Plastics Institute of America

PLASTICS ENGINEERING MANUFACTURING and DATA HANDBOOK

VOLUME 2

DESIGN • TESTING
MARKETING • REGULATIONS

edited by
Dominick V. Rosato
Nick R. Schott
Donald V. Rosato
Marlene G. Rosato

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EDITED BY

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Kluwer Academic Publishers
Boston/Dordrecht/London

Distributors for North, Central and South America:
Kluwer Academic Publishers
101 Philip Drive
Assinippi Park
Norwell, Massachusetts 02061 USA
Telephone (781) 871-6600
Fax (781) 871-6528
E-Mail <kluwer@wkap.com>

Distributors for all other countries:
Kluwer Academic Publishers Group
Distribution Centre
Post Office Box 322
3300 AH Dordrecht, THE NETHERLANDS
Telephone 31 78 6392 392
Fax 31 78 6546 474
E-Mail <orderdept@wkap.nl>

Electronic Services <http://www.wkap.nl>

Library of Congress Cataloging-in-Publication Data

Plastics engineering, manufacturing & data handbook / Plastics Institute of America ; edited by Dominick V. Rosato ... [et al.].
p. cm.
ISBN 0-7923-7316-2
1. Plastics—Handbook, manuals, etc. 2. Engineering design—Handbooks, manuals, etc. I. Title: Plastics engineering, manufacturing, and data handbook. II. Rosato, Dominick V. III. Plastics Institute of America

TA455.P5 P529 2001
668.4—dc21

2001016494

Printed on acid-free paper.

Printed in the United States of America

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VOLUME 2

DESIGN, TESTING, MARKETING, AND REGULATIONS

Foreword: Plastics Institute of America

Advancing The Plastics Industry Through Education and Research

Dr. Aldo Crugnola, Ph.D., Executive Director
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The Plastics Institute of America is a not-for-profit organization whose members come from industry, academia, and government. Its primary objective is to help advance the growth and progress of the plastics industry through education and research. Corporate members of the PIA include large and small producers of plastics products, commodity and engineering resins, additives for plastics, plastics packaging, and process machinery, as well as educators, international industry associations, government agencies, and trade publications. Major organizations that have representation on PIA's board of directors include the Society of the Plastics Industry, the Society of Plastics Engineers, the Society of Manufacturing Engineers, the Plastics Pioneers Association, and the National Plastics Center. In all its initiatives, PIA seeks to compliment, not compete, with other nationally known associations and societies.

The Early Years

The Institute was organized in 1961 by SPE because the Society's board of directors felt the organization was placing too much emphasis on sales and too little on science and technology. New polymers were being introduced at that time and the industry lacked qualified personnel to work with these materials. PIA took steps to remedy this problem by awarding fellowships to graduate schools that offered programs and conducted research in polymer science. The few educational institutions addressing these issues in those years included Princeton University, Brooklyn Polytechnic Institute, Lowell Technological Institute, and Stevens

Institute of Technology. PIA made its headquarters at the Stevens's campus in Hoboken, New Jersey.

The organization soon began offering graduate fellowships and conducting short courses aimed at updating education industry personnel and university faculty members. By working in concert with colleges and universities, PIA was able to conduct courses featuring lecturers from both industry and the academic world. The organization later expanded this effort to include three-day conferences on the "hot" industry issues of the day such as benchmarking, time-dependent effects, packaging technology, and recycling. In 1990, PIA left Stevens and established a new headquarters in Fairfield, New Jersey.

Six years later, the Institute moved once again, this time to the Lowell, MA, campus of the University of Massachusetts. The PIA offices now reside there in the same building as the Institute for Plastics Innovation, a technology center for plastics manufacturing. Coincident with that move, the Institute named Dr. Aldo Crugnola of UMass Lowell as its new Executive Director.

PIA Today

The PIA today continues to offer a diverse array of educational programs for all segments of the industry from in-plant training for workers on the shop floor to industry-specific short courses and seminars for executives. In-house programs are tailored to enhance the skill levels of machine operators, plant mechanics, electronic technicians, and other support personnel. Executive courses concentrate on administrative issues, including new technologies, concurrent engineering, work organization, and legal issues. The Institute also conducts international conferences on emerging issues such as Pecyclingplas, Foodplas, and Constructionplas. These events bring together representatives from industry, government, and academia. In addition, the PIA responds to a variety of industry needs not addressed by other organizations. These initiatives include:

- Research Fellowships that are awarded to graduate students pursuing research in plastics engineering and polymer science and Plastics Pioneers Association Technology Scholarships which go to students preparing for a career in plastics.
- Publication of a Directory of Plastics Education & Training (formerly Polymer Science & Engineering) Programs-a guide listing two- and four-year college programs, vocational school programs, short courses, video training, and computer-based self-study programs offered by commercial institutes.
- Industry surveys to determine research needs. Emphasis is on industrial research contacts.
- An informal resource and "hot line", providing knowledge/advice on plastics materials/processing.

