Handbook of Plastics and Elastomers

CHARLES A. HARPER *editor-in-chief*
Westinghouse Electric Corporation
Baltimore, Maryland

McGRAW-HILL BOOK COMPANY

New York St. Louis San Francisco Auckland Düsseldorf
Johannesburg Kuala Lumpur London Mexico Montreal
New Delhi Panama Paris São Paulo Singapore
Sydney Tokyo Toronto

Library of Congress Cataloging in Publication Data

Main entry under title:

Handbook of plastics and elastomers.

Includes bibliographies and index.
1. Plastics—Handbooks, manuals, etc. 2. Elastomers—Handbooks, manuals, etc. I. Harper, Charles A.
TP1130.H36 668.4'02'02 75-9790
ISBN 0-07-026681-6

34567890 KPKP 78432109876

The editors for this book were Harold B. Crawford and Ruth Weine, the designer was Naomi Auerbach, and its production was supervised by Teresa F. Leaden. It was set in Caledonia by Monotype Composition Company, Inc.

It was printed and bound by the Kingsport Press.

Contents

Contributors vi

Preface vii

1. Fundamentals of Plastics and Elastomers 1-1
2. Electrical Design Properties of Plastics and Elastomers 2-1
3. Mechanical Properties and Testing of Plastics and Elastomers 3-1
4. Chemical and Environmental Properties of Plastics and Elastomers ... 4-1
5. Laminates, Reinforced Plastics, and Composites 5-1
6. Properties and End Uses for Man-Made Fibers 6-1
7. Plastic and Elastomeric Foams 7-1
8. Liquid and Low-Pressure Resin Systems 8-1
9. Plastic and Elastomeric Coatings 9-1
10. Plastics and Elastomers as Adhesives 10-1
11. Commercial and Government Specifications and Standards 11-1
12. Design and Fabrication of Plastic Parts 12-1

Glossary of Terms follows Chapter 12

Index follows Glossary of Terms

Chapter 1

Fundamentals of Plastics and Elastomers

CHARLES A. HARPER

Westinghouse Electric Corporation,
Baltimore, Maryland

Introduction . . . 1-2
The Nature of Plastics and Elastomers . . . 1-3
  Thermosetting Plastics . . . 1-3
  Thermoplastics . . . 1-3
  Elastomers . . . 1-4
Polymer Structures and Polymerization Reactions . . . 1-4
  Polymer Structures . . . 1-4
  Polymerization Reactions . . . 1-4
  Raw-Material Sources of Major Plastic Materials . . . 1-5
Plastic-Processing Methods and Design Guidelines . . . 1-5
  Plastic-Fabrication Processes and Forms . . . 1-7
Plastic Properties . . . 1-15
  Standard Tests and Their Significance . . . 1-16
  Rating of Plastics by Property Comparisons . . . 1-22
  Flammability and Flame Retardancy of Plastics . . . 1-22
Thermosetting Plastics . . . 1-35
  Alkyds . . . 1-35
  Diallyl Phthalates (Allyls) . . . 1-41
  Epoxies . . . 1-45
  Melamines and Ureas (Aminos) . . . 1-52
  Phenolics . . . 1-53

Polybutadienes . . . 1-57
Polyesters (Thermosetting) . . . 1-58
Silicones . . . 1-58
Thermoplastics . . . 1-60
ABS Plastics . . . 1-62
Acetals . . . 1-69
Acrylics . . . 1-71
Cellulosics . . . 1-75
Fluorocarbons . . . 1-75
Ionomers . . . 1-78
Low-Permeability Thermoplastics . . . 1-79
Nylons . . . 1-79
Parylenes . . . 1-82
Polyaryl Ether . . . 1-84
Polyaryl Sulfone . . . 1-85
Polycarbonates . . . 1-85
Polyesters . . . 1-87
Polyethersulfone . . . 1-89
Polyethylenes, Polypropylenes, and Polyallomers . . . 1-89
Polyimides and Polyamide-imides . . . 1-91
Polymethylpentene . . . 1-93
Polyphenylene Oxides . . . 1-93
Polyphenylene Sulfides . . . 1-94
Polystyrenes . . . 1-94
Polysulfones . . . 1-95
Vinyls . . . 1-96
Glass-Fiber-Reinforced Thermoplastics . . . 1-97
Plastic Films and Tapes . . . 1-97
Films . . . 1-97
Tapes . . . 1-97
Film Properties . . . 1-100
Plastic Surface Finishing . . . 1-100
Painting of Plastics . . . 1-100
Plating on Plastics . . . 1-103
Elastomers . . . 1-106
The Nature of Elastomers . . . 1-106
Polymer Basis of Elastomers . . . 1-107
Commercially Available Elastomers . . . 1-108
Relative Elastomer Costs . . . 1-116
Physical Properties . . . 1-116
References . . . 1-120

