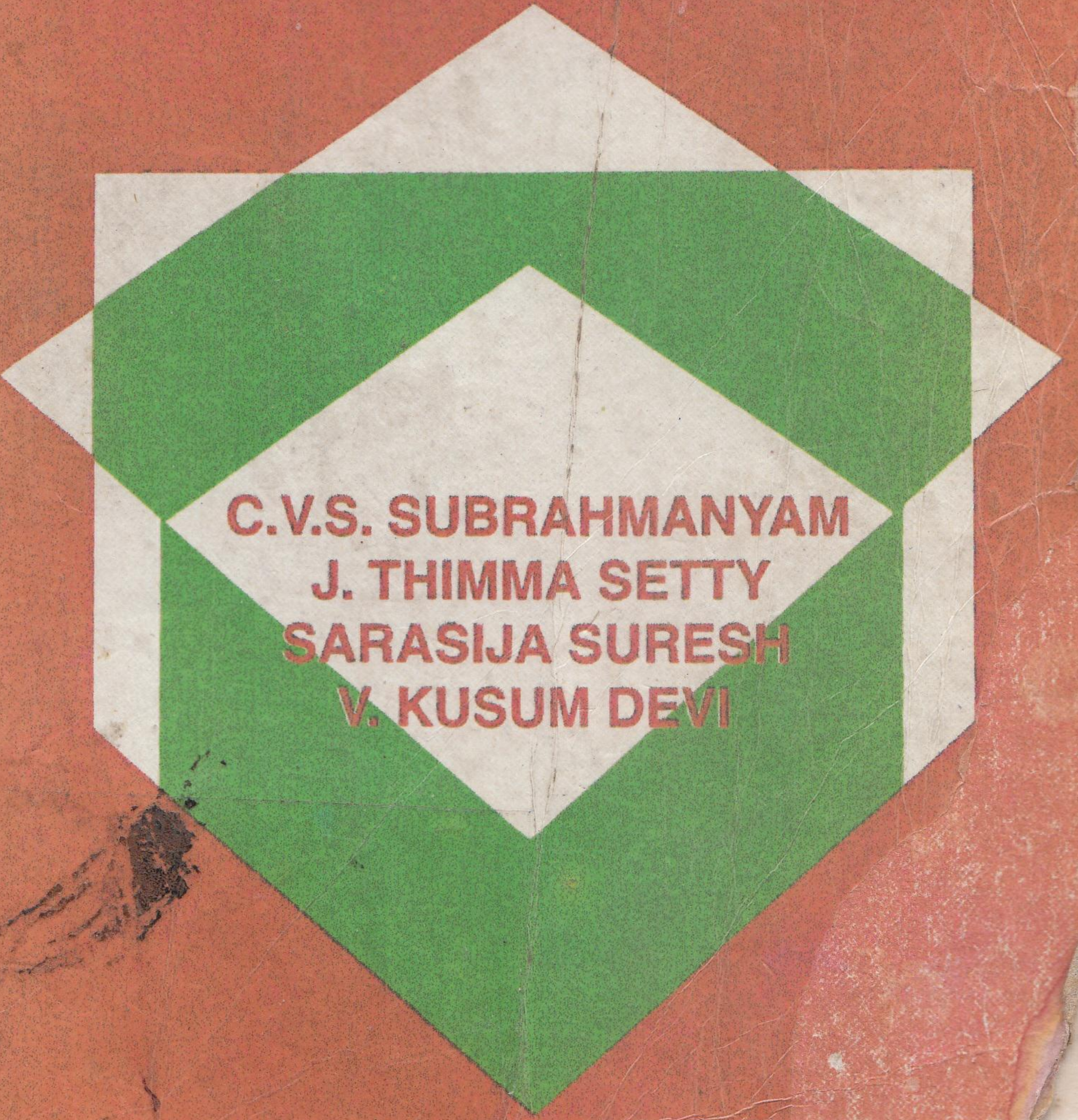


PHARMACEUTICAL ENGINEERING

PRINCIPLES AND PRACTICES



C.V.S. SUBRAHMANYAM
J. THIMMA SETTY
SARASIJA SURESH
V. KUSUM DEVI

Pharmaceutical Engineering

(Principles and Practices)

C.V.S. Subrahmanyam

M.Pharm., Ph.D

J. Thimma Setty

M.Pharm.

Mrs Sarasija Suresh

M.Pharm., Ph.D.

Mrs V. Kusum Devi

M.Pharm., Ph.D.

Mobile : 01712-090073



ঢাকা গ্রন্থা বিতান
DHAKA GRANTHA BITAN

All Kinds of Medical, Pharmacy
Books are Available Here

130, Islamia Market, Nilkhet, Dhaka-1205



DELHI
VALLABH PRAKASHAN

Dedicated to

Dr P. Gundu Rao

(Retired Professor and Principal of
College of Pharmaceutical Sciences, Manipal)
Director, Divi's Laboratories, Hyderabad.

