POWDER TECHNOLOGY SERIES

PARTICLE SIZE MEASUREMENT

Fourth edition

Terence Allen

Particle Size Measurement

TERENCE ALLEN
Senior Consultant
E.I. Dupont de Nemour and Company
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USA

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Powder Technology Series

EDITED BY BRIAN SCARLETT

Delft University of Technology
The Netherlands

Many materials exist in the form of a disperse system, for example powders, pastes, slurries, emulsions and aerosols. The study of such systems necessarily arises in many technologies but may alternatively be regarded as a separate subject which is concerned with the manufacture, characterization and manipulation of such systems. Chapman and Hall were one of the first publishers to recognize the basic importance of the subject, going on to instigate this series of books. The series does not aspire to define and confine the subject without duplication, but rather to provide a good home for any book which has a contribution to make to the record of both the theory and the application of the subject. We hope that all engineers and scientists who concern themselves with disperse systems will use these books and that those who become expert will contribute further to the series.

Particle Size Measurement
T. Allen
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Particle Technology
Hans Rumpf
Translated by F.A. Bull
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My thanks are also due to holders of copyright for permission to publish and to many manufacturers who have given me full details of their products.

Finally, I would like to thank my wife for her forbearance while the writing of this book has been in progress.

Terence Allen

Preface to the fourth edition

Powder technology is a subject in its own right, and powder characterization is central to an understanding of this discipline.

In the eight years since the printing of the third edition of *Particle Size Measurement* there have been two big changes in my life. After thirty years of academia I have returned to industry, and after a lifetime in Great Britain I have emigrated to the United States.

In industry the initial demand is to relate powder properties to product performance and then to maintain powder consistency. This requires on-line or rapid off-line analysis which, in turn, has led to the demand for a whole range of new instruments whose primary function is process monitoring.

Historically, chemical engineering courses have concentrated on the behaviour of fluids, and engineers enter industry relatively unschooled in the subject of powder behaviour. Yet, when my colleagues Reg Davies and John Boughton surveyed three thousand Dupont products, they discovered that 80% involved powder at some stage of their manufacture. The results of this survey illustrate the need for more training in this key subject.

This edition reflects the changing image of powder characterization towards in-process size analysis. Hence the chapter covering on-line analysis has been largely re-written. Apart from this, I have expanded certain sections and describe the new instruments that have been introduced since the last edition.

The emphasis here is on commercial equipment and for an up-date on research and development in this area I recommend the reviews Particle Size Analysis by Barth, H.G. and Sun, S.T., *Anal. Chem.*, **57**, 151R, 1985 and 142R, 1987, and Critical Reviews in Analytical Chemistry by Miller, B.V. and Lines, R., **20**(2), 75–116, 1988.

Terence Allen

Senior Consultant
E.I. Dupont de Nemours

Preface to the first edition

Although man's environment, from the interstellar dust to the earth beneath his feet, is composed to a large extent of finely divided material, his knowledge of the properties of such materials is surprisingly slight. For many years the scientist has accepted that matter may exist as solids, liquids or gases although the dividing line between the states may often be rather blurred; this classification has been upset by powders, which at rest are solids, when aerated may behave as liquids, and when suspended in gases take on some of the properties of gases.

It is now widely recognized that powder technology is a field of study in its own right. The industrial applications of this new science are far reaching. The size of fine particles affects the properties of a powder in many important ways. For example, it determines the setting time of cement, the hiding power of pigments and the activity of chemical catalysts; the taste of food, the potency of drugs and the sintering shrinkage of metallurgical powders are also strongly affected by the size of the particles of which the powder is made up. Particle size measurement is to powder technology as thermometry is to the study of heat and is in the same state of flux as thermometry was in its early days.