INTRODUCTION

The "Handbook of Plastics and Elastomers" will cover all the important application and use data and guidelines for the entire field of plastics and elastomers. This chapter will cover the fundamental aspects of plastics and elastomers, and subsequent chapters will present detailed coverage of the most important individual application and use subjects in the field of plastics and elastomers, as indicated by the individual chapter titles. This initial chapter will cover the nature of plastics and elastomers, including the chemical nature of polymers, testing and test significance of standard

Chapter **2**

Electrical Design Properties of Plastics and Elastomers

CHARLES A. HARPER

Westinghouse Electric Corporation,
Baltimore, Maryland

Introduction	2-2
Basic Electrical-Insulation Properties	2-2
Insulation Characteristics and Their Significance	2-3
Ratings of Plastics for Insulation Characteristics	2-3
Thermal Classifications of Insulating Materials	2-6
Electrical Tests for Insulation Properties	2-9
Thermosetting Plastics	2-26
Alkyds	2-26
Aminos (Melamines and Ureas)	2-26
Diallyl Phthalates	2-27
Epoxies	2-33
Phenolics	2-36
Polybutadienes	2-36
Polyesters	2-37
Silicones	2-38
Thermoplastics	2-41
ABS Plastics	2-42
Acetals	2-42
Acrylics	2-42
Cellulosics	2-43
Fluorocarbons	2-43

Ionomers . . . 2-54
Nylons . . . 2-55
High-Temperature Nylon (Aramid) . . . 2-56
Parylenes . . . 2-56
Polyallomers, Polyethylenes, and Polypropylenes . . . 2-56
Polyaryl Ether . . . 2-58
Polyaryl Sulfone . . . 2-58
Polycarbonates . . . 2-59
Polyesters . . . 2-61
Polyethersulfone . . . 2-61
Polyimides and Polyamide-Imides . . . 2-61
Polymethylpentene . . . 2-64
Polyphenylene Oxides . . . 2-64
Polyphenylene Sulfides . . . 2-64
Polystyrenes . . . 2-64
Polysulfones . . . 2-66
Vinyls . . . 2-67
Glass-Fiber-Reinforced Thermoplastics . . . 2-67
Elastomers and Rubbers . . . 2-68
Nature of Elastomers . . . 2-70
Electrical Properties of Elastomers . . . 2-71
Recommendations for Further Reading . . . 2-73
References . . . 2-76

INTRODUCTION

Plastics represent one of the very important classes of materials used in the electrical and electronic industries. Plastic materials are broadly used for dielectric or insulation purposes, as well as for structural or ruggedization purposes. The useful application areas are steadily increasing owing to continuing advances in plastic technology. The upper temperature limit for plastics has risen substantially in recent years, and the number of high-performance engineering plastics has increased rapidly. In addition, chemical development has led to creation of many electronic grades of plastics, that is, plastics with improved or more stable dielectric properties. Many old industry workhorse standards, not basically suitable for high-performance electronics, can now be obtained in high-performance electronic grades. It is the purpose of this chapter to discuss the types of plastics and elastomers and properties of these materials as related to electronic and electrical industry applications. The basic types and forms of plastics were presented in Chap 1, and the reader is referred to that chapter for presentations on the chemical classes and product classes of plastics and elastomers. Their role in the field of electrical design is discussed in this chapter. Presentations will be organized into basic chemical and important product groupings, however, after an initial discussion on basic insulation properties and ratings of plastics in the functional electrical categories.

BASIC ELECTRICAL-INSULATION PROPERTIES

Plastics and elastomers usually serve some selective insulation or signal-transmission function, some structural or mechanical function in electrical systems, or frequently, a combination of these.[1-4]

Although insulating materials have many important properties and characteristics, which are discussed in detail in this chapter, there are two basic categories which should be mentioned at this time. These are (1) insulation or dielectric characteristics and (2) thermal classification.

