CHEMICAL ENGINEERING IN 1928

By A. J. V. UNDERWOOD, M.Sc., A.M.I.Chem.E.

Progress in chemical engineering, if it is not to depend solely on empirical advances, must take place along two main lines. On the one hand, the principles underlying the fundamental operations of chemical engineering must be more completely elucidated so that they may find reasonably accurate quantitative expression in design. On the other hand, the constructional materials, which impose practical limitations on the designer, must be improved or their scope extended by the introduction of new materials. For the economic result, which is the purpose of chemical engineering design, the two factors are closely interdependent. The greater the uncertainty attaching to the principles of the design the larger will be the factors of safety (or "factors of ignorance") which have to be used in respect of capacity or strength, and the greater will be the extravagance in the use of the constructional materials. Until comparatively recently the materials available to the chemical engineer were few, and their inadequacy in many respects imposed serious limitations on the progress of design. Recent years, however, have seen very marked advances in the development of new materials, whereas the progress in the fundamental principles of chemical engineering design, though admittedly substantial, has not been equally rapid, and has not sufficed to enable full utilisation to be made of the advances in the former field. The controlling factor in chemical engineering progress at the present time is, therefore, the development of fundamental chemical engineering research. Judged from this standpoint, the year 1928 can show but little achievement or cause for satisfaction. Admittedly, there is increased interest in chemical engineering education, and more extensive facilities for it are becoming available and sound guiding principles for its future development have been established by the Institution of Chemical Engineers, which is all to the good for future progress. But, for the present, significant contributions to the science of chemical engineering are rare. It might, of course, be argued against this that such progress is actually taking place, but that it is not readily apparent on account of the growing concentration of industry in combines and their adoption of a policy of reticence. This possibility cannot be ruled out, though trial-and-error methods are in many ways more suited to large-scale than to small-scale manufacture. Nevertheless, for the real progress of science as a common fund of knowledge, only that knowledge which is generally available can be regarded as appertaining to the common fund, and from this standpoint it is legitimate to take absence of evidence regarding other knowledge as equivalent to evidence of absence.

Though fundamental progress has been small, developments in detail are considerably greater, and advances in other branches of engineering are being reflected in the chemical industry. In the sphere of power generation the use of independent power plants supplying process steam as exhaust is finding increasing application. The higher boiler pressures of electrical power station plant are leading to similar developments in chemical works. In fact, a boiler plant in the chemical industry, working at 600 lb. per sq. in. pressure and 780° F. steam temperature, is stated to have the highest working pressure and superheat in commercial operation in this country at the present time for an installation on such a scale. For obtaining increased boiler efficiencies, the advantages of air preheating, steam accumulation, and automatic boiler control are being more generally appreciated. An interesting example of the last type is the Hagan system installed at the British Xylonite Co.'s works, a regulator, actuated by variations in the steam flow, controlling the boiler dampers, fuel feed, and induced draught. A new, and possibly important, source of power has been opened up by the success of the Birmingham, Tame and Rea Drainage Board in utilising the sludge gas evolved in the sewage digestion tanks for the generation of power in gas engines.

The all-important and complex subject of heat transfer is gradually receiving more attention in regard to the practical application of the fundamental principles. The increase in the rate of transference of heat with increased velocity is being appreciated in the extended employment of forced circulation in evaporators. By successfully applying this principle to obtain a minimum heating surface, it has been possible to construct an economical evaporator of pure nickel for caustic soda solutions. Another subject, of great importance in the oil industries, to which attention is being directed is the effect of the variation of viscosity with the temperature on the coefficient of heat transfer in heat exchangers.

In the sphere of drying, an interesting development is the Peco dryer, a tubular dryer in which the material to be dried is carried in a current of air, multiple-effect drying being obtained by using the vapours from one effect for heating the next effect through contact with water in a heat exchanger. Rotary dryers are finding increasing application, and an interesting example of the use of this type of dryer for delicate materials is in the drying of washed rags. A novel type of rotary dryer designed to give a high thermal efficiency is the Pehrson dryer, in which the hot air enters the dryer through longitudinal slots in the drum so that it comes into intimate contact with the material to be dried. Spray drying is finding new applications, and offers special advantages in cases where waste flue gases are available for use in the spray dryer, as in the recently-developed Neill process for the manufacture of red oxide. The manufacture of beet sugar by the De Vecchis desiccation process is being extended to other countries, and the Scott dryers used in this process are being installed at factories in France and Russia. In the Fraser radial path rotating drum drier the material falls through the air space throughout the cross section of the drum, which is divided longitudinally into four cells, fitted with baffles. Though the drying surface is greater, the height through which the material falls is smaller, thus minimising any tendency to powdering. Owing to the uniformity of the heat treatment higher temperatures can be used without danger of overheating.

