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Handbook of plastics test methods

Handbook of Plastics Test Methods

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Preface

A Plastics Institute publication on the general subject of testing has not appeared since 1954*. In the intervening years the picture has changed radically. The industry itself has grown at a very rapid rate, thereby not only increasing the range of uses of plastics materials but also involving the introduction of many novel polymer compositions with improved properties. These two factors have inevitably required an increase in the number of test methods available to assess the performance of plastics, both for 'type approval' and 'quality control' purposes.

Again, since 1954 the standards and specifications picture has altered out of all recognition. Taking the United Kingdom and United States as examples, there are now volumes specifically devoted to the testing of plastics—British Standard 2782:1970 and American Society for Testing and Materials book of Standards, Part 27. On the international level progress is being made with the production of I.S.O. Recommendations, which are being written into national standards as time and opportunity allow. It might well be asked, therefore, 'Is there any need for a handbook of plastics test methods?' In answer to this, it is hoped that three justifications have been fulfilled:

1. The need to compare various standard methods and draw attention to their differences (and the differences of results obtained).
2. The necessity of providing background information to the tests available, to demonstrate what the results thereof will and will not provide.
3. The desirability of describing some useful tests which do not, at least at the time of writing (see below) appear in standards and specifications.

Again it might reasonably be questioned why elastomers should not be included, when the dividing line between them and plastics is becoming ever more diffuse; however, quite apart from any question of remit to the authors, there is already in existence an excellent textbook on the subject†.

Even within the compass of the monographs series which has so far been published by The Plastics Institute, there now exists two of considerable relevance to the subject generally:

1. GORDON, M. *High Polymers. Structure and Properties*, 2nd Ed. (1963) and
2. RITCHIE, P. D., Ed. *Physics of Plastics* (1965).

Frequent reference has been made in this handbook to these two

*COLLINS, J. H., *Testing and Analysis of Plastics, Part II: The Testing of Plastics*, 2nd (Revised) Edn.

†SCOTT, J. R., *Physical Testing of Rubbers*, Maclaren & Sons, Ltd. (London) 1965.

books in particular and, for this reason, acoustical properties of plastics, for instance, have not been discussed (as they form Chapter 9 of 'Physics of Plastics'). Likewise, subjects already well covered by existing textbooks, and particularly those on the fringe of plastics testing when interpreted literally, have not been considered in detail; however, references to textbooks and technical articles have been given wherever possible, in an endeavour to make the present volume self-contained in some degree. As a corollary, in the case of Chapter 8 a simple description of some mechanical test machines is included. In the authors' experience, these are often used by people who have no conception of the machines' capabilities, and particularly their limitations, and there does not seem to be a suitable up-to-date textbook on the subject.

Chemical analysis has not been deemed to fall within the compass of the subject in any sense (see Chapter 17) and, by and large, attention has been restricted to the general testing of plastics as such, i.e., the many methods which exist for evaluating specific shapes, forms and even some unique types of plastics have not been given more than a passing reference (again, see Chapter 17). The testing of compounding ingredients and aids to processing—solvents, plasticisers, lubricants, stabilisers, pigments and the like—has not been covered except in so far as their evaluation logically forms part of the testing of a plastics material per se.

As far as reference to national standards is concerned, attention has been restricted to British, United States and German documents, not only for reasons of space but also because there is no doubt that standardisation in these three countries is currently more advanced than elsewhere; international (I.S.O.) standards have not been described in detail because their practical value emerges only when adopted nationally. The reader interested in other sources is recommended to study Chapter 2 and particularly the appendices thereto. Many of the standard tests are described in considerable detail, *not* as a substitute for studying the official document when necessary, but to try to drive home the absolute necessity of working precisely to instructions—particularly for quality control—in such mundane matters as dimensions of tolerances; in many instances, chosen at random the actual specified tolerances have been quoted to try to drive the point home. In over twenty years of testing plastics, the authors have many times seen time wasted and effort needlessly expended in arguments between supplier and customer, for example, over disagreements in results when post mortem examination has shown that one or other party, or perhaps both, has been 'cutting corners' or deviating from the standard method in some way or another.