ISBN 81-85731-27-6

VPBN 52

First Edition 2001

Reprint 2002

Reprint 2003

Reprint 2004

Reprint 2005

Reprint (Aug) 2005

© 2002 Vallabh Prakashan

All rights reserved. No part and style of this book be reproduced or transmitted, in any form, or by any means—electronic, mechanical, photocopying, recording or otherwise, without prior permission of the publishers and authors.

Published by

M K Jain for VALLABH PRAKASHAN

AP-53A, Pitampura, DELHI-110088

Phone : (011)-27317755

e-mail : vallabh@vsnl.com

Printed at

New Gyan Offset Printers, Delhi

Preface

Pharmaceutical Engineering is concerned with the study of industrial processes required to convert raw material into value added pharmaceuticals such as drugs and excipients. It is a subject of importance both to the industrial pharmacist and the undergraduate students. Over the years, students of pharmacy have been feeling the need for a simple book, yet in sufficient depth to enable them to handle industrial operations with understanding of the principles involved therein. This book is an attempt to meet these twin objectives.

This book consists of 18 chapters: introduction to basic principles in engineering, fluid flow, liquid material transport, solid conveying, heat flow, size reduction, size separation, mixing (solids, liquids and semisolids), filtration, centrifugation, distillation, evaporation, crystallisation, drying, humidification and dehumidification, corrosion, plant materials of construction and other related aspects of pharmaceutical industry.

This book deals with unit operations and processes utilised in the production of bulk drugs, dosage forms and biological products. There is a proper blend of physical, chemical and engineering principles. One model equipment has been selected for explaining all the principles and general working though many variations and varieties of the same may be available. Hopefully this book will provide strong foundation subject, and for in-house training of technical personnel in the industry.

Special emphasis is laid on the following:

- Application of principles, practice and pharmaceutical examples.
- Illustrations and diagrams explaining the working of equipment.
- Units have been described in SI system.
- Question bank.

Suggestions and criticism are welcome.

Davangere
15th June, 2001

Authors

Reprinted after necessary corrections and improvement

Acknowledgements

We place on record our thanks to Prof. K.V. Jayadevappa, B.E., M.Sc.(Engg), Professor and HOD, and Mr. Y.J. Jagadeesh, Lecturer, Department of Mechanical Engineering, Bapuji Institute of Engineering and Technology, Davangere, for reviewing the manuscript. Thanks are due to Prof. K.S. Muralikrishna, Professor, and Mr. S.M. Vijayendra Swamy, Lecturer, Bapuji Pharmacy College, Davangere, for sharing their thoughts and critical comments on the manuscript. Thanks are also due to Mr. Giriraj Kulkarni, Lecturer, JSS College Pharmacy, Ooty for his valuable suggestions on the manuscript.

We express our thanks to Prof. Y.R. Prabhakara, Principal, BEA's School of Pharmacy, Davangere, and Prof. B.G. Shivananda, Principal, Al-Ameen College of Pharmacy, Bangalore, for their continued support in the preparation of this edition.

We thank Mr. Kiran Shenoy, Artist, Audio-Visual Section, J.J.M. Medical College Library and Information Centre, Davangere, for the preparation of figures, graphs, and artwork. We acknowledge the support extended by Miss Ranjeetha H.S., Pradeep Xerox and DTP Centre, Davangere, in the preparation of electronic script.

The authors thank their respective parent associations namely, Bapuji Educational Association, Davangere, and Al-Ameen Educational Society, Bangalore, for their encouragement in this educational endeavour.

The authors are grateful to the Curriculum Development Cell, All India Council for Technical Education, Government of India, at Indian Institute of Science, Bangalore, for the financial assistance provided for the preparation of this book. We thank them profoundly.

We also express thanks to Mr. Manish K. Jain of M/s. Vallabh Prakashan, Delhi, for his painstaking efforts to bring out this edition.

Davangere

15th June, 2001

Authors

A

Contents

Preface	(iii)
Acknowledgments	(iv)
Chapter 1. INDUSTRIAL PROCESSING & BASIC PRINCIPLES	1-24
Unit Operations—Unit Processes	3
Unit Operations—Scientific Foundations	5
Dimensions, Units, Systems and Inter-Conversions	11
Dimensions—Formulae, Equations and Analysis	16
Stoichiometric Equations—Balancing	20
Question Bank	23
Chapter 2. FLOW OF FLUIDS	25-55
Fluid Statics	26
Fluid Dynamics	31
Bernoulli's Theorem	35
Energy Losses	39
Measurement of Rate of Flow of fluids	43
Question Bank	54
Chapter 3. TRANSPORTATION OF FLUIDS	56-88
Valves	57
Pumps	62
Reciprocating Pumps	62
Rotary Pumps	74
Miscellaneous Pumps	86
Question Bank	87
Chapter 4. CONVEYING	89-102
Belt Conveyors	90
Screw Conveyors	94
Pneumatic Conveyors	96
Chain Conveyors	98
Bucket Conveyors	100
Storage of Solids	101
Question Bank	102
Chapter 5. FLOW OF HEAT	103-143
Mechanisms of Heat Flow	104
Conduction	105
Convection	113
Radiation	127