Chapter 3

Mechanical Properties and Testing of Plastics and Elastomers

GEORGE E. RUDD

RONALD N. SAMPSON

Research and Development Center,
Westinghouse Electric Corporation,
Pittsburgh, Pennsylvania

Testing Standards . . . 3-3
Mechanical-Properties Tests . . . 3-3
Basic Requirements . . . 3-3
Compression Tests . . . 3-6
Tension Tests . . . 3-6
Flexure Tests . . . 3-8
Shear Tests . . . 3-9
Hardness . . . 3-9
Poisson's Ratio . . . 3-9
Impact Testing . . . 3-9
Fatigue Testing . . . 3-10
Creep, Creep Rupture, Set, and Stress Relaxation . . . 3-11
Damping . . . 3-12
Tear Strength . . . 3-13
Deflection Temperature . . . 3-14
Physical-Properties Tests . . . 3-14
Water Absorption . . . 3-14
Moisture and Heat Resistance . . . 3-14
Outdoor Weathering . . . 3-14
Artificial Weathering and Aging . . . 3-15
Thermal Expansion . . . 3-16

Thermal Conductivity . . . 3-16
Flammability . . . 3-17
Thermoplastic Plastics . . . 3-17
ABS . . . 3-18
Acetals . . . 3-19
Acrylics . . . 3-34
Cellulosics . . . 3-34
Fluorocarbons . . . 3-36
Ionomers . . . 3-37
Nylon (Polyamides) . . . 3-38
Polyaryl Ether . . . 3-39
Polyaryl Sulfone . . . 3-39
Polycarbonates . . . 3-40
Polyesters . . . 3-41
Polyether Sulfone . . . 3-42
Polyethylene . . . 3-42
Polyimides . . . 3-43
Polymethylpentene . . . 3-43
Polyphenylene Oxide Resins (Noryl) . . . 3-44
Polyphenylene Sulfide . . . 3-45
Polypropylene . . . 3-47
Polystyrene . . . 3-48
Polysulfone . . . 3-50
Polyvinyl Chloride . . . 3-50
Reinforced Thermoplastics . . . 3-51
Thermoset Plastics . . . 3-51
Allyl Resins . . . 3-51
Epoxy Resins . . . 3-51
Melamine Resins . . . 3-63
Phenolics . . . 3-66
Polyesters . . . 3-67
Silicones . . . 3-68
Ureas . . . 3-68
Elastomers . . . 3-69
Natural Rubber (ASTM NR) . . . 3-69
Butadiene Styrene (ASTM SBR) . . . 3-69
Isoprene (ASTM IR) . . . 3-69
Nitrile Rubber (ASTM NBR) . . . 3-69
Neoprene (ASTM CR) . . . 3-69
Butyl Rubber (ASTM IIR) . . . 3-69
Polysulfide (ASTM T) . . . 3-69
Silicones (ASTM FSI, PSI, VSI, PVSI, SI) . . . 3-79
Urethane (NEMA U) . . . 3-79
Polyacrylate (ASTM ABR) . . . 3-79
Polybutadiene (ASTM BR) . . . 3-79
Epichlorohydrin (ASTM CO and ECO) . . . 3-79
Fluorosilicone . . . 3-79
Ethylene Propylene (ASTM EPM, EPDM) . . . 3-79
Chlorosulfonated Polyethylene (ASTM CSM) . . . 3-79
Fluorocarbons (ASTM FPM) . . . 3-81
Propylene Oxide . . . 3-81
Styrenated Block Polymers . . . 3-81
References . . . 3-81

Chapter **4**

Chemical and Environmental Properties of Plastics and Elastomers

OTTO H. FENNER

Monsanto Company,
Corporate Engineering,
St. Louis, Missouri

Introduction 4-2
Chemical Resistance and Performance 4-5
Thermoplastics 4-5
Fundamentals 4-5
ABS Resins 4-7
Acetal Resins 4-8
Acrylic Plastics 4-9
Cellulosic Plastics 4-20
Chlorinated Polyether 4-21
Fluorocarbons 4-22
Polyamide Resins (Nylon) 4-24
Polycarbonates 4-25
Polyethylene 4-26
Polyimide 4-27
Polyphenylene Oxide 4-28
Polyphenylene Sulfide 4-29
Polypropylene 4-30
Polystyrene 4-30
Polysulfone 4-31