I was originally asked in 1963 to write this book, but over-optimism on speed of output combined with family and business affairs has delayed its completion. I am therefore particularly grateful to my colleagues, Messrs. J. A. Mead and M. M. Riley, for so readily agreeing to undertake the writing of five of the more specialised chapters when it looked as though the project would never be completed. We are all greatly indebted to our colleague, Mr. D. B. S. Berry, for his helpful comments and criticisms. And whilst thanks are being expressed, the gratitude of all three of us is due to our colleagues in the information and library department for tracing all the textbooks and journals to which reference has been made (and every one of

which has been examined). Full titles are given to references so that the reader may be able to identify particular articles or books which may interest him beyond that matter relevant to the subject under discussion. Generally speaking, references are restricted to articles describing or discussing test methods, but where properties are being described which are not commonly quoted, sources of information are included. The more commonly available data are to be found in trade literature of the more reputable manufacturers or, for instance, in *Design Engineering Handbook. Plastics*, (Product Journals Ltd., Summit House, Glebe Way, West Wickham, Kent. BR4 OSL—1968).

When at last it seemed possible that this book would be finished in the foreseeable future, a date stop was applied of early, 1970. This means, *inter alia*, that standard methods have been taken from:

1. B.S. 2782:1970, 'Methods of Testing Plastics'
2. A.S.T.M. Parts dated 1969 (Particularly Parts 26 and 27).
3. DIN standards up to that date.

Anyone specifically interested in the most up-to-date description of a standard test method, and many are altered quite frequently, *must* examine the latest edition of B.S. 2782 and its amendments, and the latest A.S.T.M. manual, etc. All contractual arrangements, and particularly those involving government departments should call up the very latest document. For product specifications in particular, where the British Standards Institute publications are not so helpful as those of their counterparts in the U.S.A. and Germany in providing a comprehensive list in one or two documents, Appendix 2 of Chapter 2 has been prepared. To be brought right up-to-date every issue including and after June 1970 of 'B.S.I. News' should be studied—a suitable short cut is, however, possible by the judicious study of the latest issue of the British Standards Yearbook (the current coverage includes the 1970 issue).

Currently many of those countries, including the U.K., which have traditionally used Imperial units, or non-metric units generally, are in a state of transition. Internationally, a system of units known as SI (Système International d'Unités) has been agreed and is in course of being adopted in many countries; this is not the c.g.s., or metric technical, scheme but is somewhat akin thereto. Hence official standards, literature sources and information sheets may or may not have yet been 'metricated' at this moment; where they have, some give the equivalents in the traditional units, others do not. In this handbook, the policy has been generally to quote the units as given in the source of information being cited.

The subject of plastics testing could have been treated in a number of ways, but it is hoped that the one selected will be found logical and convenient to two classes of reader in particular:

1. The student of plastics technology
2. The person in industry who has either to test plastics to earn his living or who is indirectly involved in their evaluation

An advanced treatise on the subject has not been attempted, as it is considered that there are sufficient misconceptions of the subject at the relatively simple level to be ironed out, without delving too deeply into the more esoteric realms of, for instance, design data prediction.

Chapters 1 and 17 contain what could not conveniently be fitted into the other fifteen, the former describing all the matter which is common to the remainder and the latter covering the subjects left out after the first sixteen had been written. Chapter 1 is also intended to provide a gentle introduction to the subject, an aim which I am encouraged to think has been achieved at least to some degree by the comment of my (then) secretary: after typing the first few chapters she said 'I enjoyed Chapter 1 and understood it—pity you had to go on!'

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All authors, publishers and companies mentioned for their kind permission to reproduce diagrams, photographs etc. supplied and to the British Standards Institution, American Society for Testing and Materials and the Deutscher Normenausschuss for permission to reproduce extracts and diagrams from their standards, copies of which may be obtained from the addresses given in Chapter 2.

