selection; and if a standard method of describing series is adopted internationally, extended use of the 'Cardatype' machine in listing serial publications offers an opportunity for co-operation between organizations in different parts of the world in determining the availability of periodicals. The team considers that commercially available selecting machines have achieved nothing that cannot be achieved by traditional methods, although adequate costing data were not obtained and the use of such machines does not eliminate cross-referencing. The future value of the Rapid Selector line of development is also doubtful, but a simplified selector built on the principles of an electronic computer might compete in cost and speed of operation with proposed International Business Machine developments.

MECHANICAL PROPERTIES OF PLASTICS

UNDER the title of the "Mechanical Properties of Plastics", the Plastics and Polymer Group of the Society of Chemical Industry organized an all-day symposium, held at the Institution of Electrical Engineers, London, on March 7. The considerable interest in the subject was indicated by the fact that some two hundred members and visitors attended, including representatives of the Chemical Engineering Group of the Society. Five papers were presented during the day, and ample time was allocated for the vigorous discussion which followed each contribution.

In a brief introductory summary, Dr. N. J. L. Megson pointed out that since 1939 a revolution has taken place in plastics. The materials are finding increased application to the production of large items having properties not previously considered practicable. Unfortunately, because of a lack of fundamental knowledge, much of the necessary development work has to be done on an empirical basis; a symposium of the present type was therefore justified, even if it only directed attention to the gaps in our knowledge.

Dr. Megson indicated three main categories in which mechanical testing can be approached: the fundamental approach, which seeks to relate molecular shape and size, or the composition of a heterogeneous material, with mechanical behaviour; the assessment of a material for practical use, by determination of properties by means of carefully selected tests; and the empirical approach, which uses mechanical test procedures to compare one material with another or to lay down standards. He thought that, of these, the fundamental approach would be expected to prove of greatest interest at a meeting of this character. Nevertheless, this did not mean that the other categories were unimportant, and, in fact, most of the papers naturally covered more than one category in their scope. It was, of course, obvious that the practical utility of a material (the second category) must be of primary importance to the plastics industry.

In the first paper, on the "Physical Evaluation of Small Samples of Plastics", by K. H. C. Bessant, Mrs. M. G. Dilke, C. E. Hollis and J. J. Millane, Mr. Hollis explained that work had been undertaken to permit the evaluation of experimental samples (5-50 gm.). For hard thermoplastics he described

tests for impact strengths, softening-points and flow characteristics, while for elastomers (for example, polyvinyl chloride) he dealt with tensile strength and elongation at break, British Standard hardness, brittle temperatures, resilience and plasticizer loss. With suitable precautions, all these can be carried out with appropriate modifications of existing methods. Reproducibility is sufficient for making significant comparisons between laboratory samples. This paper provoked questions about the shape and size of test pieces and on plasticizer volatility, and discussion also took place on the speed of testing in dilatometric determinations and on the T_m curves for polystyrene, which become one continuous curve at equilibrium. Mr. Hollis, in reply to the last point, mentioned the investigations of Spencer and Boyer, and of Mark, which are not in agreement with those of Bekkedahl; he said that Mr. Millane and Mrs. Maclaren are shortly going to publish a paper which supports the first workers' contention that a straight-line graph is produced at equilibrium.

In a joint study of the "Interpretation of Mechanical Tests of Plastics", by C. G. Evans and H. W. Hall, the authors explained that they were concerned with the development of materials suitable for the production of aircraft structures. In particular, they referred to asbestos-reinforced phenolic resin compositions, moulded under very low pressures. They pointed out that the most important properties are strength and stiffness in tension, compression and shear, together with toughness, which is connected to some extent with impact strength. They explained the problem of translating laboratory tests into terms which will enable engineers to use the materials efficiently in practice. Mr. Hall stressed the difficulties associated with determinations of impact strength, and made a strong plea that tensile impact should replace existing methods, illustrating his remarks with information obtained from an American source. The work by the authors has involved examination of the effects caused by various reinforcing fillers with a variety of resins. The discussion on this paper covered a wide field, including the importance of moisture content in laminating material, the significance of good adhesion between filler and resin (and therefore the influence of type of asbestos on strengths, since different grades show varying adhesion), the size of test pieces and the influence of surface finish, the calculation of theoretical strengths of moulded compositions, the importance of rate of loading in testing, the possibility of developing improved sizes for glass fabrics with the idea of improving resin adhesion, the value of tensile-impact testing, and the influence of fibre length on ultimate strengths of mouldings.