Polyvinyl Chloride (PVC) 4–32
Chlorinated PVC (CPVC) 4–33
Polyvinylidene Chloride Copolymers (Saran) 4–34
Thermosets 4–34
Fundamentals 4–34
Allylic Resins 4–35
Amino Resins 4–36
Epoxy Resins 4–41
Furans 4–42
Phenolics 4–44
Silicone Resins 4–45
Unsaturated Polyesters 4–46
Polyurethanes 4–48
Vinyl Esters 4–49
Elastomers 4–50
Fundamentals 4–50
Natural Rubber 4–50
Synthetic Rubber (IR) 4–51
Acrylonitrile-Butadiene (NBR) 4–51
Polyacrylic Rubber 4–51
Butyl Rubber (IIR) 4–51
Chloroprene Rubber (CR) 4–58
Chlorosulfonated Polyethylene (CSM) 4–59
Ethylene Propylene (EPM) 4–60
Fluoroelastomers 4–60
Silicone Rubber (VMQ) 4–62
Styrene-Butadiene (SBR) 4–62
Polysulfide Rubbers (T) 4–63
Polyurethane Diisocyanate Elastomers (AU) 4–63
Plastic Testing and Evaluation 4–65
General Considerations 4–65
Initial Evaluations 4–67
Visual Changes 4–67
Standard Test Procedures 4–68
Specially Designed Test Procedures 4–69
Stress Cracking 4–69
Flexural Modulus–Flexural Strength Criteria 4–70
Nondestructive Evaluations 4–72
One-Side Exposure Panel Testing 4–72
Permeation 4–75
Plastographic-Analysis Techniques 4–76
Infrared Spectroscopy 4–77
Nondestructive Testing 4–79
References 4–79

INTRODUCTION

The role of plastics and elastomers as materials of construction for all types of products has grown fantastically during the years since the end of World War II. Many of the plastics, resins, and elastomers now in common use were either relatively unknown to industry or still waiting to be discovered or developed when the

Chapter **5**

Laminates, Reinforced Plastics and Composites

RONALD N. SAMPSON

Chemical Sciences Department, Research and Development Center, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania

Laminates . . . 5-2
Definition . . . 5-2
Design Criteria . . . 5-3
Reinforcing Fibers . . . 5-4
Laminated Materials . . . 5-10
NEMA Industrial Laminates . . . 5-34
Vulcanized Fiber . . . 5-53
Decorative Laminates . . . 5-58
Printed-Circuit Laminates . . . 5-61
Multilayer Printed Circuits . . . 5-74
Reinforced Plastics . . . 5-77
Definition . . . 5-77
Prepreg Materials . . . 5-78
Prototypes . . . 5-79
Filament Winding . . . 5-86
Pultrusion . . . 5-88
SMC and BMC . . . 5-90
Wall and Panel Systems . . . 5-91
Composites . . . 5-93
Definition . . . 5-93

High-Performance Fibers 5-93
Machining and Joining Laminates and Reinforced Plastics . . 5-100
Joining 5-105
Adhesive Bonding 5-107
References 5-110

LAMINATES

Definition

Laminates are plastic materials made by bonding together two or more sheets of reinforcing fibers, usually with heat and pressure. The fibrous sheets or webs may be fabric, paper, or mat made of cellulose, asbestos, glass fibers, or synthetic plastics. The binders—called *resins*—can be almost any polymeric material but more often are based on thermosetting resins such as a phenolic, melamine, polyester, epoxy, or silicone. These resins are dissolved in suitable solvents and used to impregnate the reinforcing sheets in a treating tower, as shown in Figs. 1 and 2. In the treater

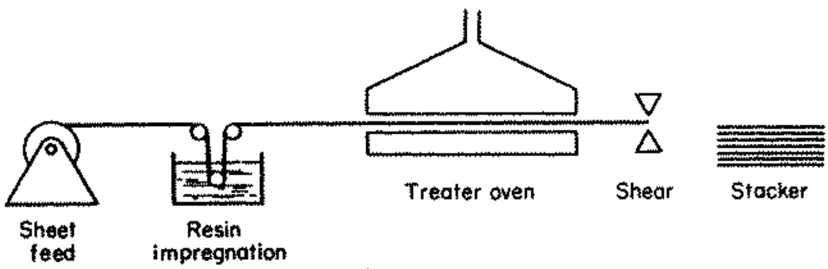

Fig. 1 Horizontal treater tower.

