration of a substance, a, in a chemical system, and is in contrast to the molecular concentration, c. It is related $a = fc$ where f is a dimensionless parameter and approaches unity in dilute solutions.

activity coefficient (Symbol γ) A correction factor that allows for the deviation from ideal behaviour of a gas or solution.

ADC *See* ANALOGUE-TO-DIGITAL CONVERTER.

a

additive A substance added in a small amount to another or mixture to improve the performance or properties in some way. Additives are added to polymers to enhance their stabilizing properties. Additives are added to foods as preservatives, and to enhance colour and flavour. Additives can also provide corrosion resistance, alter surface tension, and viscosity etc.

adiabatic A thermodynamic process that takes place without heat transfer to or from an external source. When a fluid is compressed adiabatically, there is an increase in temperature of the fluid. Likewise, **adiabatic cooling** occurs when the pressure of the fluid is reduced without any heat exchange to the surrounding. **Adiabatic expansion** of a fluid occurs without any heat transfer with the surroundings. **Adiabatic compression** is the compression of a gas without any transfer of heat to the surroundings. It results in an increase in the temperature of the gas undergoing compression.

adiabatic efficiency 1. The ratio of the work required for adiabatic compression to the real work input. **2.** The ratio of kinetic energy of a fluid through a valve to the kinetic energy obtained through the process of *adiabatic expansion.

adiabatic flame temperature The theoretical temperature of a flame during the combustion of a fuel in oxygen considered when there is no loss of energy. The temperature is dependent on whether the combustion process occurs at either constant pressure or constant volume. At constant pressure, the adiabatic flame temperature is due to the complete combustion of the fuel with no heat transfer or changes in kinetic or potential energy. Constant volume combustion results in a lower flame temperature since some of the energy is otherwise used as work to change the pressure.

adiabatic flash Another name for *flash evaporation, which involves the rapid isenthalpic evaporation of a saturated liquid into a liquid and vapour by the reduction in pressure.

adiabatic process A physical or chemical process without the loss or gain of heat. The **adiabatic equation** $pV^{\gamma} = k$ describes the relationship between the pressure of an *ideal gas and its volume where γ is the ratio of the specific heat capacities of the gas and k is a constant.

adiabatic saturation temperature The equilibrium temperature attained when a liquid and gas are brought into contact with no work or heat transfer done.

adjutage A tube inserted into a vessel to obtain a measure of its pressure or to allow the discharge of its contents.

adsorbate A substance that is adsorbed from a gas or liquid onto a solid surface or **adsorbent** during an *adsorption process.

adsorption A process in which components in gases, liquids, or dissolved substances are selectively held on the surface of a solid. It is used to remove components that may otherwise be harmful if released into the environment or may cause process difficulties further downstream such as causing the poisoning of a catalyst. Adsorption usually takes place in *fixed beds.

adsorption isotherm The relationship between the mass of *adsorbate taken up per unit mass of adsorbent at constant pressure, if a gas, or at constant temperature, if in a solution. The *BET, *Langmuir, *Freundlich, and *Temkin adsorption isotherm equations

are empirical equations used to describe the surface available for adsorption at constant pressure for gases and constant temperature for solutions.

advection The natural movement of a fluid such as air resulting in horizontal motion caused by local pressure differences. It differs from *convection since it does not include the effects of diffusion.

aeration The introduction and movement of air or oxygen at a low flow rate through a liquid medium such as a *bioreactor or *activated sludge process. Aeration is used to provide oxygen to microorganisms that are responsible for biologically catalyzed reactions. The oxygen is usually introduced through a *sparger as small bubbles that have a high surface area. Aeration is used to promote effective mass transfer of the oxygen to the liquid medium and therefore microorganisms.