Equipment—Heat Exchanger and Heat Interchangers 131

Question Bank 142

Chapter 6. SIZE REDUCTION

144-176

Mechanisms of Size Reduction 147

Modes of Stress applied in Size Reduction 148

Classification of Size Reduction Equipment 148

Size Reduction—Equipment 149

Selection of a Mill 166

Theories of Comminution 169

Energy for Comminution 171

Question Bank 174

Chapter 7. SIZE SEPARATION

177-198

Official Standards for Powders 178

Sieves 179

Modes of Motion in Size Separation 184

Sieve Analysis—Testing of Powder 187

Equipment for Size Separation 191

Question Bank 198

Chapter 8. Mixing

199-247

Section I—Mixing of Solids

199-224

Interparticle Interactions—Segregation 201

Mechanism of Mixing in Solids 202

Mixing Process—Steps 203

Degree of Mixing and Statistical Evaluation 204

Factors Influencing Mixing 212

Classification of Equipments for Solid Mixing 213

Equipment 214

Question Bank 224

Section II—Mixing of Liquids

225-240

Mechanisms of Mixing 226

Mixing Vessels 227

Mixing Devices—Flow Pattern 229

Equipment 236

Question Bank 240

Section III—Mixing of Immiscible Liquids

241-245

Equipment 241

Section IV—Mixing of Semisolids

245-247

Equipment 245

Question Bank 247

Chapter 9. FILTRATION

248-275

Mechanisms of Filtration 250

Theories of Filtration	252	
Factors Influencing Filtration	255	
Filter Media and Filter Aids	257	
Classification of Filtration Equipment	259	
Equipment	260	
Question Bank	275	
Chapter 10. CENTRIFUGATION		276-292
Theory of Centrifugation	277	
Classification of Centrifuges	280	
Equipment	282	
Question Bank	292	
Chapter 11. DISTILLATION		293-336
Theory	295	
General Equipment for Distillation	300	
Classification of Distillation Methods	304	
Simple Distillation	304	
Flash Distillation	308	
Fractional Distillation	310	
Azeotropic and Extractive Distillation	322	
Distillation under Reduced Pressure	323	
Steam Distillation	327	
Molecular Distillation	330	
Destructive Distillation	334	
Compression Distillation	335	
Question Bank	335	
Chapter 12. EVAPORATION		337-360
Factors Influencing Evaporation	338	
Classification of Evaporators	341	
Equipment	341	
Theory	353	
Multiple Effect Evaporator	356	
Question Bank	360	
Chapter 13. CRYSTALLIZATION		361-381
Characteristics of Crystals	362	
Pharmaceutical Solids—Terminology	366	
Theory of Crystallization	368	
Equipment	373	
Caking of Crystals	379	
Question Bank	381	
Chapter 14. DRYING		382-406
Theory of Drying	383	
Classification of Drying Equipment	390	

Equipment 390
Question Bank 405

Chapter 15. HUMIDIFICATION AND DEHUMIDIFICATION 407-430

Humidity Charts and Its Utility 411
Humidification 414
Dehumidification 415
Refrigeration 418
Air Conditioning 424
Question Bank 429

Chapter 16. CORROSION 431-449

Theories of Corrosion 432
Factors Influencing Corrosion 435
Types of Corrosion 438
Prevention and Control of Corrosion 444
Question Bank 448

Chapter 17. MATERIALS OF CONSTRUCTION 450-466

Factors Influencing the Selection of Materials 451
Classification of Materials for Plant Construction 453
Ferrous Metals 454
Non Ferrous Metals 457
Nonmetals—Inorganic 459
Nonmetals—Organic 462
Question Bank 466

Chapter 18. PHARMA. INDUSTRY—ESTABLISHMENT 467-485

Pharmaceutical Industry 467
Plant Location 468
Plant Layout 473
Utilities and Services 476
Industrial Pollution and Control 478
Industrial Hazards and Safety 480
Question Bank 485

APPENDIX-I : Fractions and Multiplications of Units 487

APPENDIX-II : Notations and Abbreviations 488

APPENDIX-III : Inter Conversion of Units 490

APPENDIX-IV : Definitions and Meanings 492

APPENDIX-V : Bibliography 501

SUBJECT INDEX 503