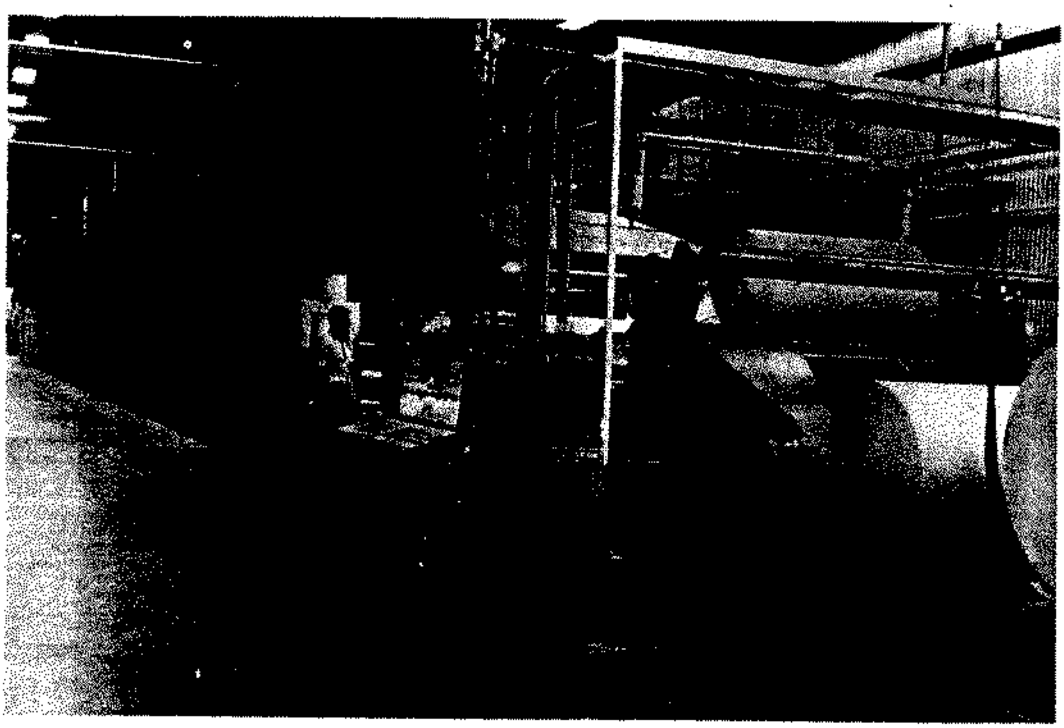

Fig. 2 Web treater. (*Westinghouse Electric Corp.*)

Chapter **6**

Properties and End Uses for Man-Made Fibers

TED V. SHUMEYKO
Shumeyko Wilson Associates, Inc.
New York, New York

RICHARD G. MANSFIELD
United Merchants and Manufacturers, Inc.,
New York, New York

Introduction 6-2
The Forms of Fibers 6-2
Processing of Fibers 6-3
Fabric Formation 6-6
End Uses 6-10
Physical Distribution 6-11
The Man-Made Fibers 6-11
Acrylic 6-11
Modacrylic 6-17
Polyester 6-17
Rayon 6-29
Acetate and Triacetate 6-31
Nylon 6-32
Spandex 6-35
Glass 6-38
Olefin 6-39
Other Generics 6-40

Significance of Property Data 6-42
Density (Specific Gravity) 6-42
Stress-Strain Behavior 6-42
Application of Stress-Strain Properties 6-45
Recovery of Fibers from Deformation 6-47
Yarn and Fabric Manufacturing 6-47
Dyeing and Finishing 6-48
Wrinkle Resistance of Fabrics 6-48
Crease or Pleat Retention of Fabrics 6-48
Fabric Liveliness or Resiliency 6-49
Other Fabric Characteristics 6-49
Recovery Testing 6-49
Chemical Resistance 6-49
Statistical Profile of the Textile Industry 6-49
Trademarks 6-51
References 6-59

INTRODUCTION

The Forms of Fibers

Textile fibers are the building blocks of yarns and fabrics. Traditionally, the term fiber referred to a discontinuous structure whose length was several hundred times its diameter and which possessed a balance of functional and aesthetic properties sufficient to suit it to yarn manufacture, fabric formation, dyeing, mechanical and chemical finishing, and end-use service.

Today, these parameters of processing and use are still largely valid but the term fiber is no longer limited by the concept of discontinuity; it is used to describe any material of natural or man-made origin which can be used to manufacture textile-mill products. And the advances made in fabric-forming technology and end-use development have broadened and made obsolete many of the property criteria formerly required to qualify a material as a textile fiber.

The physical forms which the textile fibers of today take fall into three broad categories: staple, tow, and continuous-filament. The significant usage of fibers in all three of these forms is attributable, in large measure, to the efforts of man-made-fiber producers.