G. C. IVES

Contents

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Introduction to the Testing of Plastics

Test: 'That by which the existence, quality or genuineness of anything, is or may be determined' *(The Shorter Oxford English Dictionary).*

1.1 PHILOSOPHY—WHY TEST?

Why test plastics or, for that matter, why test anything? Why not rely on experience and good workmanship, backed up by sound judgement? The answer to these apparently simple questions is not so obvious as might be first thought, particularly when it will be seen, throughout what follows, that practically every test has limitations, the data it yields being only applicable with discretion to the everyday conditions of service.

When dealing specifically with plastics materials, however, the questions posed above are already part answered by the very case history of the industry, or rather the lack of it! Very few plastics in common use today were available ten years ago in precisely the same form; even if the polymer is basically the same—and there may be refinements of processing which have led to a more pure product, for instance—the plasticiser has probably changed or a new stabiliser system has found favour. The polymer molecules of many other current plastics compositions were not even known ten years ago! Thus, there is not much experience upon which to rely. (These circumstances make it very difficult to promote the use of plastics in, for instance, structural applications where the designer may insist upon a guaranteed 50 year performance.)

Testing, then, may be undertaken to assess the performance of a material in relation to the duty which it is to perform, i.e. to establish *suitability for purpose;* the mechanical properties will be measured and correlated with the calculated stresses, the electrical properties with the known circuitry, and so on. Judicious use of such measurements ideally will obviate the inspired guess, or gross wastage because of the necessity to 'play safe', and in this way the necessary experience will be assembled with a minimum of headaches.

Not that the Plastics Industry can aspire ultimately to an idyllic future, free from tiresome and profit reducing testing, any more than the more traditional industries do today. All men and machines are fallible and liable to vary in performance for a variety of reasons; the things they produce will alter in quality correspondingly. Thus we find the second principal reason for testing, as a *control of quality*. Under this broad heading come regular quality control schemes, production batch testing by random sample, purchasers' tests and control sample examination in the case of dispute.

1.2 HOW TEST?

If it is accepted that we must test, then surely that is the end of the matter. Why write a whole book on the unfortunate necessity? After all, everyone knows that 'tensile strength' is the resistance of a material to breaking by stretching, so where can there be room for argument? In a limited sense there is little in this particular case; it is true that, for instance, vendor and purchaser would both have the same broad picture in mind in discussing the tensile strength of a material, though there are many cases where different interpretations can be put on one property name and many more where a number of names apply to the same property. More generally, however, the case of tensile strength is no exception and well illustrates why testing needs such a lengthy description.

Let us suppose that a new moulding composition has been offered, of unknown origin and with a plain statement on its container:

'Tensile strength: 8000 force units/area', say '8000X'.

It is a penny per unit weight cheaper than the material we are at present using, which is satisfactory for our application; this, we will assume for convenience, is one (highly fictional!) where only tensile forces come into play and that there are no other considerations to bother us*. Our current material also has, we have been told by our suppliers, a tensile strength of '8000X'. Why should we not change materials and save money—the same strength for a penny a pound cheaper!

In fact one good reason for looking into the matter further has already become evident. Moulding compositions are usually in the form of granules, pellets, chips or powders, but tensile strength is determined on a moulding of some form or other; therefore we must produce the appropriate test specimens and we must ensure that although small they are representative of the product as a whole, in other words our *sampling procedure* must be sound. Any moulder or fabricator will know just how much the appearance and strength of a moulding can be altered simply by varying the cycle applied to a given moulding composition. Thus our two figures of '8000X' can only be compared if the *conditions of any preheat, moulding temperature, cycle time, etc.*, are comparable or, better still, if the figures are realistic optima which can be obtained using conditions (especially of time) that are commercially feasible. (Obviously a material which only attains an adequate tensile strength after an uneconomic cycle cannot be considered.)

So far we have achieved the moulding of our test pieces and already we have run into two good reasons why the quoted tensile strengths might not be comparable; however, we have hardly started yet! Most plastics materials are affected by quite small changes in *temperature;* the stiffening of some

*For the perspicacious—the specific gravities are the same too!