The next speaker, Dr. E. A. W. Hoff, in a study of "Some Mechanical Properties of 'Perspex'", showed plainly how important is the fundamental approach of the first category mentioned by Dr. Megson. After considering the nature of polymer molecules, their entanglement and their mutual reactions, together with temperature effects, Dr. Hoff pointed out that it is unwise to take over existing metal-testing techniques with the expectation of obtaining results useful in the field of plastics. He illustrated his point by referring to the relations between molecular structure, on one hand, and fatigue results, compression and tensile testing and static loading strengths, on the other. Finally, in agreement with Mr. Hall, he emphasized the difficulty of interpreting satisfactorily the results of

conventional impact tests. Most of the comments on Dr. Hoff's paper dealt with fundamental ideas, although such practical matters as the value of impact tests were raised. There was general agreement with Dr. Hoff that it is not possible to apply metal tests to such heterogeneous materials as plastics. The mechanism of breaking was discussed, since it is not clear how molecules can become disentangled if viscous flow does not exist below the transition point. Dr. Hoff agreed there is evidence that carbon-carbon linkages are probably broken, although a mechanism involving the separation of bundles of molecules may also occur. Other topics brought up included: the production of a 'standard' scratch, the effect of plasticizer on stress/time curves, the 'memory' of test pieces after deformation (particularly in connexion with intermittent loading), and the 'weakest link' type of fracture. Finally, stress was laid on the importance of distribution curves in test work, and the necessity for keeping molecular mechanisms in mind when statistical analyses are being made.

"Two Extrusion Plastometers for use with Polyvinyl Chloride" was the subject of a paper by R. Hayes. Arising from the importance of 'flow' properties, he explained that two types of plastometer have been developed. The first consists essentially of a heated metal block containing a chamber from which plastic is forced by a known pressure through a weight-loaded lever. The time taken for extrusion of a standard volume of material is determined at various pressures, flow-time/pressure curves are drawn, and the pressure required to extrude material at a standard rate is taken as the index of flow. The second instrument is essentially a modification of the Atkinson and Nancarrow plastometer. The extrusion piston is driven down at constant speed, and develops a pressure which is recorded through a pressure capsule. Both instruments are empirical in character and were designed for development and factory control work.

In the final paper, on "Indentation Testing of Phenolic Mouldings by Brinell and Hot Needle Methods", by J. H. Bennitt and C. E. Avenell, Mr. Bennitt explained that the object was to explore the possibility of using indentation tests, which could be made quickly and accurately with minimum damage, as a means of checking properties of mouldings. The Brinell (cold ball) test has been found useful in determining compositions of mouldings and gross differences in curing. Chemical resistance can also be followed; for example, there is a direct relationship between absorption of sulphuric acid and change in depth of indentation. The hot-needle machine, originally developed by Bisterfeld and Stoltzing in Germany, gives similar correlations. Thus, depth of penetration is directly connected with degree of cure, resistance to chemicals and types of filler. Mr. Bennitt doubted whether the test is suitable for routine testing of degree of cure, but he gave various examples of its utility, for example, in showing that discoloration in mouldings had been caused by hot spots during moulding, and in following the rate of curing of silicone mouldings. This paper brought questions on the relation between indentation of mouldings and degree of water penetration, the influence of specimen thickness and the application of the hot-needle test to acid-resisting cements and to post-stoved mouldings.

Dr. D. J. van Wijk, of the Netherlands Plastics Research Institute of Delft, made an important

contribution to the ensuing discussion. He criticized normal test methods on three scores: they bear little relation to the characteristic properties of plastics; time or speed of deformation are entirely neglected; and results of destructive tests are influenced by many unknown factors. The tests fail to provide a better understanding of the real elastic, visco-elastic and plastic properties because results cannot be expressed as ultimate physical constants. As examples, he pointed out that E (modulus of elasticity) is not a constant but depends on temperature and time, and ageing-characteristics affect the results. He also mentioned the significant importance of relaxation times, and finally asked that more attention should be paid to creep and high-frequency vibration phenomena.

N. J. L. MEGSON

CHEMICAL ENGINEERING AT THE CROSS-ROADS

IN his presidential address entitled "Chemical Engineering at the Cross-Roads", delivered at the thirtieth annual corporate meeting of the Institution of Chemical Engineers, Sir Harold Hartley described chemical engineering as the fourth primary technology. He said that, just as the older technologies of civil, mechanical and electrical engineering developed when specialized knowledge increased, so the chemical engineer has evolved as a separate entity owing to the immense advances in the chemical and allied industries during the present century. The chemical engineer does not compete with engineers of the older classes, but works in harmony with them and supplements their knowledge. All engineers make use of practical experience based on scientific principles to solve the many problems which confront them; in the case of the chemical engineer, the directions in which he can apply his knowledge are so varied that it is becoming increasingly difficult to decide how he should be trained. It would seem, said Sir Harold, that even more emphasis than at present must be placed on the basic sciences and fundamental laws, so that a scientific rather than an empirical approach becomes natural, while flexibility of outlook and acquaintance with the methods of research are of vital importance. With such a background, technical details can be assimilated readily.

To illustrate the varied directions in which a chemical engineer may turn, Sir Harold quoted a few examples. One of the engineer's main tasks is the efficient use of energy; a modern steam power station depends largely upon the correct application of chemical engineering principles, while oil refining, with its most recent development the synthesis of chemicals, is a fast-expanding industry requiring chemical engineers by the hundred. Even more important will be the work of the chemical engineer when the 'fossil fuels' upon which we so largely depend for heat and power approach exhaustion. He is already attempting to produce atomic energy economically; to-morrow his task may be to utilize solar energy for controlled photosynthesis. In another direction he must devise means for extracting metals from ores of ever-diminishing richness, and in yet another he must endeavour to make increasing use of the so-called waste which arises during the pro-