In all of its initiatives, PIA seeks to complement, not compete, with other nationally known plastics associations and societies.

PIA Training Program

The Plastics Institute of America (PIA), in collaboration with the Division of Continuing Studies and Corporate Education at the University of Massachusetts Lowell, offers a series of modules providing employee training designed to enhance the knowledge, understanding and skills of mechanics and other technical staff working primarily with plastics. The following **TRAINING MODULES FOR PLASTICS MANUFACTURING PERSONNEL** program is an example of their training programs. The type of information contained in this book is typical of what is included in their different programs.

Control Systems (40 hour Module)

- Safety (Ohm's Law) lockout tagout importance, machine guarding schemes
- IO devices (operations, identification, advantages and disadvantages, purposes of encoders and resolvers)
- PLCs (basic components, analog and digital domains, basic ladder logic instruction)
- HMI (password protection, HMI functions and purpose)
- Electronic Cam Switch Bank (function review)
- Control Systems Evolution (definition, examples)
- Troubleshooting and Diagnostics (mechanical and non-mechanical problems, determination of probable problem cause, mechanic's responsibilities.)
- Servo Systems (concepts and purpose, type motors and variations, explanations and applications of direct, gearbox and screw motor-to-load coupling, motor and encoder shaft alignments, servo system concepts, servo tuning, servo profiles)

Metric Measurement (12 hour Module)

- Linear Measurement (micrometers, dial calipers, surface plates, optical comparators, scientific rotation)
- Temperature (thermometers, thermocouples, RTDs)
- Hardness/Friction/Gloss/Color
- Calibration
- Measurement and inspection re: quality control
- Overview of sizes (pins, holes, identification of sizes)
- Pressure (strain gauges, piezoelectric transducers, Bourdon gauges)
- Test methods of Plastics ASTM/ISO

Engineering Drawing (20 hour Module)

- Sketching
- Print reading and interpretation
- Standard notation and symbols
- Assembly and part drawings
- Surface finishes
- Basic machining processes and expected outcomes
- Screw threads and fasteners
- Basic shop terminology

Computer Fundamentals (12 hour Module)

- Overview of computer systems
- Windows 98: help screens, mouse, pull down menus, icons, passwords, menu bars, etc.
- Introduction to database management and databases
- Navigating through databases
- Interpreting screens produced by databases
  - —Interpreting database results
  - —Databases
- Communicating with remote sites

Statistical Process Control (20 hour Module)

- Fundamental mathematical skills
- Target values and variances
- Process variability
- Processes that are out of control
- Use of SPC to improve the processes

Polymers (20 hour Module)

- Markets for plastics
- Commercial production of plastics
- Physical properties of plastics
- Fabrication of plastics
- Applications

lntroduction to Injection Molding (16 hour Module)

- What is injection molding?
- Plasticating systems
- Clamping systems
- The electrical system
- The injection mold
- The molding process
- Process conditions
- Auxiliary equipment
- Resins-processing
- Troubleshooting
- Batch mixing
- Profile extrusions

Industrial and Molding Hydraulics (20 hour Module)

- Standards, basic fluid power law and terminology
- ANSI/ISO Circuit symbols, print interpretation
- Circuit elements and their functions
- Mechanical descriptions
- Control concepts
- Examples of molding circuits and automation circuits

Mold Design and Maintenance for Diagnostics (20 hour Module)

- Design considerations
- Mold design basics
- Cavity and core construction
- Heat transfer considerations
- Cold runner molds

- Hot runner systems
- Freeing mechanism/part ejection
- Mold maintenance

Elastomers (16 hour Module)

- General classes of elastomers
- Compounding and the rubber recipe
- Vulcanization and vulcanizing agents
- Fillers
- Processing and processability testing
- Physical testing
- Thermoplastic elastomers (TPE)

Rotational Molding (16 hour Module)

- Molds
- Equipment
- Process parameters
- Materials
- Design guidelines
- Secondary finishing
- Troubleshooting

Preventive /Predictive Maintenance (20 hour Module)

