from exinite, and the results suggested that as much as 10 per cent of the exinite used may consist of chains with about 30 carbon atoms; correspondingly, aromatic compounds from exinite tar were more highly alkyl-substituted than those from vitrinite tar. W. Waddington had compared the relative abundance of isomeric forms in tar with that to be expected from the postulated thermal reactions of a proposed structural model. He suggested that the results obtained support the view that coals contain in part a 6 alkyl-4 propyl-2 methoxy phenol type of structure; this may be gradually converted to other structures by thermal/pressure reactions during coalification. C. Kröger and R. Brücker[15] reported results from high-vacuum pyrolysis of coals and discussed these in relation to the coal structure. Products in the range 300°–575° C. were examined by gas chromatography and other methods. Rate constants and activation energies for the evolution of hydrogen, many simple hydrocarbons and the carbon oxides were estimated; and from these in turn, by means of allocation of reactions to structural elements on certain assumptions, quantitative parameters for 17 elements of structure, such as the proportion of aromatic carbon in the coal, were deduced.

There proved to be a shortage of time for formal discussion, and on the other hand many delegates remarked on the value of spontaneous extra-mural discussions. Further experiment is clearly necessary in an attempt to correct this lack of balance. It is hoped that, since these conferences continue to produce more novel material than the average delegate can comfortably digest, further innovations will be made at the next conference, to be held at Cheltenham during 1963. I. G. C. DRYDEN

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BIOCHEMICAL ENGINEERING

A SYMPOSIUM on "Biochemical Engineering" was convened by the Institution of Chemical Engineers on May 30; it is doubtful whether any two of the participants, lucid as they were on their own topics, would have agreed on a definition of the title. Though, on one hand, one may assume unanimity of outlook in chemical engineers, the term 'biochemist' has been used by many disciplines, from the quantitative biologist to the organic chemist by way of the medical analyst. Moreover, in the fields where engineers encounter Nature in the raw, ought not such a title to be amplified to 'biological chemical engineering'? It is easy to see how confusing such exercises in labelling can be, though there is always a stimulation of interest and research by collecting certain topics together under a high-sounding title, however arbitrary.

Nevertheless, many industries are now based on the controlled use of biological processes. (Strangely enough, the largest industry of this type, brewing, was already developed more or less to its present size before the terms 'biochemist' or 'chemical engineer' existed.) It was the production of antibiotics by fermentation, especially under the high pressure of the Second World War, that brought a variety of biological interests (botanists, zoologists, pharmacists, agriculturists, entomologists—for there were very few true biochemists, by any definition, available at the time) face to face with the engineer (rarely of the 'chemical' variety). The difficulties of communication were considerable and were overcome the hard way. It was also realized that similar problems existed in the food preservation industries and the sewage and effluent disposal services. To help with these problems, the establishment of courses in 'biochemical engineering' were proposed—seldom, however, with any clear idea of what the graduates should do afterwards, although the vague idea of a superman who could control both sides of the industrial scene may have been in the minds of some proponents. The problems were considerable, for whereas most of the engineers' deficiencies were conceptual and philosophical, most of the biologists' were factual and mathematical. Making good the former must have seemed easier or, perhaps, they were not so apparent and the new discipline became, at least for a time, the protégé of chemical engineering.

Two difficulties then faced the new dispensation: first, that with normal chemical engineers at a premium, the supply of new graduate output could not hope for many years to affect the position; second, that with the enormous rate of growth of each parent topic, no person could hope to keep up to date in both biochemistry and chemical engineering. It was clear, therefore, that for many years to come the two functions of engineer and biologist would have to be realized by specialists in each discipline working side by side as separate entities. It was with this aim of bringing together the two groups that this symposium was called.

In the opening paper, Dr. D. J. D. Hockenhull reviewed the formal aspects of the production of economically desirable products from micro-organisms. He stated, as an axiom, that the primary function of a living organism is to reproduce itself. It does this by a complex interlinked system of biochemical reactions on the nutrients supplied to it. Interference with these processes may lead to the accumulation of intermediates or of alternative products derived from them. Industrially important examples of such interference were: unbalanced nutrition (acetic acid), deficient aeration (alcohol), mineral deficiency (citric acid), use of trapping agent (glycerol) or of foreign precursors (penicillin) or inborn error of metabolism (lysine). It was pointed out that these 'primary colours' of metabolic interference, in Dr. G. L. Solomon's words, were most usually applied in combination to-day to obtain the best results. A more

detailed account of the biosynthesis of penicillin was then used to illustrate the concept of controlled fermentation. In the early days, it used to be sufficient to choose an appropriate medium, inoculate it with the organism and leave the fermentation to proceed under set conditions until the time for collecting. To-day, it has been found that strict control of *p*H value, sugar-level and the rate of supply of nutrient are all essential for maximal yield. Such control brings fresh problems for the engineer in the design of suitable equipment. Sensing devices capable of withstanding the conditions of sterilization and of operating satisfactorily in fermentation broths are needed. It is particularly important in this context that the biochemist and the engineer should have a true appreciation of each other's problems.

