Chapter 4

Plastic Industries

The development of plastics from laboratory curiosities to products tailored to industry's needs has brought new and economical materials of construction to the engineer and the designer. Not only can plastics replace metals and other materials, but they can also be used with them. A plastic may be defined as a material that contains a polymerized organic substance of large molecular weight as an essential ingredient, is solid in its finished state, and at some stage in its manufacture or its processing into finished articles can be shaped by flow. The common basic raw materials are coal, petrochemicals, cotton, wood, gas, air, salt, and water. Plastics lend themselves to an exceedingly large number of applications because of their toughness, water resistance, excellent resistance to corrosion, ease of fabrication, and remarkable color range.

The use of a plastic material for a specific application is dependent upon its composition, its particular properties, and the design of the part. Synthetic resins are the largest source of plastics, with cellulose derivatives ranking next. All plastic materials of construction have limitations, but, when properly selected, they can be used with the same degree of assurance as metals and alloys.

HISTORICAL. The development of a commercial phenolic resin in 1909 by Baekland was the start of the synthetic plastic industry. His discovery stimulated the search for other plastics and resulted in an industry that has grown to become one of the nation's top ten in size. The first plastic of industrial significance was cellulose nitrate (Celluloid) and was discovered about the middle of the nineteenth century. It was first used in 1869 by Hyatt who was searching for an ivory substitute.

Cellulose acetate was developed in 1894 as a less flammable material and was used extensively as a base for photographic film and as "dope" for airplane coverings during World War I. From that time on, the introduction of new polymer materials was rapid. Table 34.1 shows the date of discovery and/or commercial introduction of the earlier plastics.

CLASSIFICATION. Plastics are often divided into thermosetting, thermoplastic, oil soluble, and protein products as presented in Tables 34.2 and 34.3. On the basis of derivation, they may be grouped as natural resins, cellulose derivatives, protein products, and synthetic resins. In general, except where noted, synthetic resins formed by condensation polymerization are thermosetting (heat curing produces an infusible or insoluble product), and synthetic resins formed by addition polymerization are thermoplastic (heating softens and cooling hardens). These two polymerization reactions are fundamentally different.

Addition polymerization involves a series of conversions which produce a polymer having a recurring structural unit identical with that of the monomer from which it is formed. Condensation polymerization yields polymers whose recurring units lack certain atoms present in the original monomer. The reaction takes place by the combination of two or more units and the elimination of a small molecule such as water, methanol, or hydrogen chloride. During,

Table 34.1 Early History of Polymers

Polymer	Year Introduced
Cellulose nitrate	1868
Cellulose acetate	1894
Phenol-formaldehyde	1909
Cellulose ethers	1912
Vinyls	1927
Urea-formaldehyde	1929
Acrylates	1931
Furans	1934
Polystyrene	1937
Polyamides	1938
Melamine-formaldehyde	1939
Polyesters	1942
Silicones	1942
Polyethylene	1943
Fluorocarbons	1946
Epoxy	1948
Crystalline polypropylene	1957
Phenoxy	1962

Table 34.2 Types of Resins and Plastics, with Some Common Trade Names

Thermosetting Resins
- Phenolic resins: Bakelite, Durez, Catalin, Formica, Indur
- Amino resins: Plaskon, Beetle, Cymel, Micarta, Melmac
- Alkyd resins: Glyptal, Rezyl, Becksol, Dulux
- Epoxy resins: Epon, Araldite, Ren, Epocast, Marblette
- Polyester (unsaturated) and allyl resins: Aropol, Atlac, Dapon
- Silicone resins: Pyrotex, Dow Corning
- Polyimides: Vespel, Kapton

Thermoplastic Resins
- Cellulose Derivatives
  - Cellulose nitrate: Celluloid, Pyralin, Nitron
  - Cellulose acetate: Kodapak, Tenite, Plastacele
  - Cellulose propionates: Forticel, Reed
  - Cellulose acetate-butyrates: Tenite II, Kodapak II
  - Ethyl cellulose: Ethocel, Soplasco, Campco
- Polymer Resins
  - Acrylate or polyacrylates: Plexiglas, Lucite, Acryloid
  - Vinyls: Vinylite, Gelva, Butacite, Koroseal, Alvar, PVA
  - Polyvinylidenes: Saran
  - Styrenes: Styron, Lustrex, Loalin
  - Polyamides: Nylon, Zytel, Kevlar, Nomex
  - Polyethers: Penton, Calcon, Delrin
  - Polyethylene: Polyethylene, Poly-Eth, Tygothene, Pentothene
  - Polypropylene: Poly-Pro, Pro-fax
  - Fluorocarbons: Kel-F, Teflon, Fluorosint
  - Polyesters: Mylar, Celanex, Ekonol
  - Polycarbonates: Lexan, Merlon
  - Polysulfones: Udel, Astrel 360, Victrex, Radel