- Injection molding plasticating unit
- Heating units
- Injection molding hydraulic maintenance
- Care and maintenance of electrical components
- Safety inspection and procedures
- Storage maintenance of molds

Blow Molding (16 hour Module)

- Blow molding processes
- Materials
- Primary equipment
- Mold design
- Process controls
- Auxiliary equipment
- Troubleshooting
- Testing
- New developments

Extrusion (20 hour Module)

- Principles of extrusion
- Description of single screw extruder
- Smooth bore and grooved-feed extruders
- Blown film process
- Cast film process
- Extrusion coating
- Profile extrusion
- Materials for extrusion
- Auxiliary equipment
- Die design
- Principles process control
- Troubleshooting
- New developments

Plastics Process Control (20 hour Module)

- Principles of process control
- Instrumentation
- Data acquisition/monitoring
- Servo control for injection molding
- Control of extrusion processes
- Blow molding/parison control
- SPC/SQC
- Integrated manufacturing
- New developments

Thermoforming (20 hour Module)

- Basic process/variations
- Processing conditions
- Materials
- Mold design
- Product design
- Secondary operations
- Twin sheet forming
- Decorating
- Trimming/recycling

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Preface

This book provides a simplified, practical, and innovative approach to understanding the design and manufacture of plastic products in the World of Plastics. Its unique review will expand and enhance your knowledge of plastic technology by defining and focusing on past, current, and future technical trends. Plastics behavior is presented to enhance one's capability in fabricating products to meet performances, low cost requirements, and be profitable. Important aspects are presented such as understanding the advantages of different materials and product shapes. Information is concise and comprehensive.

Practical and scientific information presented is valuable and useful to both the novice and experienced personnel. This book is valuable for trainees, students, and to those desiring to extend their knowledge and capability in plastics manufacturing and all its related parameters that influence the behavior and characteristics of plastics.

Over 20,000 different subjects are reviewed in different chapters as summarized in a lengthy **TABLE of CONTENTS**. In turn each subject provides different reviews on materials, processes, product designs, and so on. The **INDEX** provides another means to obtain information on the different subjects. Book contains 1060 figures and 415 tables providing extensive details on the different subjects.

In working with any material (plastics, steel, aluminum, wood, etc.), it is important to know its behavior in order to maximize product performance-to-cost efficiency. Examples of different plastic materials and products are reviewed with their behavior patterns. They range from toys to medical devices to cars to boats to underwater devices to containers to springs to pipes to buildings to aircraft to spacecraft. The reader's product to be designed and/or fabricated can directly or indirectly be related to products reviewed in this book.

Important are behaviors associated and interrelated with the many different plastics materials (thermoplastics, thermosets, elastomers, reinforced plastics, etc.) and the many fabricating processes (extrusion, injection molding, blow molding, forming, foaming, reaction injection molding, rotational molding, etc.). They are presented so that the technical or non-technical reader can readily understand the interrelationships of materials-to-processes.

There is an endless amount of data available for many plastic materials worldwide that total about 35,000 different types of materials. Unfortunately, as with other materials, there does not exist only one plastic material that will meet all performance requirements. However, it can be stated that for practically any product requirement(s), particularly when not including cost for a few products, more so than with other materials, there is a plastic that can be used.

This type of information has been reviewed for many centuries with different types of materials and more recently (in just over a century) with plastics. One should recognize that the engineering design basics and fundamentals remain the same for the different materials. Their interpretation and applicability improves with time for each of the different materials. It is like saying $2 + 2 = 4$ over the many past centuries. Now we can say it with a computer where

in the recent past we used an abacus, adding machine, slide rule, etc. This type of information, with understanding the behavior of plastics, results in meeting product performance-to-cost requirements.

This book has been prepared with the awareness that its usefulness will depend on its simplicity and its ability to provide essential information. Examples are provided of different plastic products and relating them to critical factors that range from meeting performance requirements in different environments to reducing costs and targeting for zero defects. Reviews range from small to large and simple to complex shaped products.

The data included provide examples of what are available. As an example static properties (tensile, flexural, etc.), dynamic properties (creep, fatigue, impact, etc.), physical properties, chemical properties, etc. can range from near zero to extremely high values with some having the highest of any material. They can be applied in different environments from below the surface of the earth, to over the earth, and into space.

The many problems that are reviewed in this book should not occur. They can be eliminated so that they do not affect the product's performance when qualified people recognize that the problems can exist. They are presented to reduce or eliminate costly pitfalls resulting in poor product performance or failure. With the potential problems or failures reviewed, solutions are also presented. This failure/solution review will enhance the intuitive skills of people new to plastics as well as those who are already working in plastics.