The engineering problems associated with large-scale fermentations are mainly those of designing a bacterium-tight fermenter and supplying it with large quantities of sterile air. Then there are the associated problems of finding the best methods of aerating and agitating the fermentation broth to promote maximum yields of antibiotic and elimination of the foam that frequently occurs.

Other papers were concerned with more specific problems. The highly aerobic fermentations, as used for production of penicillin and streptomycin, present their own problems of aeration and agitation. Not only must the air supply be sufficient to provide all the oxygen the organism requires but it must also strip the fermentation broth of carbon dioxide which becomes toxic if allowed to build up to a high concentration. Agitation is necessary, first, to break the air into small bubbles, thus presenting a large surface area to the broth, and, second, to provide the shear action that aids mass transfer. Other functions of agitation are to keep solids and mycelium in suspension to ensure that the fermentation broth is of uniform composition. Good mixing is also important for close control of temperature. Efficient agitation also breaks down the mycelium and prevents it growing into large aggregates or clumps.

Two papers were presented on the separate aspects of aeration and of agitation of fermenter broths. Prof. P. H. Calderbank, in his third paper on physical rate processes in industrial fermentations, examined the rate of mass transfer from the liquid to solid particles suspended in mixing vessels. An attempt was made to simulate a mycelial suspension by the use of screened ion-exchange resin particles. The rate of mass transfer was assessed by introducing the acid form of the resin into a dilute sodium hydroxide solution and noting its rate of change of *p*H with time under the desired conditions of agitation and aeration. A serious restriction in transfer occurred if the solid were allowed to aggregate into large clumps. The process of liquid-to-solid mass transfer seemed to be rate-determining in many industrial fermenters.

Dr. N. Blakebrough considered aeration and agitation from a different point of view, using a photographic technique developed to examine patterns of flow in a mixing vessel. The importance of work on flow-patterns, for large-scale operations, is not so much to find out the actual distribution of velocity but rather to confirm that the broth in all parts of the fermenter is being agitated so that no stagnant zones exist.

Both Prof. Calderbank and Dr. Blakebrough approached their problems as chemical engineers. They had used bench-scale apparatus with low-viscosity Newtonian liquids, very different from the viscous non-Newtonian broths often used in industrial fermentation practice and requiring agitation and aeration in vessels of, say, 10,000 gal. capacity. It is to be hoped that, in future, more work will be directed towards the study of non-Newtonian liquids, and that some indications will be obtained on the methods of scale-up needed for predicting with confidence the degree of mixing in a large fermenter.

In aerobic fermentation of pure cultures, sterility is a special problem as the volumes of air involved are large. For example, a fermenter of, say, 10,000-gal. capacity could be fed with 1,000 cu. ft./min. air. In industrial practice absolutely sterile air can rarely be obtained. A compromise is made between the effectiveness of the sterilizing treatment and the detrimental consequences of an infection. For design purposes, a penetration of 1 in 10^{12-13} has been suggested ; that is to say, out of every 10^{12-13} organisms in the air presented to the sterilizing device only one should pass through into the fermenter.

In laboratory-scale work the most common way of sterilizing air is to pass it through a cotton-wool plug or an absorbent filter. On the large scale, filters of glass wool, slag wool or powdered carbon are generally used. Some form of air heater may also be used. The main interest in Mr. R. Elsworth's paper lay in the demonstration that sterilization by heat to kill infecting organisms can be considered as a simple chemical reaction the rate and extent of which can be predicted from an equation of the Arrhenius type. When absolute sterility is not essential, the information presented in this paper can be most useful for determining the time/temperature relationship necessary for a desired penetration.

In the laboratory, experimental work to improve the performance of a fermentation is normally carredi out with shaken conical flasks ; this is the cheapest way of finding out the effects of variations in the strain of organism or the medium used to grow it, for replicate cultures are easy to set up. However, the characteristics of aeration and agitation in shaken flasks are very different from those in conventional deep fermenters. Intermediate development work is therefore also carried out in bench-scale fermenters having a capacity of about 1 gal., and in pilot-plant units of several hundred gallons capacity.

Dr. A. Parker presented a paper on equipment for such laboratory and pilot-plant scale fermentations. After a brief review of the literature of this subject, he divided his paper into two parts, the first dealing with laboratory-scale vessels of 5-l. capacity and the second with 220-gal. pilot-plant fermenters. The wide diversity of engineering problems associated with the design of fermenters clearly illustrated the relationship between the engineering designer and the biochemist using his equipment. Another point made was the great similarity in fermenter design regardless of its size. Particular attention was needed in the design of agitation-shaft glands, the techniques of aseptic sampling and the transfer of seed cultures. Rates of oxygen transfer, as measured by the sulphite method, were given for the fermenters described, under various conditions of agitation and air flow. Sulphite oxidation-rates could not necessarily be correlated with actual fermentation results, but they did serve as a useful index of performance and were also helpful in comparing different agitation systems.