The growing use of volatile solvents in different processes is causing increased activity in regard to solvent recovery by absorption and adsorption methods, and greater attention is being paid to the principles of design of this kind of plant. A new absorbent liquid for the recovery of acetone is sulphuric acid of 70% strength, a much larger quantity of acetone being absorbed than by water or cresol. The acetone is subsequently recovered by distillation after diluting the acid to about 50% strength and the acid is then reconcentrated to be used again. Solid adsorbents, such as activated carbon and silica gel, are becoming increasingly popular for solvent recovery processes as well as for deodorising and decolorising. Activated carbon is being used for removing the unpleasant taste from carbon dioxide generated in breweries, for the bleaching of edible oils in conjunction with fuller's earth, for purifying solutions to eliminate the necessity of recrystallisation of organic preparations, and for decolorising the syrups in which fruits are boiled preparatory to canning to prevent accumulation of impurities in the syrup which would ultimately render it unfit for repeated use. A new solid adsorbent for air drying consists of calcium chloride carried on an inert siliceous base and has a high capacity for adsorbing water, which can be removed at a moderate temperature.

In the sphere of filtration, the striving for continuous operation is leading to an increased use of rotary drum filters. The type of rotary filter in which the material is fed to the inside of the drum is finding many applications, as it enables continuous filtration to be adopted with many materials which cannot be so efficiently treated on the more common type of rotary filter where the cake is formed on the outside of the drum. A new type of filter has been introduced under the name of the "Metafilter." It is a development of the edge filter, the filter-leaves being made up of perforated strips with bevelled edges. The strips are spaced by means of ribs, and the liquid to be filtered flows inwards through the converging channels, formed by the bevels, to the central drainage channels formed by the internal perforations. When a filter-aid such as kieselguhr is to be used, the converging channels are filled with the filter-aid and thus form a support for the filter-bed deposited on the surface of the filter-leaves. The filter is readily cleaned by flushing, and is very effective for the clarification of liquids containing small amounts of very fine material, such as beer, varnish, oils, etc.

The main development in grinding is in the use of closed circuit grinding, the fines being separated from the oversize, which is returned to the mill, either by air separation if dry grinding is employed or by the use of a classifier if wet grinding is adopted. The design of colloid mills to reduce power consumption is the main tendency in this type of plant. An interesting new colloid mill, which is being used for the production of dispersions employed in the manufacture of rubber goods by electro-deposition, consists of a vessel containing a large number of hard stones, which are kept in motion by means of a stirrer. The mixture to be dispersed is circulated through this emulsifier, and the coarse, undispersed material is separated from the emulsion.

The growing importance of high-pressure processes has emphasised the importance of methods of fabrication and testing of plant for these processes. Rapid progress is being made in the manufacture of hollow forgings of large size, and methods of making welded joints are being improved. The difficulties originally experienced in making welded joints of sufficient strength in high chromium steels have been overcome by the addition of nickel to the alloy, which prevents brittleness, and the disadvantage of the decreased resistance to corrosion is overcome by the addition of a small amount of silicon. Heat-resisting and acid-resisting alloy steels are finding wider application and new uses, though their price is still a serious obstacle to their general adoption. A new field for the use of "stainless" steel may be opened up as the result of some successful tests which have been made on the use of this material for building tank-wagons for the transport of milk. The "Nitrard" process of hardening steels by the action of ammonia gas at a suitable temperature is coming into use for the treatment of mechanical parts subjected to wear, and possesses the advantage that the hardness is not affected by subsequent heating up to the temperature of hardening.

Metallic coatings are being more widely adopted for protective purposes. Aluminium-plated steel is being manufactured for use instead of the ordinary tinned sheet. Further extension in the use of aluminium in the chemical industry appears likely as a result of recent developments in the coating of aluminium with thin sheet lead. The electro-deposition of protective metallic coatings is extending rapidly. Chromium plating is finding very wide application, whilst cadmium plating is being used as a substitute for galvanising, cadmium being more resistant than zinc to attack by alkalis whilst giving the same resistance to corrosion with a thinner coating.

Rubber is becoming increasingly important as a constructional material in the chemical industry. Rubber-lined metal vessels are proving satisfactory for sulphuric acid up to 50% strength and phosphoric acid up to 75% strength. Improved methods of attaching the linings are leading to the use of rubber-lined steel tank-wagons to replace those made of rubber-lined wood. A material made from rubber latex and Portland cement is finding many applications as a constructional material. Rubber linings for grinding mills are proving successful for wet grinding, though they are hardly suitable for dry grinding where heating takes place. Filter-presses made of rubber are finding application in certain processes. Rubber bearings, lubricated by water, are being used for centrifugal pumps handling abrasive materials. The resistance of rubber to abrasion is leading to its increased use as a covering for chutes carrying abrasive materials. Attempts are also being made to prevent excessive wear of the blades of exhausting fans by using rubber coatings. Bakelite enamels are proving serviceable as a protective coating against acids or acid fumes, and a bakelite-asbestos compound known as "Haveg" is finding use as a constructional material, one interesting example being a centrifugal acid pump constructed of this material.

The advantages of continuous over discontinuous operation are bringing about many important changes in

process work. Particularly in reactions or leaching processes, where gravity separation is possible, continuous sedimentation is being found highly advantageous.