This book provides the reader with useful pertinent information readily available as summarized in the **CONTENTS**, **REFERENCES**, and **INDEX**. From a pragmatic standpoint, any theoretical aspect that is presented has been prepared so that the practical person will understand it and put it to use. The theorist, for example, will gain an insight into the limitations that exist and relate to those that are present in plastics as they exist in other materials such as steel, wood, and so on. There is no material that is "perfect."

Based on over a century of worldwide production of all kinds of plastic products, they can be designed and processed successfully, meeting high quality, consistency, long life, and profitability. All that is needed is understanding the behavior of plastics and properly applying these behaviors.

The information contained in this book is of value to even the most experienced fabricators, designers and engineers, and provides a firm basis for the beginner. The intent is to provide a review of the many aspects that range from the practical elementary to the advanced or theoretical approach. This book will be useful to different people. Included are the tool maker (mold, die, etc.), fabricator, designer, plant manager, material supplier, equipment supplier, testing and quality control personnel, cost estimator, accountant, sales and marketing personnel, new venture type, buyer, vendor, educator/trainer, workshop leader, librarian, industry information provider, lawyer, and consultant. People with different interests can focus on and interrelate across subjects that they have limited or no familiarity within the World of Plastics.

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In preparing this book use was made of the PIA Board members, participating industry personnel, global information from industry and trade associations, and the authors' worldwide personal, industrial, teaching experiences.

THE ROSATOS AND NICK SCHOTT, 2001

About the Authors

Dominick V. Rosato Since 1939 has been involved worldwide principally with plastics from designing-through-fabricating-through-marketing products from toys-through-commercial electronic devices-to-aerospace & space products worldwide. Experience includes Air Force Materials Laboratory (Head Plastics R&D), Raymark (Chief Engineer), Ingersoll-Rand (International Marketing Manager), and worldwide lecturing (26). Past director of seminars & in-plant programs and adjunct professor at Rhode Island School of Design, University Massachusetts Lowell, and the Open University (UK). Has received various prestigious awards from USA and international associations, societies (SPE Fellows, etc.), publications, companies, and National Academy of Science (materials advisory board). Received ASME recognition for advanced engineering design with plastics. Senior member of the Institute of Electrical and Electronics Engineers. Licensed professional engineer of Massachusetts. Involved in the first all plastics airplane (1944/RP sandwich structure). Worked with thousands of plastics plants worldwide, prepared over 500 technical and marketing articles, and has published 21 books with contributions in over 50 books. Received BS in Mechanical Engineering from Drexel University with continuing education at Yale, Ohio State, and University of Pennsylvania.

Donald V. Rosato Has extensive technical and marketing plastic industry business experience from laboratory testing, through production to marketing, having worked for Northrop Grumman, Owens-Illinois, DuPont/Conoco, Hoechst Celanese, and Borg Warner/G.E. Plastics. He has written extensively, developed numerous patents within the polymer related industries, is a participating member of many trade and industry groups, and currently is involved in these areas with PlastiSource, Inc., and Plastics FALLO. Received BS in Chemistry from Boston College, MBA at Northeastern University, M.S. Plastics Engineering from University of Massachusetts Lowell (Lowell Technological Institute), and Ph.D. Business Administration at University of California, Berkeley.

Marlene G. Rosato Has very comprehensive international plastics and elastomer business experience in technical support, plant startup and troubleshooting, manufacturing and engineering management, business development and strategic planning with Bayer/Polysar and DuPont and does extensive international technical, manufacturing and management consulting for Plastics FALLO and PlastiSource Inc. Received Bachelor of Applied Science in Chemical Engineering from the University of British Columbia; extensive executive management training.

Nick R. Schott Nick is a Professor and Chairman of the Plastics Engineering at UMass Lowell. He has been at UML for 29 years. He started the Institute for Plastics Innovation (IPI) a Research Consortium affiliated with the university that conducts research related to Plastics Manufacturing. Nick was the Director of the IPI from 1989–1994. He is a Fellow of SPE and a former President of ENE SPE. For the past ten years he has participated at Pioneer Valley SPE as a board member and as Chairman of the Educational Committee. Nick holds a BS in Ch.E. from UC Berkeley and an MS and Ph.D. from the University of Arizona. Nick is interested in plastics processing and teaches in the area of mold design and process control/instrumentation.