MIXING IN THE PROCESS INDUSTRIES

Mixing in the Process Industries

Second edition

Editors: **N Harnby, M F Edwards, A W Nienow**

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First published 1985
Reprinted 1987, 1989, 1990
Second edition 1992

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN 0 7506 1110 3

Library of Congress Cataloguing in Publication Data
A catalogue record for this book is available from the Library of Congress

Printed and bound in Great Britain by

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Preface

'But you've no idea what a difference it makes, mixing it with other things–such as gunpowder and sealing wax' . . . Lewis Carroll, Through the Looking Glass.

Whilst we don't actually mix gunpowder and sealing wax in this book, Lewis Carroll evidently had a presentiment of some of the unlikely mixing problems which would face process engineers today. Liquids, solids and gases have to be mixed in all combinations to satisfy a very variable process or product quality requirement. Long gone are the days when process mixing was left exclusively to the experienced worker who had a 'feel' for the product; and when academic interest was limited to the power consumption of paddle mixers as a fine example of the application of dimensional analysis.

The book is based on a long-running post-experience course with the same title as that of the book. The course has been organized at the University of Bradford in association with the Institution of Chemical Engineers and has been responsive to change in the process industries. It now reflects the balance of interest shown in the topic by industrialists from both the United States and western Europe. An advantage is that each chapter is by a specialist from either industry or academia. A slight disadvantage is that this inevitably leads to some variation in style between chapters. However, we feel that this is a small price to pay for in-depth expertise in each topic and the use of the Institution of Chemical Engineers Recommended Nomenclature for Mixing[1] wherever possible has considerably increased the level of uniformity.

With so many authors involved, production problems were inevitable with some authors producing a chapter at the drop of a telephone and others requiring a long gestation period before a satisfying mix emerged. Our apologies go to the 'hares' for the long delay in publication, our thanks go to the tortoises for completing the course.

We think and hope that this highly-revised second edition satisfies the demand by industry and academia, both undergraduate and postgraduate, for a text on mixing which gives a relatively comprehensive treatment of solid, liquid and multiphase mixing process.

The editors

1 *The Chem. Engr*, no. 557 (1980).

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Chapter 1

Introduction to mixing problems

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Mixing operations are encountered widely throughout productive industry in processes involving physical and chemical change. Although much of our knowledge on mixing has developed from the chemical industry, many other sectors carry out mixing operations on a large scale. Thus mixing is a central feature of many processes in the food, pharmaceutical, paper, plastics, ceramics and rubber industries. As a result, the financial investment in both the capital and running costs of mixing processes, when viewed on an international scale, is considerable. Indeed, at a recent meeting of industrialists and academics in the U.S.A.[32] it was estimated that the cost to their process industries due to an inadequate understanding of mixing was of the order of U.S.$ 1 to 10 billion per annum.

It is therefore unfortunate that very few scientists and engineers receive a sufficiently thorough grounding in the fundamentals of mixing processes. Even degree-level courses in chemical engineering rarely leave the graduate in a position from which he can design with confidence equipment to satisfy industrial mixing duties[1]. What is more, he will even find difficulty in the selection of appropriate mixer types for a given application. To compound this problem, there are no widely accepted design codes associated with mixing, as in the case of shell and tube heat-exchangers for example.

A final problem is the performance analysis of existing installations. Generally there is very little instrumentation on mixing plant. Thus, although failure to mix adequately is obvious because of unsatisfactory product quality, there is often no means of detecting over-design. Thus, lack of knowledge of mixing processes can be hidden by overdesign and this may then go undetected if assessed by product quality. However, in terms of capital and operating costs, throughout one company's operations, the penalty for ignorance of mixing processes can be severe.

It is hoped that this book will help to provide a scientific underpinning of the mixing operations carried out in a wide range of industries. At present there are several problems which are still inadequately understood. However, the

following chapters set out the present extent of our ability to design mixing systems.

1.1 Range of problems

1.1.1 Problem identification and philosophy

Almost always, in practice, mixing operations are multi-faceted. For example, when a process is carried out within a mechanically-agitated vessel, the agitator is called upon to perform many tasks, any one of which may be the most critical. Thus, in crystallizers, one must consider bulk blending to ensure spacially correct levels of supersation, heat transfer associated with temperature control, crystal suspension, growth rates and secondary nucleation; in fermenters, the impact of mixing and rheological complexity on both homogenization, on oxygen transfer, on surface cooling, on air dispersion and aerated power draw as well on biological stability. It is vital that, when the process engineer is confronted with such situations, all those aspects affected by agitation within a particular problem are considered. These aspects should be related to the underlying process fundamentals and the most critical, in mixing terms, established. Scale-up rules are often dangerous because they tend to be applied blindly and without going through the above thought processes.

It is the intention of this book to help the above global analysis; however, in order to do so, it is useful to classify mixing operations in terms of the phases (solid, liquid or gas) involved in a particular process and following this approach, it is possible to define operations which are common to several industries. For example, mixing duties from the food and pharmaceutical industries may be brought together in this way. Thus the general classification becomes independent of a particular product or a given industry.

1.1.2 Single-phase liquid mixing

In many operations it is necessary to mix together miscible liquids, e.g the blending of petroleum products. This is sometimes regarded as a simple mixing duty since it involves neither chemical reaction nor interphase mass transfer. It is necessary only to reduce the non-uniformities, i.e. variations in concentration to some acceptable level. However, such blending operations can be difficult to achieve when the liquids have widely different viscosities[33] or densities. Also, problems can be encountered if one of the liquids to be mixed forms only a small volume fraction of the final mix. In Chapter 8 consideration is given to miscible liquid blending operations in mechanically agitated vessels, while blending using jet mixing devices is treated in Chapter 9. Some of the theory appropriate to the blending of high-viscosity materials is presented in Chapter 11.