Aeration processes for the biological oxidation of waste waters were described by Mr. A. L. Downing. In effect, the activated sludge process is a very dilute fermentation. The whole process must be carried out as cheaply as possible. Various devices used for aerating the waste liquors were described, such as the induction of air through a Venturi tube and the use of a submerged impeller and sparger. The effects of bubble diameter and depth of liquid through which the bubbles travel were also studied in tap water containing 5 p.p.m. anionic surface-active agent. The effects of surface-active agents on mass transfer were found to depend on the method of aeration. As would be expected, the rate of absorption was roughly inversely proportional to the bubble diameter, and the oxygen absorbed per unit consumption of energy tended to decrease with increased depth of liquid.

The shortness of the Symposium imposed very strict scheduling and handicapped free interchange of opinions. The discussion was held back until several principal papers had been given, and this led to some 'cooling off', which was also encouraged by the separation of question and response. There was a tendency for many of the contributions to be too restricted in scope and lacking in general philosophical content. Perhaps this is a way of saying that they were too specialized for one-half of the audience. Again, a contribution on equipment design, or even some account of the problems associated with it, even to such special details as design of valves, sampling devices, probes and electrodes, might have brought a little more practicality and scope for argument.

The meeting, although demonstrating clearly that biologists and chemical engineers speak rather different languages even when working on the same processes, did indicate that the barriers are not impassable. Moreover, who knows, in crossing the perilous mountains between the two disciplines, one might come across that 'abominable noman', the biochemical engineer. The proceedings of the symposium are to be published in *Transactions of the Institution of Chemical Engineers*. D. J. D. HOCKENHULL

COSMIC RAY RESEARCH IN LATIN AMERICA

THE third Latin-American conference and course on cosmic ray physics was held in Mexico during June 26–July 5. It was arranged by Profs. M. S. Vallarta and J. Roederer on behalf of the Latin-American Council for Cosmic Ray Research under the auspices of Unesco, the Mexican Nuclear Energy Commission, and the U.S. Space Science Board.

The meetings were held at the University of Mexico, famous for the elegance of its remarkable architecture, and at the headquarters of the Nuclear Energy Commission. There were present some 25–30 representatives from Argentina, Bolivia, Brazil, Chile, Mexico, Peru, the United States and the United Kingdom. The course consisted partly of original contributions and partly of lectures of a review nature. The topics covered in the lectures included the nature and origin of the galactic cosmic rays and solar-produced high-energy particles, the intensity variations of the galactic radiation and their relation to solar activity and the structure of the interplanetary magnetic field, the motion of primary cosmic rays in the geomagnetic field, the properties and origin of the Earth's radiation belts, and solar radio astronomy.

The Latin-American countries between them operate a chain of neutron monitors covering a wide belt of latitude from Mexico in the north to Ellsworth in Antarctica, and a good deal of the original work reported at the meeting was concerned with the analysis and interpretation of the data from these stations.

In particular, the remarkable cosmic ray intensity variations during July 1959 and November 1960 (when there were examples both of decreases in the intensity of galactic particles and of injection of additional low-energy particles by the Sun) have been very carefully analysed by the Argentinian, Bolivian and Brazilian groups. In discussing the events of November 1960 the Argentinian workers arrive at the conclusion that the main intensity increase starting at 1930 U.T. on November 12 was due to the envelopment of Earth by a cloud of magnetized solar plasma containing trapped solar particles generated by the 3+ flare which began at about 1330 U.T. on that day. They also conclude that the presence of the magnetic field associated with the plasma was responsible for producing the decrease in intensity of the galactic cosmic rays observed at this time. They attribute the increase in intensity of solar particles between 1330 and 1930 U.T., prior to the main increase, to leakage from the trapping field in the plasma.

The Bolivian group, which operates the extremely well-appointed laboratory at Chacaltaya (altitude 5,200 metres above sea-level) includes in its cosmic ray activities the study of both large air showers and intensity variations related to solar processes. Included in the work reported by this group was an account of the rapid, short-lived intensity decrease observed on November 13, 1960, by means of its neutron monitor, which has the very high counting-rate of $\sim 5 \times 10^5$ per hr. Immediately after the magnetic storm sudden commencement at 10 hr. 21 min. U.T. on that day, the cosmic-ray intensity started to decrease and shortly after 1300 hr. U.T. it dropped suddenly, remaining 3 or 4 per cent below the general prevailing level for about $1\frac{1}{4}$ hr., after which it returned suddenly to the pre-drop value. Analysis of data from other stations showed that this phenomenon happened on a world-wide scale, and the Bolivian group concludes that this kind of modulation of the galactic cosmic-ray intensity could only be produced if the solar plasma contained a very well-defined region of relatively high magnetic field strength.

The work of the cosmic ray group in Santiago at the University of Chile, reported by Prof. G. Alvial, is principally concerned with the investigation of the primary cosmic rays using nuclear emulsion techniques, and he described work which has been carried out on charge determination of heavy nuclei in a stack of *G*-5 emulsion exposed at 131,000 ft. over Minnesota. Charge determination by two methods