Staple Among the natural fibers, most have been in discontinuous form, which, as noted, was part of the definition of the textile fiber. The term staple is synonymous with this type fiber, and in fibers of natural origin is commonly used to preface the mean fiber length as well.

In man-made-fiber terminology, the term staple refers to that discontinuous form which has been purposefully manufactured during continuous extrusion of fibers via cutting to controlled lengths. This is one of a multiplicity of controls which separate the processing and use-function aesthetics of man-made fibers from those of the natural fibers. Together they provide the textile technologist with raw materials which more closely resemble engineering materials than any of the natural fibers and have changed the economic profile of the textile industry.

For the most part, natural and man-made-fiber staple is the raw material of the spinning process whose output is a yarn. After one or more of several possible aftertreatments such as lubrication, twisting, and dyeing, such spun yarns become raw materials for fabric-forming processes or for handcrafts.

Tow Again the history of natural-fiber processing has furnished a term commonly used in man-made-fiber technology, but in the case of tow, the meaning has been altered considerably.

Originally, bast fibers such as flax were buffeted to separate relatively short fibers

Chapter **7**

Plastic and Elastomeric Foams

R. W. BARITO
and
W. O. EASTMAN

Major Appliance Laboratories,
General Electric Company,
Louisville, Kentucky

Introduction	7-2
Polyurethane	7-6
Polystyrene	7-19
Polyolefins	7-30
Polyvinyl Chloride	7-36
Epoxy	7-44
Syntactic	7-44
Elastomers	7-49
Blowing Agents	7-50
Structural Foam	7-57
Miscellaneous Foams	7-60
Summary	7-62
References	7-77

Chapter **8**

Liquid and Low-Pressure Resin Systems

LEONARD S. BUCHOFF

Technical Wire Products, Inc.,
Cranford, New Jersey

Introduction 8-2
Advantages of Liquid Resins 8-2
Selection of the Resin 8-3
Processing Liquid Resins 8-3
Epoxies 8-5
Basic Types of Epoxy Resin 8-5
Curing Agents 8-11
Epoxy Modifiers 8-17
Fillers 8-18
Applications 8-22
Polyesters 8-22
Basic Types of Polyesters 8-23
Monomers 8-23
Curing Systems 8-25
Fillers 8-27
Applications of Polyesters 8-27
Polyurethanes 8-28
Types of Polyurethanes 8-29
Curing Agents 8-29
Applications 8-33
Hydrolytic Stability 8-33

Silicones 8–37
Types of Silicone and Their Applications 8–37
Cast Phenolics 8–42
Allylic Resins 8–42
Types Available 8–42
Processing Characteristics 8–42
Properties 8–46
Applications 8–49
Polybutadienes 8–50
Hydroxyl Terminated Resins 8–50
Carboxyl Terminated Resins 8–51
Resins Containing Pendant Vinyl Groups 8–54
Butyl LM Rubber 8–54
Polysulfide Rubber 8–54
Cast Nylon 8–56
Acrylics 8–56
Vinyl Plastisols 8–59
References 8–60

INTRODUCTION

The materials covered in this chapter are resins that are liquids at room temperature or solids that melt up to 200°C. The chapter will not cover materials that are liquids by virtue of being dissolved in solvents, i.e., solvent-based adhesives, or suspended in water, e.g., rubber. Their common attribute is conversion to a solid by the action of heat and/or a curing agent. Most of the materials are cross-linked during the curing, resulting in an infusible, insoluble thermoset. Some, like cast acrylic, are converted to a thermoplastic. In a third group, typified by vinyl plastisols, the conversion from liquid to solid is accomplished by a physical process, with no chemical change. In general, if solvents are used with these resins, they play a minor role in the conversion of the formulation, or function other than as a solvent. They may enter into the reaction, as styrene does in polyester.

Liquid resins are useful in the fields of encapsulation, art, adhesives, laminates, foams, coatings, construction, resurfacing, centrifugal casting, embedments, tooling, and model making. Other chapters in this handbook deal with adhesives, foams, laminates, coatings, and electrical insulation. In this chapter, properties and guides to the selection of materials and compounds will be presented.

Advantages of Liquid Resins

Liquid resins are important because of their versatility and ease of application. Compounding is often accomplished by dispersing curing agents, fillers, and other ingredients at room temperature with a simple propeller mixer. Fillers are wetted better by the liquid resins than by molten polymer, and the fillers can be chemically bound. A variety of properties are readily available by changing formulations; stiffness, color, strength, and electrical properties can be tailored to specific needs by changing proportions and types of ingredients.