aeration number A dimensionless number, N_a, used in the aeration-mixing of bioreactors and relates the gas flow rate, G, to the impeller speed, N, and diameter, D, as:

$$N_a = \frac{G}{ND^3}$$

aerobic process A biochemical process involving microorganisms that require the presence of oxygen, usually in the form of air. Many organisms require the presence of oxygen to survive and grow, such as plants, animals, and many microorganisms. They are dependent on oxygen for the breakdown of sugars into carbon dioxide and water, and for the release of energy through aerobic respiration. In comparison, anaerobic respiration releases energy in the absence of oxygen.

aerogel A highly porous material based on metal oxides or silica. It has a very low density below 10 kg m^{-3} and has excellent heat and electrical resistance as well as acoustic properties. Aerogels can be formed using the process of *supercritical drying using carbon dioxide to remove a solvent such as ethanol used in their formation. Being supercritical and without a gas–liquid interface, it avoids the crushing effects of capillary forces on the porous structure during a conventional drying process.

aerosol A dispersion of fine droplets of liquid or particles of solid within a gas such as air. The particles are often very small and colloidal in size. An aerosol spray can contains propellants that are liquefied under pressure and used to create an aerosol when released into the air.

agglomeration The process of bringing a suspension of small or fine particles together to form larger and more coarse particles or aggregates.

aggregated fluidization *See* FLUIDIZATION.

aggregation The formation of large groups of molecules or particles. With particles, aggregation consists of both *flocculation and *coagulation.

agitated vessel A vessel in which the contents are stirred by mechanical means through the use of an agitator, paddle, or stirrer. Impellers and propellers are commonly used to provide good mixing characteristics. It is also known as a **stirred tank**.

agitation intensity A measure of the power consumption of the shaft of an agitator used to mix a liquid in a stirred tank or *agitated vessel. Agitation intensities are expressed

as the power supplied per unit volume of liquid. The SI units are $W\ m^{-3}$. The magnitude of the agitation intensity is dependent on the nature of the liquid being stirred. Biological solutions containing flocculating materials are significantly affected by the level of agitation.

agitator A simple stirring device used to provide turbulence and mixing of the contents of a vessel containing a liquid. It is typically used to provide homogeneity, provide good oxygen transfer in fermentation vessels, and in the prevention of particles settling.

An agitator consists of blades attached to a rotating shaft. Impellers have flat blades and provide radial flow patterns whereas propellers provide axial flow movement. Paddle agitators consist of tilted flat blades providing a combination of radial and axial flow movement. Selection of the appropriate agitator depends on the processing requirements, the fluid properties, and the materials of construction.

AIChE *See* American Institute of Chemical Engineers.

air An odourless and colourless mixture of gases and vapours that surround the Earth. At sea level, the composition of dry air is mainly nitrogen (78.09 %) and oxygen (20.95 %), with an average relative molecular weight of 29. Other gases include argon (0.93 %), carbon dioxide (0.03 %), neon (1.8×10^{-3} %), helium (5.2×10^{-4} %), and lesser amounts of methane, krypton, hydrogen, nitrous oxide, xenon, and radon in decreasing amounts, respectively. Air is a common source of oxygen used in many processes such as *combustion.

air conditioning The process of controlling the environmental air conditions in buildings through control of the temperature and level of relative humidity, as well as through filtration of particles to provide human comfort. The movement and cleanliness of the air are also involved.

air filter A type of filter used to remove particles such as dust, soot, and microorganisms from the flow of air. They are often used for ensuring a sterile flow of air or oxygen to bioreactors as well as for clean rooms and sterile cabinets used for analytical work. The pore sizes of the filter are larger than the particle size to be removed such that the filter relies on the depth of the filter to entrap the particles within a fibrous mesh structure. Fibrous filters are relatively cheap and robust, and have a low pressure drop in comparison with *absolute filters.

air-lift A pumping device used to raise a liquid from a depth such as a well. It consists of a vertical pipe extending down into the well into which compressed air is injected at the bottom. As the air bubbles rise, the reduced hydrostatic pressure results in a flow of liquid up the leg. The air or gas is disengaged from the liquid at the top of the leg. It is used for raising oil from wells.