Only in the case of a sphere can the size of a particle be completely described by one number. Unfortunately, the particles that the analyst has to measure are rarely spherical and the size range of the particles in any one system may be too wide to be measured with any one measuring device. V.T. Morgan tells us of the Martians who have the task of determining the size of human abodes. Martian homes are spherical and so the Martian who landed in the Arctic had no difficulty in classifying the igloos as hemispherical with measurable diameters. The Martian who landed in North America classified the wigwams as conical with measurable heights and base diameters. The Martian who landed in New York classified the buildings as cuboid with three dimensions mutually perpendicular. The one who landed in London gazed about him despairingly before committing suicide. One of the purposes of this book is to reduce the possibility of further similar tragedies. The above story illustrates the problems involved in attempting to define the size of particles by one dimension. The only method of measuring more than one dimension is microscopy. However, the mean ratio of significant dimensions for a par-

ticulate system may be determined by using two methods of analysis and finding the ratio of the two mean sizes. The proliferation of measuring techniques is due to the wide range of sizes and size dependent properties that have to be measured; a twelve-inch ruler is not a satisfactory tool for measuring mileage or thousandths of an inch and is of limited use for measuring particle volume or surface area. In making a decision on which technique to use, the analyst must first consider the purpose of the analysis. What is generally required is not the size of the particles, but the value of some property of the particles that is size dependent. In such circumstances it is important whenever possible to measure the desired property, rather than to measure the 'size' by some other method and then deduce the required property. For example, in determining the 'size' of boiler ash with a view to predicting atmospheric pollution, the terminal velocity of the particle should be measured; in measuring the 'size' of catalyst particles, the surface area should be determined, since this is the property that determines its reactivity. The cost of the apparatus as well as the ease and the speed with which the analysis can be carried out have then to be considered. The final criteria are that the method shall measure the appropriate property of the particles, with an accuracy sufficient for the particular application at an acceptable cost, in a time that will allow the result to be used.

It is hoped that this book will help the reader to make the best choice of methods. The author aims to present an account of the present state of the methods of measuring particle size; it must be emphasized that there is a considerable amount of research and development in progress and the subject needs to be kept in constant review. The interest in this field in this country is evidenced by the growth of committees set up to examine particle size measurement techniques. The author is Chairman of the Particle Size Analysis Group of the Society for Analytical Chemistry. Other committees have been set up by The Pharmaceutical Society and by the British Standards Institution and particle size analysis is within the terms of reference of many other bodies. International Symposia were set up at London, Loughborough and Bradford Universities and it is with the last-named that the author is connected. The book grew from the need for a standard text-book for the Postgraduate School of Powder Technology and is published in the belief that it will be of interest to a far wider audience.

Terence Allen

Postgraduate School of Powder Technology
University of Bradford

Editor's foreword to the first edition

The study of the properties and behaviour of systems made up of particulate solids has in the past received much less attention than the study of fluids. It is, however, becoming increasingly necessary to understand industrial processes involving the production, handling and processing of solid particles, in order to increase the efficiency of such systems and to permit their control. During the past few years this has led to an increase in the amount of study and research into the properties of solid particle systems. The results of this effort are widely dispersed in the literature and at the moment much of the information is not available in a form in which it is likely to influence the education of students, particularly in chemical engineering, who may later be employed in industrial organizations where they will be faced with the problems of solids' handling. It is also difficult for the engineer responsible for the design or selection of solids' handling equipment to make use of existing knowledge, with the result that industrial practice is not always the best that is achievable. It is hoped that the publication of a series of monographs on Powder Technology, of which this is the first, will help by providing accounts of existing knowledge of various aspects of the subject in a readily available form.

It is appropriate that the first monograph in this series should deal with the measurement of the size of small particles since this is the basic technique underlying all other work in powder technology. The reliability of research results, for example, on the size reduction of solid particles, cannot be better than the reliability of the particle size measurement techniques employed. Too often the difficulties and limitations of size measurement are ignored in such work, so that any conclusions become suspect. The importance of a thorough understanding of the problems involved in measuring the size of small particles for anyone working in any aspect of powder technology is therefore difficult to overestimate. It is hoped that this monograph, written by an experienced size analyst who has studied critically most of the methods described, will be of value in encouraging an informed and critical approach to the subject and that it will help in the selection of equipment and in realistic assessment of the value of particle size measurements.

J.C. Williams

Editor's foreword to the fourth edition

This book has now reached its fourth edition and is undoubtedly the standard reference book on particle size measuring techniques. The book started life as a short course text and, in its successive editions, it has been polished and extended to become a balanced and comprehensive text, full of information and reflecting great experience. This book is the flagship of the series and I hope that many other books will follow it to the same level of maturity.

Brian Scarlett

January 1990

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