A range of cure temperature and times is available. Most classes of liquid resins can be formulated to cure at room temperature, eliminating the need for ovens. Equipment in general can be very simple and inexpensive; although automated, highly sophisticated machinery is available for metering, mixing and dispensing, and curing. Often, disposable containers can be used for hand mixing to prepare material for repairs or use in remote areas, such as in making field repairs on electrical equipment, in resurfacing highways and concrete floors, or in installing sealants or tiles.

Chapter 9

Plastic and Elastomeric Coatings

JOHN A. MOCK

Materials Engineering,
Reinhold Publishing Corporation,
Stamford, Connecticut

Introduction 9-2
Types of Plastic Coatings 9-3
Alkyds 9-10
Acrylic 9-11
Cellulosics 9-12
Epoxies 9-13
Fluorocarbons 9-15
Melamine 9-20
Nylon (Polyamide) 9-22
Phenolic 9-24
Polyester 9-26
Polyethylene 9-27
Polyimide 9-27
Polyphenylene Sulfide 9-29
Polypropylene 9-32
Polyvinyl Chloride 9-32
Silicone 9-34
Elastomeric Coatings 9-37
Butyl 9-37
Chlorinated Rubber 9-38
Chlorosulfonated Polyethylene 9-38

Fluoroelastomers 9-38
Neoprene 9-39
Nitrile 9-40
Polysulfide 9-40
Polyurethane 9-41
Styrene Butadiene 9-44
Application Methods 9-44
Ecology 9-48
References 9-50

INTRODUCTION

Surface coatings have been used for many thousands of years. The Egyptians developed a weather-resistant coating based on beeswax which was applied in the molten state. Bitumen was used to preserve the wooden hulls of ships, as noted in the Biblical story of Noah's ark, which was treated within and without with pitch.

In the Middle Ages the use of casein solubilized by means of lime was discovered. Up until the twentieth century, most organic coatings were based on natural resins.

One of the first plastic-base coatings to come into general use was rosin-modified phenolic, which was introduced in 1913. Nitrocellulose was introduced as a binder in lacquers in 1920, and alkyd, as well as 100 percent phenolic, were introduced in 1928. The 1930s saw the introduction of such important synthetic-resin binders as chlorinated rubber, vinyl, and modified urea.[1]

Synthetic resins enjoy wider use today than natural resins because of their more consistent quality, the generally improved properties of vehicles made with them, and the wide choice of unique qualities which they give to a surface coating. A modern finish can be individually tailored to a given application by selecting a given synthetic resin or combination of resins. Cost, of course, varies with type of resin. Table 1 lists prices of typical resins used in coatings.

TABLE 1 Prices of Some Resins Used in Finishes

Resin	Dollars per lb
Acrylic copolymer emulsions	0.21½–0.22
Acrylonitrile-styrene copolymer	0.44–1.00
Alkyd for high-grade flat finishes	0.2065
Butadiene-styrene lattices (dry)	0.29½–0.35
Epoxy liquid resin	0.65–0.78
Fluorocarbon resin:	
Aqueous dispersion	5.15–8.00
Maleic esters	0.21–0.27¼
Maleic resin for lacquers	0.23½
Melamine-formaldehyde resin	0.32¾–0.40
Nylon resins	1.18–1.28
Phenolic coating resin	0.30–0.58
Polyamide resin	0.52–0.90
Polyester coating resin base	0.36
Polyethylene, low-molecular-weight powder	0.30–0.37
Polystyrene emulsions	0.20
Saran latex–vinylidene chloride–acrylonitrile 52%	0.45
Styrene polymer, naturals, clear	0.40½–0.43½
Urea-formaldehyde resins	0.20½–0.47¼
Vinyl acetate resin, solution in acetone, per gallon	5.10
Vinyl chloride resins	0.23½–0.46½
Vinyl chloride–acetate resins	0.23½–0.64

Chapter **10**

Plastics and Elastomers as Adhesives

EDWARD M. PETRIE

Westinghouse Electric Corporation, Research and Development Center, Pittsburgh, Pennsylvania