The desirability of accurate control of any operation is leading to many developments in the perfection of remote control and of automatic control to eliminate the inevitable errors due to the human factor. Automatic boiler control with mechanical-grate or pulverised fuel firing is proving highly efficient and economical, and may be expected to become standard practice. Automatic control of hydrogen-ion concentration has proved successful in certain cases, and is likely to extend considerably. The use of the thermionic valve as an amplifier has rendered possible many improvements in accurate control. One such application is to automatic titrations where the colour of the solution controls the light falling on a photo-electric cell, and the resulting current is amplified and regulates the addition of liquid to the solution. Another interesting example is in the continuous recording of the moisture content of a moving web of paper and the automatic control of the drying. The paper forms the dielectric of a plate condenser, and changes in capacity cause minute changes of current, which are amplified and used to record the moisture content and to control the steam valves by which the drying is regulated. The rapid development of methods of automatic control of various operations in recent years is likely to lead to the adoption of these methods, and of new methods which will no doubt be evolved, on a very wide scale with resulting increased accuracy in control and substantial economy in operating costs.

A SUGGESTION WITH REGARD TO ANTI-OXYGENIC ACTION

By KENNETH C. BAILEY, Sc.D.

C. Moureu and C. Dufraisse have recently (CHEMISTRY AND INDUSTRY, 1928, 47, 819, 848) summarised their important researches on anti-oxygens.

They justly consider as one of the most striking phenomena of anti-oxygenic catalysis the "extraordinarily small number of molecules of the anti-oxygen which are able to prevent the oxidation of an enormous number of molecules of the auto-oxidisable substance by the action of oxygen." For example, one molecule of hydroquinone prevents the oxidation of forty thousand molecules of acrolein, and similar results were obtained with benzaldehyde.

Their well-known theory explains this phenomenon by supposing that only those benzaldehyde or acrolein molecules which possess a certain minimum energy are capable of reacting with oxygen, and that, as these molecules occur in very small proportion at ordinary temperature, a very small number of hydroquinone molecules is capable of dealing with them.

They draw a comparison with the arrest of the host of Xerxes in the pass of Thermopylæ by Leonidas and his three hundred Spartans, whose temporary success was due to their concentration in the narrow pass, and add that "the anti-oxygens . . . are able to hold auto-oxidation in check in the new and impassable Thermopylæ *which is represented by the activation of the molecules.*"

While admitting the hypothesis of active molecules with a certain minimum energy, it seems to the writer that such molecules, when mingled with many thousands of inactive molecules, might circulate for a long time without coming within the sphere of influence of a molecule of hydroquinone (present also in small concentration) and that autoxidation might readily take place during this period. The small number of the activated molecules is therefore not sufficient to account for their control by minute quantities of hydroquinone.

The author has recently (*J. Chem. Soc.*, 1928, 1204) described experiments on the reaction of ethyl alcohol and acetic acid, and has shown that this reaction takes place in two ways, (*a*) on the surface of the containing vessel, and (*b*) in the body of the liquid. The reaction (*a*) is completely inhibited by traces of pyridine, which, on the limited surface of the vessel, is capable of dislocating the alcohol-acid complexes before reaction can be completed, while the reaction (*b*) is only slightly affected even by the addition of much larger quantities of pyridine. The investigation has since been extended

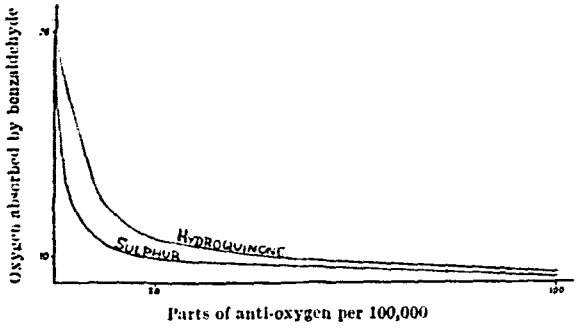

FIG. 1

to the inhibitory effect of quinoline, piperidine, and other alkaline compounds, and a detailed explanation of the inhibition is offered in a communication accepted for publication in the Journal of the Chemical Society.

These experiments suggest an explanation of the difficulty mentioned above. If autoxidation takes place only at the oxygen-benzaldehyde or the glass-benzaldehyde interface or both, a small number of hydroquinone molecules adsorbed at the surfaces will be able to deal with those of the active molecules which approach the surfaces. The narrow pass of Thermopylæ, in the inspired comparison of Moureu and Dufraisse, will then be represented by the surfaces, which are capable of being guarded by a relatively small number of Spartan molecules of anti-oxygen.

Fig. 1 has been constructed from the data given by the graphs of Moureu and Dufraisse (C.R., 1924, 178, 1861—4) for the inhibition by hydroquinone and sulphur of the autoxidation of benzaldehyde. (The figures for acrolein are not sufficiently certain for graphic representation, as pointed out by Moureu and Dufraisse (C.R., 1922, 175, 128—9).)