air-lift reactor A type of bubble column reactor into which air is sparged at the bottom as bubbles to promote oxygen transfer and cause circulation of the liquid. The reactor is cylindrical and mounted on its axis. It has an inner tube up which the air or oxygen rises. An external-loop air-lift-type reactor consists of a U-tube within which the sparging takes place promoting oxygen transfer and liquid circulation.

air lock 1. Trapped air or some other gas or vapour within a pipe that prevents the intentional flow of a liquid. **2.** The intentional seal in a process that relies on a differential pressure to prevent the undesirable loss of material.

air pollution The release of particles, vapours, and gases into the environment that are harmful to human health and to the environment such as plants, forests, and animals. Carbon dioxide is a product from the combustion of fossil fuels in power stations, vehicles, aeroplanes,

and numerous industrial processes, and is a greenhouse gas responsible for contributing to the warming of the Earth's atmosphere. Methane is another greenhouse gas as are chlorofluorocarbons (CFCs), which were once widely used as refrigerants and as aerosol propellants but are now banned due to their known damaging effect on the Earth's ozone layer. Sulphur dioxide is another product of the combustion of fossil fuels and is known as the cause of *acid rain.

In the UK, an Act of Parliament was introduced in 1956 to reduce the level of air pollution. It was a landmark in environmental protection and was responsible for reducing the level of smoke pollution as well as sulphur dioxide emitted into the environment.

In the US, the Clean Air Act introduced in 1963, together with its subsequent amendments as a federal law, has been responsible for controlling air pollution. Other governments have also taken measures to control air pollution and limit the emission of carbon dioxide and other greenhouse gases. The Kyoto Protocol is an international agreement between countries to reduce the emissions of carbon dioxide emissions and restrict or ban the emission of certain chemicals such as CFCs. One way of restricting carbon dioxide emissions is to raise the level of taxation on fuels so that people and industrial companies have greater incentives to conserve energy and pollute less.

SEE WEB LINKS

- Official website of Environmental Protection UK.

air separator A device used to separate solid or liquid particles from air in which centrifugal force is used. The device has a cylindrical body with a conical base. The particle-containing air enters tangentially and the particles leave from the bottom while particle-free air leaves from the top. It is also known as a *cyclone separator.

air-to-close A type of pneumatically operated control valve that automatically opens in the event of a loss of instrument air pressure. An **air-to-open** valve is a pneumatically operated control valve that automatically closes in the event of a loss of instrument air pressure. For example, the fuel supply to a furnace should automatically shut on air failure.

ALARA An abbreviation for **a**s **l**ow **a**s **r**easonably **a**chievable, it is a management tool used in the controlling of risks. For example, it is used to manage the exposure to chemicals and ionizing radiation doses in humans working in the nuclear industry. *Compare* ALARP.

alarm An indicator used to alert operators and personnel that there has been a significant deviation from an expected measured *process variable or process condition. The alarm may be audible in the form of a siren, bell, or other noise, or may be a flashing or continuous light signal. Alarms are a feature of control panels where the process is displayed on screens with associated alarms. **Alarm flooding** is a condition in which alarms appear on control panels in *control rooms at a rate which exceeds that which an operator can comprehend or respond to quickly or effectively. It therefore prevents the operator from identifying the cause of the process upset and consequently limits the scope for an effective response.

ALARP An abbreviation for **a**s **l**ow **a**s **r**easonably **p**racticable, it is a management tool used to determine the level to which risks are to be assessed and controlled. It involves a rigorous and systematic assessment of the minimization of risk and the costs in terms of time, money, and effort to achieve it. As a form of good practice requiring judgement between risk and societal benefit, it was developed through the UK parliamentary Health and Safety at Work Act (1974). Outside the UK, similar forms of engineering practice are used and this includes *ALARA (as low as reasonably achievable) in the US for radiation protection.

SEE WEB LINKS

- Official website of the Health and Safety Executive UK offering risk assessment advice.