Introduction to Adhesives	10–2
Definition	10–2
Advantages and Disadvantages of Adhesive Bonding	10–3
Nomenclature	10–5
Theories of Adhesion	10–6
Requirements for a Good Bond	10–7
Mechanism of Bond Failure	10–9
Basic Adhesive Materials	10–11
Adhesive Composition	10–15
Adhesive-Bonding Process	10–16
Design and Testing of Adhesive Joints	10–16
Types of Stress	10–16
Maximizing Joint Efficiency	10–17
Joint Design	10–19
ASTM Test Methods	10–23
Federal Test Specifications	10–30
Surface Preparation	10–30
Importance of Surface Preparation	10–30
General Cleaning Methods	10–30
Evaluations of Cleaned Parts Before and After Bonding	10–35
Substrate Equilibrium	10–36

Specific Surface Treatments and Adherend Characteristics	10–36
Primers and Adhesion Promoters	10–54
Types of Adhesives	10–54
Structural Adhesives	10–58
Nonstructural Adhesives	10–78
Selecting the Adhesive	10–82
Factors Affecting Selection	10–82
Sources of Information	10–86
Adhesives for Metal	10–86
Bonding Plastics	10–86
Adhesives for Bonding Elastomers	10–108
Adhesive Bonding of Wood	10–109
Adhesives for Glass	10–110
Effect of Environment	10–110
High Temperature	10–110
Low Temperature	10–116
Humidity and Water Immersion	10–117
Outdoor Weathering	10–119
Chemicals and Solvents	10–119
Vacuum	10–121
Radiation	10–121
Processing and Quality Control of Adhesive Joints	10–122
Measuring and Mixing	10–122
Application of Adhesives	10–123
Bonding Equipment	10–126
Quality Control	10–127
References	10–132

INTRODUCTION TO ADHESIVES

Definition

Modern structural adhesives are primarily synthetic materials based on plastic or elastomeric compounds. Adhesives were first used many thousands of years ago, and until relatively recently most adhesives were derived from vegetable, animal, or mineral substances. Synthetic polymeric adhesives displaced many of these products owing to their stronger adhesion and greater resistance to operating environments. Because of the importance and wide use of plastic- and elastomeric-based adhesives, they are the principal concern of this chapter.

An adhesive is defined as a substance capable of holding materials together by surface attachment. Unfortunately, a material conforming to this definition does not necessarily ensure success with an assembly problem. For an adhesive to be useful, it must not only hold materials together but also withstand operating loads and last the life of the product.

The successful application of an adhesive depends on many factors. Anyone intending to use adhesives faces the complex task of selecting the proper adhesive and correct time-temperature-pressure relationship that allows it to harden. He must also determine the substrate-surface treatment which will permit an acceptable degree of permanence and bond strength. The adhesive joint must be correctly designed to avoid stresses in the bond that could cause premature failure. Also, the physical and chemical stability of the bonded joint must be forecast with relation to its service environment. This chapter is intended to be a guide in the selection and use of adhesives so that adequate strength and service life may be realized in adhesive-bonded assemblies.

Chapter **11**

Commercial and Government Specifications and Standards

ARTHUR H. LANDROCK
and
NORMAN E. BEACH*
Plastics Technical Evaluation Center,
Picatinny Arsenal, Dover, New Jersey

Introduction	**11-2**
How to Use Specification Literature	**11-2**
Specification Sources	**11-3**
U.S. Government Sources	**11-3**
Nongovernment Sources	**11-45**
Miscellaneous Sources	**11-60**
Identification of Materials Specifications, Test Methods, and Standards	**11-62**
References	**11-74**

* Mr. Beach, who prepared the tabular material used in the section on Identification of Materials Specifications, Test Methods, and Standards beginning on p. 11-62, passed away some months after submitting this material. Mr. Beach had retired from the Federal Service a few years earlier.

Chapter **12**

Design and Fabrication of Plastic Parts

PERCY GRAFTON

Boonton Molding Company,
Boonton, New Jersey

Introduction 12-2
  Thermoset Molding 12-2
  Thermoplastic Molding 12-2
  Material Selection 12-3
Design Features and Guidelines 12-4
  Flow Patterns 12-4
  Heavy and Uneven Sections 12-5
  Delicate Sections 12-5
  Designed Undercuts 12-5
  Parting Lines 12-6
  Designed Mismatch 12-8
  Gates 12-8
  Hinges 12-9
  Ejector Pins and Vents 12-10
  Holes and Threads 12-11
  Warpage 12-11
  Sinks 12-12
  Lettering and Etching 12-13
  Tolerances 12-14
  Inserts 12-15